SMITHSONIAN STUDIES IN AIR AND SPACE • NUMBER 1

# Astronaut Observations from the Apollo-Soyuz Mission

*Farouk El-Baz*

SMITHSONIAN INSTITUTION PRESS
City of Washington
1977

ABSTRACT

El-Baz, Farouk. Astronaut Observations from the Apollo-Soyuz Mission. *Smithsonian Studies in Air and Space,* number 1, 400 pages, 280 figures, 11 tables, 1977.—During the Gemini, Apollo, and Skylab flights, orbiting astronauts collected valuable information by means of observations and photography of Earth. Strengthened by the experience gained on these flights, the Earth Observations and Photography Experiment was carried out as one of the American objectives of the Apollo-Soyuz Test Project in July 1975. The main goal of the experiment was to utilize the special capabilities of trained observers (namely, the American astronauts of the joint mission) in visually studying and photographing specific Earth features and dynamic phenomena. These special capabilities include the sensitivity of the human eye to subtle color variations (e.g., to desert sands or sea water), and the speed with which the eye-brain interaction results in interpretation of the scene and recognition of important features. This latter capability allows instantaneous selection of important sites for photographic documentation at any moment, which in turn, enhances the quality of photographic data from space platforms. Another goal of the experiment was to establish the role of human observers in future space programs, particularly the Space Shuttle.

This book contains a detailed account of the experiment objectives, training of astronauts, preparation of aids for their use, and the results of experiment performance. These details serve as a historical-archival record and as a guide for conducting similar projects in the future.

The scientific objectives of the experiment included the collection of data in support of ongoing research in the fields of geology (particularly desert studies), oceanography, hydrology, meteorology, and environmental science. A summary of significant results is given; however, detailed scientific analyses are currently being performed by a number of investigators in various fields in the United States and abroad and their results will be published later, as a special publication of the National Aeronautics and Space Administration.

Official publication date is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, *Smithsonian Year.*

---

Library of Congress Cataloging in Publication Data
El-Baz, Farouk
Astronaut observations from the Apollo-Soyuz mission.
(Smithsonian studies in air and space ; no. 1)
Bibliography: p.
Includes index.
1. Earth—Observations. 2. Earth—Photographs from space 3. Astronauts. I. Title. II. Series.
QB631.E48 551 77-608094

---

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 047-005-00013-2

# Contents

# Foreword

It gives me great pleasure to introduce this new monographic series, *Smithsonian Studies in Air and Space,* which will deal with the history of, and advances in, air and space flight and planetary exploration. An earlier series, *Smithsonian Annals of Flight,* although successful since its inception in 1964, was the product of the National Air Museum before "Space" was added to its name, and thus did not reflect the expanding horizons that the space age has opened to research. This new series of the National Air and Space Museum joins other series publications, begun several years ago, of the National Museum of History and Technology and the National Museum of Natural History. *Smithsonian Studies in Air and Space* will present volumes of archival value as well as scientific research papers and monographs that review the state-of-the-art. The overriding theme will be that the publications of this series, based on scholarly research, will provide a better understanding of past accomplishments and a possible guide to future ventures in air and space exploration.

I am pleased to introduce the first volume in this series a short time after the opening of the new National Air and Space Museum in July 1976. The present monograph and future volumes will be dedicated by the museum staff and contributing colleagues from other institutions of learning to the "increase and diffusion of knowledge" in the dynamic, ever expanding fields of air and space.

This first volume is an outgrowth of the "Earth Observations and Photography Experiment," which was successfully performed during the Apollo-Soyuz mission in July 1975. The astronauts' view from orbit turned out to be not only beautiful but also extremely useful.

The author, Dr. Farouk El-Baz, was Principal Investigator of this experiment. His responsibilities included the selection of sites for observation and photography and the integration of the experiment's requirements into the flight plan. In addition, he prepared my former colleagues, astronauts Thomas P. Stafford, Vance D. Brand, and D. K. Slayton, for the flight by means of an extensive scientific training program. The elaborate preparation paid off, and Dr. El-Baz is now coordinating a scientific data analysis program involving several government agencies and academic and research organizations in the United States and abroad.

I hope that this book and future volumes in *Smithsonian Studies in Air and Space* will serve as a useful source of knowledge and that these publications will inspire future generations to continue exploring the unknown.

MICHAEL COLLINS
*Director*
National Air and Space Museum

# Acknowledgments

This book was inspired by the highly successful American Earth Observations and Photography Experiment. The high priority assigned to this experiment could not have been achieved without the generous support of Capt. Chester M. Lee, ASTP Program Director. Chet did this with a deep appreciation of what was accomplished in this field during the Apollo lunar flights. His continued support of the experiment and his interest in its results through the present data analysis phase are deeply appreciated.

Staff members of the Apollo-Soyuz Program Offices at both NASA Headquarters in Washington, D.C., and the Lyndon B. Johnson Space Center (JSC) in Houston, Texas, also lent support to the experiment. Dr. Glynn Lunney, the ASTP Program Manager, was especially understanding of what he must have felt were seemingly unending film requirements. Implementation of the tasks was greatly helped by S. N. Hardee, the Experiment Monitor; Dr. Thomas Giuli, the Program Scientist; and their staff at the Planetary and Earth Sciences Division, JSC.

Drs. Joseph Allen of NASA and Gordon Swann of the U.S. Geological Survey (USGS) participated in the very early planning phases of the experiment. Their efforts and their help are acknowledged. Helpful comments during the same early phase were received from former Apollo astronauts Col. David Scott and Col. Alfred Worden.

The author is indebted to the co-investigators and experiment "team members" for their help and support throughout the planning phases of the mission. The following co-investigators gave much time and thought to the experiment: James C. Barnes, Environmental Research and Technology, Inc.; Peter G. Black, National Oceanic and Atmospheric Administration (NOAA); Carol S. Breed, Museum of Northern Arizona and the USGS; William J. Campbell, University of Puget Sound; Robert Dietz, NOAA; George A. Maul, NOAA; Edwin D. McKee, USGS; William R. Muehlberger, University of Texas at Austin; P. R. Pisharoty, Indian Space Research Organization; Leon T. Silver, California Institute of Technology; Robert E. Stevenson, Scripps Institute of Oceanography; and Charles Yentsch, Bigelow Laboratory. I would like to particularly mention that many have given their time above and beyond the call of duty, including Ms. Carol Breed and Drs. George Maul, William Muehlberger, Leon Silver, and Robert Stevenson. The latter was responsible for the coordination of most ocean investigations by United States and foreign naval research vessels. I am also indebted to all those who participated in giving background lectures to the astronauts; classroom instruction was very necessary to prepare the crew for the task.

Delia Mitchell, research assistant, Smithsonian Institution, helped me throughout the experiment planning phases and during the mission operations. She assisted in the selection of observation sites and integration of the requirements in the flight plan. Ms. Mitchell also assisted me in the preparation of this book by collecting the necessary materials and preparing the figures. She helped in compiling the verbal comments for Appendix 1; Jane Murphy Abdel Rahman of my staff worked with her in the editing of the various transcripts.

My research assistant Susan McLafferty was very helpful in planning and implementing the crew training program and the preparation of its summary. She also prepared all the manuals of the training flights (flyovers), reproduced here as Appendix 2 after being redrafted by Ann Gifford. Dr. Robert Wolfe, also of my staff, assisted James Regan of JSC in the preparation of the color wheel. He also worked on the ground motion simulation films, which were made by Mr. John W. Massey at the Special Projects Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

My thanks and appreciation to Ron Weitenhagen of the Crew Training and Procedures Division, JSC, for his influence in implementing the experiment requirements. Ron was also very helpful in the preparation of the Earth Observations Book that was used by the astronauts (Appendix 3). He was assisted in this task by Robert Mocata. Joseph McKinney was influential in the rapid publication of these products by the Defense Mapping Agency's Aerospace Center at St. Louis, Missouri. Larry Schimmerman of the same organization kindly advised me on the selection and accuracy testing of the Hasselblad mapping camera system.

In matters dealing with flight planning, that is, the selection of proper spacecraft attitudes and viewing conditions, and the assignment of the observation targets to specific astronauts during certain segments of time, I am grateful for the efforts of Tom Holloway, Chuck Stough, Elvin Pippert, and their staff at the Flight Operations Directorate of JSC. James Taylor and his staff of the same Directorate were very helpful in the selection and testing of photographic equipment. Mr. Taylor also provided the necessary information to describe the cameras in this book.

Noel Lamar and Harold Lockwood of the Photographic Technology Laboratory, JSC, contributed their expertise to the selection of film, filters, and exposure settings to satisfy all the photographic requirements. They also provided the necessary information to summarize the task in this book. Richard Underwood indexed the photographs as soon as the film was developed at JSC.

Support of mission operations by Gerry Griffith, Don Incerto, Chuck Nash, and Alta Walker is acknowledged. A. Sanderson made the necessary interpretations of weather data to institute flight plan changes because of cloud cover. In addition, the Smithsonian Institution's Center for Short-Lived Phenomena, under the supervision of Dr. Robert Citron, alerted us to the locations of volcanic eruptions and oil spills that occurred during the mission.

The success of the experiment is due first and foremost to the interest, perseverance, and dedication of the Apollo astronauts, Gen. Thomas P. Stafford, Vance D. Brand, and Donald K. (Deke) Slayton. Their contributions to our understanding of the Earth will greatly affect the course of orbital observations in the future.

Astronauts of the "backup crew" are usually the forgotten ones; not in the case of the Apollo-Soyuz mission. Capt. Alan Bean, Capt. Ron Evans, and Col. Jack Lousma heavily participated in all phases of this experiment and helped improve it. Al Bean in particular, constantly "interrogated" me for more information and specific details, and questioned every onboard aid. This resulted in a far better plan than was initially conceived. My thanks to him for his interest and enthusiasm.

The support crew of Comdr. Richard H. Truly, Lt. Col. Robert F. Overmyer, Comdr. Robert L. Crippen, and Lt. Col. Karol J. (Bo) Bobko was also effective. Truly, in particular, showed much enthusiasm for the experiment.

I have gained much from the crews of Apollo missions 13 through 17 and Skylab 4, particularly an understanding of the capabilities and limitations of the astronaut as an observer. Astronauts Gerald Carr and William Pogue of Skylab 4 made many useful recommendations for the performance of the Earth Observations and Photography Experiment on ASTP.

Elbridge O. Hurlbut, the Smithsonian Institution's Contracts Officer, ably handled all contractual aspects under S.I. contract 174160. The experiment was performed under NASA contract NAS9–13831.

Sources of photographs and sketches are acknowledged in the legends of the figures, and also in the introductory paragraphs to the appendixes.

Donna Hennen, my secretary, typed numerous versions of the manuscript. Her careful attention, perseverance, and conscientiousness are acknowledged. Julienne M. Goodrich and Julie E. Murphy proofed the manuscript. The following individuals reviewed the manuscript and made helpful comments: Vance D. Brand, Patricia El-Baz, Thomas R. Giuli, Delia A. Mitchell, Alan C. Warner, Albert L. Ruffin, Jr., and John Whitelaw. The excellent editing by Joan Horn of the Smithsonian Institution Press greatly improved the manuscript.

Last but not least I wish to thank my wife, Patricia, and my four daughters, Monira, Soraya, Karima, and Fairouz. Instead of my spending weekends and nights with them, I was either traveling or working at my desk at home. Their understanding and support are deeply appreciated.

# ASTRONAUT OBSERVATIONS FROM THE APOLLO-SOYUZ MISSION

*Farouk El-Baz*

## Introduction

Despite achieving great advances in international space cooperation, the highly successful Apollo-Soyuz Test Project (ASTP) marked the end of an era in American spaceflight. It was the last flight of an Apollo spacecraft and will be the final American manned space activity until the Space Shuttle begins routine flights in the 1980s. As such, the Apollo-Soyuz Test Project, which was launched on 15 July 1975, provided the last opportunity in this decade for American astronauts to systematically observe and photograph the Earth from space.

The Apollo-Soyuz astronauts agreed with all others who have flown in space that the Earth is very beautiful. Whether it is seen from the vicinity of the Moon or from an Earth orbit, the Earth appears so breathtaking that astronauts can neither forget it nor adequately describe it. As astronomers see Mars as a red planet, the astronauts see Earth as a blue one; ocean water covers nearly three-fourths of the globe. In spite of this generalization, Earth displays to orbiting astronauts an unending array of beautiful colors and cloud patterns. Variations in patterns of land and sea unfold like a map of the world that has suddenly come alive.

To observe the Earth in wonder or to contemplate its beauty is all an untrained observer can do. However, during the Mercury, Gemini, and early Apollo flights, it was quickly realized that orbiting astronauts could expertly photograph significant features. An additional fact was more slowly recognized; the astronauts, because they could see more than expected, were able to make visual observations that increased the information value of their photographs.

As the Apollo missions progressed, it became feasible to undertake a program to test the observational capabilities of astronauts. This program paid handsomely and provided us with a plethora of scientific information that was otherwise not available. The task of observing was then called "visual observations from lunar orbit." The Principal Investigator's responsibilities for this task included training astronauts to perform the work and selecting sites for observation and photography.

When the Skylab program (1973–1974) began, astronaut observations from Earth orbit were established as an objective. A training program was implemented for the three Skylab crews. However, the best results were obtained on the last of the three manned missions (Skylab 4). Observations made by the Skylab crews added a new dimension to Earth resources investigations.

Based on previous experience, a proposal was submitted to the National Aeronautics and Space Administration (NASA) to conduct an "earth observation and photography" experiment on the Apollo-Soyuz mission. The proposal was accepted and planning activities began nearly a year-and-a-half before the mission. The magnitude of the job proved to be much more than foreseen, for the simple reason that interest was voiced by many more scientists from more fields of specialization than expected. Furthermore, this interest was not limited to investigators from the United States, and solutions to Earth science problems were sought for many parts of the world.

*Farouk El-Baz, Research Director, Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560.*

# Scientific Objectives

## Historical Background

Photographs of the Earth, used chiefly for land surveys and geological mapping, are usually obtained from airplanes. During the past decade, however, earth scientists have recognized the contribution of space photography to scientific investigations. For the purpose of photographing Earth, orbiting spacecraft have three advantages over airplanes: (1) a spacecraft travels at higher altitudes (several hundred kilometers) and can, therefore, view a larger area and depict broader features; (2) since spacecraft travel above the atmosphere, they avoid gusts of wind and air pockets that make aircraft relatively unsteady; and (3) a spacecraft follows an orbit around the Earth with a precision that increases the value of the photographs.

During the United States' first manned space flights, several types of imaging systems were successfully used to photograph the Earth from orbit. Some of the first truly orbital photographs were taken with 70 mm Hasselblad cameras during Project Mercury. According to Cameron (1965) the scope and sophistication of scientific experiments on these missions was restricted by the limited space and weight capacity of the Mercury spacecraft (about one-fourth the weight of the Apollo command module).

An informal surface observations and photography experiment was conducted on the four manned orbital missions, Mercury 6 through 9. The most valuable pictures were obtained on Mercury 9 by astronaut Gordon Cooper, who also made several unusual observations. From an altitude of over 160 km, Cooper reported seeing individual buildings on the Tibetan plateau, the wake of a boat on a large river, and even the smoke of a steam locomotive moving along its track. Photographs and visual observations on Project Mercury generated considerable interest among the scientific community and encouraged plans for more formal experiments on future missions.

During the ten manned Gemini missions, a number of valuable pictures were taken as part of the Synoptic Terrain Experiment (Lowman and Tiedemann, 1971). These included photographs of unmapped geological structures such as a volcanic field in northern Mexico. Strikingly beautiful photographs of the Sahara Desert in North Africa were also obtained (Figure 1), providing a regional view of one of the most remote and inaccessible areas in the world. Three types of cameras were used on Gemini: the Hasselblad 500C, the Maurer Space Camera, and the Hasselblad Super Wide Angle Camera. By the end of the Gemini program, over 1000 color photographs were available for study.

Visual acuity tests were performed during Gemini missions 5 and 7. Orbiting astronauts were asked to observe white markers (50 to 200 m long) laid out in patterns on the ground near Laredo, Texas, and Carnarvon, Australia. The astronauts were successful in observing and describing these patterns, proving that the human eye could detect more than the available cameras. Orbiting astronauts sometimes had difficulty interpreting the view, however. For example, astronaut James McDivitt was not able to recognize familiar landmarks during the flight of Gemini 4. He was unable to locate El Paso, Texas, although he had flown over it hundreds of times as a pilot. Similarly, as he approached the delta of the Nile River (Figure 2), he momentarily thought that the dark bluish triangle was an immense field of lava (Lowman, 1966: 645). This indicates the importance of pre-mission training.

Although the Apollo program was dedicated to lunar exploration, Earth photographs were taken on the Apollo 7 and 9 Earth orbital missions. The Multispectral Terrain Photography Experiment on Apollo 9 provided the first orbital photographs of the Earth's surface in three spectral bands; green, red, and infrared (Kaltenbach, 1970). For this experiment, four Hasselblad cameras, each with a different film/filter combination, were mounted on the command module's hatch window. Photographs were taken simultaneously at fixed intervals so that the same scene would appear in all four multispectral pictures. A wide variety of terrain in the southern United States and northern Mexico was photographed (Figure 3). The pictures taken on Apollo 9 helped establish the value of multispectral orbital photography and paved the way for the development of imaging systems for the Earth Resources Technology Satellite (ERTS; now called

Landsat) and the Skylab missions.

Because of the success of astronaut observations and photography from Earth orbit, similar tasks were performed during the Apollo lunar flights. The potential value of astronaut observations was recognized after the first circumlunar flight, Apollo 8. After observing lunar surface color, the crew of that mission stated that "regional variations in lunar surface colors are in

FIGURE 1.—This Gemini photograph of the Sahara Desert shows the vast, circular, Marzuq Sand Sea of Libya. Al Haruj al Aswad, a Quaternary volcanic field, appears as a dark mass between the yellowish sand sea and the blue Mediterranean. (NASA photograph S66–54525)

FIGURE 2.—A Gemini photograph of the triangular-shaped Nile Delta with the Mediterranean Sea to the left and the Sinai Peninsula toward the top. During the flight of Gemini 4, astronaut James McDivitt momentarily identified the dark blue-green triangle as an immense field of lava. (NASA photograph S65–34776)

shades of gray, possibly with faint brownish hues similar to the color of dirty beach sand" (Anders, Lovell, and Borman, 1969:1).

On Apollo 10, the astronauts also paid some attention to lunar colors and reported "definite brown tones on the gray lunar surface features, except near the sunrise and sunset terminators . . . the mare surface was generally brown, highland areas were tan, and the bright halos and rays around some craters were a chalky white like gypsum" (Stafford, Cernan,

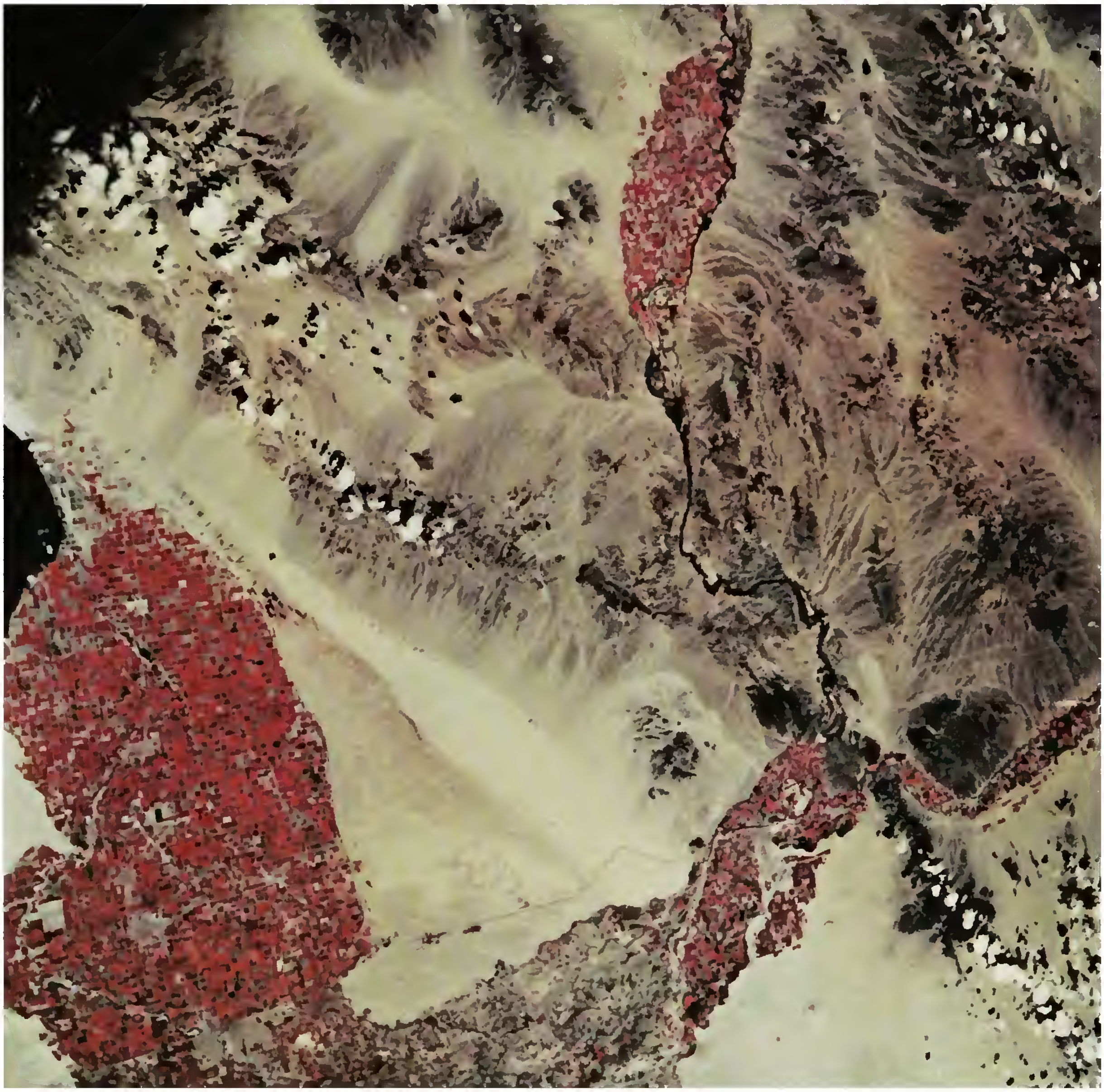


FIGURE 3.—An Apollo 9 color infrared photograph of the Imperial Valley of California, the Colorado River, and the Algodones sand dunes. The Salton Sea is just visible at the center left of the photograph. In this view, healthy vegetation appears red. (NASA photograph AS9–26A–3698)

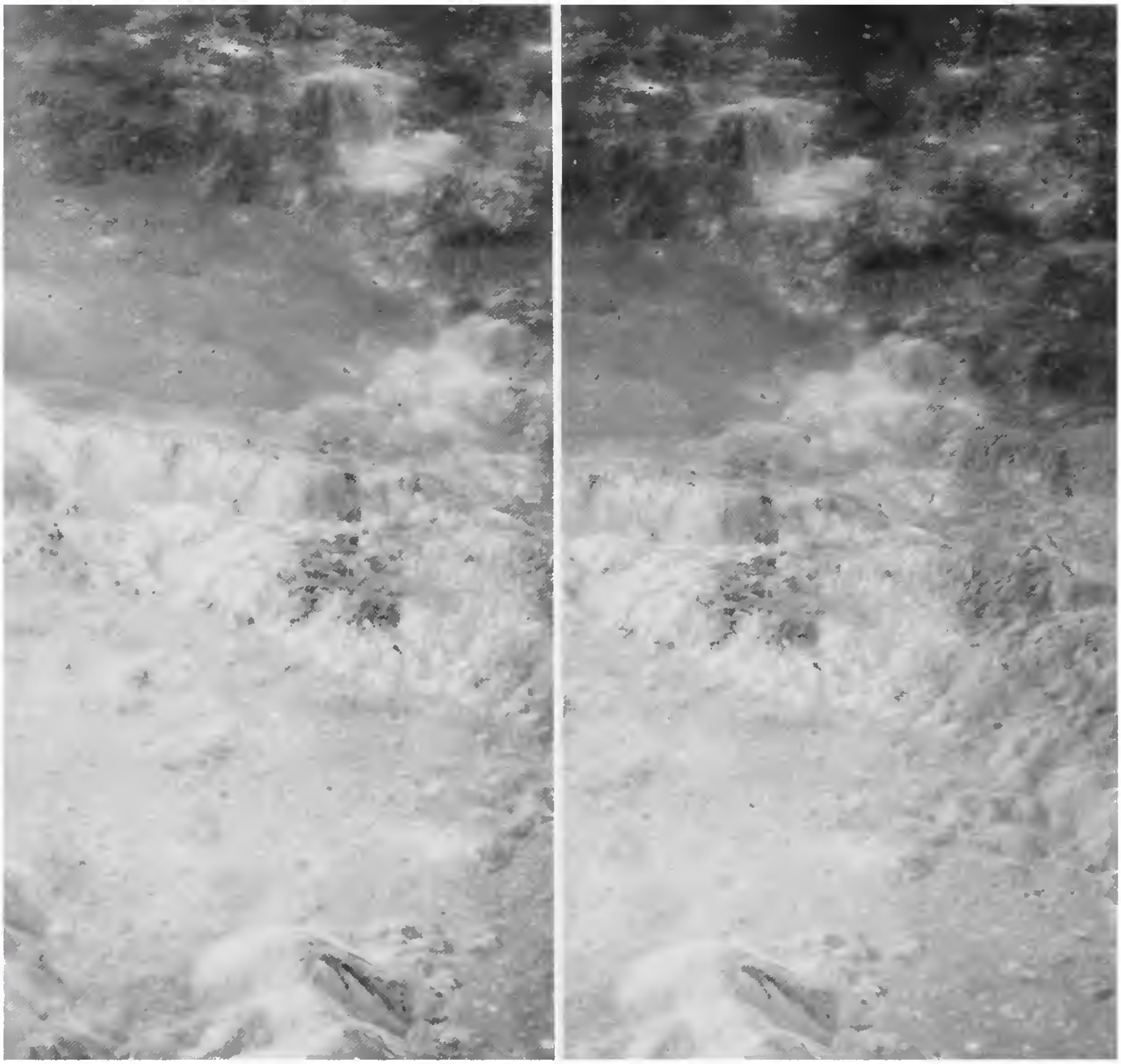


FIGURE 4.—Stereoscopic view of the northwest sector of the 70-km diameter crater King on the lunar far side. The black rocks near the center of the photographs were first observed by astronaut John Young on Apollo 10; the nature of these rocks remains an enigma. The elevated peaks at the bottom of the stereo pair are part of the central mountains within the crater floor. Beyond the white and black rocks of the crater's northern rim is a relatively smooth deposit of either impact or volcanic origin. (NASA photograph AS10–30–4351 and 4352)

and Young, 1971:1). On the same mission astronaut John Young discovered and photographed what seemed to be black rocks within a crater (King) on the lunar farside (El-Baz, 1969). To this day, these rocks continue to be a matter of scientific curiosity (Figure 4).

The first attempt to test the observational capabilities of astronauts began with the training of the Moon-bound astronauts of Apollo 13. Because this mission was aborted, however, the crew of Apollo 14 was the first to perform visual observations from lunar orbit, with encouraging results (El-Baz and Roosa, 1972).

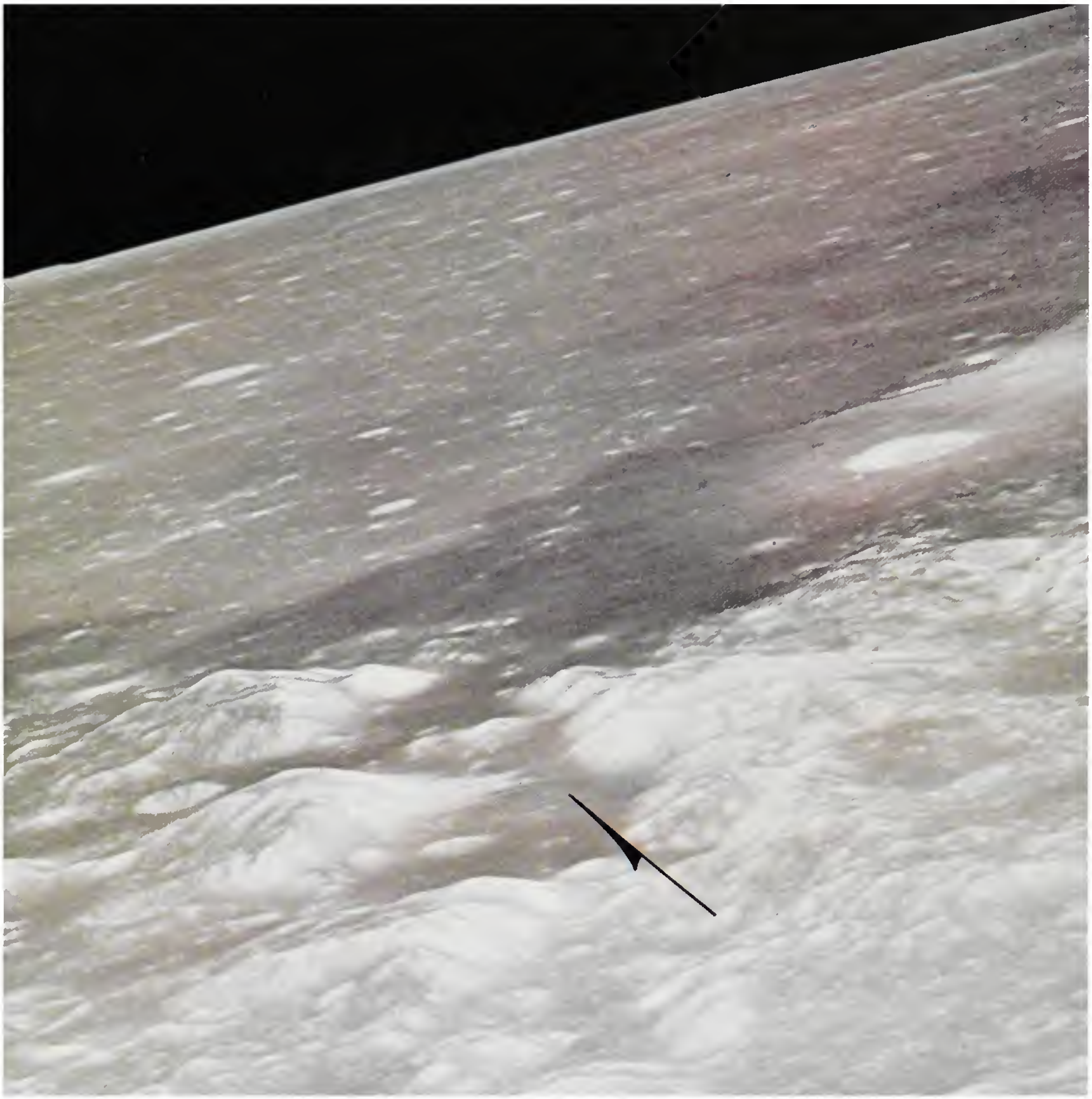


FIGURE 5.—Photograph of the southeastern part of the Serenitatis basin on the Moon's near side. The photograph is taken obliquely, looking westward from a 100-km lunar orbit. The arrow shows the direction of flight and indicates the Apollo 17 landing point. The astronauts landed in the dark, blue-gray unit that is surrounded by mountains over 2 km high. (After Evans and El-Baz, 1973:28–24)

The systematic acquisition of scientifically relevant visual observation data from lunar orbit began with Apollo mission 15. A program was developed to train astronauts for the task, then considered a detailed test objective. The author was Principal Investigator for this activity on Apollo 15 and the succeeding two missions. Detailed descriptions of the accomplishments were published in the mission reports of Apollo 15 (El-Baz and Worden, 1972); Apollo 16 (Mattingly, El-Baz, and Laidley, 1972); and Apollo 17 (Evans and El-Baz, 1973).

On Apollo 15 it was realized that "man must be trained to be a good observer, and the task of looking must be planned before flight and conducted systematically. Otherwise, man will look but he may not see" (El-Baz, Worden, and Brand, 1972:103). Another valuable result of the Apollo 15 mission was the observation of cinder cones in the Taurus-Littrow area (Figure 5). This was partly responsible for the selection of the area for the Apollo 17 landing. Analysis of Apollo 17 samples confirmed the existence of volcanic glass, probably resulting from pyroclastic volcanic eruptions (El-Baz, 1975:511).

Apollo 16 orbital observations resulted in the recognition that the lunar light-colored plains must be of varying, rather than uniform, ages. Also observed were "high-lava" marks at the boundaries of lunar maria, suggesting that lavas rose to higher levels on the Moon than their present levels (Mattingly and El-Baz, 1973:55).

By the time Apollo 17 circled the Moon, orbital observation techniques had nearly been perfected, and a handsome amount of scientific information was gathered. Among the significant results was the recognition of numerous subtle colors that characterize lunar surface units (Figure 6). All recognized colors were indicative of both the composition and age of observed materials (Schmitt, 1974; Lucchitta and Schmitt, 1974). One exciting find, made by two astronauts on the surface, of orange soil on the rim of crater Shorty (Figure 7) was investigated during the mission by their orbiting crewmate. This resulted in the first discovery of orange-tinted, volcanic materials on the rims of other lunar craters elsewhere on the Moon (Figure 8). The exercise proved beyond doubt the value of concurrent investigations on the surface and from orbit (El-Baz and Evans, 1973), a process that later was to be successfully used during the Apollo-Soyuz mission.

After the Apollo lunar program was terminated, the Sklab program began. Skylab provided the first opportunity since Apollo 9 to pursue a systematic study of the Earth from orbit. In support of this objective, an extensive remote sensing investigation, the Earth Resources Experiment Program (EREP), was carried out. The EREP facility onboard Skylab included six instruments that sensed the visible, infrared and microwave regions of the electromagnetic spec-

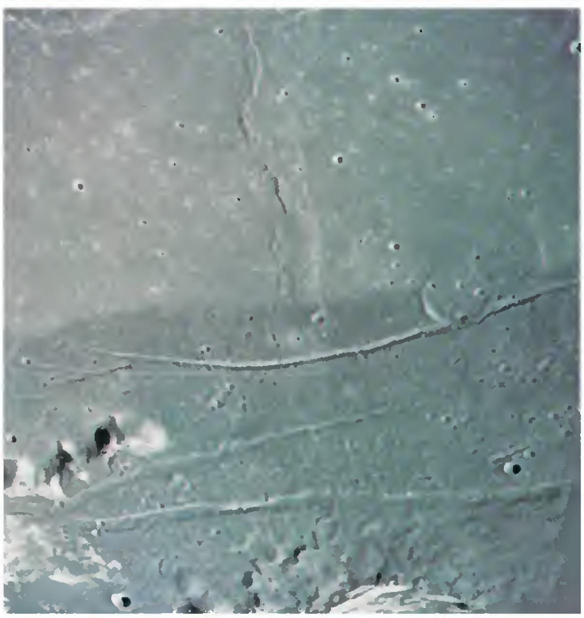


FIGURE 6.—Sharp color boundary between two mare (volcanic rock, basalt) units in southern Mare Serenitatis. The darker, blue-gray unit in the bottom half of the photograph is older than the lighter, tan-gray unit north of it. Observable color differences of this type have been used to substantiate a relative-age scheme for the Moon's surface units. (NASA photographs AS17-150-23069)

FIGURE 7.—A view of the area on the rim of crater Shorty showing the highly publicized orange soil that the Apollo 17 crewmen found at the Taurus-Littrow site. The tripod-like object serves as a reference to establish local sun illumination angle, scale of photograph, and lunar surface color. This orange-tinted soil was also observed from lunar orbit during the same mission. (NASA photograph AS17-137-20990)

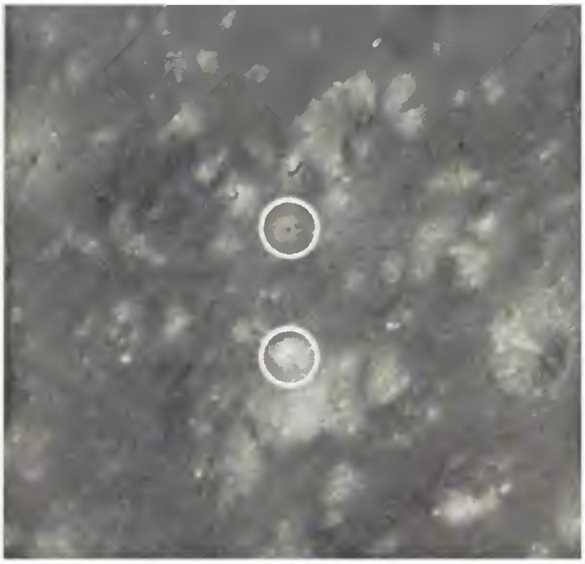


FIGURE 8.—Orange-tinted soil was observed from lunar orbit in the Sulpicius Gallus region, over 600 km west of the Apollo 17 landing site. This photograph shows two craters similar in size (500 m diameter), one exhibiting a light-colored ejecta and the upper one orange-tinted ejecta. The difference is due to the fact that orange materials occur in the dark unit but not in the light-colored hills. (After Evans and El-Baz, 1973:28–23)

trum. These included: (1) a multispectral array of six cameras each with a film/filter combination sensitive to a specific spectral band; (2) a high resolution Earth terrain camera; (3) an infrared spectrometer; (4) a multispectral scanner; (5) a microwave radiometer/scatterometer and altimeter; and (6) an L-Band radiometer. Handheld 70 and 35 mm cameras were also used by the Skylab astronauts to acquire photographs. At the end of the program, thousands of pictures of land, ocean, and weather features had been taken (NASA, 1974a).

A visual observations program for the Earth was also performed for the first time on Skylab 4. This program combined pre-mission crew training with helpful onboard aids, such as maps and photographs, to obtain photographic and observational data of specific Earth features. Because of the long duration of that particular mission (84 days), it was possible to conduct repeated observations of the same area (Figure 9). Observations on Skylab 4 and their documentation with photographs proved to be a very worthwhile effort and resulted in significant findings (Kaltenbach, et al., 1974).

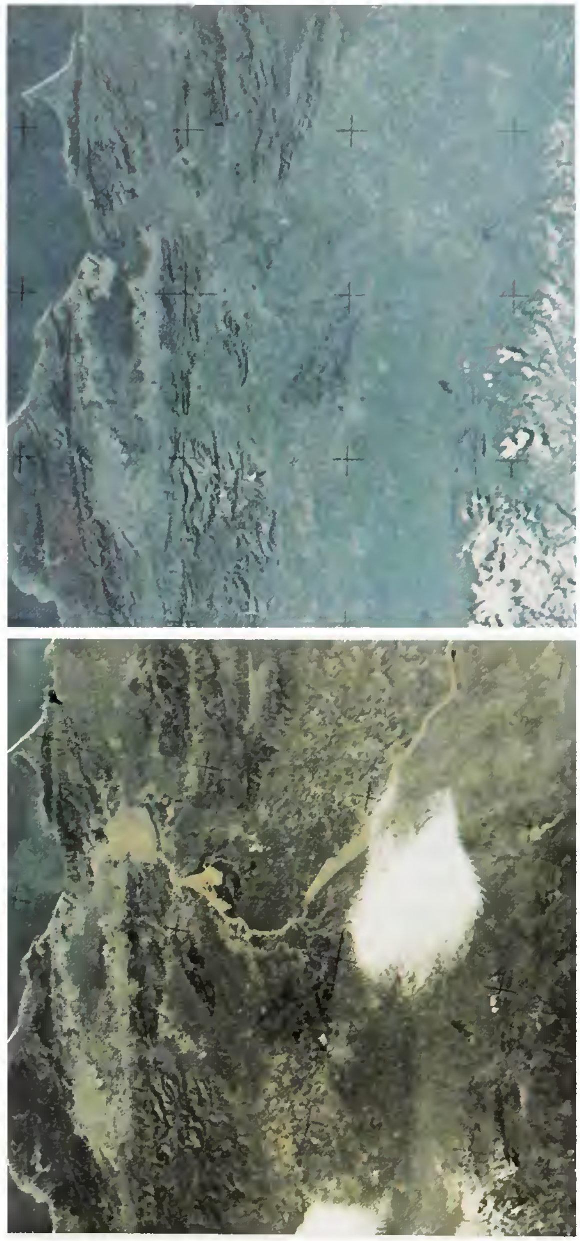


FIGURE 9.—Skylab 4 photographs of California showing San Francisco area, the Sacramento Valley, and the Sierra Nevadas. These two photographs, taken on different days and under different viewing conditions, reveal a number of interesting features: snow caps the Sierra Nevadas (*above*) and a low sun angle enhances faults and fractures. After the snow had melted (*below*) a higher sun angle emphasizes color while topography is subdued. (NASA photographs, (*top*) SL4–138–3843, (*bottom*) SL4–142–4532)

## Detailed Objectives

The aforementioned experiences of the United States' manned space flights proved that scientifically interesting features on the Earth and Moon could easily be studied from orbital altitudes. Space photographs and astronaut observations have provided scientists with a new way of exploring and studying the Earth and have become basic tools in Earth resources investigations.

As previously stated, one of the most obvious characteristics of orbital photographs is their large areal coverage. A single orbital photograph permits direct study of large structures, such as the San Andreas Fault system in California, and of broad distributions, such as snow-cover patterns in mountainous regions. Orbital photographs can also provide coverage of remote and inaccessible parts of the globe, like the Sahara Desert or the Pacific Ocean, where size makes conventional surveys impractical. Space pictures are particularly suited to a number of applications, including updating and correcting maps, monitoring Earth resources, studying dynamic geologic processes, and surveying ocean features.

The Apollo-Soyuz Test Project (ASTP) was approved as a joint US/USSR venture in 1972. During the same year, the first of a series of satellites, then known as the Earth Resources Technology Satellite (ERTS), was launched. The second in the series, now known as Landsat, established its orbit half a year prior to the flight of Apollo-Soyuz. These satellites can provide repetitive coverage of the entire globe every 18 days. The sensors on board the satellites generate images that are exceedingly useful in land and resource surveys, and particularly in studies of seasonal or annual variations (Williams and Carder, 1976). For this reason, the photographic objectives of the Apollo-Soyuz mission were limited to the documentation of astronaut visual observations, and the acquisition of oblique and high-resolution vertical color photographs that could not be obtained by the Landsat systems.

On ASTP, the Earth Observations and Photography Experiment (designated MA-136 by NASA) provided the first opportunity in two years to reexamine selected Earth features studied in the Skylab 4 visual observations program. Human observers possess several unique capabilities, including the extensive dynamic range and color sensitivity of the eye, and the speed with which the eye-brain system can interpret what is seen and distinguish what is significant. In fact, human observers in space can often see more color and textural variations than will be recorded on the best available photographic film. Therefore, the main objective of the Earth Observations and Photography Experiment was to use these unique capabilities of a trained observer to identify, describe, and photograph scientifically interesting features on the Earth's surface.

Early in the planning phase, a team of experts was assembled to assist in the planning and execution of the ASTP Earth Observations and Photography Experiment. The team membership comprised 42 individuals (Table 1), including myself as Principal Investigator (PI) and twelve co-investigators (CI). Many of the team members had participated in the Skylab 4 visual observations program and, thus, were familiar with the considerations involved in planning the experiment. The responsibilities of this group of experts included: (1) suggesting problems in the various disciplines that could best be solved with the help of orbital observations and photography; (2) participating in crew training with the aim of familiarizing the astronauts with the types of Earth features they would observe and photograph; (3) supporting realtime mission operations; and (4) analyzing the results of the experiment.

Because of the short duration of the ASTP mission (only 9 days), the detailed objectives had to be specified ahead of time. It was not practical to expect the astronauts to select investigation sites in realtime. Nor was it possible to conduct lengthy discussions between the astronauts and the Mission Control Center at Houston, Texas, as was previously done on Skylab 4. The crew had to follow specific instructions to observe each of the sites that were selected for detailed investigation. These sites were chosen on the basis of their value to ongoing research in the fields of geology, oceanography, hydrology, meteorology, and environmental science.

### Geology

Features of interest to geologists were given the highest priority among the experiment objectives because most geological features are static and, therefore, can be more reliably specified before the mission; hence, they are easier to recognize and locate from orbital altitudes. Another reason was that since color and texture are important factors in studying geological features, the human eye can deal better with

TABLE 1.—Earth observations team (from El-Baz and Mitchell, 1976)

| Name | Discipline | Affiliation |
|---|---|---|
| Apel, J. R. | Oceanography | NOAA |
| Barnes, J. C.[1] | Snow mapping | Environmental Research and Technology, Inc. |
| Black, P. G.[1] | Meteorology | NOAA |
| Borstad, G. | Oceanography | Bellairs Research Institute, McGill University, Canada |
| Breed, C. S.[1] | Deserts | Museum of North Arizona and USGS |
| Brill, N. S. | Red tide | Commonwealth of Massachusetts |
| Campbell, W. J.[1] | Hydrology | University of Puget Sound |
| Citron, R. | Short-lived phenomena | Smithsonian Institution |
| Cousteau, J. | Sea farming | Cousteau Society |
| Dietz, R.[1] | Marine geology | NOAA |
| Dunkelman, L. | Atmosphere | University of Arizona and GSFC |
| El-Baz, F.[2] | General | Smithsonian Institution |
| Ewing, G. | Oceanography | Woods Hole Oceanographic Institute |
| Holz, R. K. | Demography | University of Texas at Austin |
| Hovis, W. A. | Oceanography | GSFC |
| Junghans, R. C. | Environment | NOAA |
| Kaltenbach, J. L. | Skylab results | JSC |
| Lenoir, W. B. | Skylab results | JSC |
| MacLeod, N. H. | Deserts and agriculture | American University |
| Maul, G. A.[1] | Oceanography | NOAA |
| McEwen, M. C. | Skylab results | JSC |
| McKee, E. D.[1] | Deserts | USGS |
| McLafferty, S. | General | Smithsonian Institution |
| Mitchell, D. A. | General | Smithsonian Institution |
| Muehlberger, W. R.[1] | Geology | University of Texas at Austin |
| Murphy, J. A. | General | Smithsonian Institution |
| Nagler, K. M. | Weather patterns | NOAA |
| Odell, D. K. | Oceanography | University of Miami |
| Pirie, D. M. | Oceanography | Army Corps of Engineers, California |
| Pisharoty, P. R.[1] | Hydrology | ISRO |
| Pitts, D. E. | Color science | University of Houston |
| Ramseier, R. O. | Hydrology | Department of the Environment, Canada |
| Sherman, J. W. | Meteorology | NOAA |
| Silver, L. T.[1] | Geology | California Institute of Technology |
| Stevenson, R. E.[1] | Oceanography | Scripps Institute of Oceanography |
| Suliman, F. M. | Deserts | College of Education, Qatar |
| Swann, G. A. | Geology | USGS |
| Vonder Haar, S. P. | Oceanography | University of Southern California |
| Wilmarth, V. R. | Skylab results | JSC |
| Wolfe, R. | General | Smithsonian Institution |
| Yentsch, C.[1] | Red tide | Bigelow Laboratory, Maine |
| Youssef, M. | Deserts | Ain Shams University, Egypt |

[1]Co-Investigator

[2]Principal Investigator

them than can photographic film. Following are the specific geological features selected as objectives of the Apollo-Soyuz observations.

### *Desert Colors and Landforms*

VARIATIONS IN THE COLOR OF DESERT SANDS.—Norris (1969) and others have indicated that desert sands become redder with time as the sand grains are coated with iron oxides. Several regions were studied to explore the possibility of establishing a color/age relationship within deserts of North Africa, the Arabian Peninsula, Australia, China, and the southwestern United States.

SAND MOVEMENT AND RESULTING LANDFORMS.—Sand movement and its effect on the desertification of land was studied. Emphasis was placed on the drought-stricken areas of sub-Saharan Africa. Dune shapes were studied as possible terrestrial analogs to wind-blown features on Mars (El-Baz, 1976).

VEGETATION VERSUS MOVING SANDS.—Patterns of vegetation in desert areas were studied in the Lake Chad region and also in Algeria where a "Great Barrier" of trees was planted preventing shifting sands from encroaching on fertile soils.

FEATURES OF THE WESTERN DESERT OF EGYPT.—This desert was selected for detailed investigation because "the free interplay of sand and wind has been allowed to continue for a vast period of time, and here, if anywhere, it should be possible in the future to discover the laws of sand movement, and the growth of dunes" (Bagnold, 1933:121). Also the area was selected because groundtruth data would be provided by a team of Egyptian geologists.

### *Fracture Patterns and Earthquake Zones*

SAN ANDREAS FAULT SYSTEM.—As one of the most interesting systems of continental crustal fracturing, information was gathered on parts of the San Andreas Fault and its subsidiary fracture systems in southern California. Included in this effort were attempts to locate traces of older faults and rock units, difficult to recognize in ground investigations, in the foothill metamorphic range of the Sierra Nevadas.

RED SEA AND LEVANTINE RIFTS.—Structures were studied and photographed along the Red Sea Rift starting with the Afar Triangle in eastern Africa. Of particular interest was its northern extension known as the Levantine Rift. This extends over 700 km from the Gulf of Aqaba northward into Turkey.

CENTRAL AMERICAN STRUCTURES.—Several fault lines were investigated in Central America. Among these were faults in Guatemala and Mexico, which have been the sites of recent earthquakes.

ANATOLIAN AND ALPINE FAULTS.—Similar investigations were conducted of the Anatolian Fault in the Caucasus Mountains region and the Alpine Fault of New Zealand. Information was collected on these fracture systems for a better understanding of the tectonic patterns of the Earth's crust.

### *Growth of River Deltas*

Photographs of river deltas were required to compare with others taken a decade ago. Comparison of these photographs would help determine the rate of growth of the river deltas in question. Establishing the rate of growth is economically important since ancient deltaic sediments are often a site of gas and oil accumulations. Photographic targets included deltas of rivers, such as the Mississippi, Nile, Niger, Danube, and Zambezi.

### *Mineral Alteration Zones*

As a test of the ability of a trained observer to search for mineral deposits from orbit, several mining localities were selected for observation. These included the Lake Superior mining district and the Bingham copper mine in the United States, the Sudbury mining area of Canada, and the El Teniente mining district in the Chilean Andes.

### *Plumes of Active Volcanoes*

The distribution of volcanic ash and dust is a matter of great interest to volcanologists. Plumes emanating from volcanoes can be observed clearly from Earth orbit. The Apollo-Soyuz astronauts were alerted to the possibility of observing and photographing plumes from Kilauea, Vesuvius, and Mt. Baker volcanoes.

### *Circular Features of Impact Origin*

The final objective of geological interest was the search for circular structures that may be ancient meteoritic impact scars or astroblemes (Dietz, 1961). Photographs of astroblemes increase our knowledge of the interaction of the Earth and meteoritic bodies, and aid in the location of new areas for possible economic exploitation. (The Sudbury astrobleme in Canada supports a one-billion-dollar per year nickel mining industry.) Particular attention was given to little-known circular structures in Brazil.

## Oceanography

Ocean features were also given considerable attention on the Apollo-Soyuz mission. Skylab observations and, to a lesser degree, some Landsat imagery indicated that the ocean surface displays a plethora of features. Many of these, such as ocean currents and eddies, are important to the shipping and fishing industries. The ocean observations listed below were made in support of investigations by the National Oceanic and Atmospheric Administration (NOAA), the U.S. Navy, and a few private research organizations.

### *Ocean Currents and Their Boundaries*

Gulf Stream of the Northern Atlantic.—The Gulf Stream was one object of study from the Apollo-Soyuz orbit. Of interest were its start at the western Caribbean Sea, the Gulf Loop Current and its continuation as the Florida Current, the main part of the Gulf Stream off the east coast of the United States, and the confluence of the Gulf Stream with the Labrador Current in the Northern Atlantic. The Gulf Stream was recognized by the difference in color from the surrounding water due to its higher temperature.

Falkland Current of the Southern Atlantic.—The Falkland Current was observed and photographed on Skylab mission 4 (Figure 10). It was obvious to the eye and also on film because of a greenish color due to a high concentration of plankton. The current was selected for additional observations because of its significance to both the shipping and fishing industries. Of interest were its boundaries off the coast of southern South America and its confluence with the Brazil Current farther north.

Currents of the Pacific Ocean.—Several currents that ring the Pacific Ocean were the object of study on the ASTP mission. These included the Humboldt Current off South America, currents off the islands of New Zealand, the Kuroshio Current off the Japanese islands, and the California Current off the southwestern United States.

Currents near Africa.—The Guinea Current was also selected for observation on the Apollo-Soyuz mission. The Arabian Sea, where no specific currents were previously observed, was selected for observation to look for any visible current boundaries.

### *Internal Waves in the Oceans*

Internal waves are interesting features that have puzzled oceanographers since they were first recognized in Landsat images (Apel and Charnell, 1974). They are not related to surface waves, but occur deep within the ocean. These waves extend for hundreds of kilometers. They are believed to occur at temperature or density discontinuities between water layers, and characteristically have a wavelength of a few kilometers. They appear to be visible from above due to the accumulation of scum lines atop their crests. Areas selected for internal wave investigations included the Mediterranean Sea, the Atlantic Ocean west of Spain, the waters between the two islands of New Zealand, and the waters of the Gulf of California.

### *Ocean Eddies and Gyres*

Eddies.—An eddy is usually a circular mass of water that is either colder or warmer than the surrounding waters. Location and characteristics of eddies are important to fishing and to studies of sound propagation through waters (and thus for submarine navigation, hiding, and detection). A semipermanent, 200 km wide eddy off the east coast of Australia was the subject of investigation during the Apollo-Soyuz mission. This study was in support of a joint research program by Australia, New Zealand, and the United States (thus the nickname ANZUS Eddy). Smaller eddies were sought in the Caribbean Sea, the Coral Sea, and the Mediterranean Sea. Eddies that were first observed on Skylab 4, were visible either because of a different water color or because clouds usually encircle them, both due to a difference in water temperature (Figure 11)

Gyres.—These are small bodies of water that usually spin off a fast moving current. Gyres were observed off the California coast, in the Gulf of Mexico, off the Gulf Stream, and in the Mediterranean Sea.

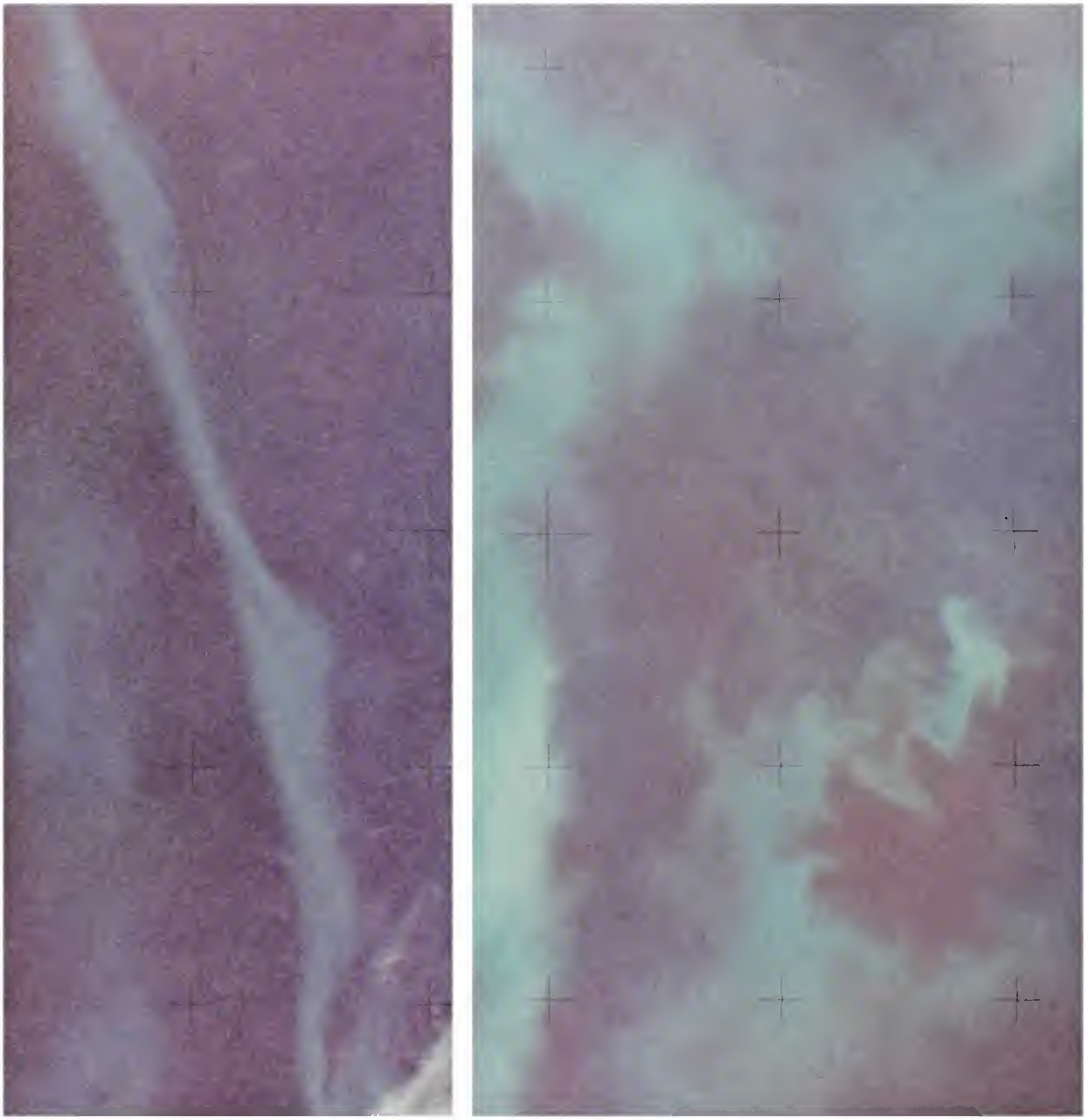


FIGURE 10.—The Falkland Current off the coast of Argentina was easily observed by Skylab 4 crewmen because of the vividly colored plankton blooms. These blooms often occur along current boundaries where water upwelling brings nutrients up from the ocean depths. (NASA photographs, (*left*) SL4–138–3843, (*right*) SL4–142–4534)


FIGURE 11.—Skylab photograph of a cold-water eddy in the Atlantic Ocean east of the Bahamas. Convective cumulus clouds encircle the eddy and make it easily observable. (NASA photograph SL2–81–225)

*Upwellings and Bow Waves*

Around several islands in the Pacific Ocean two phenomean were previously observed. The first is that colder water rising from the ocean depths brings nutrients and often appears darker than the surrounding water. The other phenomenon is that of bow waves that indicate the direction of water motion where no current boundaries are visible. Islands selected for observing water upwellings and bow waves include the Galapagos, the Azores, and the islands off the California coast.

*River Sediments*

Major rivers discharge sediments in varying quantities into the oceans. The water of one river in particular, the Orinoco, which drains parts of northern South America, is usually saturated with humic compounds. The observation program on the ASTP mission included investigation of the color, texture, nature, and extent of the yellow-tinted water near the mouth of the Orinoco River.

## HYDROLOGY

Problems of interest to hydrologists include several that could be investigated from Earth orbit. Among these problems are the extent of snow cover and the nature of snow melt patterns; the circulation of water within closed basins; river sinuosity and drainage patterns; and the quality and distribution of icebergs that break off the Arctic and Antarctic ice packs. The following items were considered for observations and photography on the Apollo-Soyuz mission.

*Snow Cover Mapping*

THE HIMALAYAS.—The Indian Space Research Organization (ISRO) participated in the Earth Observations and Photography Experiment by requesting the acquisition of data on the amount of snow cover in the northwestern Himalayas. The information was required to estimate water runoff during the summer for both flood control and water use in irrigation.

THE CASCADES.—Information was sought on the amount and extent of snow cover on the Cascade Mountains in the northwestern United States. The information was necessary to conclude studies related to the utility of snow cover as the source of fresh water in that region.

OTHER MOUNTAINOUS REGIONS.—To allow comparative studies, snow cover was observed and photographed in the regions of the Wasatch, Alps, and Caucasus mountains.

### *Closed-Basin Water Circulation*

Utah's Great Salt Lake was selected for study of water circulation, or lack of it, within a closed basin. The construction of a railroad causeway in 1956 virtually divided the lake into two bodies (Figure 12). The northern half of the lake received no fresh water and its increased salinity resulted in the growth of an algae that tinted the water with a reddish color. Drainage from the nearby Wasatch range drastically increased the water level fluctuations in the southern half. The circulation of water within the lake, which might be indicated by sediment plumes, was an object of study on ASTP.

### *River Sinuosity in South America*

The sinuosity of major rivers in central South America and the patterns of their tributaries was selected for visual study on the Apollo-Soyuz mission because of importance in predicting future river courses. Also photographs were requested of a region recently chosen as a site for constructing a dam along the course of the Parana River.

### *Icebergs and the Edge of Antarctica*

Icebergs have received considerable attention in the past few years as a possible source of fresh water if "towed" to arid regions (Campbell, et al., 1974). This is rather significant when one considers the fact that 88 percent of the fresh water on Earth is frozen at the North and South Poles. Information was obtained on the size, number, and characteristics of icebergs, particularly in the Southern Hemisphere. Attempts were also made to photograph the edge of Antarctica and, if possible, to study large icebergs that break off from the Antarctic ice pack.

## METEOROLOGY

In support of ongoing investigations of the atmosphere of the Earth and its weather patterns, meteorological objectives were considered for the Apollo-Soyuz mission. Two items of interest to meteorologists were emphasized: cloud features and tropical storms. Photography of the very bright clouds was intentionally underexposed to increase contrast and make cloud textures more visible.

### *Cloud Features*

Although clouds can be a nuisance when they inhibit observation of what is beneath them, they display interesting patterns that shed some light on the nature of the Earth's atmosphere, hydrosphere, and even lithosphere. Of special interest were: (1) Bénard cells that form over the open ocean; (2) Von Kármán vortices that occur over isolated topographic highs on land and particularly over islands in the ocean; (3) cloud waves over mountainous regions that indicate wind direction and velocity; and (4) convective cloud features that are usually associated with thunderstorms.

### *Storm Centers*

Causes for the development, circulation, and dissipation of tropical storms (hurricanes in the Atlantic and typhoons in the Pacific) are not yet fully understood by meteorologists. The Skylab 4 crew provided the first photographs indicating that storm centers are not cylindrical but conical in shape; the base of the cone being at the top of the cloud mass (Figure 13). Additional observations and stereo photographs were required for use in the construction of computerized models of severe storm development and dissipation.

## ENVIRONMENTAL SCIENCE

Environmental scientists concern themselves with changes in our surroundings. These changes can be natural (such as sediments in rivers, or red tide blooms in coastal sea waters) or man-made (such as pollution from chemical industries and oil spills).

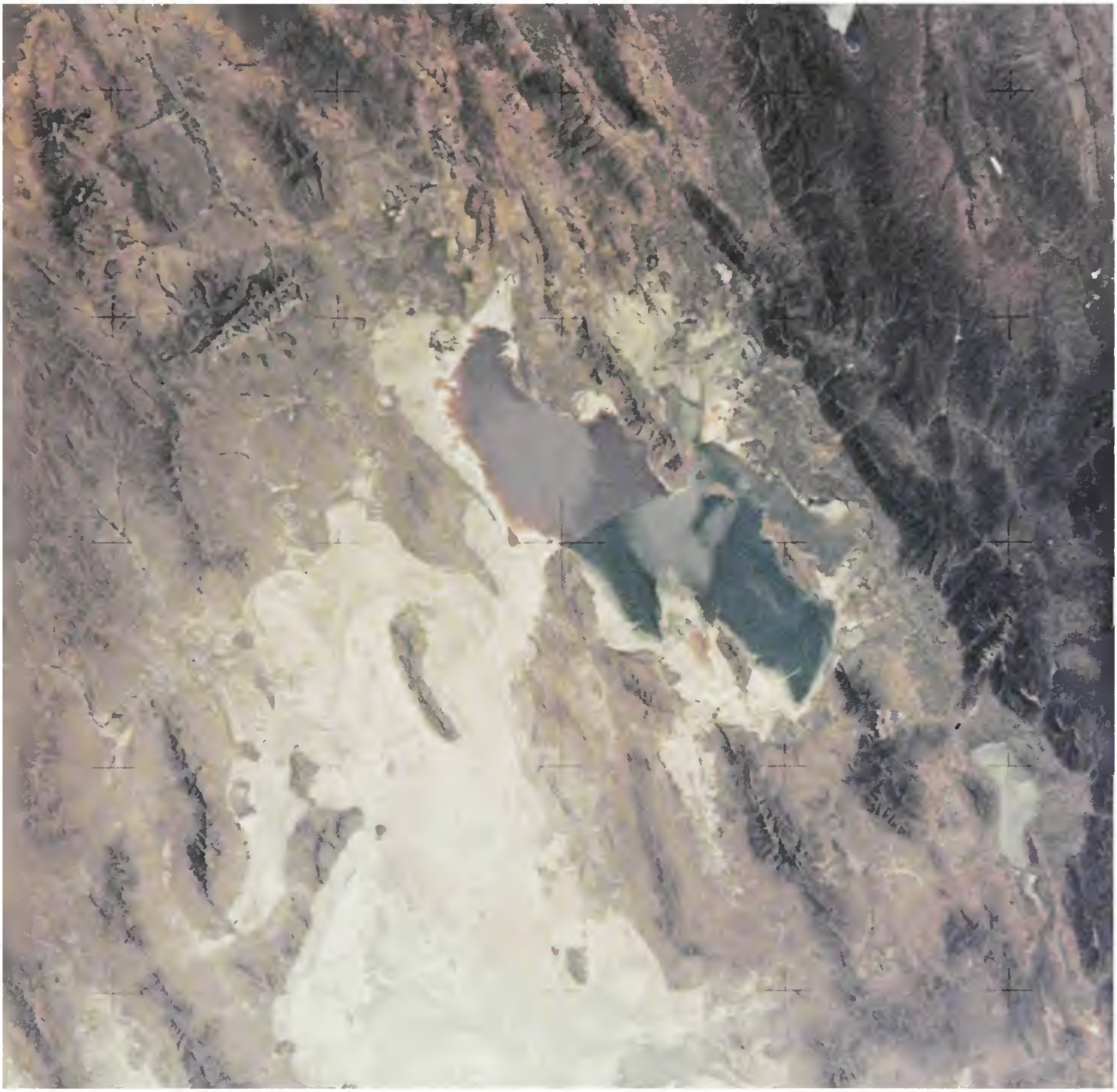


FIGURE 12.—Utah's Great Salt Lake showing the difference in color between its northern and southern halves, which are separated by a railroad causeway. Most of the fresh water drained from the Wasatch Mountains on the east side of the lake reaches the southern but not the northern half. The increased salinity in the northern half encourages the accumulation of a red-tinted algae, giving it a distinct color. (NASA photograph SL3–116–1996)

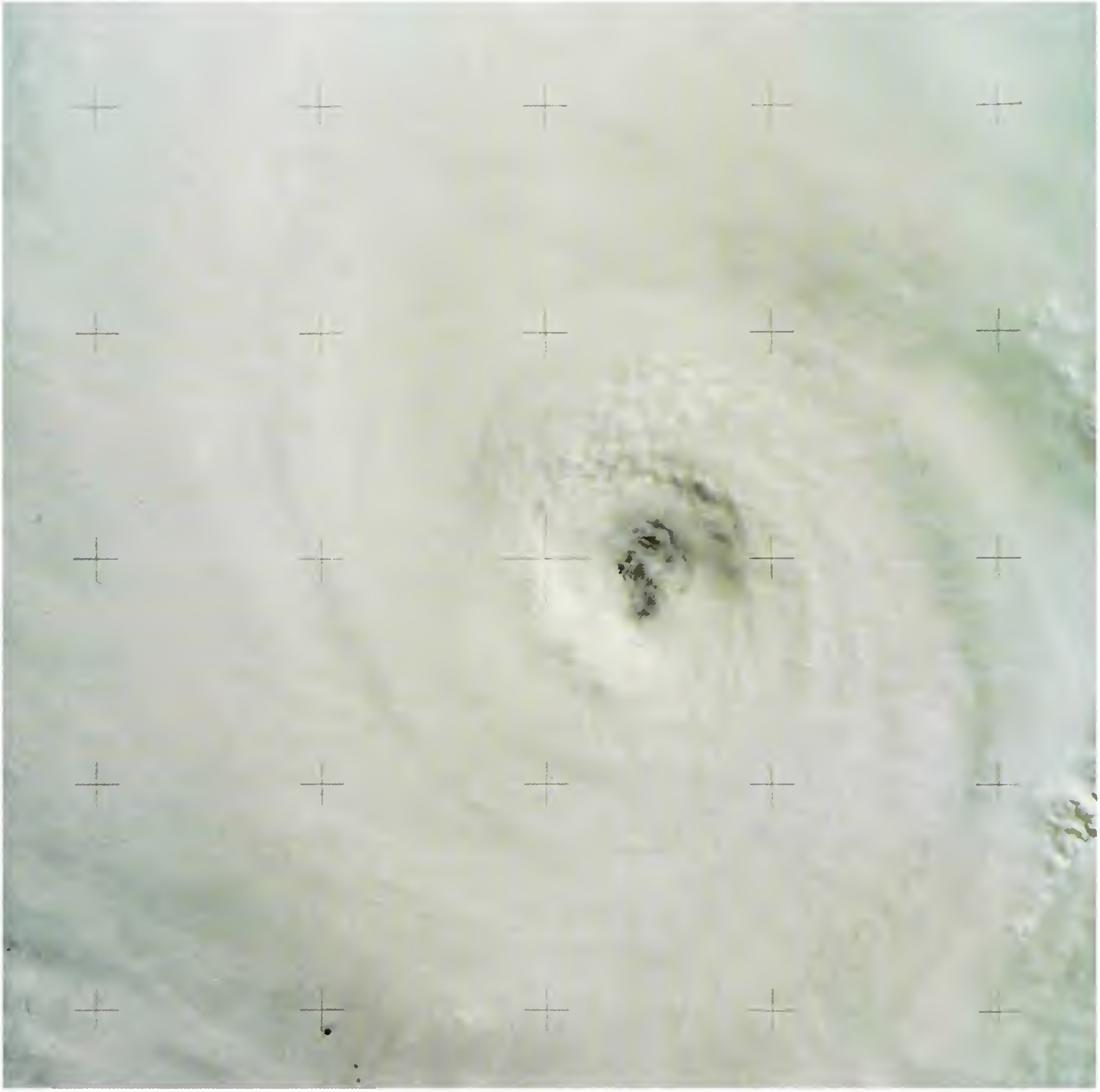


FIGURE 13.—Near-vertical Skylab photograph of Hurricane Ellen taken on 21 September 1973. This photograph provided the first evidence that the eye of a tropical storm is conical with the diameter of the eye much larger at the top of the storm than at the bottom. (NASA photograph SL3–122–2602)

### *Natural Pollution*

RED TIDE.—The term "red tide" describes the reddish tint in coastal waters resulting from the presence of a microscopic dinoflagellate, particularly the poisonous variety (Yentsch, 1974). This organism contaminates fish and shellfish, and affects the respiratory system of humans that ingest it. Therefore, it constitutes a major health hazard, particularly off the coast of New England. Investigations of red tide were conducted primarily in support of research at the Bigelow Laboratory, Boothbay Harbor, Maine. Similar work was conducted in cooperation with the Department of Public Health of the Commonwealth of Massachusetts. Observations of possible red tide infestations were also made off the west coast of Florida and near California.

SEDIMENT PLUMES.—Rivers unload their sediments in bays, channels, and sounds. Sediment boundaries and dissipation rates were studied in Puget Sound, the Chesapeake Bay, and the English Channel.

### *Pollution by Human Activities*

INDUSTRIAL AND HUMAN WASTES.—Effects of chemical pollution are very obvious from orbital altitudes. Astronauts are usually able to locate and trace these effects to the source of pollution plumes in the water or in the atmosphere (such as gas fires in oil fields). Water pollution was investigated in the Potomac River and in the Boston and London Harbors.

OIL SLICKS.—The International Maritime Commission cooperated in reporting oil slicks in the northern Atlantic along major shipping routes. Local, small oil spills were also described and photographed on the Apollo-Soyuz mission.

## VISUAL ACUITY

To determine the limits of visual acuity of orbiting astronauts, the following targets were selected for visual observation under varying conditions.

### *Lake Bonneville Racetrack*

Utah's Lake Bonneville is a dry lake that is covered by highly reflective salt deposits. Because the salt beds are extremely flat, the areas is used for testing and racing automobiles, with a single track being favored. The astronauts were requested to locate this track against the Lake's bright background as a test of their ability to discern linear patterns from orbit.

### *Glaciers and Firn Lines*

Another test of the eye's sensitivity to a bright scene was that of glaciers in snow-covered areas. Glacier ice, since it is denser, is less reflective than snow. If glaciers were recognized the astronauts used an enlarging telescope to see if they could detect the firn line separating exposed ice from snow-covered ice of the same glacier.

### *Nazca Markings*

The markings left by ancient inhabitants of the Peruvian coastal plain were also the object of visual acuity tests. These Nazca lines were interpreted by some to have been constructed for use by "ancient astronauts" (see McIntyre, 1975). If so, "modern astronauts" should be able to recognize these markings (as will be discussed later they did not, although the viewing conditions were not very favorable).

### *Pyramids of Giza*

The three Great Pyramids of Giza, southwest of Cairo, are the largest buildings of ancient man. They have never been seen from Earth orbit, most probably because the reflectivity of their materials is nearly identical to that of surrounding rocky plains. With this in mind, and with hints as to where to look, the ASTP astronauts were asked to find these structures.

### *Bioluminescence*

Certain biota, including microscopic organisms and a type of jellyfish, luminesce in the dark. High concentrations of these biota exist in the Red Sea and the Persian (Arabian) Gulf. The astronauts were requested to attempt observing patterns of bioluminescence during nighttime in the two sites. This was a test of the sensitivity of the human eye to a faint glow on the Earth's surface.

# Astronaut Training

As stated before, the experience gained during previous space missions showed that astronauts did significantly better in Earth observations when they were thoroughly familiar with the details of the specific tasks. Therefore, to insure the scientific relevance of astronaut observations, an extensive training program was initiated one year before the mission. Crew training was divided into two separate but complementary parts consisting of classroom lectures and aircraft flights or "flyover" exercises.

## Classroom Instruction

Before the ASTP training program started, the American members of the Apollo-Soyuz crew attended the Skylab 4 visual observation debriefings. The debriefings were held from 12 through 20 March 1974 and covered observations of oceanographic, atmospheric, and terrain features and phenomena. These debriefings proved very helpful in familiarizing the ASTP crew with the scope of Earth observations from orbit and allowing them to make their own judgments on the relative merits of observations in each of the various scientific fields. For example, following the Skylab 4 debriefings, the ASTP crew indicated that studies of vegetation patterns and cultural features ought to be given lower priorities on their mission. The crew recognized that studies in both fields are best made through the use of repetitive gathering of data by unmanned satellites, such as Landsat.

Due to the short duration of the ASTP mission (and the resulting limited ground coverage), all observation tasks had to be scheduled in the Flight Plan, leaving relatively little potential for selecting "targets-of-opportunity" in realtime. For this reason, it was important to familiarize the astronauts with the details of the observation tasks and to train them to be good observers. The objectives of the classroom instruction program were as follows: (1) to review visual observations programs conducted on previous Earth orbital missions, particularly Skylab 4; (2) to instruct the crew on background information and basic theory in the fields of investigation: geology (including desert study), oceanography, hydrology, meteorology, and environmental science; (3) to familiarize the astronauts with the scientific terminology used in each of these fields so that they would be able to enhance the content of their communications during the mission; (4) to discuss details of observation sites and their importance to ongoing investigations in the earth sciences; (5) to familiarize the astronauts with the mission groundtracks and the use of landmarks to minimize the time required for site recognition; (6) to explain the scientific and operational requirements for each observation site and photographic target. These objectives were discussed in detail with the crew and a mutually acceptable schedule was set up (Table 2). This schedule divided the allocated classroom training time into two parts, one for each half of the training year.

During the first six months of classroom instruction, the first three objectives listed above were accomplished, namely, Skylab 4 results, background information, and terminology familiarization. Experiment team members who briefed the crew were familiar with manned space missions in general and with astronaut training in particular. To assure the continuity of the briefings and to make a complete record of what the crew learned, either I or one of my staff attended the briefings.

To reinforce knowledge gained from these training sessions, a training booklet was prepared for the astronauts. This "Earth Observations Training Book" was issued for internal NASA distribution on 22 April 1975. Its contents were based on the classroom training sessions and were assembled by Robert Wolfe, Smithsonian Institution, and Ron Weitenhagen, Johnson Space Center, Houston. The booklet contained sections dealing with background information on four fields of study: geology (fault systems and drainage patterns); deserts (arid lands, sand seas, and dune types); oceanography (coastal and open ocean); and hydrology (snow cover and glaciers). In addition to the definition of terms and explanation of theories, the training booklet included numerous illustrations and orbital photographs of the Earth (Figure 14).

During the second half of the year, classroom training was dedicated to the study of specific targets.

TABLE 2.—Classroom training sessions (from El-Baz and Mitchell, 1976)

| Date | Subject | Lecturer |
|---|---|---|
| 5 Aug 74 | Plan for Earth observations and photography | El-Baz, F. |
| 16 Aug 74 | Global tectonics and astroblemes | Dietz, R. |
| 10 Oct 74 | Background, terminology, and Skylab 4 results (oceanography) | Vonder Haar, S. P. |
| 18 Oct 74 | Snow and ice | Barnes, J. C., Campbell, W. J., and Ramseier, R. O. |
| 6 Nov 74 | Southwest U. S. tectonics | Silver, L. T. |
| | Site selection procedures | El-Baz, F. |
| 15 Nov 74 | Ocean currents and eddies | Maul, G. A. |
| | Sites for observation | Stevenson, R. E., and Ewing, G. |
| 3 Dec 74 | African rift system and Central America | Muehlberger, W. R. |
| 20 Dec 74 | Deserts and sand dune patterns | McKee, E. D., and Breed, C. S. |
| 7 Jan 75 | Cloud features and tropical storms | Black, P. G. |
| 31 Jan 75 | Groundtracks and sites | El-Baz, F. |
| 5 Mar 75 | Onboard site book | El-Baz, F. |
| 18 Mar 75 | Visual observation sites | El-Baz, F. |
| 19 Mar 75 | Ocean observation tasks | Oceanography team |
| 1 Apr 75 | Groundtracks and sites | El-Baz, F. |
| 9 Apr 75 | Groundtracks and sites | El-Baz, F. |
| 20 May 75 | Review of observation tasks | El-Baz, F. |
| 2 Jun 75 | Review of observation tasks | El-Baz, F. |
| 20 Jun 75 | Review of observation tasks | El-Baz, F. |
| 8 Jul 75 | Review of observation tasks | El-Baz, F. |
| 13 Jul 75 | Review of observation tasks | El-Baz, F. |

The first three months of this period included discussion of sites by several team members. However, the crew preferred that the last three months of the training program be devoted only to briefings by the author. This made it possible for the crew to "stabilize" the terminology, and to discuss only the observation tasks that were included in the flight plan.

The first 18 sessions were held in Building 4 of the Johnson Space Center (JSC) in Houston, Texas. The 19th session was held while the crew was quarantined at JSC (Figure 15), and the final review session was conducted at the Kennedy Space Center (KSC) in Cape Canaveral, Florida, two days before launch.

The training sessions were usually attended by both the prime and backup crews. Some of the support crew members who would later serve as capsule communicators (Capcom) attended a number of the sessions, particularly the reviews of observation tasks. It was necessary to familiarize the Capcom with the experiment objectives and scientific terminology; the Capcom served as the only link between the scientists and the astronauts during the mission. One session was normally given in the morning with either the prime or the backup crew in attendance and a second was given in the afternoon for the other crew members. Each session had an average length of two and one-half to three hours.

Because of the nature of their job, the astronauts were used to briefings. They were most attentive when the briefings were rather informal and when there was an exchange of comments and questions between briefer and crew. At the beginning of the program, some crew members questioned the value of Earth observations on such a short duration mission and were skeptical of their ability to make significant con-


NILE RIVER

COLORADO RIVER


MISSISSIPPI RIVER

FIGURE 14.—Three types of river deltas. When a river flows into a standing body of water, it loses its energy by friction. The suspended material carried by the river is deposited to form a delta. The coarser material settles first in dipping layers or beds and builds the delta seaward. Finer material is carried further and deposited in thin, horizontal beds. (From the "Earth Observations Training Book")

FIGURE. 15.—The three American ASTP prime crew astronauts during an Earth observations briefing by the author (wearing face mask). They are (*left to right*) Apollo Commander Thomas P. Stafford, Command Module Pilot Vance D. Brand, and Docking Module Pilot D. K. (Deke) Slayton. The briefing was held while the astronauts were quarantined in Building 5, JSC, and thus the face mask. (NASA press release photograph S-75-28230; photo courtesy of A. R. Patnesky, JSC photographer)

tributions to satellite imagery. Thus, it was important for the briefers to explain the reasons for doing research in their fields of study and to relate how the crew could make specific contributions to this research.

A summary was prepared after each of the sessions that dealt with background information and terminology familiarization. These summaries were mailed to each of the crew within a week to serve as memory-joggers and a permanent record. They also were distributed to crew members who were not able to attend a particular session.

### SUMMARY OF INDIVIDUAL SESSIONS

The author gave the first lecture to the crew to introduce the Earth Observations and Photography

Experiment. Examples of Skylab photographs were shown to illustrate the five fields of study planned for the experiment. The lecture was followed by a discussion of an astronaut's ability to perform visual observations and photography. A plan for crew training was presented that called for about 60 hours of classroom training, in addition to at least two flyover exercises.

The second training session included a two-hour lecture on global tectonics and a one-hour lecture on astroblemes. Both were given by Dr. Robert Dietz of NOAA. The global tectonics lecture covered the theories of continental drift and plate tectonics. It was stated that the Earth's crust is made up of discrete, rigid blocks that move relative to each other and to the Earth's spin axis. The products of plate motion (transform faults, subduction zones, and sea floor spreading) were also discussed. It was stressed that the ability of the human eye to trace similar rocks, colors, and structures across different continents, and to observe rift zones from Earth orbit would further enhance the study of plate tectonics. The last hour of the session was devoted to astroblemes and meteorite craters. The discussion included many known and several possible examples of astroblemes, such as the 1.7 billion year old Sudbury structure of Canada. Dietz also noted that most known astroblemes would be visible from orbit, and that a trained observer would have an opportunity to discover unknown locations.

The topic of the third lecture was "background terminology and Skylab 4 results in oceanography." The lecture was given by Stephen VonderHaar of the University of Southern California. He first discussed examples of ocean features in Skylab 4 photographs; specifically, sediment patterns in the Gulf of California, and plankton blooms, eddies, and internal waves around New Zealand. The background and terminology briefing was divided into two segments: coastal zones and the open ocean. The discussion of coastal zones covered the topics of sediment patterns, surface waves, and types of coastlines. It was emphasized that coastal processes have a direct impact on navigation, fishing, pollution, and coastal living conditions. The phenomena of upwelling, ocean currents, and cold water eddies were explained during the discussion of the open ocean.

Snow and ice were the topics of the fourth session. Mr. James Barnes of Environmental Research and Technology, Inc., Lexington, Massachusetts, discussed the importance of snow and ice in affecting the albedo of the Earth (which influences changes in both short range weather and long range climatology) and acting as a hydrological reservoir that, when released, affects conditions of flooding, irrigation, and hydroelectric power. The synoptic view gained from Earth orbit and the astronaut's ability to distinguish clouds from snow cover would greatly aid in determining the extent of snow cover and snow melt patterns. These factors have direct impact on the knowledge of how much, when, and where water is released from snow.

Dr. William Campbell of USGS, Tacoma, Washington, briefed the crew on glaciers and icebergs (Figure 16). Using the Southern Cascades Glacier as an example, he explained how glaciers form and move, and how to distinguish glacier ice and snow from Earth orbit. He stated that a team of five scientists planned to provide groundtruth on the Southern Cascades Glacier during the ASTP mission. Data were to be collected to correlate with orbital photographs of the glacier and provide a frame of reference for distinguishing glaciers in remote areas of the world.

Dr. Campbell also covered the study of floating icebergs near the polar regions. Ice, which is the most common "rock" on Earth, is also the least used natural resource. He discussed the economics of "towing" floating icebergs from Antarctica for use as fresh water supplies. For example, an iceberg 4 × 10 km would lose 20 percent of its mass in the 7000 km long trip from Antarctica to Australia. It would cost 0.001 dollars per meter width for delivery. Sightings of large icebergs on the ASTP mission were, therefore, expected to provide much needed information on size, abundance, and distribution of tabular icebergs. Finally, Dr. René Ramseier of the Canadian Department of Environment discussed the need for photography of the ice sheet and ice pack of Antarctica, especially near the ice edge.

During the fifth training session, Dr. Leon Silver of the California Institute of Technology discussed the tectonic setting of the southwestern United States. His briefing included the major fault systems of Southern California and Baja California, as well as the geologic problem of desert varnish in the Mojave Desert. He emphasized that no "great discoveries" were expected, but that little bits of data would be integrated with current knowledge in order to augment the constructive growth of models of plate

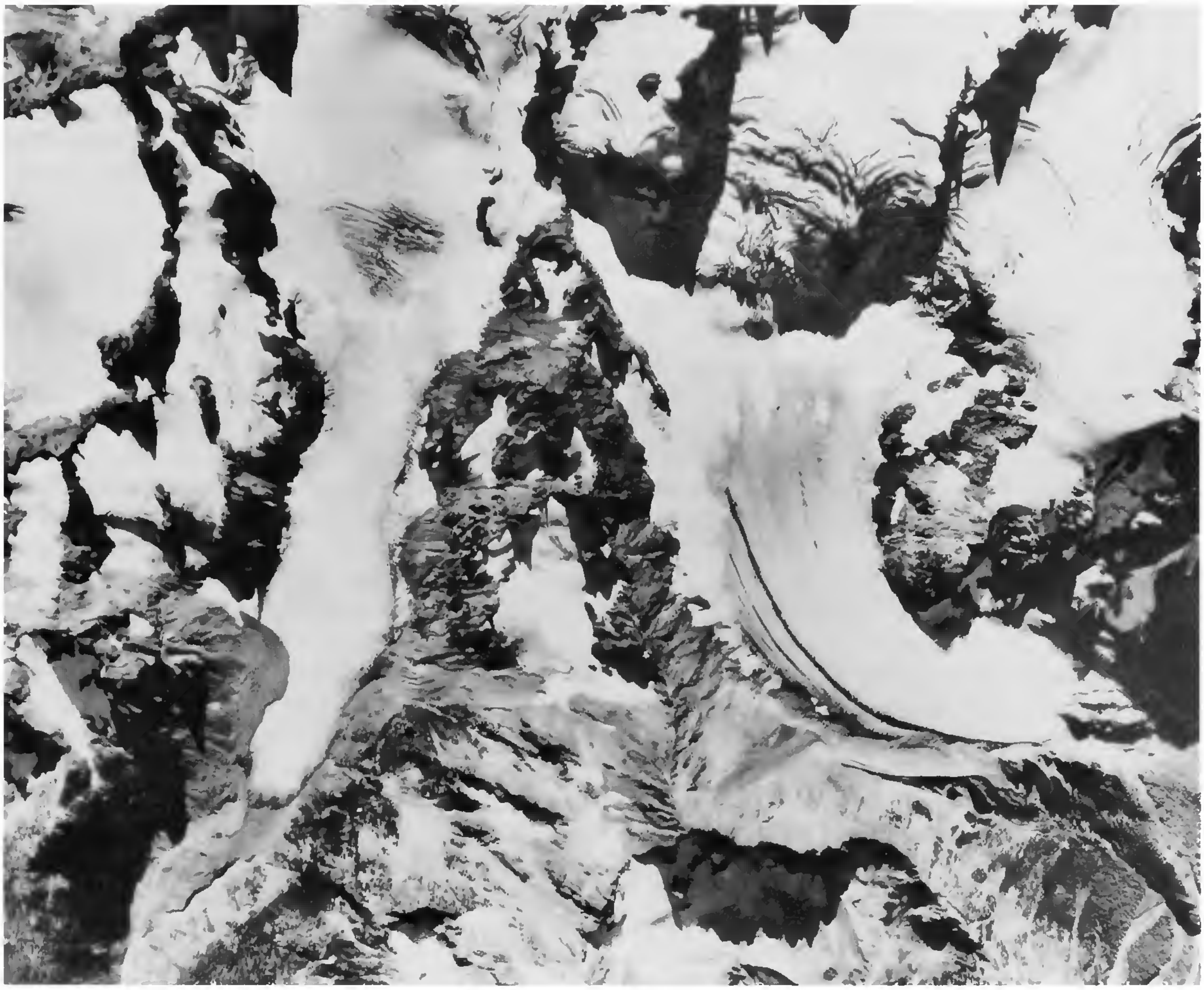


FIGURE 16.—Alpine glaciers on Mt. Olympus in Washington State. The approximate limit of firn lines is easily distinguished as a color boundary. (Photograph Washington 1–B, USGS Professional Paper 590)

tectonics. For practical applications during the training flight over California, Dr. Silver also discussed how faults may be recognized by the presence of a scarp, or by differences in color, vegetation, or rock and soil on either side of a lineament. During the remainder of the session, I discussed with the crew the rationale of site selection, the onboard orbital charts, and the problem of selecting colors for the color wheel.

Ocean currents were the topic of the second session in oceanography. Dr. George Maul of NOAA discussed the dynamics of the Gulf Stream, internal waves, the Coriolis Force, and the Pacific Equatorial Zone. Dr. Robert Stevenson of the Office of Naval Research's Scripps Institute briefed the crew on the significance of sun glitter or sunglint and the utility of water color in recognizing boundaries in the ocean. He discussed using sediment, plankton, and ice as current tracers; and distinguishing clouds that form around cold water eddies from Bénard cells. For the purpose of ocean observations during training flights, Dr. Stevenson also discussed the interactions of ocean currents along the coast of Southern California.

The seventh training session, given by Dr. William Muehlberger of the University of Texas at Austin, covered the tectonic setting of two areas: the African

Rift zone and the fracture systems of Central America. East Africa is significant to the theory of plate tectonics in that it is one of two places in the world where rifting can be observed on land. His detailed discussion of this area included the down-dropped, lake-filled valleys of the southern zone; the Afar Triangle, which is an area of spreading and crustal buildup in three directions; the sense of movement of the Arabian subplate; and the extension of the Red Sea Rift north of the Sea of Galilee. Central America represents a complex tectonic setting, which, as Dr. Muehlberger discussed, includes the line of volcanoes that parallel the offshore trench along the Pacific coast; the north-south valley on the Istmo de Tehuantepec, and the east-west trending line of volcanoes west of that valley; and the Bartlett Fault running from the east end of Cuba across the Caribbean Sea and through Guatemala.

Deserts and sand dunes were the topics of the eighth training session. Dr. Edwin McKee of the USGS in Denver, Colorado, discussed the processes of dune formation and the resulting internal structure of dunes. Carol Breed of the Museum of Northern Arizona, now with the USGS, briefed the crew on the geographical locations of world deserts and on a classification scheme of dune types based on the number of slip faces. Observations during the ASTP mission were to include changes in type, size, spacing, and color of dunes within dune fields, character of interdune areas, any barriers such as lakes or mountains, and color comparison between individual deserts.

The final session of the general background and terminology series was on meteorology. Dr. Peter Black of the Pennsylvania State University (now with NOAA) briefed the crew on the structure of hurricanes and tropical storms, and the requirement to obtain photographs of scientific value. The need for stereophotography was emphasized for the purpose of viewing features in three dimensions. The ability to map the topography of a storm would allow meteorologists to improve theories and build better computer models of how storms form and dissipate.

Because the short duration of the ASTP mission meant a limited number of passes over each site, the remaining eleven sessions were used to train the crew members on how to recognize the sites on first approach. This was accomplished by careful review of the groundtracks and through use of maps and displays of previously obtained photographs of these sites. During the first three sessions I discussed the groundtracks, the selected sites, and the "Earth Observations Book" (Appendix 3). During the fourth session, Drs. Maul and Stevenson joined in discussing the ocean observation tasks with the crew. Alex Maelenhoff of the Office of Naval Research, Scripps Institute, was also present and reviewed the broad aspects of plate tectonics and emphasized the need for photography of the Himalayan and Atlas mountain ranges.

The remaining seven sessions were devoted to reviews of observation tasks. During most of these sessions, the crew was divided into three groups—Apollo commanders (AC), command module pilots (CP), and docking module pilots (DP)—to allow discussion of individual tasks. These review sessions recapitulated the specific observation requirements, elucidated the language of questions in the "Earth Observations Book" that was to be carried onboard the spacecraft, and increased the astronauts' knowledge of the sites and their surroundings.

The ASTP classroom training program was very successful. Its scope satisfied both the crew and Principal Investigator. At the end of the training program it was possible for any crew member to discuss all the important questions relative to a site assigned to him without referring to any of the onboard aids. This made it easier for the astronauts to perform their tasks during the mission when there was little time to read the instructions or to check the maps.

## Ground Motion Simulations

Every astronaut who has orbited the Earth has always been amazed by the speed at which the scenery goes by. They are amazed regardless of how much training they receive and how many postmission crew debriefings they attend. We attempted to prepare the Apollo-Soyuz crew by making films of the Earth's surface to simulate the exact motion of ground scenes on their flight. This was done in cooperation with Mr. John Massey, Concept Verification and Test of the Special Projects Office, George C. Marshall Space Flight Center, Huntsville, Alabama. The films simulated the appearance of the Earth from orbit, using as a base either photographs or maps, with the approximate velocities and viewing angles of seven ASTP orbital revolutions. The 16 mm films were shipped to Houston, but unfortunately, the crew never did get to review or use them due to lack of time. These films might have proved useful to the crew, particulary since during the flight, they had difficulty recognizing some targets due to the ASTP's low (fast) orbit.

## Training Flights

The most realistic simulation training is from high-speed, high-altitude aircraft. Astronauts have access to such aircraft and use them in connection with other aspects of their pre-mission training to round out their total training effort.

Aircraft training flights, known simply as "flyovers," are the best way of providing an astronaut with experience in making meaningful observations. During the Apollo program, astronaut training for visual observations from lunar orbit included a few flyover exercises in both low-flying and high-altitude aircraft. These were undertaken by the command module pilots, particularly of the last three Apollo missions (El-Baz and Worden, 1972; Mattingly, El-Baz, and Laidley, 1972; Evans and El-Baz, 1973). The flyovers significantly increased both the knowledge of the astronauts and their confidence in their own abilities as "scientific observers."

The task of performing Earth observations on Skylab 4 was accomplished without the benefit of flyover exercises. This was because the observations program was implemented only a short period before the mission and, thus, the Skylab astronauts received only classroom training. However, self-taught, on-the-job training was accomplished during the first two or three weeks of the 84 day mission.

A program of training flights was established mid-

TABLE 3.—Flyover exercises (see Table 5 for explanation of site numbers) (from El-Baz and Mitchell, 1976)

| Flyover | Observation targets |
|---|---|
| Houston to Los Angeles | Texas coastal plain<br>Karst topography<br>Basin and range topography<br>Volcanic features<br>Sonora and Mohave deserts (site 2A)<br>San Andreas Fault system (site 2A) |
| California | San Andreas Fault (site 2A)<br>Garlock Fault (site 2A)<br>Desert varnished hills (site 2A)<br>Sand dunes in the Algodones Desert<br>Ocean features in waters off California (site 2A) |
| Gulf Coast | Coastal sediments<br>Mississippi River Delta<br>Gulf Loop Current (site 5A)<br>Red tide off the western coast of Florida (site 5E) |
| Florida | Gulf Stream (site 5B)<br>Red tide (site 5E) |
| East Coast | Gulf Stream (site 5B)<br>Sediment and pollution in Chesapeake Bay (site 5G)<br>Internal waves<br>Sand dunes on Cape Cod<br>Red tide off Massachusetts and Maine (site 5F) |
| Southwestern United States | Dune patterns at White Sands and Great Sand Dunes National Monuments<br>Circular structures in the San Juan Mountains<br>Copper mines |
| Northwestern United States | Fault systems in northern California (site 2A)<br>Metamorphic foothills of the Sierra Nevadas (site 2A)<br>Snow-covered peaks in Washington (site 4A)<br>Blue Glacier and Southern Cascades Glacier<br>Sediments in Puget Sound |

way in the ASTP crew training cycle. The program aimed at giving the crew practical experience in target recognition and photographic site selection; allowing the astronauts to practice describing and interpreting observed features and phenomena; familiarizing the crew with the types of features that they would be expected to observe from orbit; and allowing the astronauts to practice utilizing flight books, cameras, lenses, and other observation aids that they would use in the spacecraft.

Planning flyovers for the Apollo-Soyuz astronauts involved a number of steps, including (1) selection of a suitable locality and identification of sites for specific observations; (2) preparation of a flight manual (Appendix 2) that included the flight plan and the questions to be answered during the flight; (3) briefing the astronauts by experts on the selected locality, a task that was usually accomplished as part of the classroom instruction; (4) performing the flight over the preselected sites in high-flying jets piloted by the astronauts themselves or their crewmates; (5) debriefing the astronauts following the flight to elucidate the highlights of the exercise; (6) repeating the flyovers if necessary with some modifications and additions to the objectives.

The concept and format of the flyover exercises for the ASTP crew were based on those conducted during the Apollo lunar program, with improvements and changes where necessary. Table 3 lists all flyover exercises prepared for and performed by the ASTP crew. Due to difficulty in scheduling and lack of funds, no low-altitude (2000 m) flights (where both astronauts and teacher could observe together) were conducted during the ASTP training program.

## Designing the Flyovers

All flyover exercises of the ASTP crew were designed for T–38 aircraft (Figure 17) flying at an altitude of about 12.5 km (41,000 ft.). However, the astronauts occasionally flew their aircraft at 8 km (26,000 ft.) to simulate the apparent terrain speed as would be seen from the ASTP orbit. Each flyover exercise consisted of one to four "legs" or flights. A flight leg involved one to one and one-half hours of flight time, and about one hour of ground time for refueling and take off. Thus, a maximum of four legs could be made during the daylight hours of one day. The optimum length of each leg was 1100 to 1300 km (600–700 nautical miles). On a flight leg 1480 km long (800 nautical miles) little fuel was left in reserve. A distance of approximately 185 km (100 nautical miles) was required to climb up to and down from cruising altitude. Cruising speed was approximately 1000 km per hour (about 500 knots).

Flight routes were planned using the Enroute High Altitude U.S. maps, which are available as U.S. government flight information publications. The routes ran in a straight line from one VORTAC to another (a VORTAC is a VHF/UHF radio aid to navigation) and restricted areas were avoided where possible. Long straight lines were much easier to navigate and consumed less fuel than zigzag flight lines. It was preferable to land and refuel at military bases rather than commercial airports since service and maintenance for the aircraft were more readily available at government facilities.

Two approaches were used in designing the flyover exercises. In the first approach, visual observation sites were chosen along flight routes frequently traveled by the crews, such as the route from JSC, Houston, to KSC, Florida. The second approach was used where specific features such as sand dunes or ocean currents were to be studied. In this approach it was necessary to determine what area of the country and what flight lines would best suit the observation of the selected feature. The selection of observation sites for any given flight was based on what the crew had learned from classroom training, what types of observations were required during the ASTP mission, and what could be seen from the aircraft altitude.

Aids that were most useful for terrain familiarization included the Landsat mosaic of the United States at 1:1,000,000 scale, international maps of the United States at 1:1,000,000 scale (supplied by USGS), physiographic maps of individual states (from USGS), operational navigation charts from the Defense Mapping Agency at 1:1,000,000 scale, geological maps from USGS, Skylab photographs, selected aerial photographs of geological features in the United States (USGS, 1968).

Due to the variable nature of ocean features, maps were of little use. The prime source of information concerning ocean observation sites were the oceanographers of the experiment team. The following references also provided much useful information: Shepard and Wanless (1971) on ocean sites; Norris and Norris (1961) and Norris (1966) for the California land flyover; Pirie and Steller (1974) concern-


FIGURE 17.—The T–38 jet aircraft that were used by the Apollo-Soyuz crew for the training flight exercises (flyovers). (NASA photograph S–72–41386)

ing the California ocean flyover; White (1958) for the Florida flyover; and Rocky Mountain Association of Geologists (RMAG, 1972) and McKee (1966) concerning the Southwestern United States flyover.

Once the location of possible observation sites was determined, the process of establishing flight lines (if not already predetermined) began. Two factors influenced the decisions. First, for optimum viewing, observation sites were selected several kilometers on either side of the subvehicle point, because of difficulty in seeing straight down from a T–38 aircraft. (One crew member turned the aircraft upside down to better see and photograph some snow-covered peaks below him, Figure 18). Second, observation sites were evenly and widely spaced. Generally, one site between two VORTACs allowed enough time for acquiring and describing any feature.

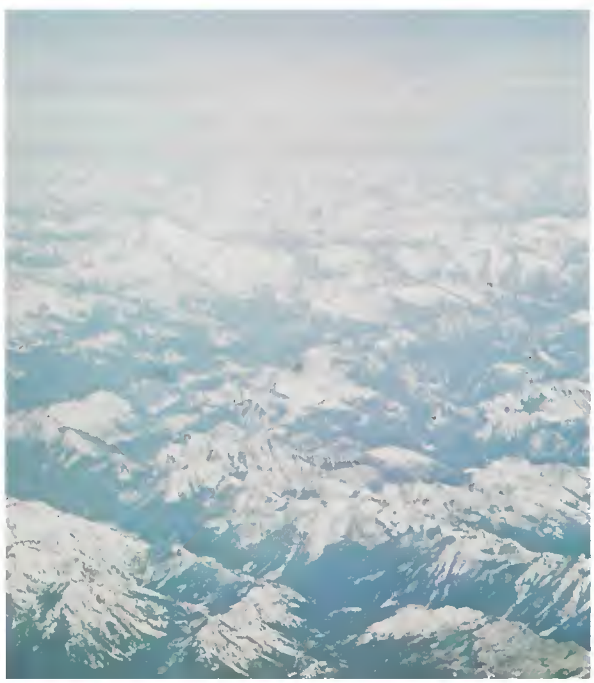


FIGURE 18.—Photograph of the Cascade Range taken by astronaut R. E. Evans during the Northwestern U.S. flyover. Evans turned his T–38 aircraft upside down (Figure 17) to observe and photograph these snow-covered peaks.

After flight lines had been finalized and sites selected, the questions for each site were prepared. Close contact with the experiment team members allowed selection of questions to be as similar as possible to those that would be prepared for ASTP observation targets.

### Preparing the Flyover Booklets

For each flyover exercise a booklet outlining specific tasks was prepared (Appendix 2). These flyover booklets contained photographs, maps, sketches and procedures to guide the crew in observing each site. No booklets were larger than 21 × 28 cm (8½ × 11 in) in size with pages mounted on hardboard to facilitate easy handling in the cockpit. The first page usually showed a physiographic map or a sketch of the entire route of the flyover.

The first page of the booklet provided a summary of each leg of the flight including the end points, distances covered, and features to be observed. If photography was planned during the exercises, the second page contained a table of camera settings, film type, lens, time of day, and types of features to be photographed. This information was obtained from the Photographic Technology Laboratory at JSC, Houston. Occasionally an additional reference page was included giving scientific terms that might be helpful during the exercise.

The remainder of each flyover booklet was divided into sections corresponding to each leg of the flight. The first page consisted of a summary map of the flight route with the location of the VORTACs and the features to be observed. The map was usually oriented in the general direction of the flight. The succeeding part comprised the actual "site" pages. Each page included a sketch and/or photograph of the area to be observed, and the questions to be answered. (All questions were typed in large boldface type for easy reading). Usually an individual page covered a segment of the flight between two VORTACs. This allowed the crew to make the necessary "pilot conversations" at each VORTAC center while turning the page in order to begin observing the next site.

Sketches of the coastline were usually used for ocean routes, and polaroid photographs, mostly of Landsat imagery, were used for land flights. Smaller scale photographs or sketches of specific observation sites were sometimes used to supplement the regional views; the VORTACs were plotted on the regional view for reference. The scales in kilometers and the north arrow were plotted near all sketches or photographs.

These flyover booklets were prepared with such detail that they could be used by an astronaut, or anyone else for that matter, without prior experience. These booklets are reproduced in Appendix 2 to serve as a guide in training the Shuttle astronauts. They may be used in conjunction with the only available book on Earth observations from an airplane, that by Wood (1975).

### Briefing and Debriefing the Crew

The astronauts were briefed for about an hour prior to each flyover. The briefings included a discussion of the general geologic and/or oceanographic setting, and the details of the flight route and the observation sites. Briefing aids included maps, Landsat images, and Skylab and aerial photographs, many of which were reproduced in the flyover booklets.

Before flying, the crew members had to file a flight plan which included points of take-off and landing, time of take-off, distances covered, and overflown VORTACs. This could be done shortly before the flyover exercise. In some cases, however, special permission had to be granted for flying over restricted areas and for using landing fields during off hours. These arrangements were best made a few days before the flight. Last minute preparations included checking the batteries on the Sony tape recorders used to record voice descriptions, the color wheel, if needed, and the camera, lenses, and film if photography was planned.

The debriefing, which took place immediately to several days after the flyover, allowed the crew and the author to convey their impressions and to criticize and comment on the operation. Tape cartridges were returned to the Principal Investigator for evaluation and transcription, if necessary. Film was sent to JSC's photolab for development and subsequently returned to the author for evaluation and cataloging.

### Description and Results of Training Exercises

#### *Houston to Los Angeles Flyover*

This exercise served as a study of the different types of terrain between Houston and Los Angeles.

The flyover booklet contained four maps of the Southwestern United States: (1) a geographic map; (2) a tectonic map showing the major escarpments and faults; (3) a physiographic province map showing the major plains, plateaus, and mountain ranges; and (4) a geologic province map that emphasized volcanic and intrusive units. The choice of which map to use was left up to the individual crew member.

The flight route, plotted on each map, was divided into four segments. The major features were labeled on each segment with a short description printed beneath. The Houston to Austin segment contained the Coastal Plain. The Austin to El Paso segment included the Balcones Escarpment, Llano Uplift, Edwards Plateau, Central Basin Platform, and Diablo Platform. The El Paso to Blythe segment covered the basin and range province including many volcanic areas. The Blythe to Los Angeles segment included the Sonora and Mojave deserts, the San Andreas Fault system and the peninsular ranges.

This first package was sent to the crew at the beginning of November 1974. Since no specific observations were requested, there was no feedback from the crew about the flyover.

### *California Flyover*

The California flyover consisted of two legs: a land route, which was usually overflown in the morning, and an ocean route, which was normally covered in the afternoon. Both legs originated and terminated at the Los Angeles airport.

The land leg involved a study of faults, rock types, and sand dunes. The flight path covered most of southern California, from the San Joaquin Valley to the Imperial Valley and from the Pacific coast to the Arizona border. Five segments of observations were as follows: (1) Santa Barbara to Bakersfield included east-west trending valleys along the San Andreas Fault (North); (2) Bakersfield to Palmdale included the intersection of the Garlock and San Andreas faults; (3) Palmdale to Twenty Nine Palms included the San Andreas Fault (South) and its intersection with the San Jacinto Fault; (4) Twenty Nine Palms to Blyth included four desert-varnished hills; and (5) Yuma to Imperial to Thermal included sand dunes in the Algodones Desert.

The ocean leg involved a study of currents, internal waves, gyres, eddies, sedimentation patterns, upwellings, island wakes, and refraction patterns. Also included were sites of sand dunes and faults. The ocean flight path covered Pacific Ocean waters from Pt. Conception to San Diego, over 350 km to the south. Santa Catalina Island and the Channel Islands (San Miguel, Santa Rosa, and Santa Cruz) were also overflown. The 10 observation sites were as follows: (1) San Diego Bay, (2) the coastal current between San Diego and Oceanside, (3) Dana Point, (4) Santa Monica Bay, (5) Santa Barbara Channel, (6) offshore currents off Pt. Conception, (7) textures of San Miguel Island, (8) Channel Islands, (9) Santa Catalina Island, and (10) fault scarps between Oceanside and Thermal. This was the first full-fledged flyover complete with a preflight briefing and a postflight debriefing given by Dr. Leon Silver and the Principal Investigator.

The prime crew and one member of the backup crew (Capt. Alan Bean) flew the California flyover during the period of clear weather on 22–24 November 1974. On the first day Vance Brand and Alan Bean ran low on fuel and had to land short of Los Angeles in Ontario, California. The first route was subsequently revised and shortened. The remaining flyovers went smoothly, although several procedural problems were revealed. The main problem was the crew's difficulty in orienting themselves and locating observation sites. It was solved in part by improving the flyover booklets. Several sketches, maps and photographs were added to provide regional views of each site. All illustrations were oriented parallel to the flight lines, and a scale and north arrow were also added to each page.

Another problem concerned the question of whether two crew members should fly in one aircraft. When a crew member flew alone, he would have to fly the aircraft, handle radio communications, and make visual observations. If two flew together, one could handle the operation of the aircraft including radio communications while the other could devote his attention to visual observations. However, this meant that the pilot would have to fly some other time in order to make his own observations, which was done in several cases.

In spite of the various problems, the crew's response to this flyover was enthusiastic. Although the astronauts had flown over southern California many times before, they expressed surprise at how many interesting features they were able to see when they looked for them. After the flyover, there was a marked increase in their active participation during the classroom training sessions.

A study of the crew's taped comments on this flyover revealed that they needed further practice in making visual observations. The two primary criticisms were that some specific questions were not answered (instead, there were discussions of related or even unrelated topics); and that many comments could have been more precise, especially with the proper use of terminology.

In spite of these criticisms, the crew members made many astute observations; for example, recognition of subtle faults, description of the local mountain ranges and valleys, and discussion of how these physiographic features fit in with the regional geology. Stafford made the following comments in answer to the first question: "Where do the eastward trending valleys (between Santa Barbara and Bakersfield) terminate?"

> The hills on the river, the Ventura River, those hills that run east and west totally stop, possibly truncated by a fault that runs 90 degrees into the Ventura River. These east-west lineations do stop right in that area about 20 to 30 miles east of Ventura where you have the east to north-south lineations. The ridges of these mountains run all the way right to the point on the Pacific Ocean, then kind of dip in right at the point and disappear. In fact, from here, the whole thing tends to dip at that point. Again those are east-west ridges, and you can see upthrusting and fault lines parallel to the ridge itself. Something like the back of an ancient dinosaur!

Through observations of land features, the crew members learned the importance of sun angle illumination. High sun angles were best for observing variations in color while low sun angles were required for observing topographically related features such as fault scarps and sand dunes. Even the direction of viewing with respect to the sun was important. For example, the following description of sand dunes in the Algodones Desert (Figure 19) was made by Capt. Alan Bean while flying toward the southeast:

> The dunes were mainly more in the center of the Algodones section. . . It sort of looks like the dunes on the north side are rather linear, in the center they have that rather pock-marked appearance. Almost giving the impression that 1000 bombs have fallen down there or something. I cannot from this direction really say that they are star dunes, though.

Compare this with the description that he himself later gave when flying toward the north:

> We have a much better viewing situation for the dunes. You see the shadows with the sun coming from the east making the dunes show up nicely. And on top of the major swells, especially, I see the barchan type dunes. The north to south ridges on the southwest side show up very well.

The crew also learned how important sun angle and sunglint were in observing ocean features. When flying in one direction an astronaut would see nothing on the ocean surface; but while flying in another direction he would be able to discern surface textures and ocean features through the use of sunglint (the sun's reflection or "glitter" off the water's surface). The crew reported seeing a variety of features in sunglint, including: boat tracks, wave refraction patterns, current boundaries, island wakes, and gyres. Following is a discussion of a phenomenon seen in sunglint in the area between Santa Barbara and Pt. Conception:

> BEAN: Yeah, look at those little kind of blobs out there. There is one out there that could be upwellings or something. It is a completely different color water and it does not appear to be any reason it should be. A localized patch. Maybe that has oil on it or something.
>
> BRAND: It is kind of sparkling. A little bit as if it is a sparkling of a flock of ten million birds on the water.
>
> BEAN: Maybe a spill, may be oil or a spill that is giving us a lot of reflection per amount of light that hits it.

A few minutes later the same phenomenon was observed out of sunglint:

> BRAND: Hey, look at the color change now. Hey, those look like oil spills.
>
> BEAN: Yeah, look at that. You bet, I'll bet they are. A pollution of some sort in the water.
>
> BRAND: The same thing that we saw that was shimmering, now we see out of sunglint, and it is a light-colored blob sort of, could be oil spills.
>
> BEAN: I bet they are. They just have the kind of edges and the color. It is not too far fetched for the sheen you see, that is kind of pearl gray, more fluorescent color to it.

Although there were no sediments from the rivers with which to trace ocean currents, two of the crew members observed patches and streaks of reddish brown discolorations, which hugged the coastline from San Diego to north of Los Angeles. The crew members later identified this phenomenon as red tide when they were shown examples of red tide, sediment, and kelp in low-altitude photographs.

An excellent example of the observer's ability to

FIGURE 19.—Apollo 9 color infrared photograph of the Algodones dunes east of the Imperial Valley in California. These dunes were described by astronaut Alan Bean on the California flyover. (NASA photograph AS9–26A–3799A)

discern unfamiliar features occurred during the ocean route on the California flyover. From the air, San Miguel Island is characterized by a series of alternating light and dark colored stripes which run in a northwest to southeast direction. The light colored stripes are actually linear sand dunes (Figure 20). Without having seen the island before, and not being told what the features were, the crew were asked to observe, describe, identify, and interpret these features. The following is the ensuing discussion between Vance Brand and Alan Bean:

BRAND: Oh, yeah, on San Miguel? Horizontal stripes. What were those?

BEAN: We do not know. They just wanted us to observe and see what we thought and describe them and then make an observation—whatever it says there.

BRAND: Okay, I was out of the room when you talked about that. Okay, they look like different color rocks. Sand-colored compared to dark brown. Finger-like, they seem to be oriented all in one direction.

BEAN: All along the fault lines perhaps. Maybe those are exposures of the faults that run, which would look like, into the west of the rest of the island.

BRAND: The way they are oriented, I wonder—they look like a glacier, something scrubbed across there. Yeah. And they gouge the island in one direction, leaving. . . . Could it be vegetation patterns? It does not quite look like it, does it? Wind could govern vegetation patterns on that island.

BEAN: Maybe. I'll tell you what it could be. We could be looking up the valleys and beach sand is being blown down the valleys and not on tops of the mountains.

BRAND: Looks like we have a tremendous prevailing wind in the same direction as those cuts. That is one good observation site, I think. Could it be sand that is streaking all the way across the island in that direction?

On 24 January 1975, the backup crew flew the California flyover. Recorded observations were received and transcribed from all three crew members for the ocean flight and from Jack Lousma for the land flight. This flyover went more smoothly than the first one as a result of the prime crew's experiences, and improvements later made to the flyover booklets. The observations made were similar to those of the first flyover, although the crew also observed occurrences of kelp, red tide, and sediments. They were able to

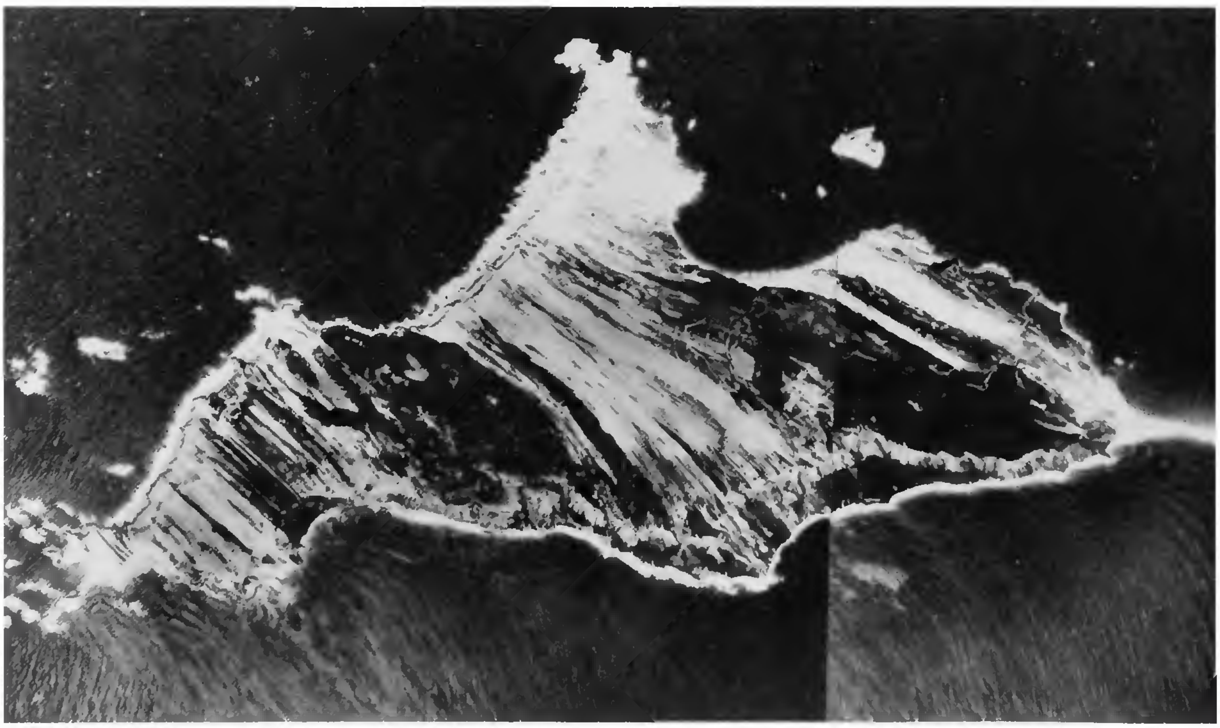


FIGURE 20.—San Miguel Island as observed by Vance Brand and Alan Bean on the California flyover. Note the series of alternating light- and dark-colored stripes running in a northwest to southeast direction. These stripes are linear sand dunes. (Photograph California 35, USGS Professional Paper 590)

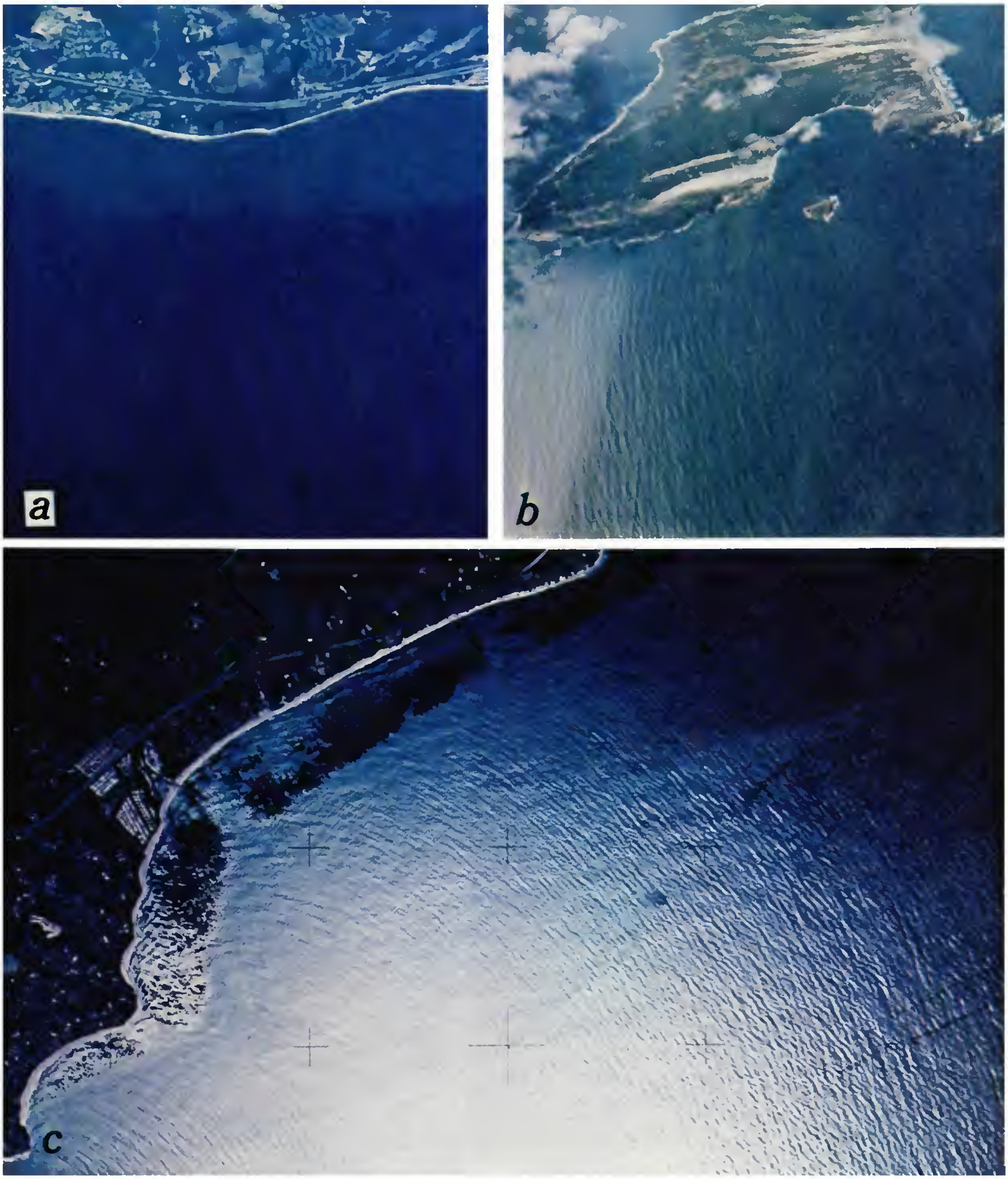



FIGURE 21.—Photograph taken by the Apollo astronauts Stafford and Slayton during flyover exercises of ocean features: *a*, sediment plumes along the southern California coast; *b*, textured water in the vicinity of San Miguel Island; *c*, kelp beds and textured water along the southern California coast.


FIGURE 22.—Photographs taken by Slayton and Stafford: *a*, the Mojave Desert, with a dark-colored lava flow at the right; *b*, scarp of the San Andreas Fault near its probable junction with the San Jacinto Fault; *c*, the complex texture of the Algodones dunes east of Imperial Valley California.

use sediment and red tide to trace gyres and learned to look for textural changes in sunglint and color changes out of sunglint.

On 15 March 1975, Tom Stafford and Deke Slayton repeated the California flyover, recording their visual observations and taking a total of some 200 photographs. Examples of these photographs are shown in Figures 21 and 22.

### *Gulf Coast Flyover*

This training flight came about as a result of the crew's frequent trips to KSC in Florida. The route followed a nearly straight line from Ellington Air Force Base near Houston to Patrick Air Force Base in Cape Canaveral, Florida. It included overflying Leeville, Louisiana, the tip of the Mississippi delta, Covia reporting point (27°56'N, 84°44'W) in the Gulf of Mexico, and St. Petersburg and Tampa, Florida.

The observation sites between Ellington AFB and Leeville included (1) High Island, which is an oil-producing salt dome, (2) coastal sediments and aggrading beach ridges between Sabine Lake and Vermillion Bay, and (3) offshore oyster reefs from Marsh Island to Atchafalaya Bay. The section between Leeville and Covia included observations of the (4) modern Mississippi River Delta and (5) a large eddy spun off from the Gulf Loop Current. The segment between Covia and St. Petersburg involved (6) an offshore shoal area, (7) red tide along the west coast of Florida, and (8) sediments in the Tampa Bay area. The final observation sites, between St. Petersburg and Patrick AFB, were over (9) central Florida and involved studying the texture of the terrain and the alignment of lakes.

The Gulf Coast flyover was also combined with the Gulf-Florida or East Coast flyovers. In these cases a more simplified version did include (1) coastal sediments, (2) the Mississippi River Delta, (3) ocean current boundaries due to a large eddy, (4) Tampa Bay, and (5) central Florida.

The first version of the Gulf Coast flyover was completed in early December 1974. The crew usually took the booklets along with them whenever they flew this route. They studied the questions carefully although they did not initially record their observations. Recorded observations and photographs of this route were received during the Gulf-Florida flyover.

### *Gulf-Florida Flyover*

This flyover combined the Gulf Coast overflight and a U-shaped flight path around the Florida peninsula. The Florida loop began at Patrick AFB on Cape Canaveral, proceeded south to the Bimini Islands, west to Key West, and north to MacDill Air Force Base near St. Petersburg. A simplified version of the Gulf Coast flyover was used for sites between Ellington AFB and Patrick AFB. The sites along the Florida flight route involved observation of (1) the Gulf Stream off the east and southern coast of Florida, (2) algae blooms in Florida Bay, (3) turbulence patterns in the Keys, and (4) red tide along the west coast of Florida. The Gulf-Florida exercise was undertaken by Vance Brand on 1 March, Deke Slayton on 8 March, and the backup crew on 31 March 1975. Photography including a roll of IR film and tapes were received from Vance Brand and Deke Slayton.

Along the Texas-Louisiana coast, sediment plumes were observed especially in the vicinity of Sabine Lake. The width of the sediment band along the coast between Galveston and the Mississippi River Delta appeared to be related to wind direction. During one flyover a wide sediment pattern was observed with the wind coming from the north. A week later, a narrow band of sediment was observed with the wind coming from the southwest. Sharply defined sediment boundaries in the vicinity of the Mississippi River Delta delineated three gradations of water; very muddy, less muddy, and very clear (Figure 23).

No evidence of current boundaries off the Gulf Coast was seen on the first leg. However, on the return trip (third leg), one crew member observed two north-south trending boundaries about 16 to 24 kilometers apart with marked changes in the water color. Another crew member observed a long discontinuity characterized by offset bands of color which he (Brand) described as "a lighter blue track that zigzags like a lightning flash."

On the second leg, the crew members found that the best method for observing the Gulf Stream was through the use of clouds, which marked the warmer waters of this current (Figure 24). Changes in texture were reported when the sun angle was favorable. Color changes were observed but it was difficult to ascertain whether these changes were due to changes in water depth or to the boundary of the Gulf Stream.

Over the Florida Bay, crew members observed both dark and light green patches of water; however, they

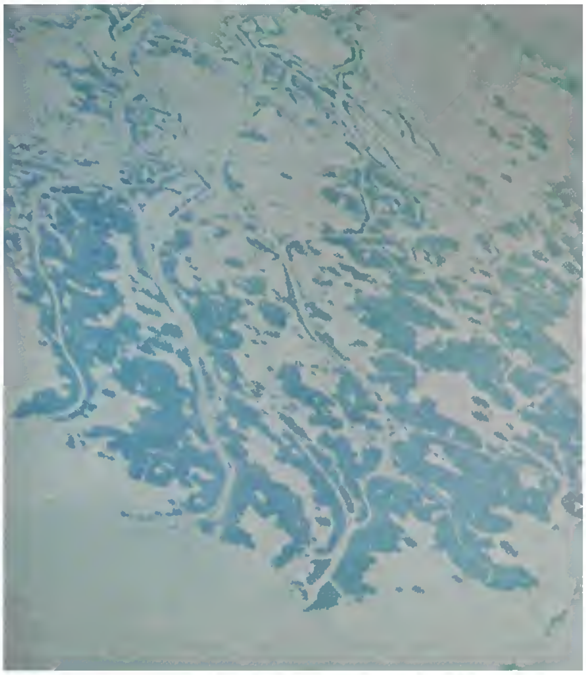


FIGURE 23.—Photograph taken by astronaut Vance Brand on the Gulf-Florida flyover showing the sediment laden waters of the Mississippi River Delta.

FIGURE 24.—Sediment plumes in the Gulf Loop Current of the Gulf of Mexico. These plumes probably originate from the Mississippi River (Photograph by Vance D. Brand)

could not determine if the changes in coloration were due to algae blooms or bottom topography. The turbulence patterns through the north-south elongated Florida Keys were described as looking like "meandering flow patterns" and "shallow channels in a flooded area." The direction of sediment flow was dependent on the tide; while one crew member observed sediment on the north or bay side of the Keys and clean water on the south, or oceanside, another observed a sediment plume entering the ocean (Figure 25).

No red tide was observed off the west coast of Florida. However, sediment plumes were observed in the Naples-Fort Meyers area and in Tampa Bay. One crew member observed that the sediments in Tampa Bay were aligned in the direction of the wind as indicated by the direction of smoke plumes.

### *East Coast Flyover*

This exercise followed the Gulf Coast route to Patrick AFB in Florida and then north along the East coast of the United States as far as Boothbay Harbor, Maine.

The first leg of the route was the simplified version of the Gulf Coast flyover (p. 37) and the first leg of the Gulf-Florida flyover. The second leg followed a route from Patrick AFB to Dover, Delaware, passing over Wilmington, North Carolina, and Norfolk, Virginia. Observation sites on this leg included (1) the Gulf Stream and (2) a large eddy between Patrick AFB and Wilmington, (3 and 4) sediment patterns around Cape Hatteras, and (5 and 6) sediment and pollution plumes in the Potomac River and Chesapeake Bay, the latter being one of the observation sites of the ASTP mission.

The third leg involved a route from Dover north to Suffolk, Long Island, then northeast to Nantucket Island, north to Boothbay Harbor, Maine, and a loop south to land at Pease AFB in New Hampshire. The sites included observations of (1) pollution in New York Harbor, (2 and 3) internal waves in ocean waters between Dover and Nantucket Island, (4) sediment patterns in Pleasant Bay, Cape Cod, (5) sand dunes on northern Cape Cod, (6) pollution in Boston Har-

FIGURE 25.—Florida Keys on the Gulf-Florida flyover taken by D. K. Slayton.

bor area, (7) Atlantic water color, and (8) the glacial coastline near Boothbay Harbor, Maine.

The fourth leg followed the third leg in reverse and terminated at Andrews AFB in Washington, D.C. On 12 April, Deke Slayton completed the East Coast flyover. No visual observations were recorded but a number of photographs were taken over the New England coast (Figure 26).

### *Southwestern United States Flyover*

This flyover exercise was designed primarily for observations of sand dunes and mining activities. It consisted of three legs following routes from Biggs AFB near El Paso, Texas, to Buckley AFB near Denver, Colorado, to Williams AFB near Phoenix, Arizona, to Los Angeles airport in California.

The route of the first leg made a loop east, north, and then west to Truth or Consequences, New Mexico, and then followed a northeasterly path over Albuquerque, New Mexico, and Alamosa, Colorado, ending at Buckley AFB. Observation sites included (1) dunes at White Sands National Monument, New Mexico, (2) the Nacimiento Fault, (3) volcanics in the Los Alamos area, and (4) dunes at Great Sand Dunes National Monument, Colorado.

FIGURE 26.—Views of the Cape Cod area taken on the New England flyover and showing the green-tinted waters: *a*, central part of Cape Cod, Cape Cod Bay, and Barnstable; *b*, northern tip of Cape Cod, Provincetown. (Courtesy of D. K. Slayton)

The second leg originated at Buckley AFB and terminated at Williams AFB to the southwest. Observation sites were as follows: (1) Fossil Ridge, a triangle of sedimentary rock near Gunnison; (2) circular structures in the San Juan Mountains; (3–5) sand dunes on Comb Ridge, the Kaibito Plateau, and the Moenkopi Plateau in Arizona; (6) linear features on the Coconino Plateau; and (7) copper mining at the Big Bug Mountains near Prescott, Arizona.

The third leg followed a zigzag route between Williams AFB and Los Angeles. The observations included a study of (1–4) copper mining at Little Dragoon Mountains, Bisbee, Sierrita Mountains, and Ajo, (5) sand dunes in the Gran Desierto just south of the U.S./Mexican border, and (6) Indian intaglios, human and animal figures 30 to 50 meters in length scratched in the sand near Blythe, California.

During 12–15 June 1975, the prime crew and Capt. Alan Bean flew the Southwestern United States flyover. Tapes were received from the prime crew although Stafford's turned out to be blank. Vance Brand and Deke Slayton took photographs but Slayton's pictures were never received by the Principal Investigator.

On the first leg, large parabolic dunes and smaller crescentic dunes were reported in different parts of the White Sands region. The Nacimiento Fault was distinguished by a line of upturned blocks along the edge of the volcanic field, and by a stream that followed the fault and drained into the Rio Grande. The concentric and radiating features and individual flows of the Los Alamos volcanic field were difficult to observe because of vegetation; in fact one crew member did not realize that the area was a volcanic field.

Dune forms and patterns in the Great Sand Dunes National Monument were also observed; Vance Brand described these features as "crescentic dunes. . . . Waves of them overlapping on each other. Aligned crests generally NW–SE direction. Big and small, typical crescentic dunes."

Deke Slayton described the dunes in the following manner: "Call those crescent dunes, maybe star dunes on the southeast side. Farther to the west, are small crescent dunes that are getting larger and larger as they approach the mountains."

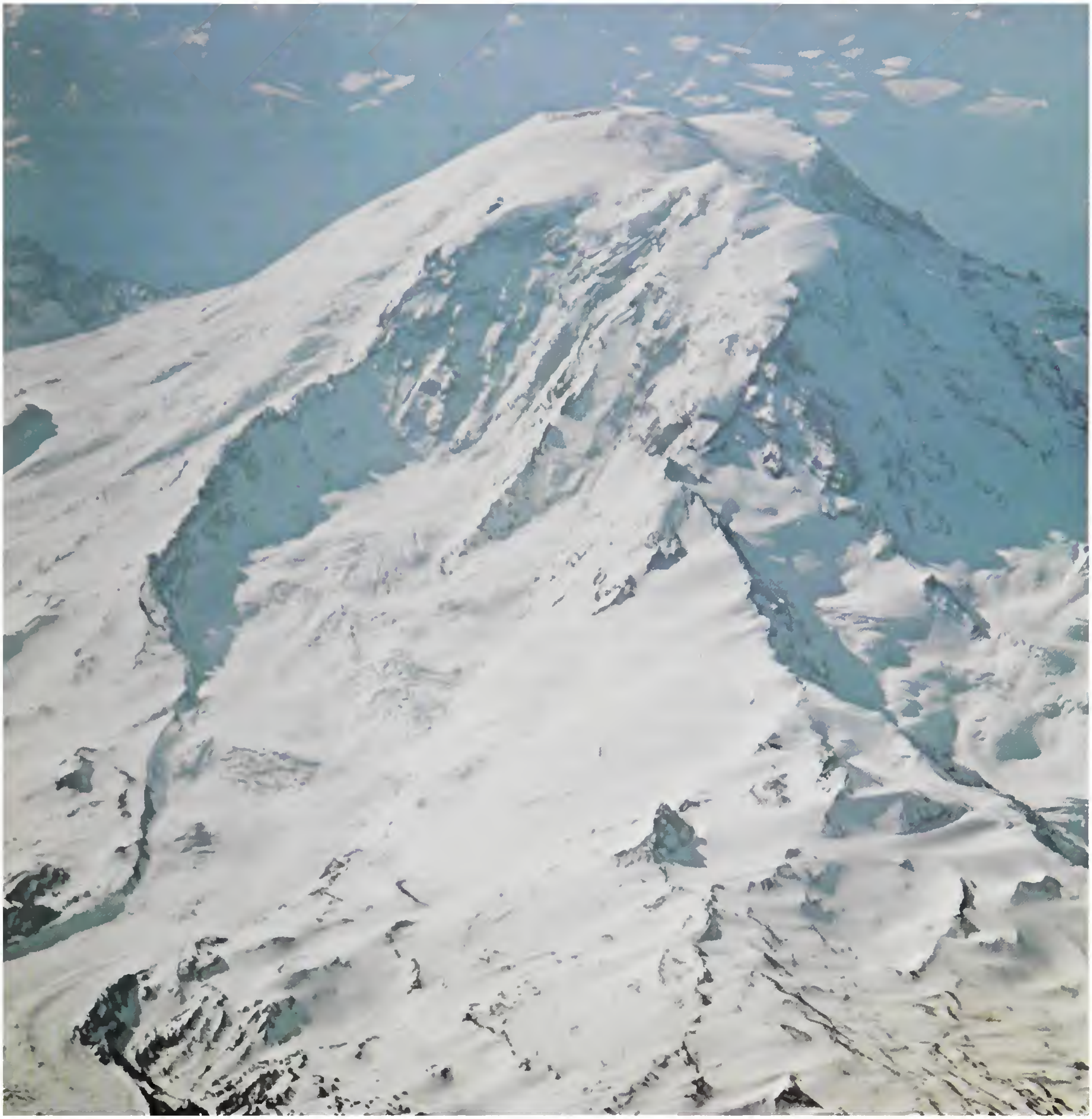


FIGURE 27.—Northward-facing glaciers of Mt. Rainier, photographed by astronaut R. E. Evans on the Northwestern flyover.

The observation that some of the dunes may be star-shaped is significant for it is thought that Great Sands may represent the transition between crescentic and star dunes.

On the second leg, the Fossil Ridge was described as a series of about five ridges formed probably by erosion. The circular features in the San Juan mountains were not observed due to snow and cloud cover. Observations of sand dunes in Arizona included descriptions of crescentic dunes and SW–NE trending linear dunes. Vance Brand described the dunes on the Moenkopi Plateau as looking like "knitting fibers stretched out on top of a table." The linear features on the Coconino Plateau were not easily distinguishable. In the mining area of the Big Bug mountains, an open pit and north-south trending faults were easily observed.

On the third leg, Brand's tape recorder malfunctioned and almost all observations were lost. Slayton was unable to obtain clearance to fly over the restricted areas and thus had to fly north of the planned route to Yuma. He did observe the red and blue-green coloration associated with other copper mining areas and commented on the common association of volcanic areas with the mining locations. The types of sand dunes in the Gran Desierto were too far away to identify and the Indian intaglios did not have enough contrast to be seen at the aircraft altitude. On his return trip, Slayton was able to comment on the relationship between the Pinacates volcanic field and the sand dunes. He made the excellent observation that the sand was encroaching on the volcanic field from the southwest and that craters on the north side were partly sand filled.

### *Northwestern United States Flyover*

This training flight was designed to familiarize the crew with U.S. sites planned on the ASTP mission and to study glaciers and snow-covered peaks. The flyover originated at Los Angeles and followed a route northward. It consisted of two legs with a midpoint at Klamath Falls, Oregon, and an end point at Fairchild AFB near Spokane, Washington.

The first leg included the route from Los Angeles to Santa Barbara, Avenal, Linden and Klamath Falls. The two observation sites were (1) faults west of the San Andreas in the stretch from Avenal to Monterey Bay and (2) the location of a metamorphic foothill range of the Sierra Nevada in the vicinity of Linden. The questions for both sites were taken directly from the "Earth Observations Book" used on the ASTP mission. The second leg followed a route from Klamath Falls northward to Portland, Hoquiam, and Abbotsford, and then eastward to Fairchild AFB. The observation sites included (1) the four prominent peaks of Mt. Hood, Mt. St. Helens, Mt. Adams, and Mt. Ranier; (2) the Blue Glacier on Mt. Olympus; (3) sediments in Puget Sound; and (4) the Southern Cascades Glacier near Glacier Peak.

Vance Brand and Deke Slayton were scheduled to fly the Northwestern United States flyover the day after completing the Southwestern United States flyover. Vance Brand flew the first leg over California, although the remainder of the flyover was canceled due to cloudy weather in the Northwest. He took photographs of the faults west of the San Andreas. Over the Sierra Nevada foothills, Brand reported that he could not see gray outcrops of metamorphic rock; only the gray of roads, and where the soil was upturned from mining activities in the Linden area.

Before the Northwestern United States flyover was designed, Capt. Ronald Evans flew on his own from Los Angeles to McChord AFB in Washington on 12 May 1975. He photographed all of the major snow and glacier covered mountain peaks along the way. On the following day, he flew eastward to photograph the northward-facing glaciers of Mt. Ranier (Figure 27) and the reddened soil due to iron mines near Lake Superior, which were sites on the ASTP mission.

## Conclusions

The flyover exercises gave the Apollo-Soyuz crew valuable practice in making visual observations and acquiring photographs. Specific accomplishments made during these essential training exercises include the facts that the astronauts (1) observed examples of some of the various types of landforms and of ocean features that they would view from Earth orbit on ASTP, (2) became familiar with some of the sites scheduled for observation during their mission, such as the San Andreas Fault and the Gulf Stream, (3) gained experience in using various lighting conditions for visual observations and photography of both land and ocean sites, (4) practiced verbalizing their observations and using the terminology learned in the classroom training sessions, and (5) gained practical experience in handling the cameras, lenses, color wheel, and the tape recorder during flight.

# Flight Planning

## Site Selection

The selection of Earth observation sites was a continually changing process involving a number of considerations. These included recommendations from the Earth observations team, particularly the co-investigators (Table 1), time available in the flight plan for experiment activities, spacecraft attitude with respect to the Earth, and optimum viewing conditions for the various features.

The first preliminary site list was prepared in September 1974 and was based entirely on suggestions from team members. This list, giving the geographic coordinates of over 120 sites, was submitted to the Mission Planning and Analysis Division (MPAD) at JSC. A trajectory analysis was performed there to determine which sites would be overflown during daylight portions of the mission. The resulting site acquisition data were published in a JSC document (NASA, 1974b) and were used to schedule sites in the ASTP flight plan.

Because of flight plan restrictions, the time available for visual observation activities was limited, making pre-mission planning very critical. Flight planners attempted to achieve an Earth-looking attitude during sun-lit passes. (During "nighttime" halves of each revolution, the spacecraft was oriented skyward for astronomical observations.) If a crewman was available this allowed the undertaking of visual observation tasks. However, this was only worthwhile when viewing conditions were good, and if there was sufficient time to locate, identify, describe, and photograph a target. Important viewing conditions include exact spacecraft attitude, weather constraints, and sun angle. For example, color variations and contrast are best perceived with high sun-angle illumination. On the other hand, topographic relief is enhanced by low sun angles. Sunglint is also useful for observing various ocean features, such as internal waves and oil slicks.

Revised suggestions from the Earth observations team resulted in a number of changes to the site list and consequently in the flight plan allocations. Eleven photographic mapping passes (Table 4) and sixty visual observation targets (Table 5) were finally scheduled. For convenience in referring to each visual observation target, the globe was arbitrarily divided into twelve sections called sites (Figure 28). For example, site 5 encompasses the eastern United

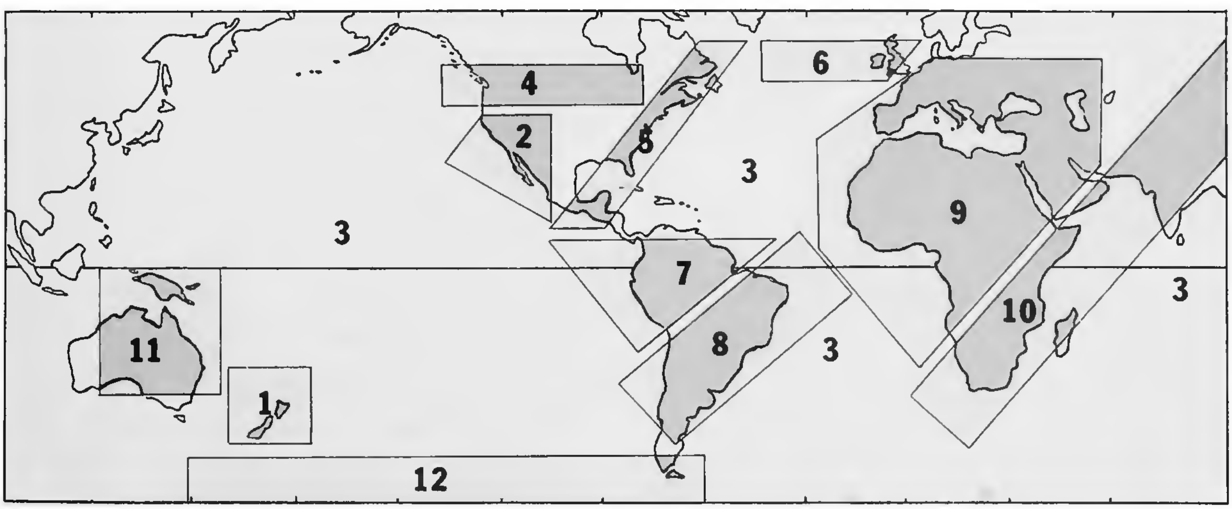



FIGURE 28.—Boundaries of the 12 sites of the Earth Observations and Photography Experiment on the Apollo-Soyuz mission. Specific observation areas within these sites are referred to as targets (Table 5).

TABLE 4.—Photographic mapping passes (from El-Baz and Mitchell, 1976)

| No. | Name | Objective |
|---|---|---|
| M1 | Gulf Stream | The Gulf Loop Current and the Gulf Stream from eastern Florida to its confluence with the Labrador Current |
| M2 | New Zealand | The Alpine Fault in South Island and the coastal waters between the two islands and north of North Island |
| M3 | Southern California | Coastal waters off California, the San Andreas Fault system, and the Mohave Desert |
| M4 | Himalaya Mountains | Ocean features in the Indian Ocean and Arabian Sea, the flood plain of the Indus River, drainage patterns, and snow cover in the Himalayas |
| M5 | Arabian Desert | The Afar Triangle, dune patterns in Ar-Rub Al-Khali, and coastal processes at Doha, Qatar |
| M6 | Australia | Dune patterns and erosional features in the Simpson Desert, the Great Barrier Reef, and eddies in the Coral Sea |
| M7 | African drought | Vegetation and land use patterns in the Sahel, desert colors in northeastern Africa, the Nile River Delta, and the Levantine Rift |
| M8 | Falkland Current | The Falkland Current and its confluence with the Brazil Current east of South America |
| M9 | Sahara | Vegetation and land use patterns in the Salnel, desert colors and dune patterns in the Sahara, and the coastal waters off Tripoli |
| M10 | Northern California | Coastal waters off northern California and subsystems of the San Andreas Fault |
| M11 | New England | Eddies and gyres in the Gulf of Mexico, the Mississippi River Delta, Chesapeake Bay, and coastal waters off New England |

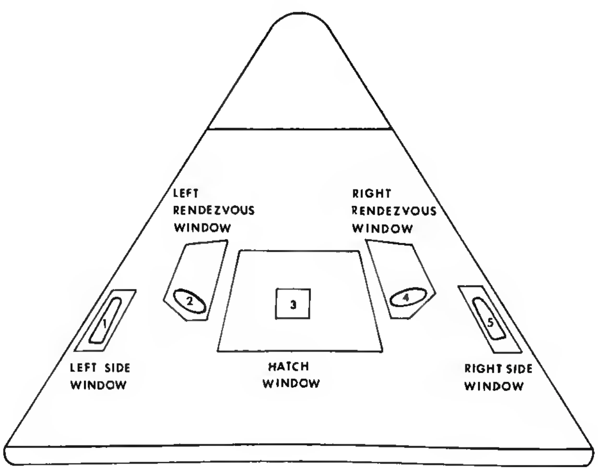



FIGURE 29.—Schematic of the five windows of the Apollo command module. At the time of launch, the Apollo commander sat in the area of windows 1 and 2. The docking module pilot sat in the area of windows 4 and 5, and the command module pilot sat behind window 3. The latter has the largest window pane and was used most in observing Earth on the Apollo-Soyuz mission.

TABLE 5.—Visual observation targets (see Figure 28) (from El-Baz and Mitchell, 1976)

| Site no. | Target | Site no. | Target |
|---|---|---|---|
| 1 | New Zealand | 8 | Southern South America<br>8A Falkland Current<br>8B Chilean Andes<br>8C Dune field<br>8D Paraná River<br>8E Circular structures |
| 2 | Southwestern United States<br>2A Southern California<br>2B Baja California<br>2C California Current<br>2D Great Salt Lake<br>2E Guadalajara | 9 | Africa and Europe<br>9A Afar Triangle<br>9B Arabian Peninsula<br>9C Guinea Current<br>9D Desert colors<br>9E Oweinat Mountain<br>9F Nile Delta<br>9G Levantine Rift<br>9H Niger River Delta<br>9I Algerian Desert<br>9J Tripoli<br>9K Strait of Gibraltar<br>9L Alps<br>9M Danube River Delta<br>9N Anatolian Fault<br>9O Volcanics<br>9P Bioluminescence |
| 3 | Weather Belt<br>3A Cloud features<br>3B Tropical storms<br>3C Hawaii<br>3D Kuroshio Current | 10 | Africa and India<br>10A Great Dike<br>10B Somali Current<br>10C Arabian Sea<br>10D Himalaya Mountains<br>10E Takla Makan Desert |
| 4 | Northern North America<br>4A Snow peaks<br>4B Puget Sound<br>4C Superior iron<br>4D Sudbury nickel | 11 | Australia<br>11A Playas<br>11B Coral Sea<br>11C Simpson Desert<br>11D ANZUS Eddy |
| 5 | Eastern North America<br>5A Gulf of Mexico<br>5B Gulf Stream<br>5C Labrador Current<br>5D Central American structures<br>5E Florida red tide<br>5F New England red tide<br>5G Chesapeake Bay | 12 | Antarctican ice<br>12A Icebergs |
| 6 | Northern Atlantic<br>6A Oil slicks<br>6B London | | |
| 7 | Northern South America<br>7A Humboldt Current<br>7B Nazca Plain<br>7C Internal waves<br>7D Peruvian desert<br>7E Orinoco River Delta<br>7F Galapagos Islands<br>7G Caribbean Sea | | |

States; a specific target within site 5 is assigned a letter, eg., "5G" is Chesapeake Bay. The term "mapping pass" refers to stereo strip photography of a swath of the Earth's surface. The eleven mapping passes (M1 to M11) varied in length from about 1500 km to over 6500 km.

The final schedule required approximately 12 hours of inflight crew time. The plan called for three basic types of tasks. These were (1) visual observations of selected Earth features, (2) handheld oblique photography to document observation targets, and (3) stereo mapping photography of areas of significant scientific interest. To perform these tasks, it was necessary to use two or more of the five spacecraft windows (Figure 29). Ground coverage of each window depended on the use of two different spacecraft attitudes. In the first case, called the mapping attitude, the right side window, number 5, was oriented parallel to the Earth's surface at the subvehicular point (nadir). In that position the mapping camera would take near-vertical photography if mounted in window 5. If visual observations were scheduled during the mapping pass, the observer would have to use the hatch window, number 3, with coverage to the right of the groundtrack. In the second case, called the visual observation attitude, the spacecraft was maneuvered to a position that put window 3 parallel to the Earth's surface at the subvehicular point (nadir). This attitude was used if a mapping pass was not scheduled. It allowed observations from the three spacecraft windows 1, 3, and 5 (Figure 30).

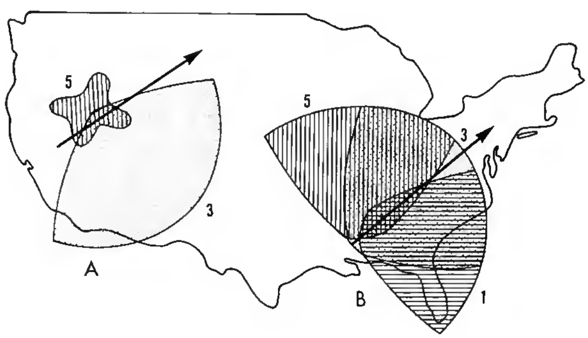



FIGURE 30.—Ground coverage of Apollo spacecraft windows 1, 3, and 5 as the observer stands 15 cm (6 in) away from the window pane (A = mapping attitude, where command module window 5 is oriented parallel to the groundtrack; B = visual observations attitude, where the center of window 3 is oriented at the spacecraft's nadir).

## Visual Observation Aids

It was important to assemble books, equipment, and other items to aid the astronauts in making the best use of all the flight plan time allotted to the Earth Observations and Photography Experiment. Visual observation aids, referred to by NASA as the "flight data file," were assembled and tried during the astronaut training cycle. In addition to the flight plan, these aids consisted of the "Earth Observations Book," the World Map Package, a color wheel, a ground scale, and an enlarging telescope.

### Flight Plan

All visual observation targets and mapping passes were marked in the ASTP flight plan that contained a detailed schedule of mission operations, crew tasks, and experiment activities. The flight plan advised the crew of upcoming Earth observations. However, for detailed information on specific tasks and camera settings, the crew had to refer to the "Earth Observations Book" (Appendix 3).

The flight plan is a very complex looking document. As a matter of fact, with all its acronyms, abbreviations, and cryptic signs, the flight plan is a masterpiece of utterly incomprehensible English. It was interesting, during the planning for the ASTP mission, to watch first-time Principal Investigators trying to decipher the unfamiliar document. Just as I did seven years ago, they remained baffled and looked mystified for a long time. After a while, however, one is able to learn enough of the seemingly foreign "NASA-ese" language to get by. This language was developed to reduce a great amount of information in a small amount of space.

The page from the flight plan shown in Figure 31 includes Earth observations activities on revolution number 70/71. The two time-scales along the left side of the page represent Houston local time (CDT, Central Daylight Time) and the time elapsed since the Soyuz launch (GET, Ground Elapsed Time). Specific crew activities are listed in three columns, one each for each astronaut: CP (V D. Brand), AC (T. P. Stafford), and DP (D. K. Slayton). Therefore, on revolution 70/71, Vance Brand performed visual observation tasks, while Deke Slayton operated the mapping camera. The term "Earth Obs Book" told Brand to refer to the "Earth Observations Book" for more specific information on the upcoming sites (Mapping Pass M7, and visual observation targets 9C, 9D, 9E, 9F, and 9G; see crew assignments of all Earth observation tasks in Table 6). The approximate times for target acquisition are indicated along the GET column to alert the astronauts, who always have one eye on their GET time display on the spacecraft instrument panel.

### "Earth Observations Book"

The "Earth Observations Book" was the principal aid that was carried onboard the Apollo spacecraft (Appendix 3). It contained detailed information on all visual observation tasks and camera configurations. This book was divided into three major sections. The first section contained a time line summarizing the visual observation tasks and mapping camera operations, and a stowage list and a summary of operational procedures.

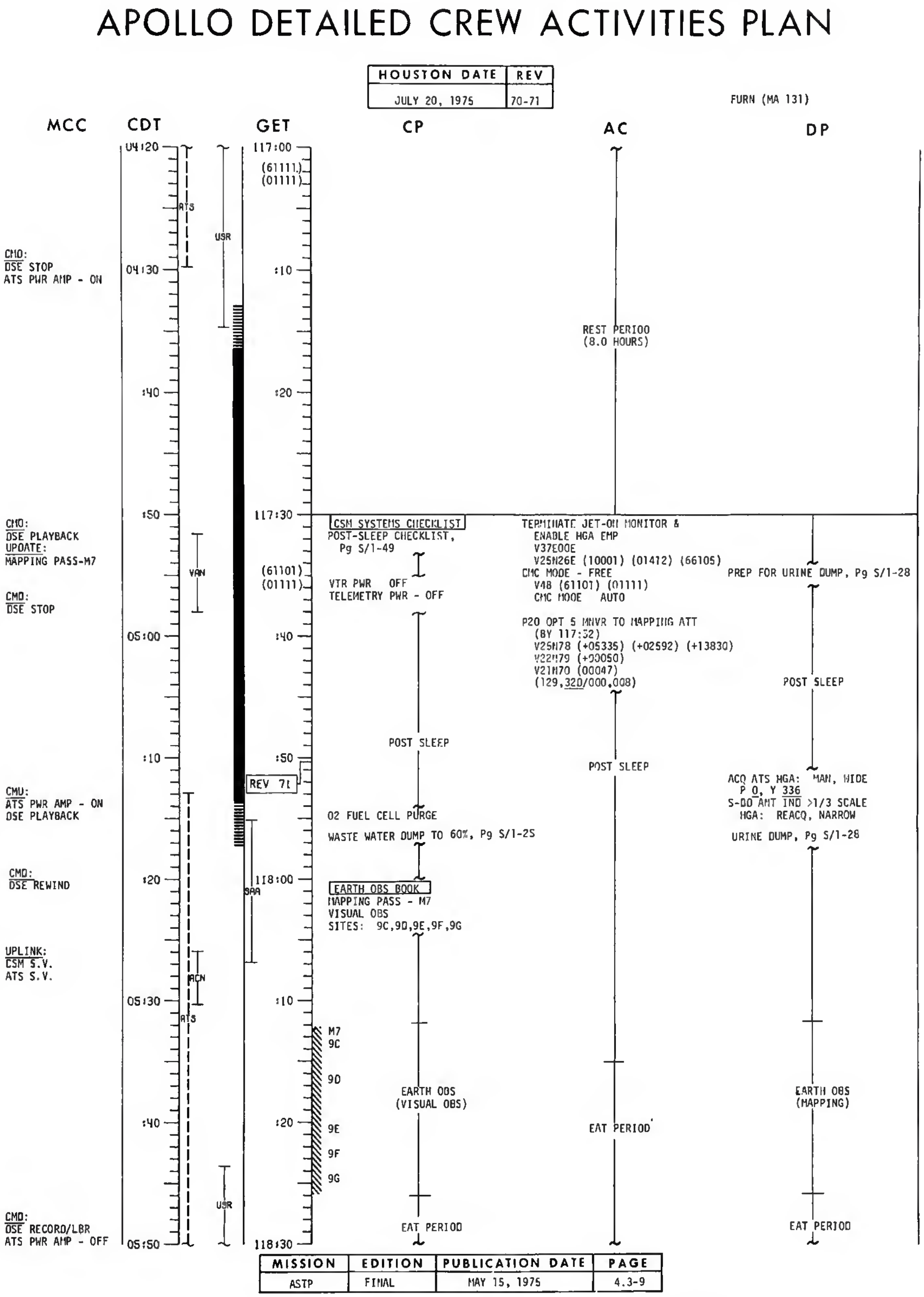



FIGURE 31.—Example of the ASTP flight plan. For description of entries refer to the text.

TABLE 6.—Planned assignments of experiment tasks to Apollo astronauts (see Table 4 for mapping passes, Table 5 for visual observations targets, and abbreviations list for crew members) (from El-Baz and Mitchell, 1976)

| Revolution | Mapping passes | | Visual observation targets | |
|---|---|---|---|---|
| | No. | Crew-member | No. | Crew-member |
| 15 | M1 | AC | 5A, 5B, 5C | DP |
| 17 | M2, M3 | DP | 12A, 1, 3A, 2A, 4C, 5C | CP |
| 39 | M4 | DP | 10A, 10B, 10C, 10D, 10E | DP |
| 40 | M5 | DP | 9A, 9B | DP |
| 42 | | | 8A, 3A, 9H, 9I, 9J | DP |
| 45 | | | 5D, 5A, 5E, 5F, 5C | DP |
| 46 | | | 2E, 4D | CP |
| 64 | M6 | AC | 11C, 11B, 3A | CP |
| 71 | M7 | DP | 9C, 9D, 9E, 9F, 9G | CP |
| 72 | M8, M9 | AC | 12, 8A, 9H, 9I, 9J | DP |
| 73 | | | 3A, 9K, 9L | AC |
| 74 | | | 7B, 7C, 6A, 6B | AC |
| 78 | | | 3C, 4A | DP |
| 79 | | | 11A, 11B, 3A | DP |
| 88 | | | 8B, 8C, 8D, 8E, 3A, 9K, 9L | AC |
| 90 | | | 5D, 5A, 5E, 5G, 5F, 5C, 6A, 9P | DP |
| 104 | | | 7A, 7D, 7E | AC |
| 106 | | | 3B, 2B, 2E, 4D | CP |
| 107 | M10 | CP | 2C, 2D | CP |
| 108 | | | 3C, 4B | CP |
| 123 | | | 11D | DP |
| 124 | | | 4A, 4C, 4D | CP |
| 134 | | | 7F, 7G, 6A, 6B, 9M, 9N, 9P | AC |
| 135 | M11 | DP | 3B, 5A, 5G, 5F, 6A, 9L, 9O, 9P | CP |

*Listed in order of mission performance.

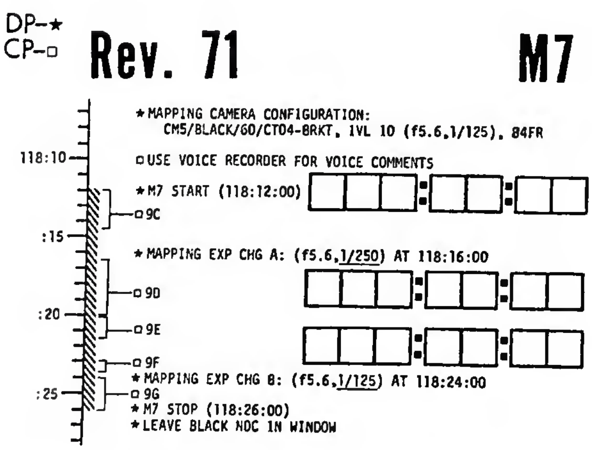



FIGURE 32.—Example of the experiment time line from the ASTP "Earth Observations Book." For description of entries refer to the text.

Figure 32 gives the time line for experiment activities on revolution 71. It includes all the information needed to operate the mapping camera—if you read NASA-ese, that is! Visual observation targets are listed, although specific details on observational and photographic tasks are given in the second section of the book. On the revolution 71 time line, all starred comments refer to the mapping pass, M7, which was the responsibility of the DP, Deke Slayton. The mapping camera configuration is given as: CM5/BLACK/60/CT04–BRKT, IVL 10 (f5.6, 1/125), 84FR. This told Slayton the following:

| | |
|---|---|
| CM5 | Use spacecraft (side) window number 5 |
| BLACK | Use the black-painted (mapping) camera |
| 60 | Attach the 60 mm lens to said camera |
| CT04 | Attach film magazine labeled CT04 to camera |
| BRKT | Camera should be attached to a bracket-mount |

| | |
|---|---|
| IVL 10 | Automatic intervalometer should be set at 10 seconds |
| f5.6 | Lens should be set at f/stop 5.6 |
| 1/125 | Shutter speed is to be 1/125 of a second |
| 84FR | The camera will use 84 frames on this pass |

The time to activate the mapping camera is given as "M7 START." If all goes well the mapping camera would then continue to take pictures automatically every 10 seconds, until turned off at the time marked "M7 STOP." If the camera settings need to be adjusted during the pass, the time of change and the new exposure settings are indicated.

Information in the second section of the "Earth Observations Book" pertains to specific visual observation targets and is arranged according to site numbers. For each site, a summary page with a map displayed the revolution groundtracks of all visual observation passes over that site. These groundtracks are vertical projections onto the Earth's surface of the spacecraft's flight path. For example, on revolution 71, all the visual observation targets were in "Site 9: Africa and Europe." The summary page for Site 9 (Figure 33) shows the revolution 71 groundtrack (solid lines) and the location of visual observation targets (broken lines). It also shows the center line of viewing from spacecraft window 3, in the mapping attitude. (While the spacecraft is in Earth observation attitude, the center line of the same window, CM3, would be identical to the revolution groundtrack (Figure 30).

One of the visual observation targets on revolution 71 was "9E: Oweinat Mountain" (Figure 34). This mountain is located in the extreme southwestern corner of Egypt in a remote and almost inaccessible desert region. To help the crew locate the target, the revolution 71 groundtrack was plotted on an oblique Skylab photograph (SL3–115–1887) of the area. Observational and photographic tasks were listed at the bottom of the page. In this case, the crew was asked to obtain photographs and to look for structural features and oxidation zones on the mountain. The handheld camera data are given in the same format as the mapping camera data described above. The next visual observations target, 9F, is also indicated so that the astronaut does not have to refer back to his flight plan or summary timeline to figure out what comes next. As the mission progressed, many notations had to be added to the original art of the book (Appendix 3), particularly of those features that were not familiar to the crew. Therefore, the illustrations represent an evolutionary progression of notations superimposed on the original visual aids.

The last section of the "Earth Observations Book" served as a reference. It included maps of the distribution of volcanoes, ocean currents, the anticipated July cloud cover, etc.; and diagrams of various Earth features such as drainage patterns, ocean phenomena, dune types, and faults. Although it was never used during the mission, it was practical to include this data as a memory jogger.

## Orbital Chart

On previous missions, astronauts carried a map of the world with a transparent overlay of one orbital track that could be moved to any specific revolution position. For the Apollo-Soyuz mission, I recommended a map with all orbital tracks indicated. The orbital chart was thus prepared and showed the sunlit parts of each revolution (Figure 35). Revolution numbers were placed on the corresponding tracks. This chart was useful during pre-mission training and during the flight.

## World Map Package

A package of world maps was also included in the flight data file. The package consisted of seventeen 1:10,000,000 scale geographical maps. These maps were photo-reduced from the "Global Navigation Charts" published by the Defense Mapping Agency. The Skylab 4 crew had found such a package very useful during their long duration mission. The ASTP crew, however, never used the maps; as a matter of fact, they did not even come across the package in flight, as it was "buried" beneath the rest of the items in the flight data file.

## Color Wheel

As previously stated, the human eye is more sensitive to subtle color variations than any commercially manufactured film. Under laboratory conditions, the eye is estimated to be able to distinguish 7.5 million color surfaces, a precision that is two to three times better than most photoelectric spectrophotometers (Committee on Colorimetry, 1963:129). This capability has many important applications. For example, in oceanography, measurements of water color are

# SITE 9: AFRICA AND EUROPE

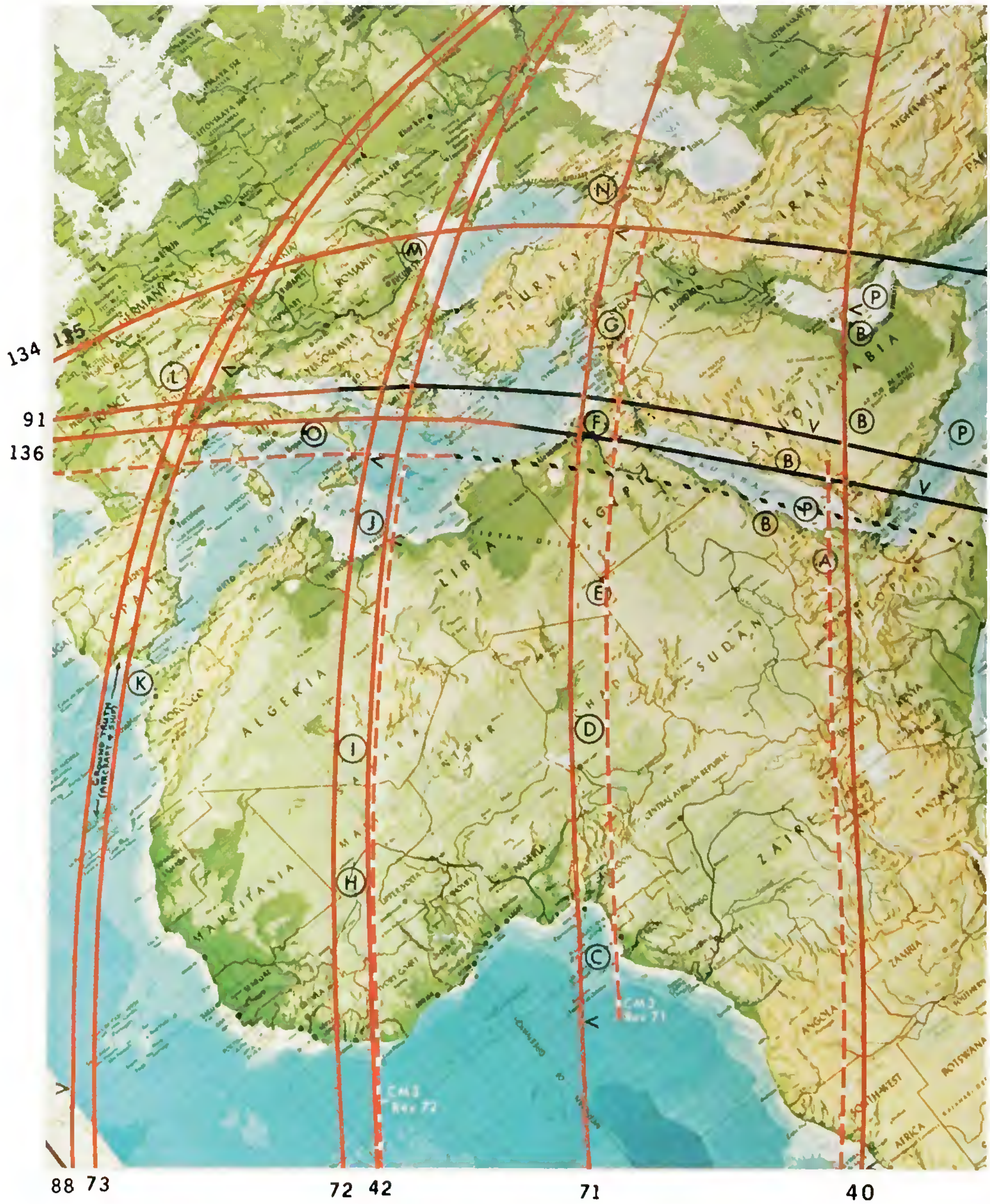
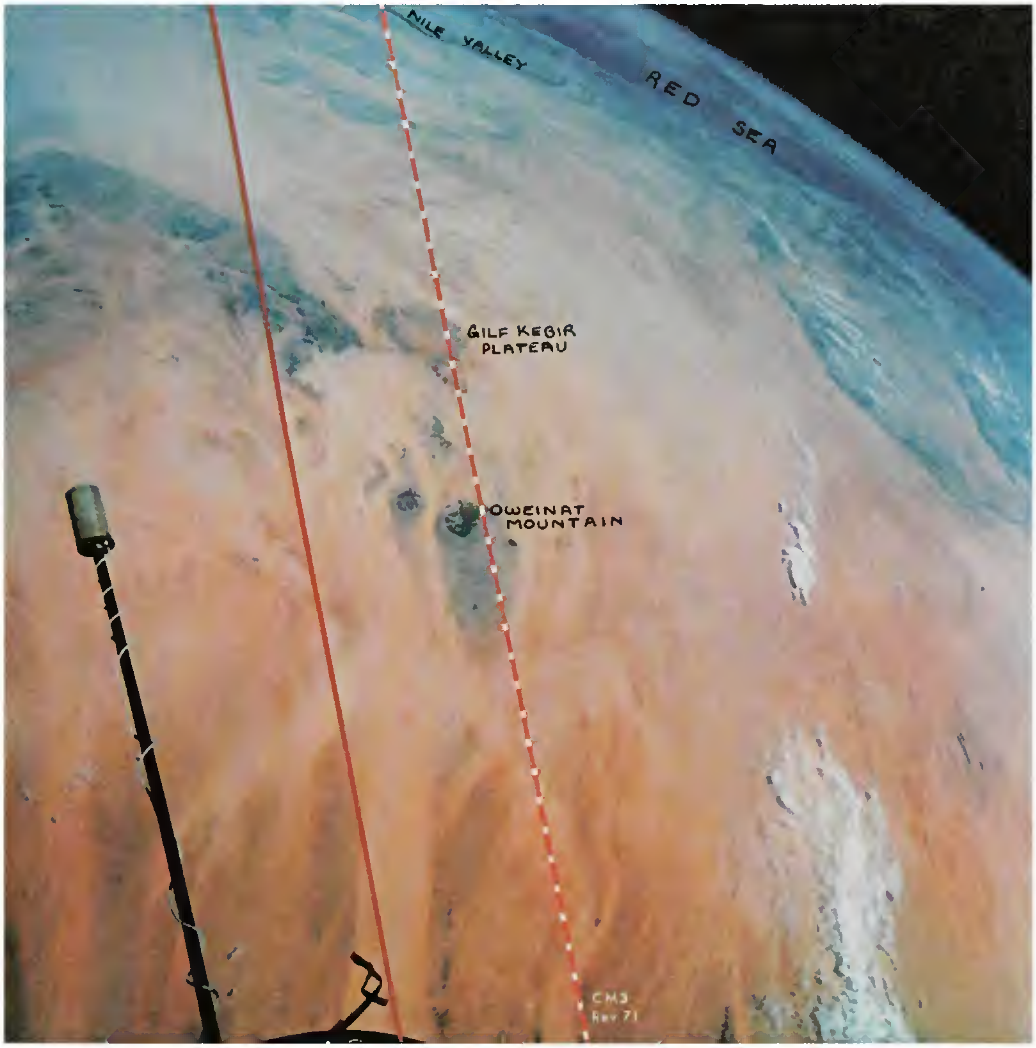



FIGURE 33.—Example of "site" pages of the ASTP "Earth Observations Book." The mission groundtracks in daylight are shown in solid red lines. The line-of-sight of command module window 3 in the spacecraft mapping attitude is plotted in dashed lines. Black lines indicate revolution groundtracks during nighttime with the corresponding revolution number in the margin. Circled letters indicate the approximate locations of specific observation targets.

# 9E OWEINAT MOUNTAIN




71

1. OBTAIN 3 STEREO PHOTOGRAPHS OF OWEINAT MOUNTAIN AND ADJACENT DUNEFIELDS.
2. CAN YOU RESOLVE ANY STRUCTURES IN THE MOUNTAIN?
3. ARE THERE ANY COLOR OXIDATION ZONES ON THE MOUNTAIN?

REV 71: CM3/SILVER/250/CX12(f11,1/500) 3FR,[NEXT SITE: 9F]

FIGURE 34.—Example of "target" pages of the ASTP "Earth Observations Book." The revolution groundtrack is shown in a solid red line; the dashed red line indicates the projection of the center point of command module window 3 on the ground. Instructions and specific questions are listed beneath the photograph in the order of their importance. Below the questions are the data for camera operation, which are described in the text.

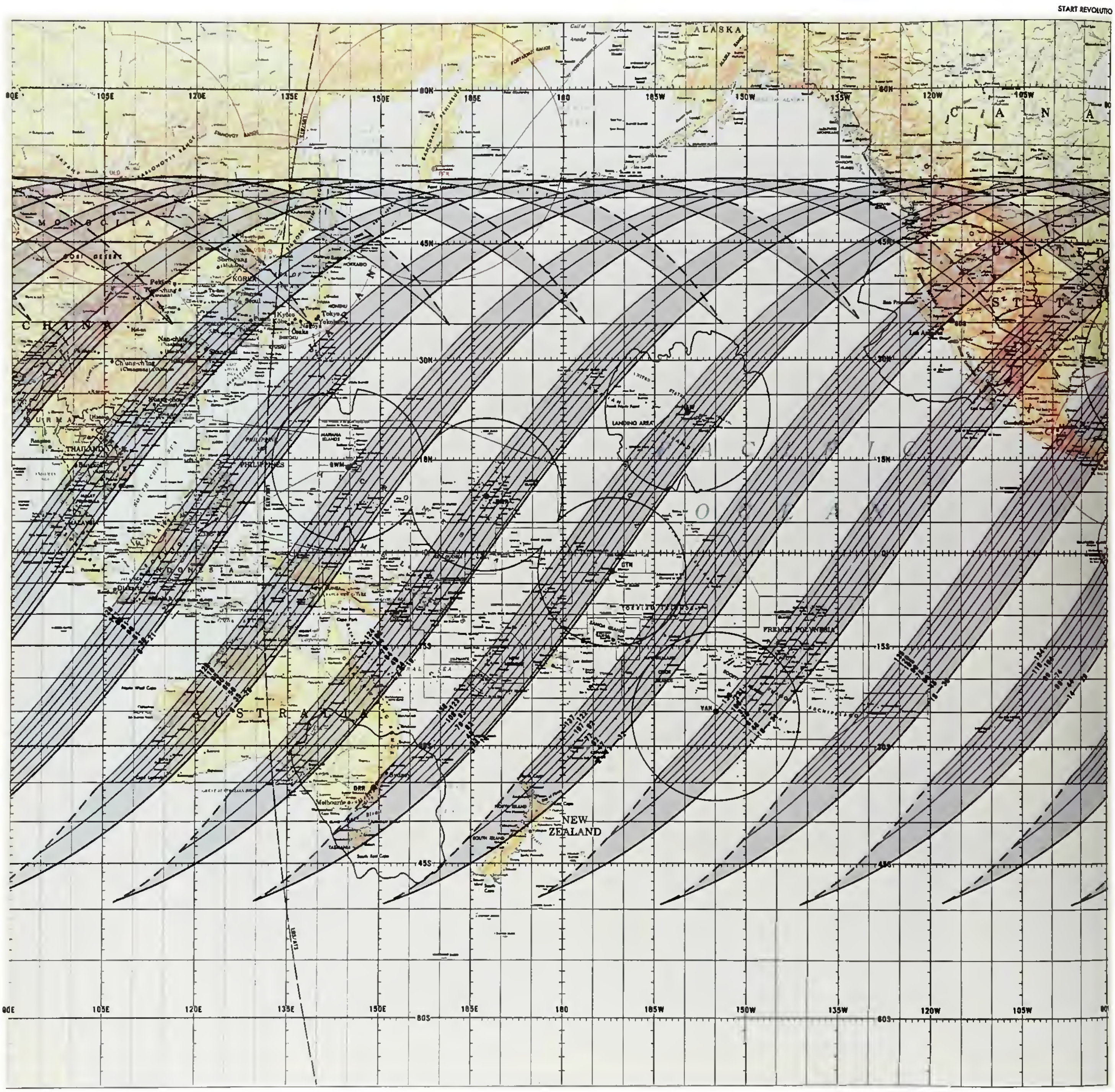
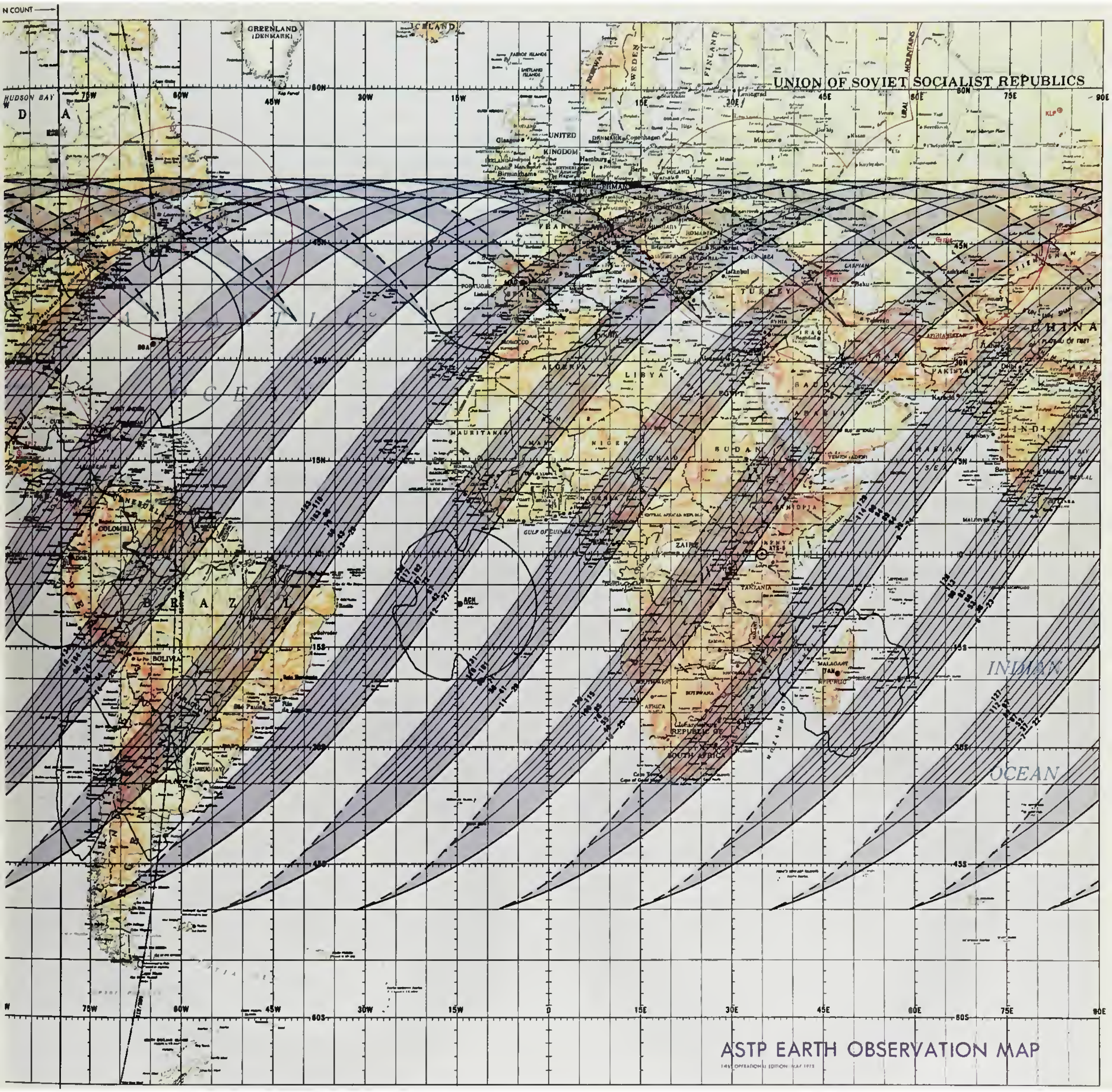



FIGURE 35.—Orbital chart carried by the astronauts to facilitate identification of geographic position. The daylight parts of the mission groundtracks covered 16 zones. Areas in between were not overflown by the Apollo-Soyuz mission. Revolution numbers are indicated on each track. The circled areas mark the coverage of ground tracking stations.


GREENLAND (DENMARK)
ICELAND
UNION OF SOVIET SOCIALIST REPUBLICS
HUDSON BAY
UNITED KINGDOM
FRANCE
SPAIN
TURKEY
LIBYA
ALGERIA
MAURITANIA
NIGER
CHAD
SUDAN
CHINA
PAKISTAN
INDIA
ARABIAN SEA
BRAZIL
COLOMBIA
BOLIVIA
ZAIRE
TANZANIA
REPUBLIC OF SOUTH AFRICA
INDIAN
OCEAN
ASTP EARTH OBSERVATION MAP

important in identifying distinct ocean currents, eddies, and areas of biological productivity (Jerlov and Nielsen, 1974:87). Also, in desert regions, a study of color variations could supply information on sand sources and the relative ages of sand seas (El-Baz and Mitchell, 1976:10–12).

An important objective of the Earth Observations and Photography Experiment was to quantify desert and water colors observed by the crew. This was achieved through the use of a two-sided color wheel composed of carefully selected Munsell colors (Table 7). Numerous versions of the color wheel were used by the crew on flyover exercises to obtain data on land and water colors. Actually, the colors of the wheel were selected on the basis of experience gained during the flyovers.

The color wheel was fabricated at JSC, primarily by Mr. James Regan, in a "doughnut" shape with a 20.3 cm (8 in) diameter and a 12.7 cm (5 in) central hole (Figure 36). It was constructed of 3 mm (⅛ in) thick aluminum with double rows of Munsell standard color chips fastened to both sides. Each color chip was identified with a row identifier ("A" or "B") and a numeral which identified its position in the row. A total of 108 different color chips were fastened onto the wheel. The doughnut configuration allowed the crew members to conveniently hold the device and to rotate it until the proper color in either row A or B matched the scene on the Earth's surface.

## Ground Scale

It is difficult from orbital altitudes, and even from airplane heights, to estimate the size of observed objects, particularly where no familiar landmarks exist. A linear scale was designed, particularly with the help of Capt. Alan Bean (backup AC), to help the astronauts estimate object sizes and ground distances. The scale was manufactured at JSC and was temporarily fastened to the wall with velcro for handheld use at arms' length.

## Enlarging Telescope

To assist the crew in locating small-sized targets, 20-power binoculars were originally included as visual observation aids. However, after the crew tested these binoculars and other enlarging devices during flyover exercises, they preferred to use a 20 to 45-power zoom spotting telescope device with a 20-power wide angle eyepiece (Figure 37). This monocular, which was referred to as the "spotting scope," was believed to provide a more convenient means of locating targets and checking the eye's resolution. During postmission

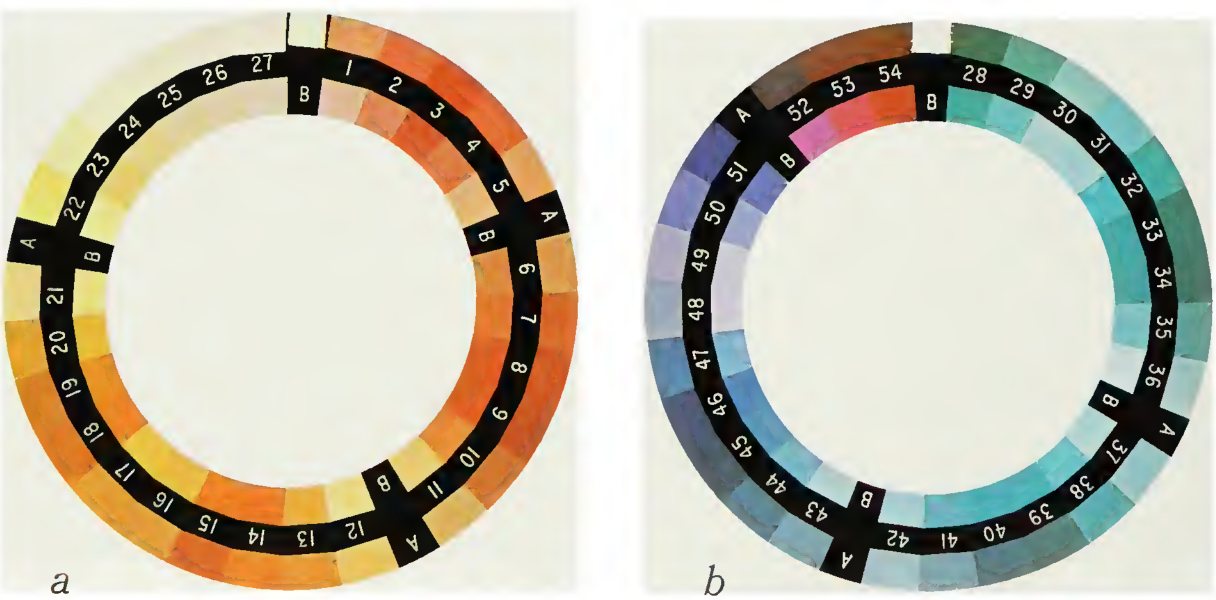



FIGURE 36.—Both sides of the color wheel used by the Apollo-Soyuz astronauts to determine (*a*) desert and (*b*) ocean colors. Color chips were selected from Munsell colors (Table 7).

TABLE 7.—Munsell designations for the ASTP color wheel (Figure 36). Each color designation indicates hue, value, and chroma in the form H V/C; hue is divided into 10 groups (red, yellow-red, yellow, green-yellow, green, blue-green, blue, purple-blue, purple, and red-purple); each color is further subdivided by use of numerals (2.5, 5, 7.5, and 10); value is specified on a numerical scale from 1 (black) to 10 (white); chroma is indicated numerically from 0 to 12 (from El-Baz and Mitchell, 1976)

| Color wheel no. | Desert colors | | Color wheel no. | Ocean colors | |
|---|---|---|---|---|---|
| | A | B | | A | B |
| 1 | 2.5R 6/6 | 2.5R 7/8 | 28 | 10BG 4/4 | 10BG 5/6 |
| 2 | 2.5R 5/8 | 2.5R 6/10 | 29 | 10BG 5/4 | 10BG 6/6 |
| 3 | 5R 4/10 | 5R 5/12 | 30 | 10BG 6/4 | 10BG 7/6 |
| 4 | 5R 5/8 | 5R 6/10 | 31 | 2.5B 6/6 | 2.5B 7/8 |
| 5 | 5R 6/6 | 5R 7/8 | 32 | 2.5B 5/6 | 2.5B 6/8 |
| 6 | 7.5R 6/6 | 7.5R 6/8 | 33 | 2.5B 4/6 | 2.5B 5/8 |
| 7 | 7.5R 5/8 | 7.5R 6/10 | 34 | 5B 4/4 | 5B 5/6 |
| 8 | 7.5R 4/10 | 7.5R 5/12 | 35 | 5B 5/4 | 5B 6/6 |
| 9 | 10R 4/8 | 10R 5/10 | 36 | 5B 6/4 | 5B 7/6 |
| 10 | 10R 5/6 | 10R 6/8 | 37 | 7.5B 6/6 | 7.5B 7/8 |
| 11 | 10R 6/4 | 10R 7/6 | 38 | 7.5B 5/6 | 7.5B 6/8 |
| 12 | 2.5YR 7/6 | 2.5YR 8/8 | 39 | 7.5B 4/6 | 7.5B 5/8 |
| 13 | 2.5YR 6/8 | 2.5YR 7/10 | 40 | 10B 4/8 | 10B 5/10 |
| 14 | 2.5YR 6/10 | 2.5YR 6/12 | 41 | 10B 5/6 | 10B 5/8 |
| 15 | 5YR 5/8 | 5YR 6/10 | 42 | 10B 6/6 | 10B 6/8 |
| 16 | 5YR 6/6 | 5YR 7/8 | 43 | 2.5PB 5/6 | 2.5PB 6/8 |
| 17 | 7.5YR 6/6 | 7.5YR 7/8 | 44 | 2.5PB 4/6 | 2.5PB 5/8 |
| 18 | 7.5YR 5/8 | 7.5YR 6/10 | 45 | 2.5PB 3/6 | 2.5PB 4/8 |
| 19 | 10YR 5/5 | 10YR 6/10 | 46 | 5PB 3/8 | 5PB 4/10 |
| 20 | 10YR 6/6 | 10YR 7/8 | 47 | 5PB 4/8 | 5PB 5/10 |
| 21 | 10YR 7/4 | 10YR 8/6 | 48 | 5PB 5/6 | 5PB 6/8 |
| 22 | 2.5Y 8/6 | 2.5Y 8.5/6 | 49 | 7.5PB 5/8 | 7.5PB 6/10 |
| 23 | 2.5Y 8/4 | 2.5Y 7/4 | 50 | 7.5PB 4/10 | 7.5PB 5/12 |
| 24 | 7.5YR 8/4 | 7.5YR 7/[illegible] | 51 | 7.5PB 3/10 | 7.5PB 4/12 |
| 25 | 2.5YR 8/4 | 2.5YR 7/4 | 52 | 5P 2.5/4 | 5P 3/10 |
| 26 | 7.5R 8/4 | 7.5R 7/4 | 53 | 5RP 2.5/4 | 5RP 3/6 |
| 27 | 2.5R 8/4 | 2.5R 7/4 | 54 | 5R 2.5/4 | 5R 3/4 |

FIGURE 37.—The 20-power enlarging telescope used by the ASTP crew to spot small observation targets. (Courtesy of J. A. Taylor)

evaluation, the astronauts indicated that the usefulness of the spotting scope was curtailed by the speed with which a target passed outside their field of view.

## Photographic Equipment

The Apollo-Soyuz photographs of observation and mapping sites were taken with two 70 mm Hasselblad camera systems, a 35 mm Nikon camera, a 16 mm motion picture camera, and a television camera. Detailed information on these camera systems is given in a JSC publication (NASA, 1973). Following is a description of the photographic equipment as it relates to the experiment.

### Hasselblad Cameras

Two Hasselblad 70 mm camera systems were required to allow both automatic vertical strip photography and astronaut-selected oblique photography simultaneously. Each camera was equipped with its own accessories of film magazines, lenses and filters (Figure 38). To distinguish between the two cameras, acronyms had to be invented by NASA: HDC for the Hasselblad data camera (used mainly for automatic vertical photography); and HRC for the Hasselblad reflex camera (equipped with a single lens reflex mechanism and usually handheld by the astronauts for selected-target photography).

Because the HDC was equipped with a "reseau" plate (a glass plate, placed firmly against the film, with an array of 25 crosses to improve the geometric accuracy and facilitate construction of controlled photomosaics and photomaps), it was also referred to as "Hasselblad Reseau Camera" or HRC. Confusion of terminology ensued and the astronauts were frustrated. Since one camera was painted black (HDC) and the other was coated with silver-colored paint (HRC), to avoid confusion, they were simply known as the "black camera" and "silver camera," respectively.

The black camera was equipped with 60 and 100 mm interchangeable lenses. The choice between these depended on the required ground coverage and/or photographic resolution (Figure 39). The camera used film magazines that included approximately 150 exposures. Nominally, it was mounted on a bracket that was fastened to the frame of spacecraft window 3. An intervalometer was used to actuate the camera every ten seconds for the 60 mm lens and every 6.25 seconds for the 100 mm lens. This provided stereoscopic coverage with at least 60 percent overlap of successive frames. Clicks of the film shutter were telemetered to the ground via the PCM cable to allow it to register the exact time of picture taking. This was necessary since the camera was used mainly to support photographic mapping objectives.

In general, photographs taken with the black camera are excellent, with the exceptions of a few short segments of unplanned photography that were out of focus, and one mapping pass over the northeastern United States on which the wrong lens was used.

Photographs of the 60 visual observation targets were made using the silver camera. This Hasselblad system consisted of a camera body with reflex viewing


FIGURE 38.—Hasselblad cameras used by the ASTP crew: *a,* data or "black" camera used for vertical, stereo-strip photography; *b,* reflex or "silver" camera with a single lens reflex mechanism and usually handheld, used to photograph observation targets. (Courtesy of J. A. Taylor.)

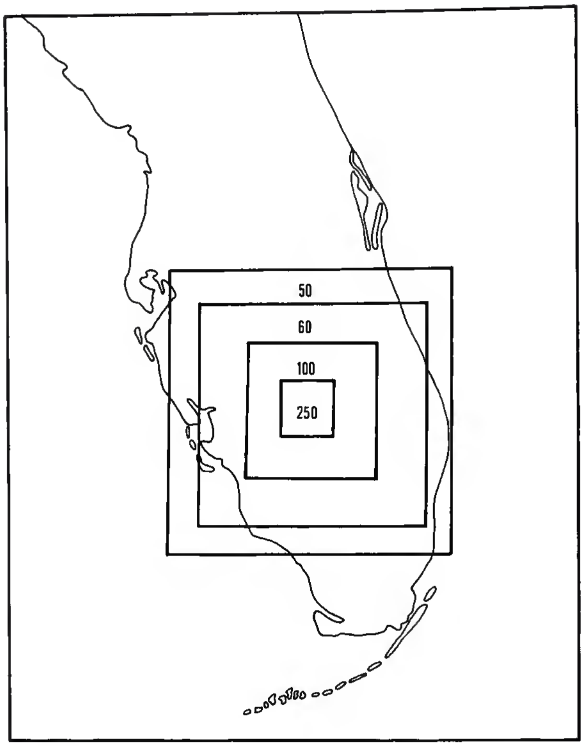



FIGURE 39.—Sketch showing the vertical ground coverage of the 250, 100, 60, and 50 mm lenses in relation to Florida.

capability, a prism viewfinder, a 50 mm lens, a 250 mm lens, and 13 film magazines of approximately 70 exposures each. The single lens reflex mechanism allowed the astronaut to see what he was photographing and to precisely aim the camera at his target. Naturally, frame footprint (ground coverage) depended on the degree of obliquity, or how far the target was from the subspacecraft point (Figure 40). The crew reported that light loss through the 250 mm lens made it difficult to locate the target and to center it within a frame; however, all photographs taken with that lens were excellent.

### NIKON CAMERA

The 35 mm camera used on the ASTP flight was a modification of a commercially available Nikon camera. It incorporated reflex viewing and through-the-lens light metering (exposure control) with motorized film advance. This camera was basically used for the interior photography, that is, astronauts taking pictures of each other during the joint phase of the mission. When, however, the film for the Hasselblad cameras nearly ran out, the astronauts utilized the Nikon camera (with its 35 mm lens) to take pictures of features on Earth.

### MOTION PICTURE CAMERA

A Maurer 16 mm camera, dubbed by NASA "the data acquisition camera" or DAC, was used to take sequential film of land and sea to ascertain color variations. Of particular significance was photography of the Western Sahara of North Africa, taken to provide a record of color zone transitions in the largest sand sea in the world. For this sequence, the DAC was handheld in window 3 and operated at 2 m (6 ft) per second for 11 minutes.

### TELEVISION CAMERA

A color television video system was used on Apollo-Soyuz mainly for public broadcasts of mission activities. The camera was also used for the acquisition, in realtime, of images of Earth features. In addition, the video tape recorder (VTR), was used to record television images for later playback, particularly during the daylight portion of revolution 124 over the Pacific Ocean. These color television images of the Earth provide new data on poorly studied areas or regions that are too vast for conventional surveys. The images may also give scientists an astronaut's perspective of target acquisition and tracking, and when re-formatted may possibly be used in stereographic and radiometric analyses. An added feature of these images is their adaptability for use in geography courses and for training of the Shuttle crews.

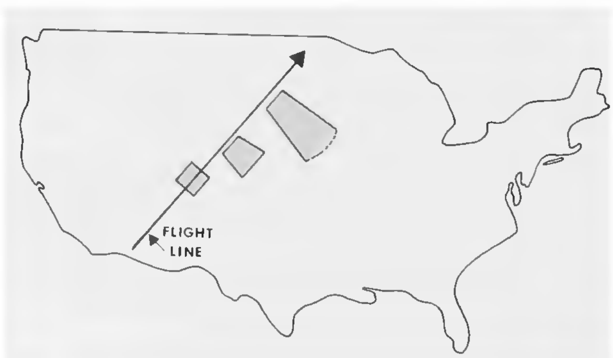



FIGURE 40.—Sketch showing the ground coverage of the 50 mm lens at various degrees of obliquity, or tilt angles from the normal to the subvehicle point.

### Films and Filters

The Hasselblad cameras constituted the most important photographic system used on the ASTP mission, basically because of the relatively large (70 mm) film format. Therefore, it was necessary to select the proper films and test them for adequacy.

Seventeen magazines of color film were used including Kodak SO–242 high definition aerial film for the black camera (mapping sites); and Kodak SO–368 Ektachrome MS for the silver camera (observation targets). Two magazines of Kodak 2443 color infrared aerochrome were also used with the silver camera to facilitate identification of features such as volcanic rocks and red tide blooms. The required exposure for each site was calculated along with the system modulation transfer function (MTF). This "system function" is the product of the individual MTF's of the film and the lens (used at a specific aperture), plus an MTF due to image motion, calculated at the shutter speed required for each film.

While Kodak SO–242 is far superior to SO–368 and 2443 in resolution, it is over two stops slower in film speed. This low sensitivity necessitates the use of large apertures and/or slow shutter speeds. Evaluation of these calculations was used in establishing the following guidelines for the use of each lens:

50 and 60 mm lenses: The high definition film (SO–242) is superior to the moderate resolution films (SO–368 and 2443) at a shutter speed of 1/125 of a second or faster.

100 mm lens: The high definition film is superior to the moderate resolution films at a shutter speed of 1/250 of a second or faster.

250 mm lens: Image motion dominates system performance and the high definition film is unacceptable. Every effort was made to use the 250 mm lens at 1/500 second when the light level permitted.

On the basis of these criteria, SO–242 was generally used for mapping passes and SO–368 for visual observations targets. The color infrared film was used for selected targets in which vegetation or lithologic discrimination was required.

Photography of the Earth from very high altitudes necessitates considerations of the effects of the atmosphere on light traveling through it from the subject to the camera. These effects are well known, and numerous approaches to correcting them through the use of a filter have been demonstrated. The net effect is a predominance of shorter wavelength radiation, which causes a blue veiling in uncorrected color photographs.

Of the three films selected, Kodak SO–242 was especially manufactured with a yellow filter overcoated on the film. Due to the false color rendering of the 2443 aerochrome infrared film, it was necessary to utilize a blue-blocking filter with an approximate cutoff of 510 nanometers. Specific emulsions can benefit in terms of the interlayer sensitivities by selecting filters with cutoffs over a rather narrow range of 490 to 540 nanometers. A 520 nanometer filter was available in the approved flight hardware inventory, and sufficient film with various emulsion coatings was available to select an emulsion that exhibited the desired sensitometric properties when used with the 520 nanometer cutoff filter.

Selection of a 2A (420 nanometers) filter for use with the SO–368 film created some initial difficulties as the 2A or equivalent short-wavelength blocking filters for the Hasselblad camera were not in the approved flight hardware inventory. Procurement of the proper filters and checkout for approval as flight hardware presented a difficult scheduling problem. An alternative to a lens filter was proposed which would produce the same photographic effect in the imagery. The alternative was to "coat" a filter directly on the film to be used. This proposal was accepted, thereby alleviating the filter scheduling difficulties, reducing the number of onboard items required to support the experiment, and simplifying the procedures required for the astronauts to conduct the experiment. The procured film was designated QX–807 emulsion 1–32 by Eastman Kodak. Additional information concerning this approach can be found in a report by NASA (1975a).

# Mission Operations

## Mission Profile

The Apollo-Soyuz mission was the first manned space flight conducted jointly by two nations. The three primary objectives of this joint American-Soviet venture were to develop and test systems for manned spacecraft rendezvous and docking that would be suitable for use as a standard international system; to demonstrate the capability of crew transfer between two different spacecraft; and to conduct a series of science and applications experiments (Hardee, 1976:2–1).

Because of the different pressures and compositions of the Apollo and Soyuz spacecraft atmospheres (5 to 14.7 pounds per square inch, respectively), a cylindrical "docking module" (DM) was built. This tunnel-like body was basically an airlock that permitted the crews to transfer between the two spacecraft. It had docking facilities on each end, permitting it to join the Apollo and the Soyuz (Figure 41).

The Apollo spacecraft was similar in most respects to those that were used on the Skylab missions. For the Apollo command/service module (CSM) some modifications were made to fit mission needs. Additional controls for the docking system and special DM umbilicals were added, together with experimental packages and their controls. Also, the steerable high-gain antenna that was used for deep space communications during the Apollo lunar missions, but was not needed for Skylab, was reinstalled for the Apollo-Soyuz CSM. The antenna locked onto a communications satellite, known as the "applications technology satellite" (ATS–6), placed in synchronous orbit over the east coast of Africa. The combination of ground stations and ATS–6 provided communications (including scientific data telemetry) with the Mission Control Center at Houston, Texas, for an average of 63 percent of each spacecraft revolution.

On 15 July 1975 at 12:20 Greenwich mean time (GMT) the Soyuz spacecraft was launched into Earth orbit in a northeasterly direction from the Baykonur launch complex in the Kazakh Soviet Socialist Republic. Seven and one-half hours later, the Apollo was launched from Kennedy Space Center, Launch Complex 39B (Figures 42, 43).

The Apollo CSM separated from the Saturn S–IVB stage one hour and 14 minutes after lift-off and began proceedings for extraction of the DM from

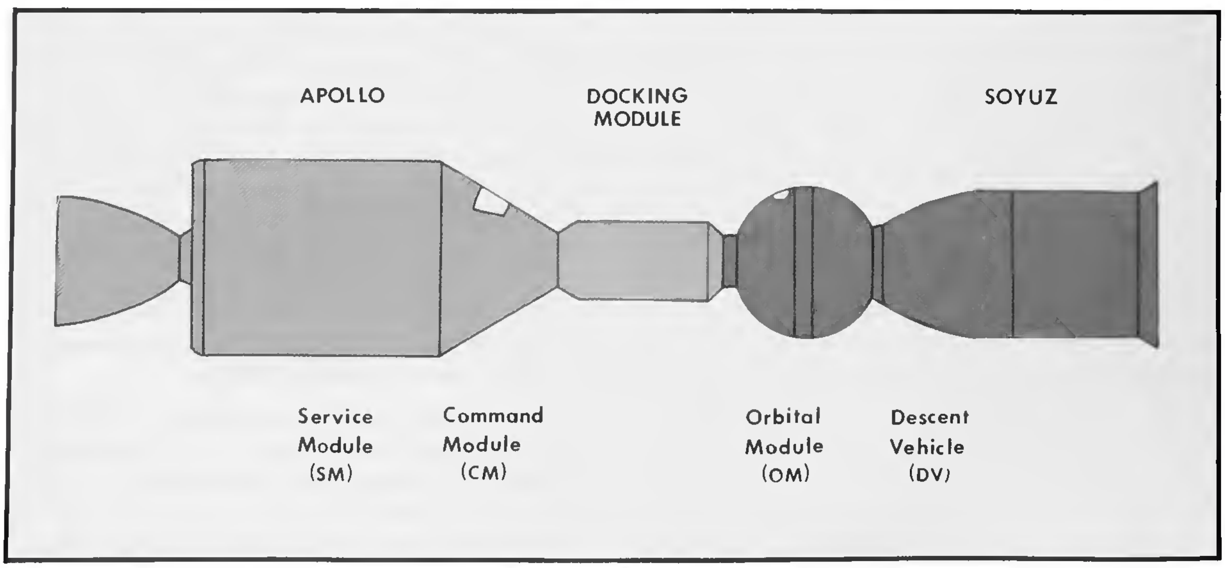



Figure 41.—Schematic of the Apollo and Soyuz spacecraft in the docked configuration.

the launch vehicle. After the DM was extracted, a misrouted pyrotechnic connector cable hindered the removal of the docking probe until a corrective procedure was successfully used to remove the probe. During this "pre-joint phase" several science experiments were conducted, including portions of the Earth Observations and Photography Experiment.

On 17 July 1975, after the Apollo circularization and rendezvous maneuvers were completed, the first docking was performed. During the following two days the Apollo remained docked with the Soyuz for joint operations; there were four crew transfers. Joint activities included television tours of both spacecraft and views of parts of the United States and the Soviet Union, a press conference and commemorative ceremonies, and scientific experiments.

The Earth Observations and Photography Experiment was not considered one of the joint endeavors.

FIGURE 42.—The Soviet Soyuz space vehicle (*left*), carrying cosmonauts Aleksey A. Leonov and Valeriy N. Kubasov, at time of launch from the Baykonour Cosmodrome in Kazakhstan (NASA press release photograph S–75–33375); and Apollo Saturn–I launch (*right*) on 15 July 1975 from the John F. Kennedy Space Center, Cape Canaveral, Florida. (NASA press release photograph S–75–28550)

TABLE 8.—Apollo-Soyuz mission events and scientific data (from El-Baz and Mitchell, 1976)

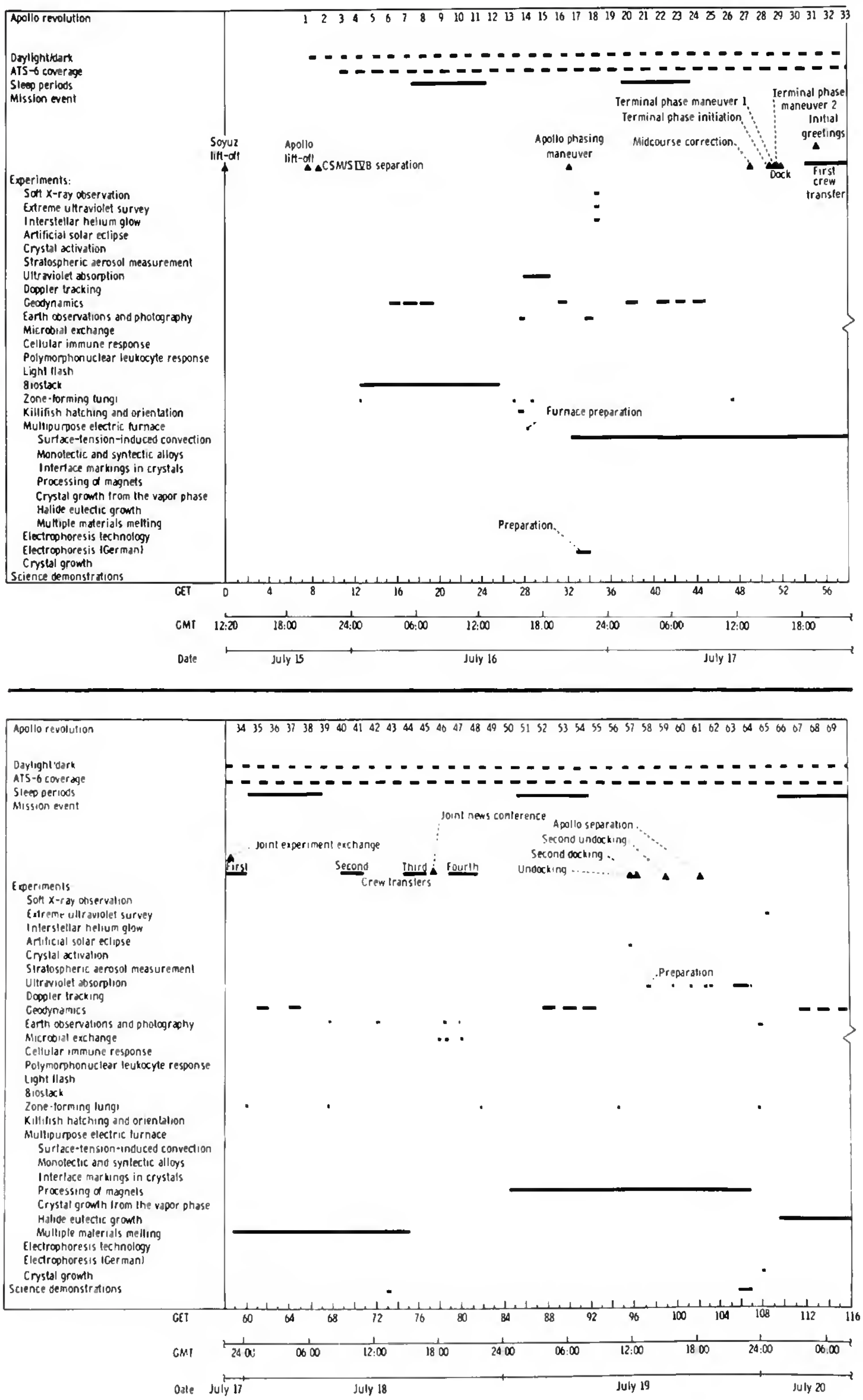
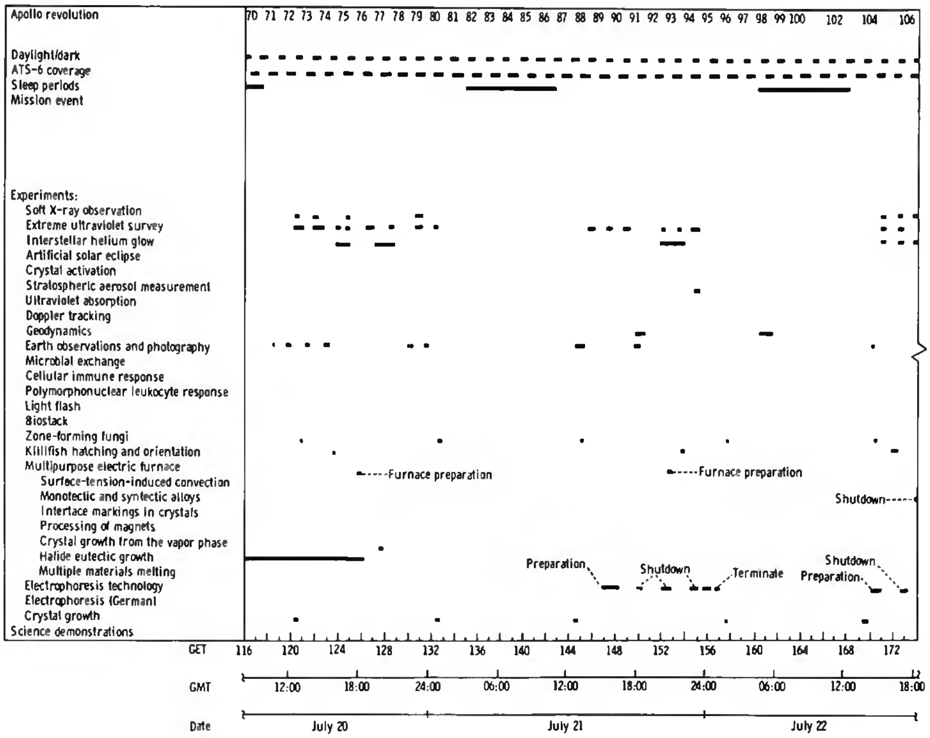
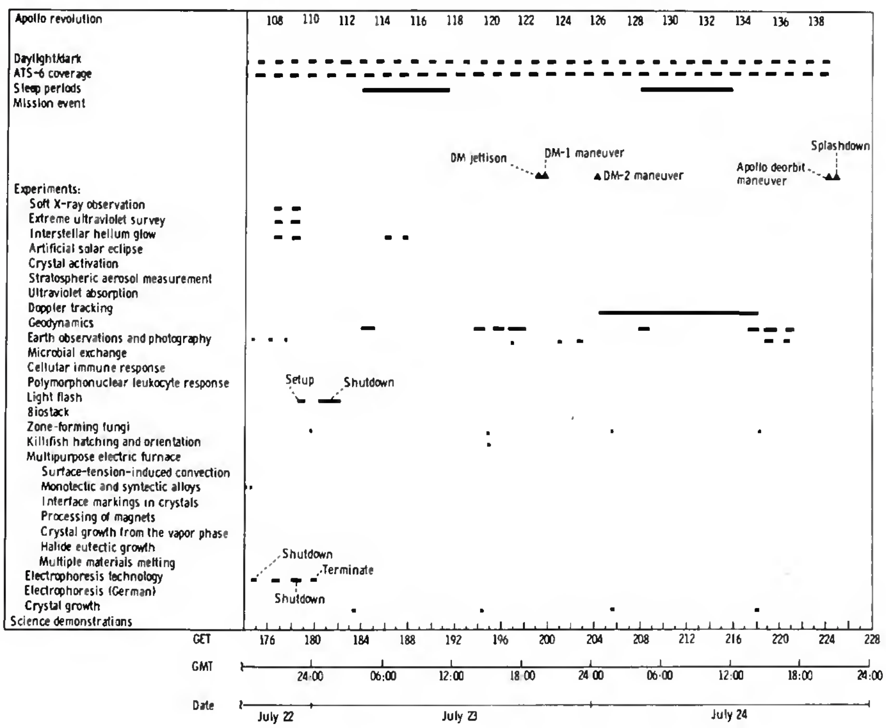


TABLE 8.—Continued



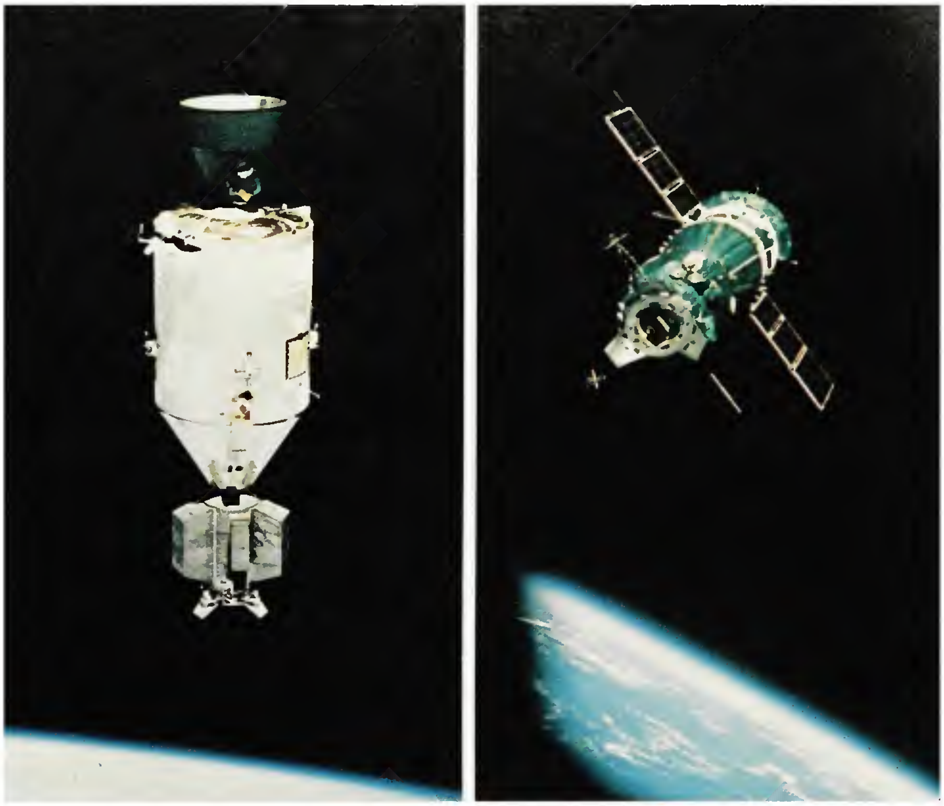


FIGURE 43.—The Apollo spacecraft (*left*) and the Soyuz spacecraft (*right*) as photographed by each other after undocking in Earth-orbit. The wing-like extensions of the Soyuz are two solar-power panels. The Apollo command and service module is pointing the docking module towards Earth.

However, many of the targets selected for observations and photography were to be overflown, under favorable conditions, only during the joint phase. The way to remedy the situation was to indicate in the flight plan activities related to the experiment prior to and after the joint phase as "Earth Obs"; during the joint phase, the same activities were labeled "Orbital Science." It is interesting to note that during a later Soviet Earth orbital flight of Soyuz 22 in September 1976, emphasis was placed on "Earth resources photography" (*Aviation Week*, 1976).

Almost 44 hours after the first docking, Apollo undocked from the Soyuz and served as a sun-occulting body for the Artificial Solar Eclipse Experiment. A second docking test was performed to exercise the docking system in a different mode of operation. Final undocking occurred at 15:20 GMT on 19 July (Figure 43). Forty-three hours after this last undocking, the Soyuz began its descent and touched down safely in Kazakhstan on 21 July at 10:51 GMT.

The Apollo remained in orbit for four additional days. On 24 July, after a flight of 217 hours and 28 minutes, the Apollo command module splashed down in the Pacific Ocean only 1.3 km from the target point. Recovery operations were performed by the U.S.S. *New Orleans*. A detailed outline of major mission events and scientific data collection periods is given in Table 8 (from Hardee, 1976).

## Experiment Support Activities

### MISSION SUPPORT

#### *Science Support Team*

One of the responsibilities of the Principal Investigator (PI) for each experiment is to provide scientific expertise during the mission. During the Earth Observations and Photography Experiment, the astronauts required answers regarding their observations from specialists. The PI served as the liaison. Furthermore, since weather conditions could not be forecast in advance of the mission, necessary adjustments during the flight had to be initiated and approved by the PI. As will be discussed below, several research parties were to conduct investigations (in the air, on land, and at sea) concurrent with crew observations. This also required the exchange, through the PI, of data from the astronauts to the research parties and vice versa.

A science support team was established prior to the mission. This team included, in addition to myself, two geologists (W. Muehlberger and C. Breed); two oceanographers (R. Stevenson and G. Maul); three members of my staff and one research associate, all of whom are also geologists (R. Wolfe, D. Mitchell, S. McLafferty, and A. Walker); and four NASA personnel from JSC (G. Griffith, R. Weitenhagen, D. Incerto, and C. Nash). This large number of people was necessary in order to provide technical support on a 24-hour-per-day basis. Even while astronauts slept, planning for the next day's activities required science support team participation.

All team members had been briefed on the rules of mission operations. Many had also participated in mission simulations or "sims." Sims are usually conducted in a realistic fashion, including dealing with malfunctions, changing the flight plan, and following every conceivable alternate procedure and plan. As a matter of fact the tremendous success of NASA's flights is attributable in large part to these sims, where the simulation supervisor (affectionately called "sim-soup") attempts to go over every phase of the mission again and again.

These simulations were quite thorough. They even included "fake" observations by the astronauts. The purpose of these was to test the system, crew, flight controllers, and science team alike. The sims were conducted on location at the MCC in Houston, Texas. This center includes the mission operations control room (MOCR) and a host of other support rooms on the second floor of JSC building 30. The simulations that involved the Earth Observations and Photography Experiment were held during the four months that preceded July 1975: 4 March (Rev 15, 16, 17), 3 April (Rev 72, 73, 74), 16 May (Rev 64), 23 May (Rev 106, 107, 108), 4–6 June (Rev 90, 91, 104, 106, 107, 108), and 24 June (Rev 15, 16, 17).

*Realtime Activities*

During the mission, the science support team operated in one of the support rooms adjacent to the MOCR that was dubbed "Earth Obs SSR" for the Earth observations and photography science support room. In communications during the flight the operation was simply referred to as "Vis Obs," for "Visual Observations." These communications followed a rigid flow; as for everything else, NASA had a flow chart of who was to talk to whom, formally or informally (Figure 44). The "buck" stopped at "Flight," that is, whoever was serving at the console of the Flight Director at the MOCR. Flight was also the only person to talk directly to the Capcom (or capsule communicator, an astronaut usually from the support crew), who in turn was the only one to talk to the orbiting astronauts.

The layout of the science support room (Figure 45) included a console with two positions (one for the PI and one for a representative from JSC's Flight Operations Directorate), a televisor and a nearby large wall for display of maps and photographs, two mission status desk positions ("land desk" and "ocean desk"), and a general file area with a telephone link to ground support investigations. Figure 46 illustrates the working conditions of the science support room.

The flight operations position was occupied by JSC personnel (G. Griffith, R. Weitenhagen, or D. Incerto), who kept an experiment log. In that log all events, comments, and changes that affected the performance of the experiment were kept. Figure 47 shows that a significant change was made in the spacecraft's visual observations attitude. The new attitude allowed the astronauts to see the ground beneath them while they were right-side-up, rather than in the uncomfortable upside-down position that had been selected.

The other console position served as a 24-hour-per-day "command post" for the Principal Investigator or his representative. If the author was not serving at this position, Dr. Robert Wolfe, or another team member had to be there. My schedule at the console looked like this:

| | | |
|---|---|---|
| Wednesday | 16 July | 12 noon to 8pm |
| Thursday | 17 July | 7am to 5pm |
| Friday | 18 July | 12 midnight to 3pm |
| Saturday | 19 July | 12 noon to 9pm |
| Sunday | 20 July | 3am to 8pm |
| Monday | 21 July | 4am to 1pm |
| Tuesday | 22 July | 5am to 4pm |
| Wednesday | 23 July | 3pm to 8pm |
| Thursday | 24 July | 6am to 2pm |

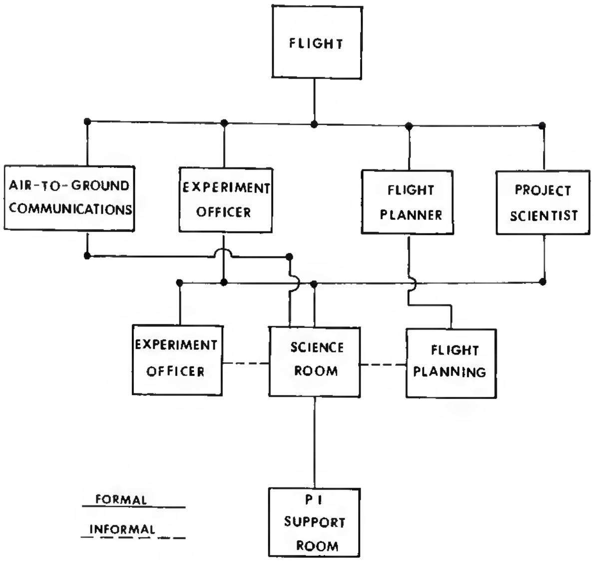



FIGURE 44.—Flow chart indicating the lines of communications during the Apollo-Soyuz mission.

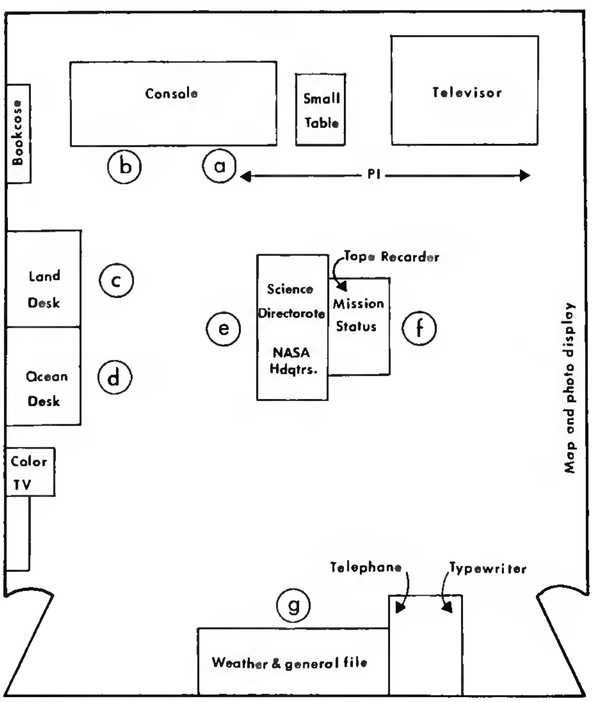



FIGURE 45.—Layout of the science support room of the Earth Observations and Photography Experiment at the Mission Control Center, Houston (a = Principal Investigator's position, b = Flight operations position, c = co-investigators for land observations, d = co-investigators for ocean observations, e = JSC's science and applications and NASA headquarters' representatives, f = mission status desk, g = weather files and secretarial support).

During these periods, the most significant mission activities were performed. In addition to these times, other responsibilities included daily PI meetings, daily report preparation and submission, planning meetings, press briefings, and preparation of a summary mission report at the end of the mission.

The science press briefings were always lively and interesting. Science reporters who covered the Apollo-Soyuz mission were knowledgeable and had the experience of many space missions to present a challenge to the PIs. On occasion, however, the reporting did concentrate on anomalies and controversies.

The science support room console was equipped with plugs for listening devices to monitor relevant conversations at the Mission Control Center. Unfortunately, there were usually three to six "relevant" conversations at any one time, for example, conversations related to the flight plan, spacecraft attitude, weather conditions, experiments status, astronaut observations. The trick was to be able to pick only a few words from each conversation to keep up to date with what was going on, and to mentally filter out all the rest.

It was also possible to push a button on the console's panel to activate the "talk-back" capability in order to take part in the conversations. A special "science conference loop" was established at my request to allow talking directly to both Flight and the Capcom. With this, however, came written instructions that PI utilization of the loop would be restricted to amplification of instructions, clarification of procedures or techniques, initiating time critical instructions or queries, or for responding to crew originated queries relating to MA–136 observations or techniques. Furthermore, discussion and coordination of MA–136 activities which might result in changes to documented procedures or to the flight plan will be conducted over the normal voice loops used for these purposes.

In instances where talking through these "loops" was cumbersome and too time consuming for an urgent task, it was possible to pick up a badge that allowed one to enter the MOCR and talk to Flight or the Capcom "face-to-face." It all worked out very well—a tribute to the flexibility of the system.

One of the most important activities of the Principal Investigator was the initiation of "mission notes." These notes were necessary to send instructions to the astronauts. They were prepared in quadruplicate. One copy was kept for the experiment log mentioned

FIGURE 46.—Activities in the science support room: *a,* seated at the console are (*left to right*) F. El-Baz, R. Weitenhagen, and G. Griffith, talking to members of the temporary mission support staff; *b,* W. Muehlberger (*left*) discusses an observation target with F El-Baz at the televisor table; *c,* science support team members during the "nighttime shift" of the Apollo-Soyuz mission operations; *d,* F El-Baz points to the location of an upcoming visual observation activity while discussing applicable weather condition with A. N. Sanderson; *e,* the map and photo display being updated by Susan W. McLafferty, while C. Nash looks on; *f,* Delia A. Mitchell at the mission status desk, recording visual observation comments in realtime. (Courtesy of A. R. Patnesky, NASA photographer)

/7

| SITE ACQ-LOS | FLIGHT EVENTS HISTORY BRIEFING |
|---|---|
| | |
| 127:10 | WEATHER OD SHOWS AN IMPROVEMENT FOR SITE 4A ON REV 78. MOST |
| | OF THE CLOUDS NOW ARE OFF THE COAST. |
| | |
| 127:40 | USING REV 76 TRAJ. DIGITALS |
| | Δλ 42 MIN WEST |
| | ΔT 22 SEC LATE |
| | PUT DISPLAY IN LOG |
| | |
| 129:00 | GAVE EXP. BRIEFING ON REV 78 AND 79 USING WEATHER OD. |
| | |
| 130:08 | REV 78 ATTITUDE IS NOMINAL FOR VIS OBS. |
| | |
| 130:12 | CREW COMMENTED - BASED ON CLOUD FEATURES PACIFIC IS FULL OF |
| | EDDIES HAWAII IS OVERCAST & DP - DUE TO CLOUDS TOO FAR NORTH |
| | FOR THIS PASS. CM3 ATTITUDE GOOD FOR ACQUIRING BUT SITE GOES |
| | BY SO FAST (5 SEC) FOR TAKING DATA. HOWEVER, DOES NOT WANT TO |
| | RECOMMEND A CHANGE AT THIS TIME. |
| | |
| 130:30 | CREW IS RECOMMENDING CM3 TO BE POINTED AT NADIR AND NEXT PASS |
| | REV 79. THEY WILL RUN THE PASS AT APPROXIMATELY 30° PITCH |
| | DOWN. PI CONCURS WITH CREW RECOMMENDATION OF PITCH DOWN 30. |
| | FAO WILL COMPUTE ANGLES FOR 30° FOR REV 79 VIS OBS PASS. |
| | |
| 130:46 | CREW GIVEN UPDATES FOR VIS OBS PASS REV 79 ATTITUDE CHANGE. |
| | |
| | |

JSC Form 1441 (Apr 66)
NASA-JSC

FLIGHT DIRECTOR'S MISSION LOG

FIGURE 47.—Example page of the log book in which were recorded all events that significantly affected the conduct of the Earth Observations and Photography Experiment during the Apollo-Soyuz mission.

above. Three copies were placed in a metal container, which was transported through an elaborate air-pressurized pipe system to appear in front of the Flight Director, the Capsule Communicator, and the Flight Planner.

Mission notes were written in a clear, concise language to make it easy for the Capcom to read the instructions to the astronauts. (Capcom would do so only after Flight's approval which came after the Flight Planner gave his blessings). The Capcom was supposed to give precise instructions to the astronauts based on these notes. If he did not, confusion developed as in the following example.

During the mission, Dr. Charles Yentsch, an experiment Co-Investigator, reported to us from his ship at sea that he noted a red color (usually attributed to red tide blooms) in the area of Boothbay Harbor, Maine. Since an opportunity presented itself to schedule additional photography of the area in realtime, we sent on the following Mission Note (El-Baz, n.d.a.): "Revolution 105/106; New Item: New England Red Tide; GET 173:09 to 173:13: Photograph New England Coastline from Boston to New Brunswick: CM3/Silver/50 (f9.5, 1/500) Frame interval 6 seconds." We also added the following explanatory sentence: "Our support ship at sea reported red tide discoloration at Damariscotta River in Boothbay (Site 5F)."

Instead of reading the instructions that called for continuous photography of the coastline from Boston to New Brunswick, the following conversation occurred between the Capcom Robert Crippen, and astronaut Slayton (from unedited mission transcript, NASA 1975b:843–844):

CRIPPEN: Incidentally, Deke, on our upcoming pass across the States, we are going to have an opportunity to look at the red tide. And I was going to get you some information about that whenever it's convenient for you to copy it.

SLAYTON: Okay. Stand by for it.

CRIPPEN: What might be convenient for you, Deke, is if you can just get out your Earth Obs book on target 5 Foxtrot,[1] and I can just relate it to you on there.

SLAYTON: Okay. Fine. Just a second—Okay. Go ahead.

CRIPPEN: Okay. To describe to you where the ship spotted it if you're looking at 5 Foxtrot, right above where we've got the word "Boothbay" written in, you can see there's a river that looks like it's flowing—flowing south there that comes out. Well, it was right at the mouth of that river that the red tide was spotted.

SLAYTON: Okay. Got you.

CRIPPEN: Okay. And our recommendation on the camera is— Well, for the window, it should be visible out of CM–3. Want you to use the silver camera, of course. And use 50, with an f-stop of 9½ and a speed of 1/500.

SLAYTON: Okay. Got that.

CRIPPEN: Frame intervals should be about 6 seconds—every 6. And we should be passing over that, if you want to note it, at about 173:09 to 13. And we'll— can give you a call just before that if you'd like a reminder.

SLAYTON: Okay. 173:09. And you want to shoot a mapping strip through there, essentially, huh?

CRIPPEN: Negative. You can go ahead and just use it and take a shot about every 6 seconds or as you see fit.

SLAYTON: Okay.

Since Slayton did not know where the Damariscotta River was, he waited to see red-colored water

[1] It is common practice in communications to verbally clarify the alphabet by expanding the letter into a word, e.g., "5F" becomes "5 Foxtrot."

to start his photography. It turned out that he waited too long and photographed the Bay of Fundy of Canada instead; thus information on New England was not obtained. The example illustrates the need for direct communications between the PI and the orbiting astronauts to diminish the possibility of giving them incorrect or incomplete instructions.

A visit to the science support room by French oceanographer Capt. Jacques Cousteau resulted in the generation of numerous mission notes. Capt. Cousteau had talked to Brand and Slayton on an earlier occasion concerning his idea of "sea farming." Because of time considerations he was able to supply us with his list of specific sites only during the mission. These "sea farming sites" are coastal areas of high productivity, which he considers suitable for fish farms (Figure 48). His campaign to save these regions from pollution has been gaining recognition. Therefore, it was necessary to obtain data on the characteristics of these regions. Several of the sites were scheduled in realtime to acquire the necessary data.

The televisor was used to explain new activities or changes to the flight plan to the mission operations personnel, particularly Flight and Capcom. A television camera with zoom capability was mounted on a properly lit table for televised transmission of charts and other material within the Mission Control Center. Televised images could be seen by anyone who selected channel 78.

The experiment team provided a way of making available to Mission Control depictions of the individual groundtracks of all revolutions during which the Earth Observations and Photography Experiment was conducted. The ingenious device was a 12.7 cm (5 in) film-reel on which were rolled strips of a 1:22,000,000 scale map. The strips straddled the groundtrack of the mission revolutions in sequence. With this device and the use of the television camera it was possible to televise the position of the astronauts and what they were looking at throughout the mission.

The televisor was extensively used for weather briefings. Changes in weather patterns and particularly cloud cover were monitored at Houston through the use of data from NOAA's synchronous meteorological satellite (SMS). The satellite was geostationary, since it had a geosynchronous orbit at 36,000 km altitude. An example of the satellite's photography is given in Figure 49.

The weather experts supplied information as to the location of cloud cover based on the best available data. The percent of cloud cover (0–3/10, 4–7/10, 8–10/10) was plotted on 1:40,000,000-scale charts. The forecast was usually given several hours ahead

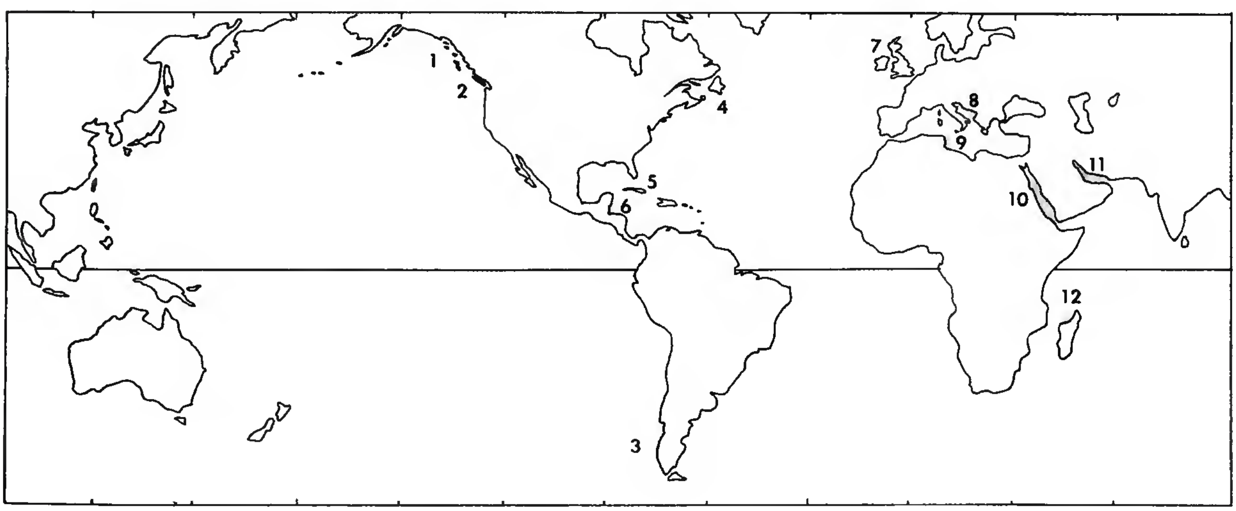



FIGURE 48.—Locations of sites that are considered by French oceanographer Captain Jacques Cousteau to be adequate for fish farming (1 = Alexander Archipelago, 2 = Strait of Georgia, 3 = southern coast of Chile, 4 = south coast of Newfoundland, 5 = southern coast of Cuba, 6 = Gulf of Honduras, 7 = coastal waters of Scotland, 8 = Adriatic Sea, 9 = Gulf of Gabes, 10 = Red Sea, 11 = Persian (Arabian) Gulf, 12 = northwest coast of Madagascar).

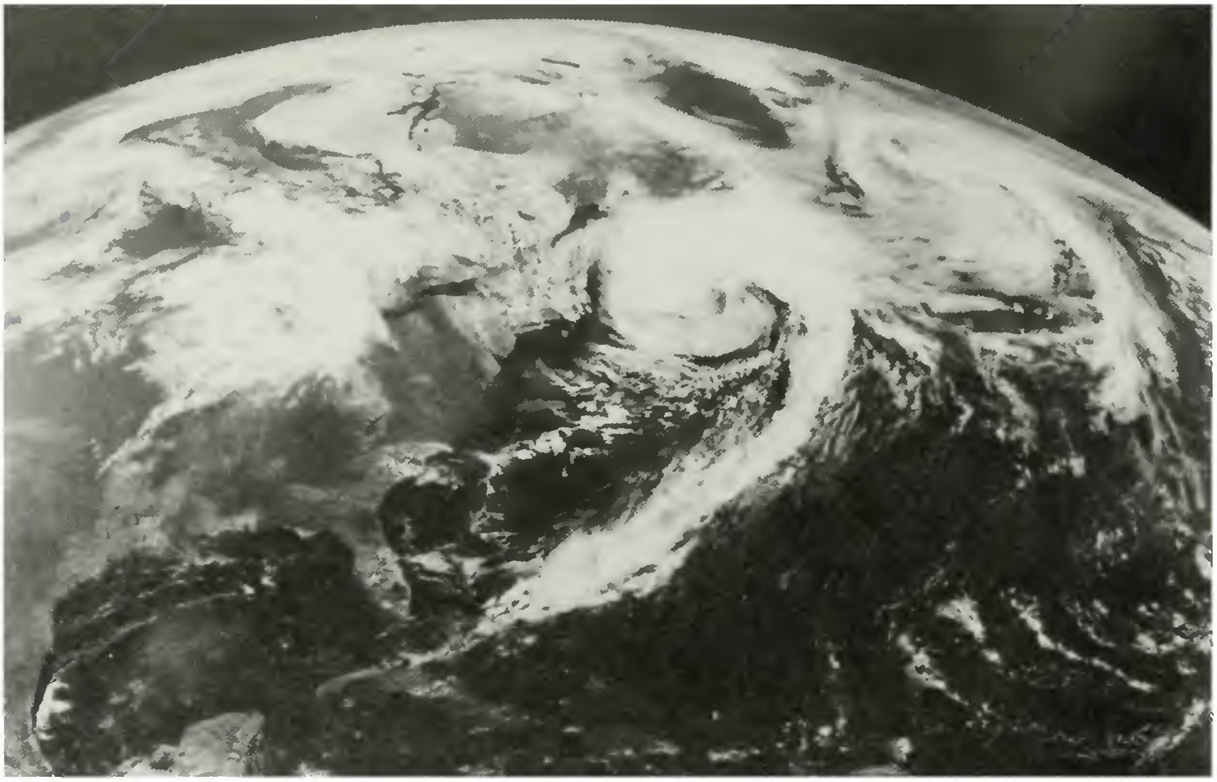


FIGURE 49.—Image acquired by the Synchronous Meteorological Satellite (SMS) showing weather conditions over the North American continent. Image resolution is about 3.2 km. (NOAA photograph SMS–1 Pic. 52, 5/28/74)

of the time of an Earth observations activity, and the most recent SMS images were received on a facsimile machine that did not provide high resolution data. This limited capability proved to be a handicap. There are several advantages to having realtime SMS sectorized images at the usual 30 minute intervals on a high resolution recording device. If an observation site is seen to be cloud-covered, the flight plan can be modified accordingly.

In addition to weather briefings, the television setup was also used to display photographs and data from ground support investigations for the information of mission support personnel. At one time when the crew indicated that they were using more film than anticipated and feared that they would run out of film before the mission was over, we jestingly televised the reply shown in Figure 50. It generated a few cheers from the challenge-seeking NASA engineers.

The mission status position in the science support room (Figure 45) was where all air-to-ground con-


FIGURE 50.—Artist's conception of the Space Shuttle orbiter vehicle. The picture and message beneath were televised from Houston's Mission Control Center.

MA136 - Earth Observation and Photography

Rev 57 (GET 95:42-96:28): TV transmission of undocking provided a tour of North African and Asian deserts covering the Central Sahara in Africa to the Gobi Desert of China. Algerian Tifernine Dunes, Irrarene Dunes and Erg Oriental (Great Eastern Erg) appeared much redder than the lighter-colored desert to the south, in Mali and southern Algeria, and toward the north in Tunisia. Pass continued over the Mediterranean past Sicily to the Black Sea. Although over the South Altantic Ocean no significant deep ocean features were observed, between Sicily and Italy, a distinct oceanic feature was observed, probably caused by wind shadowing changing the albedo of the surface. Cloud cover over USSR, clearing over Mongolia. Several lakes were visible. Last part of pass over the Gobi Desert east of the Hai Ho (river) and west of the Hwan Ho (Yellow River). End of pass at the cloud cover over the Alashan and Holanshan Mountains at eastern edge of the Alashan Desert.

Rev 64: Mapping pass - M6 Australia
Vis. Obs. 11C Simpson Desert
11B Coral Sea
3A Cloud Features

Weather: 11C - 0-3/10 over Simpson Desert
From 144°E to about 147°E along groundtrack, a patch of 4-7/10 and 8-10/10.

11B - 0-3/10 along coast and Great Barrier Reef. 4-7/10 over Coral Sea.

3A: 8-10/10.

Crew Remarks: At 107:42 Brand reported that he was in the middle of the Earth Obs pass. Although the spacecraft might have been a few degrees off groundtrack because of the incomplete P52 maneuver, it is believed that the pass was accomplished as planned.

The NASA B57 plane flew the New England pass today.

It started with the northernmost site off the coast of Maine. The weather was clear, but the pilot reported some haze. They flew both lines as per flight plan.

The flight over Cape Cod was also completed. The two flight lines were divided into four lines. The weather was clear. There was some cloudiness over Buzzards Bay.

The plane also overflew one of the two Long Island passes, that was cut short by 40 miles because of cloudiness. Pilot reported that they estimated that they obtained 75% of requested data in clear weather.

The B57 will fly the Florida Pass tomorrow per flight plan.

FIGURE 51.—Example of the mission daily reports concerning the Earth Observations and Photography Experiment. This report covered experiment-related activities during 19 July 1975.

versations relating to the experiment were recorded on tape. (These tape recordings were later checked against the mission transcripts from two sources to compile the edited transcripts in Appendix 1.) The status of experiment performance was also kept on a chronological basis.

In addition to participating in the aforementioned activities, the Co-Investigators had the responsibility of contributing to the daily report (Figure 51) and monitoring the groundtruth investigations. These concurrent support activities will be described below. The CIs also received and screened the daily reports that arrived from the Smithsonian Institution's Center for Short-Lived Phenomena, which provided information on transient phenomena developing on the Earth's surface. The center used its network of more than 3000 correspondents in 148 countries to prepare the daily reports on short-lived events occurring during the mission and to transmit information on events observed by the astronauts. Significant reports included those on an oil spill off the Florida Keys; volcanic eruptions in New Zealand, Costa Rica, and Hawaii; and earthquakes in Mexico and the Philippines.

## Concurrent Investigations

Prior to and during the flight of Apollo-Soyuz, numerous investigations were conducted in support of the Earth Observations and Photography Experiment. This simultaneous groundtruth data collection program was the largest ever conducted in support of a manned space mission. Data collection was to complement the postmission interpretation of orbital observations and photography, and possibly to affect the conduct of the experiment in realtime. Data were collected through aircraft flights, land investigations, and ocean surveys in many parts of the world (Figure 52).

### *Aircraft Flights*

England (sites 6A and 6B).—The Royal Air Force flew missions on three days over ocean waters off southern Ireland and England to support observations and photography of the English Channel. Expendable bathythermographs (XBT) were dropped from the planes to provide data on water temperature as a function of depth.

New Zealand (site 1).—The Royal New Zealand Air Force flew P–3 airplanes along the revolution 17 groundtrack starting from East Cape, New Zealand, then north-northeast over the Pacific Ocean to obtain photographic data and to plot cloud types and heights. A New Zealand Navy research vessel made a transit along the same line and acquired oceanographic data, including water temperatures and sound velocity measurements.

United States (sites 2A, 4A, 4B, 5B, 5E, 5F).—Several high-altitude flights were conducted over the United States with WB–57 aircraft based at JSC, Houston, and U–2 aircraft based at the NASA Ames Research Center, Moffett Field, California. Photographs were taken using a metric RC–10 camera and a multispectral Vinten System A camera. Photographic sensor data are provided in Table 9. Photo-

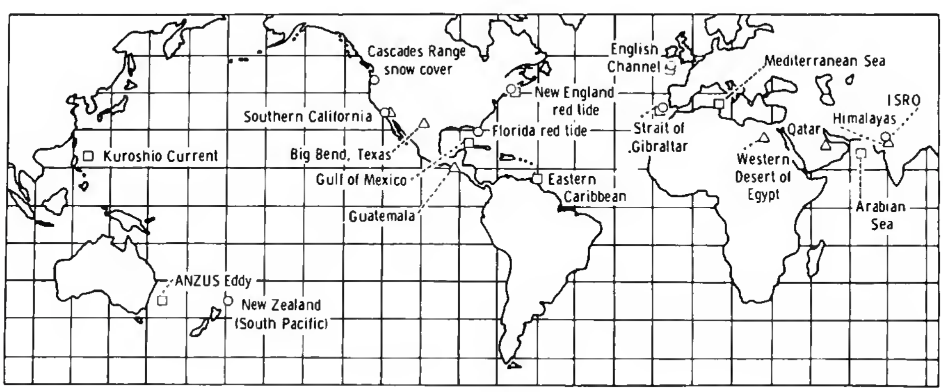



Figure 52.—Locations of support efforts of the ASTP Earth Observations and Photography Experiment. (After El-Baz and Mitchell, 1976: 10–48)
○ aircraft support □ oceanography support △ ground support

TABLE 9.—Aircraft photographic sensor data (from El-Baz and Mitchell, 1976)

| Sensor type | Lens focal length, cm (in.) | Film type | Filtration | Spectral band, nanometer | Percent of overlap |
|---|---|---|---|---|---|
| Vinten | 4.45 (1.75) | Panatomic-X, 3400 | Schott GG 475 and Schott BG 18 | 475 to 575 | 60 |
| Vinten | 4.45 (1.75) | Panatomic-X, 3400 | Schott OG 570 and Schott BG 38 | 580 to 680 | 60 |
| Vinten | 4.45 (1.75) | Infrared Aerographic, 2424 | Schott RG 645 and Corning 9830 | 690 to 760 | 60 |
| Vinten | 4.45 (1.75) | Aerochrome Infrared, 2443 | Wratten 12 | 510 to 900 | 60 |
| RC-10 | 15.24 (6) | Aerial color, SO-242 | 2.2AV | 400 to 700 | 60 |

graphic coverage was acquired over the East Coast (coastal areas of New York, Massachusetts, and Maine); Florida (coastal areas); the northwestern United States (Washington, Idaho, and Oregon); and the southwestern United States (from Kingman, Arizona, to Santa Maria, California). These photographs are very useful in providing an intermediate scale between spacecraft and ground investigations (Figures 53, 54).

### *Land Investigations*

CENTRAL AMERICA (site 5D).—Prior to the mission, geologists from the University of Texas at Austin conducted photogeologic investigations of the tectonic setting of the Yucatán Peninsula, particularly the Bartlett Fault system. This system was the site of recent earthquakes in Guatemala.

EGYPT (sites 9E and 9F).—Following the mission, geologists from the Ain Shams University, Cairo, conducted field surveys in parts of the area covered by the mapping camera on revolution 71, including the Abu Rawash region and Baharia Oases. Ground investigations included studies of desert erosion patterns and sand grain transportation. The major objective was to use the geological data in verifying color zoning and other features recorded on the ASTP film.

INDIA (site 10D).—Hydrologists of the Indian Space Research Organization made surveys of the amount of snow cover and the drainage patterns of the northwestern Himalayas. These studies were performed to acquire necessary data for water use and flood control.

UNITED STATES (site 2A).—Geologists from the California Institute of Technology conducted field surveys that are related to astronaut observation of southern California. Emphasis was placed on fracture patterns that are related to the San Andreas Fault system, and the process of desert varnish in the Mojave Desert.

### *Ocean Surveys*

ANZUS EDDY (site 11D).—The Australian ship *Bombard*, stationed in the Tasman Sea, surveyed the warm water ANZUS (Australia-New Zealand-United States) Eddy. Oceanographic data indicated that the nearly circular eddy was 145 to 160 kilometers in diameter with surface temperatures 2° warmer than the surrounding water. Ship personnel also reported a cumulus cloud formation over the center of the eddy and a number of trawlers fishing for tuna within the eddy.

CARIBBEAN SEA (site 7G).—To support crew observations and photography of the extent of organic acid outflow from the Orinoco River, the Bellairs Research Institute of McGill University, Montreal, sponsored three cruises from the island of Barbados on 21, 22, and 23 July. Observations and measurements were made of sea state, water color, sea surface temperature, salinity, chlorophyll content, cloud cover, and wind speed and direction.

GULF OF MEXICO (site 5A).—The National Oceanic and Atmospheric Administration (NOAA) research vessel *Virginia Key* made a transect of the Gulf of Mexico from Miami to the Yucatán Penin-

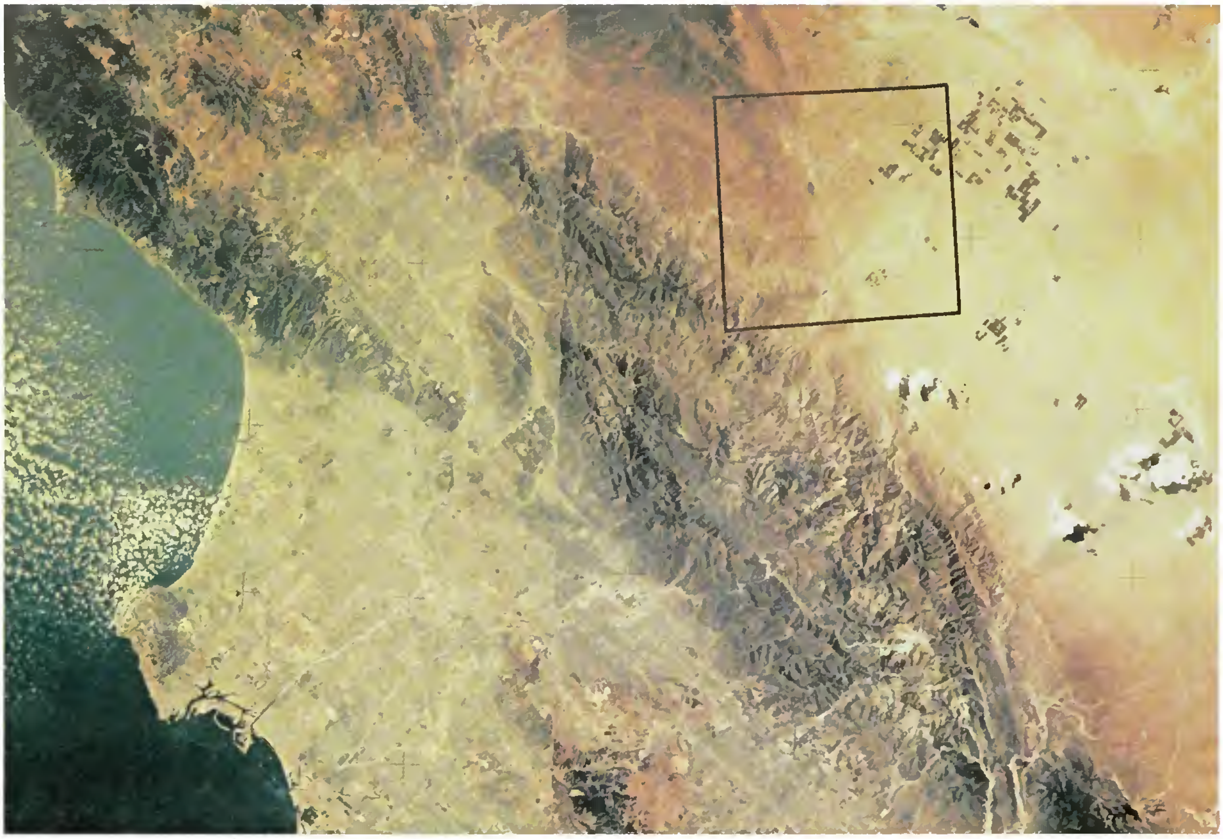


FIGURE 53.—Mosaic of two Apollo-Soyuz photos showing Los Angeles, the San Gabriel Mountains, the San Andreas Fault, and the Mojave Desert. The marked-off area shows the coverage of Figure 54. (NASA photographs AST–14–881 and AST–14–882)

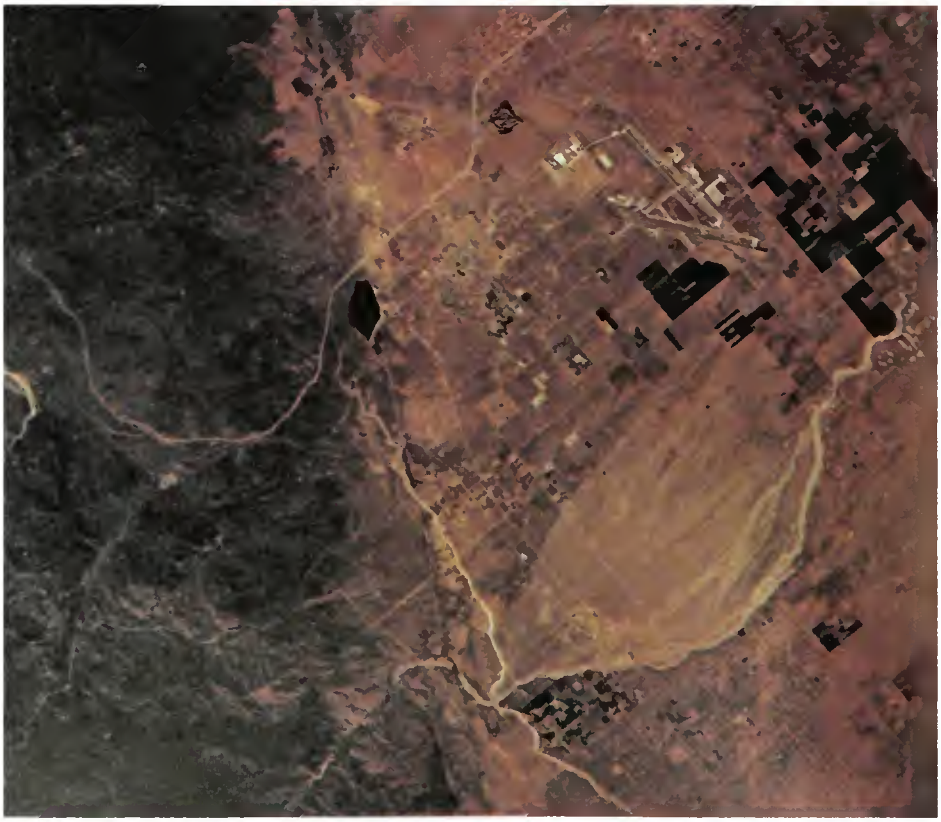


FIGURE 54.—Aerial photograph taken from an altitude of 20,000 meters by a U–2 aircraft based at the NASA Ames Research Center. This photo was taken during the ASTP mission to provide an intermediate scale between spacecraft and ground investigations. (NASA/JSC 239–16–0040)

sula and obtained data on the location of the Gulf Loop Current. In addition, an ocean research vessel made measurements in the Gulf Stream north of Jacksonville, Florida, on the distribution, size, and velocities of eddies. The ship also released four drifting buoys that had transmitters to the Nimbus-F satellite. The buoys were positioned about once a day throughout the mission and provided data on current direction and velocity. Approximately 20 NOAA ships were also stationed around the Mississippi River delta.

NEW ENGLAND (site 5F).—In New England, two Bigelow Laboratory research vessels, the *Bigelow* and the *Challenge*, made a traverse of the Gulf of Maine from Portland to the Bay of Fundy and also southward to Cape Cod. Data were obtained on the size, shape, and location of red water patches due to toxic phytoplankton and included measurements of sea surface temperatures, salinity, chlorophyll content, and water color. In addition to the red tide observations off the coast of Maine, support ships and sampling stations of the Commonwealth of Massachusetts acquired water color, salinity, and biological content data. A high chlorophyll content in the coastal waters off New England was reported and was possibly the result of abnormally heavy rains carrying an increased amount of biota into the sea.

STRAIT OF GIBRALTAR (sites 9J and 9K).—The U.S. Navy research vessel *Kane* obtained oceanographic data along a line paralleling the revolution 73 groundtrack from the Canary Islands to Spain. These data were obtained to support crew observations of a current boundary extending north and south off the western coast of Portugal. The Navy also flew a P-3 aircraft along this line dropping XBTs. East of the strait in the Mediterranean Sea, the carrier U.S.S. *Kennedy* obtained oceanographic and meterological data.

# Summary of Results

This book was completed about one year after the Apollo-Soyuz mission; however, the scientific value of the Earth Observations and Photography Experiment have not yet been completely realized. A data analysis program involving some twenty research groups is under way. These groups are affiliated with several government agencies, academic institutions, and research organizations in the United States and abroad. The "Summary Science Report" is being prepared for publication by NASA as volume 2, special publication SP-412.

## Scientific Findings

### Geology

#### *Desert Colors*

Deserts occupy nearly one-sixth of the Earth's land masses; however, detailed descriptions of most desert regions are lacking because size, remoteness, and inaccessibility make conventional surveys impractical and costly. Photographs acquired on the ASTP have added to existing data from Earth-orbiting spacecraft. These photographs include new information relating to both desert colors and dune patterns in several regions (Figure 55).

Synoptic photography and astronaut observations provide valuable information on desert color. Desert surfaces and sand dunes often contain iron compounds which, due to weathering, oxidize into red-colored oxides (Norris, 1969). Therefore, photographs of color zoning within a desert where all the sand is derived from the same source can be used to determine relative ages of the exposed material; the redder the surface, the more oxides it contains, and the older it is.

This property was studied particularly in the Sahara Desert of North Africa, where, in addition to visual observations and color wheel readings, the ASTP data included two vertical stereo mapping strips over Algeria and Egypt (Figure 55), a motion picture film of color zone transitions in Algeria obtained with the 16 mm camera, and numerous handheld photographs. Of particular interest is the photography of the Western Desert of Egypt and the Great Sand Sea of the Libyan Desert. In the "silica glass" region,

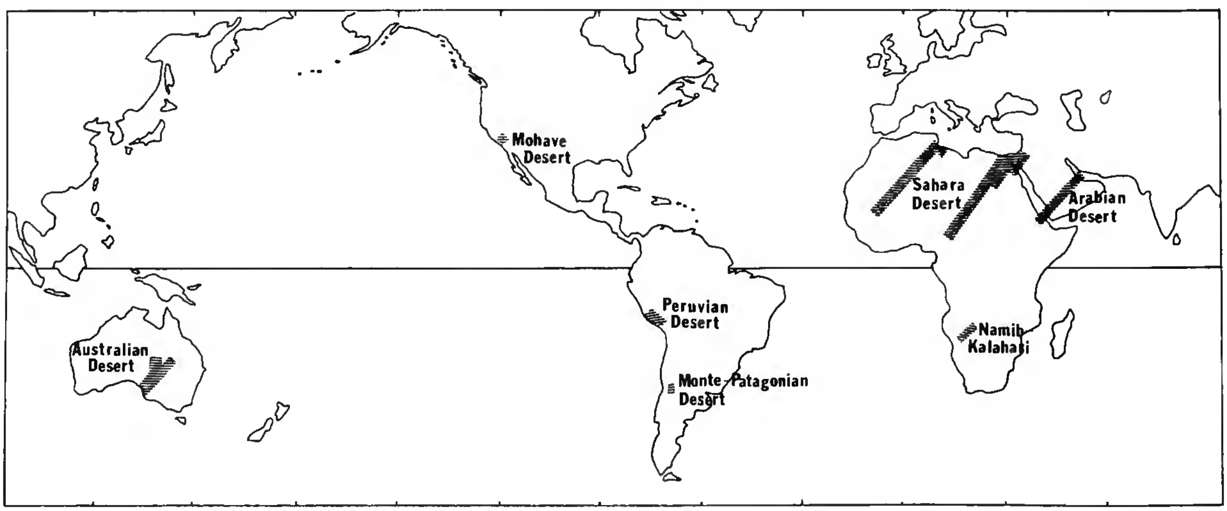



FIGURE 55.—Desert regions where observational and photographic data were acquired on the Apollo-Soyuz mission. Stereoscopic photostrips were obtained of the Simpson Desert (Australia), western and eastern Sahara Desert (North Africa), and the Arabian Desert. (After El-Baz, 1976:238)

FIGURE 56.—Vertical photograph taken with the Hasselblad camera as part of a mapping strip of stereo photography on ASTP. The displayed area is part of the Western Desert of Egypt. A sharp color change marks the boundary between the younger, yellow sands of the Great Sand Sea to the north, and the older, orange-red desert surface associated with the Gilf El-Kebir Plateau. The photograph covers an area of 195 km on the side. (NASA photograph AST–16–1246)

these color photographs clearly delineate the boundary between the younger, yellow sands of the Great Sand Sea and the relatively older, reddish plains of the Nubian Sandstone (Figure 56).

In the western Sahara, the crew noted the reddening in a large expanse of the Algerian Desert from the Hoggar Mountains to the dunes of the Grand Erg Oriental (comments by astronaut Slayton in El-Baz, n.d.b.: 22):

> We are now coming to the very dark, barren-looking hills with red areas interspersed between them and some very red sand to the north. In fact, it looks almost like a massive parabolic shape, black hills with red sands behind them to the north. North of that is an area with dunes a little better defined; they look like sand domes. And farther to the north we see the linear sand dune pattern.

This sequence of redder and older sands accumulating inland and away from the younger sands nearer to the coastline is duplicated in the Namib Desert of southwestern Africa (McKee and Breed, 1974: 9–3).

Reddening of sand as it moves away from the source is exemplified in the Simpson Desert of Australia. Apollo-Soyuz photographs of the Lake Blanche area show the lake as the sand source for closely spaced linear dunes. The color of the linear dunes is clearly zoned with darker (redder) colors away from the lake (Figure 57).

The above indicates that in some cases desert color can be used as a relative-age indicator. The ASTP data are being analyzed to construct a relative-age scheme for the photographed deserts. Groundtruth data are also being collected in the Western Desert of Egypt to verify the patterns in orbital photographs. This relative-age scheme, together with studies of sand dune patterns, will help establish directions of desert growth particularly in the drought-stricken areas of northern Africa.

### *Dune Patterns*

The Apollo-Soyuz astronauts photographed numerous desert sand patterns that are reminiscent of windblown features on Mars (Figure 58). For example,

FIGURE 57.—ASTP photograph of Lake Blanche (45 km in length) in southeastern Australia showing linear dunes emanating from the dry lake. The fine, subparallel dunes north of the lake show zones of color: brighter (more tan) near the sand source, and darker (more red) away fom the lake. (NASA photograph AST-16-1133)

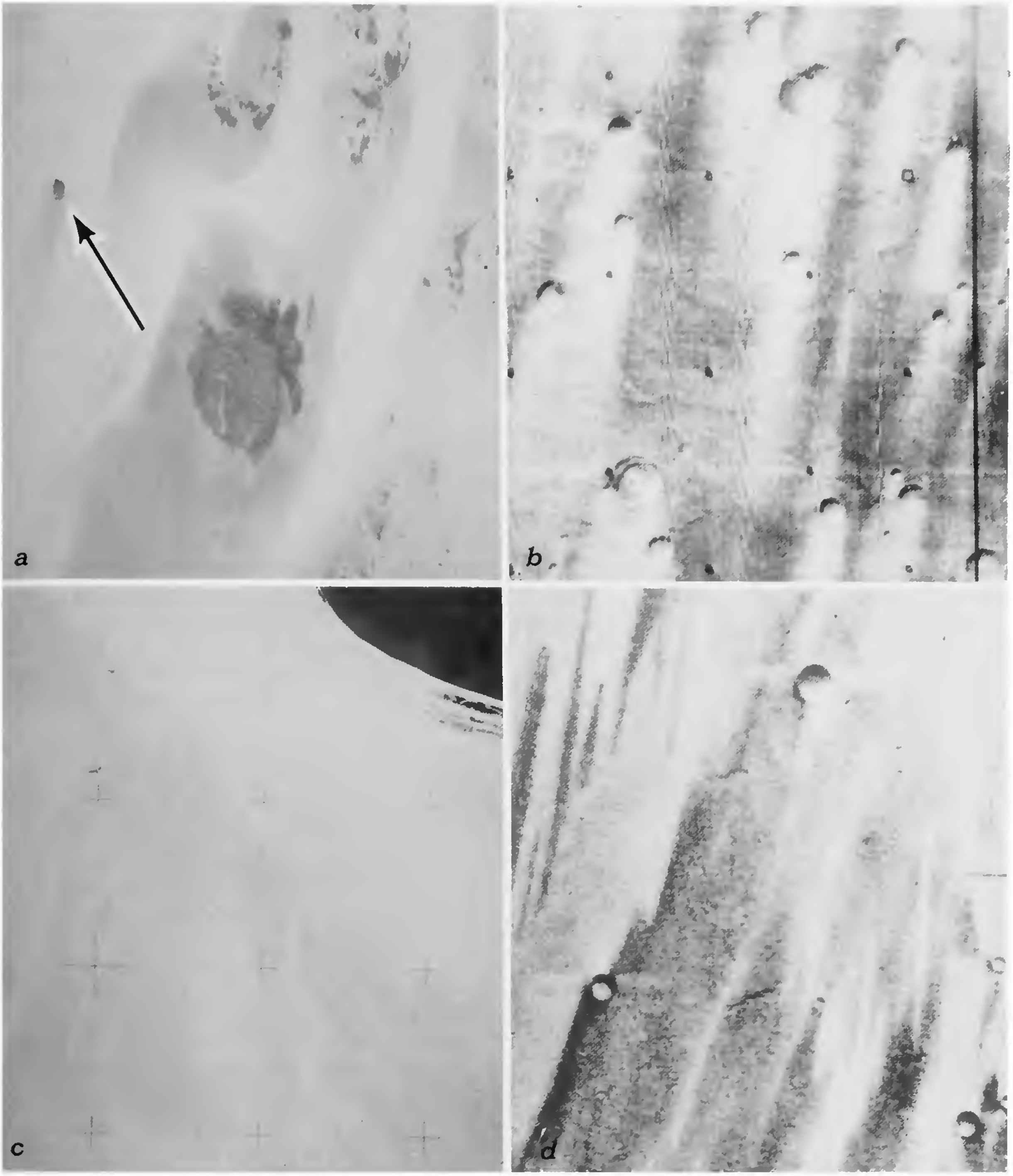



FIGURE 58.—Dune patterns on Earth and Mars: *a*, sand streaks in the Oweinat and Arkenu mountain region near the southwestern corner of Egypt—arrow points to Hagar El-Garda volcanic cone (ASTP photograph 2–127); *b*, streaks emanating from craters in the Hesperia Planum region of Mars, 23°S, 241°W (Mariner 9 photograph 4155–84); *c*, sand ridges in the Western Desert of Egypt, southwest of Alexandria (ASTP photograph 16–1255); *d*, dark and bright streaks on the slope of Syrtis Major Planitia on Mars, 11°N, 283°W (Mariner 9 photograph 4186–69).

photographs of the area of Oweinat and Arkenu mountains near the southwestern corner of Egypt clearly display the relationship between regional sand movement and topography (Figures 34, 58*a*). The pattern of bright sand streaks is controlled by the large basement ring complexes that form the mountains. The sand streaks trend from northeast to southwest. When compared to the north-to-south trending linear dunes of the aforementioned Great Sand Sea, the pattern of sand distribution in this part of the Sahara confirms the hypothesis (Bagnold, 1941:234) of a prevailing wind direction of clockwise rotation centered near Kufra Oasis in southeastern Libya.

In the same area, the smallest elevation appears to act as a barrier to sand deposition; for example, the small volcanic cone marked by an arrow in Figure 58*a*. The cone must have acted as a barrier to the southwest shifting sands to produce a sand-free dark shadow in the lee of the cone. Arvidson and Mutch (1974) describe a similar setting in the Pinacate volcanic field of Mexico, where sand has been blown from the south against and around but not behind the cone. This pattern of a shadow zone was also produced in wind tunnel simulations by Greeley, et al. (1974) who concluded that some Martian dark streaks are surfaces that have been swept free of windblown particles.

Light and dark colored streaks on Mars were photographed by Mariner 9 (McCauley, et al., 1972; Sagan, et al., 1973; McCauley, 1973; Hartmann and Raper, 1974). These streaks (Figure 58*b*) appear to be "the result of deposition by strong winds, whose patterns are disturbed by craters and other topographic irregularities" (Hartmann and Raper, 1974: 44). The similarity between terrestrial and Martian streaks in this case appears to result from disturbance of the wind regime by circular mountains in the case of Earth and by high crater rims in the case of Mars.

Sand streaks emanating from dry lakes were also photographed in Angola (NASA photograph AST–14–883) and Australia (NASA photograph AST–19–1548). In these cases, the dry lakes, rather than mountains or volcanic cones, must have served as the wind-disturbing topographic irregularity (El-Baz, 1976).

In addition to broad wind streaks, the ASTP astronauts photographed linear sand dunes in numerous deserts whose patterns are also similar to features on Mars (Figure 58*c*, *d*). Based on their bright color, the growth of linear features in the northern part of the Western Desert of Egypt (Figure 58*c*) appears to be from north to south. During aircraft flights over these same features, the author observed small sand "starlets" on top and sand domes at the end of some ridges. This observation was recently checked on a field trip during which the morphology of the dunes was examined and sand samples were taken for detailed study. The field check indicated that the irregularities on top of dunes are not due to the presence of sand starlets, but due to changing dune slipfaces by varying wind directions (Figure 59). However, the occurrence of star dunes atop linear dunes was described by the ASTP crew while observing the Gobi Desert of China (El-Baz, 1976).

In addition to positive sand accumulation in the Sahara Desert, wind-etched semiparallel grooves occur. The ASTP mission photographed such grooves near the east edge of the Hoggar Mountain in Algeria (NASA photograph numbers AST–2–124 through 9–552). These grooves, which probably originated as joints widened by wind erosion, have counterparts on Mars. For example, McCauley (1974) described an occurrence at 5°N, 146°W in the relatively smooth uncratered plains of southern Amazonis, where he ascribed the pattern to control by bedrock fractures.

The ASTP mission also photographed an unusual and little studied dune field in the northern part of the Monte-Patagonian Desert of Argentina (Figure 60). The dune field lies east of San Juan in a depression bounded by mountains on three sides. It is approximately 55 × 35 km in size. It displays a fish-scale pattern composed of numerous irregular crescentic dunes and linear sand ridges. These ridges are probably caused by the elongation of the horns of crescentic dunes. The overall pattern is that of two sets of discontinuous and parallel lines trending approximately N70°W and N30°W, respectively. Superposed on the larger features are finer, linear dunes

FIGURE 59.—Crest of a barchanoid dune, northeast of Baharia Oasis in the Western Desert of Egypt. Crests of barchan dunes are usually smooth, exhibiting a sharp line between the gentle slope of the windward side and the steep slope of the dune's slip face. The barchanoid dunes in this region show an unusual pattern. Here a 2–3 m segment of the crest displays grooves that form an angle of about 45° with the main direction of the crest. This pattern may be caused by multidirectional winds. (Photograph by the author)

FIGURE 60.—Two little-known dune fields photographed by the Apollo-Soyuz astronauts in the Monte-Patagonian Desert of Argentina. The larger of the two dune fields is 55 × 35 km and exhibits sharp boundaries with the alluvial fan at the base of the surrounding mountains. The major dune pattern is crescentic, with a superposed secondary linear pattern. (NASA photograph AST–27–2340)

whose trends generally follow the trends of the larger ones. This dune field is currently under investigation by a field party belonging to the National Geological Service of Argentina.

The pattern of this dune field is nearly duplicated by another field that is enclosed within a crater in the Hellespontus region of Mars (Figure 61). The Mars dunes have been described by Cutts and Smith (1973:4142) as a "series of prominent subparallel ridges 1–3 km apart and trending N15°W to N35°W . . . . Ridges of this system are crossed by narrow apparently sharper-crested ridges trending N30°E." The Hellespontus dune field has been compared to other terrestrial dune fields by Breed (1976). Its similarities to the Argentine dune field photographed by ASTP, however, are more convincing. The fact that the dune field in Argentina is surrounded by mountains on three sides makes the analogy even more interesting. Furthermore, as in the case of the dune field on Mars, it displays sharp boundaries with the surrounding terrain.

FIGURE 61.—Mariner 9 photograph of a suspected dune field (55 × 35 km) within a crater in the Hellespontus region of Mars. (After Cutts and Smith, 1973:4140)

### *Levantine Rift*

The Apollo-Soyuz astronauts observed and photographed some areas of major continental crustal fracturing. Of particular interest is the Red Sea–Levantine Rift zone, a pattern of fractures between eastern Africa and Asia Minor. Major fractures of the zone south of the Sea of Galilee are well known from both ground mapping (Dubertret, 1953; Freund, et al., 1970; Baker, 1970; McKenzie, 1970; Neev, 1975) and Skylab orbital photography (Muehlberger, et al., 1974). The ASTP astronauts were asked to provide information regarding the northern extension of the Levantine Rift by studying all fracture patterns from the Sea of Galilee northward (Figures 62–65).

The astronauts observed during the mission that the major fracture line of the Dead Sea/Sea of Galilee forks into three major faults: "one makes a bend and goes along (northward) parallel to the Mediterranean coast; two goes to the northeast and seems to be obscured and ends in a lot of jumbled country; and three could be traced clear up to the river (Euphrates) eastward" (comments by astronaut Brand in NASA, 1975b).

This fan-shaped complex of faults is shown in Figure 63. The Apollo-Soyuz observations and photographs of the area support the interpretations that fault number 1 continues in a north-northeast direction to the central part of Turkey near the town of Lice (the site of recent earthquakes) and that there is a strong northeast to east component of the fracture pattern resulting in the fan-shape. This pattern may lend support to the possibility that the Arabian crustal subplate rotates counterclockwise in a northeasterly direction. This plate, moving at an estimated rate of 6 cm per year (Bird, Toksöz, and Sleep, 1975:4415) may be pivoting at the point of convergence of the fan-shaped fractures just northwest of the Golan Heights (Figures 63, 64).

### *Volcanoes and Volcanic Plumes*

The Apollo-Soyuz astronauts obtained excellent photographs of several areas that display volcanic structures and also observed an eruption of the Mt. Etna volcano.

Among the studied volcanic structures are those that make up the Galapagos Islands. These islands, which straddle the equator in the eastern Pacific Ocean, are shield volcanoes with central caldera de-

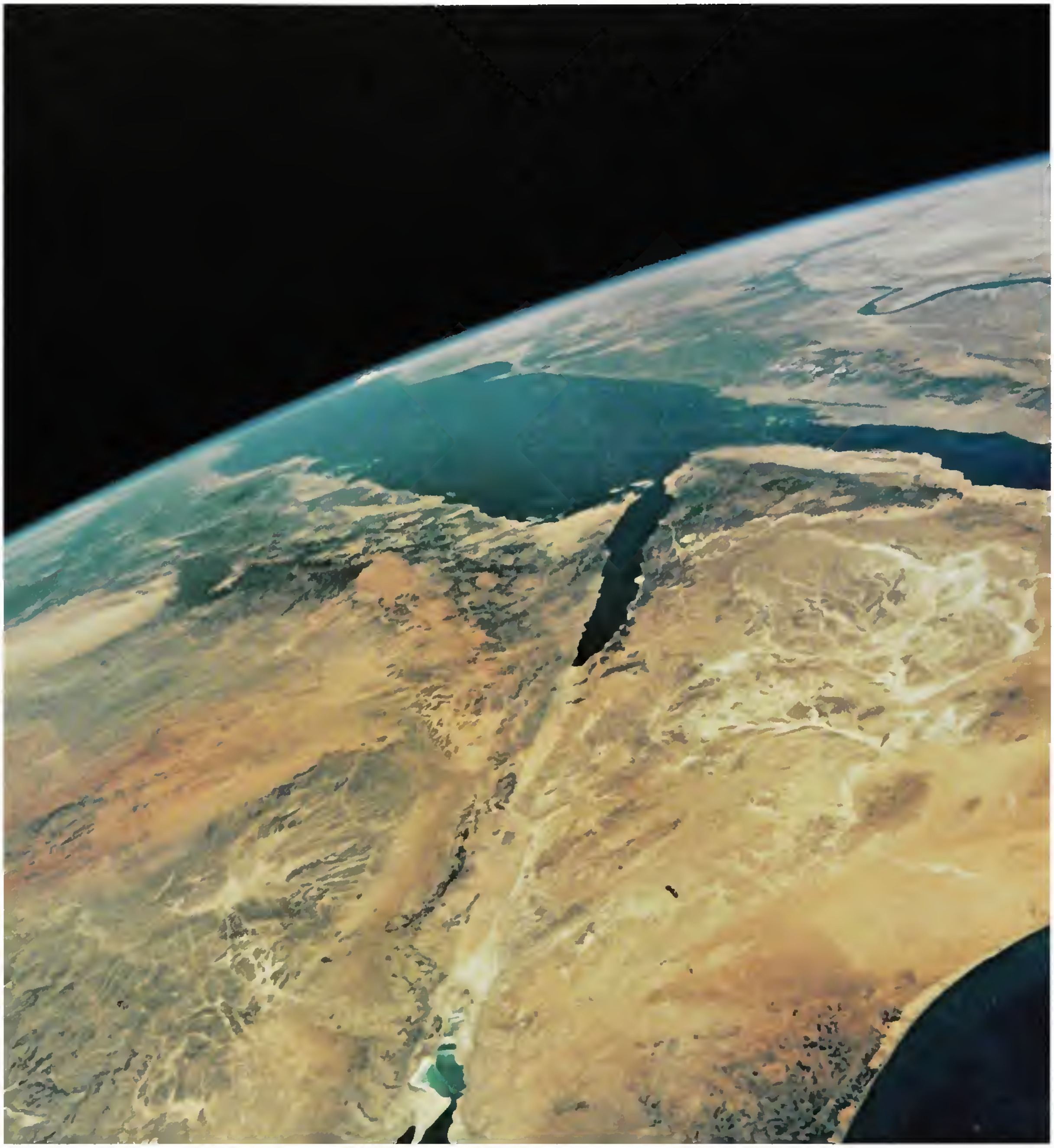


FIGURE 62.—Oblique view of the southern part of the Levantine Rift looking southward at the Sinai Peninsula and the Red Sea. (NASA photograph AST–9–560)


FIGURE 63.—ASTP photograph of the middle part of the Levantine Rift zone. Some of the fault lines are emphasized by black lines. Among these are major faults that form a fan-shaped pattern. Fault number 1 continues in a north-northeast direction to the central part of Turkey, and fault number 2 continues eastward to the Euphrates River valley in Syria. (NASA photograph AST-9-564)

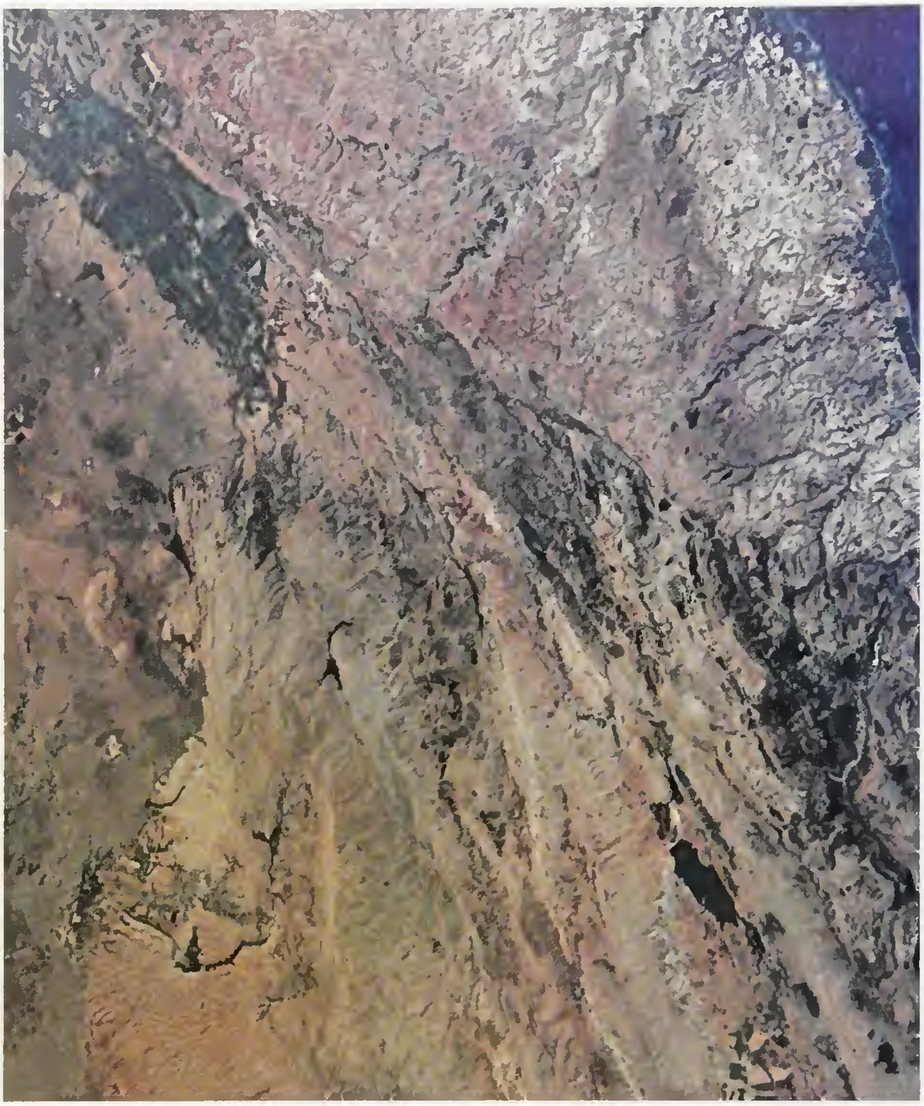


FIGURE 64.—A high resolution (250 mm lens) view of the area near the junction of the fan-shaped faults shown in Figure 63. Note the large number of small-scale lineaments. (NASA photograph AST–2–141)

pressions. The volcanoes are characterized by ring-injection lava dikes rather than radial-injection as in the case of Hawaii (Macdonald, 1972:309).

Figure 66 exemplifies one of several near-vertical photographs of the Galapagos volcanoes taken on 24 July 1975. The islands appear wreathed in clouds and six volcanic craters project above the clouds. According to Dietz and McHone (1976:7), the two islands of Isla Isabela and Isla Fernandina offer an unusual opportunity for volcanic surveillance by spacecraft, because they lie in a remote and uninhabited region of the world. The volcanoes are of the alkalic-plume type with their magmas originating below the asthenosphere. Eastward drift of the Nazca crustal plate over the Galapagos "hot spot" largely confines recent volcanic activity to these two islands, Isabela and Fernandina.

Another volcanic area photographed by the Apollo-Soyuz astronauts is the Transverse Volcanic Zone, which dominates the geologic structure of central

FIGURE 65.—Stereoscopic view of the northern extension of the Levantine Rift in Syria. (NASA photographs AST–16–1267 and AST–16–1268)

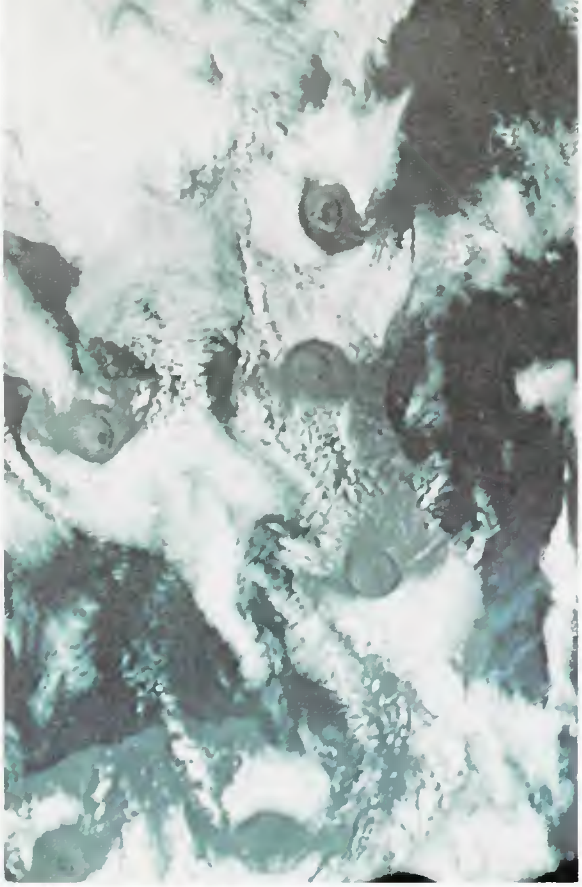


FIGURE 66.—Near-vertical photograph of volcanoes on Isla Fernandina (left center) and Isla Isabela (island with three volcanoes) of the Galapagos chain. The unusual cloud patterns are related to the orographic effects of the islands intercepting the southeast trade winds. (NASA photograph AST-10-579)

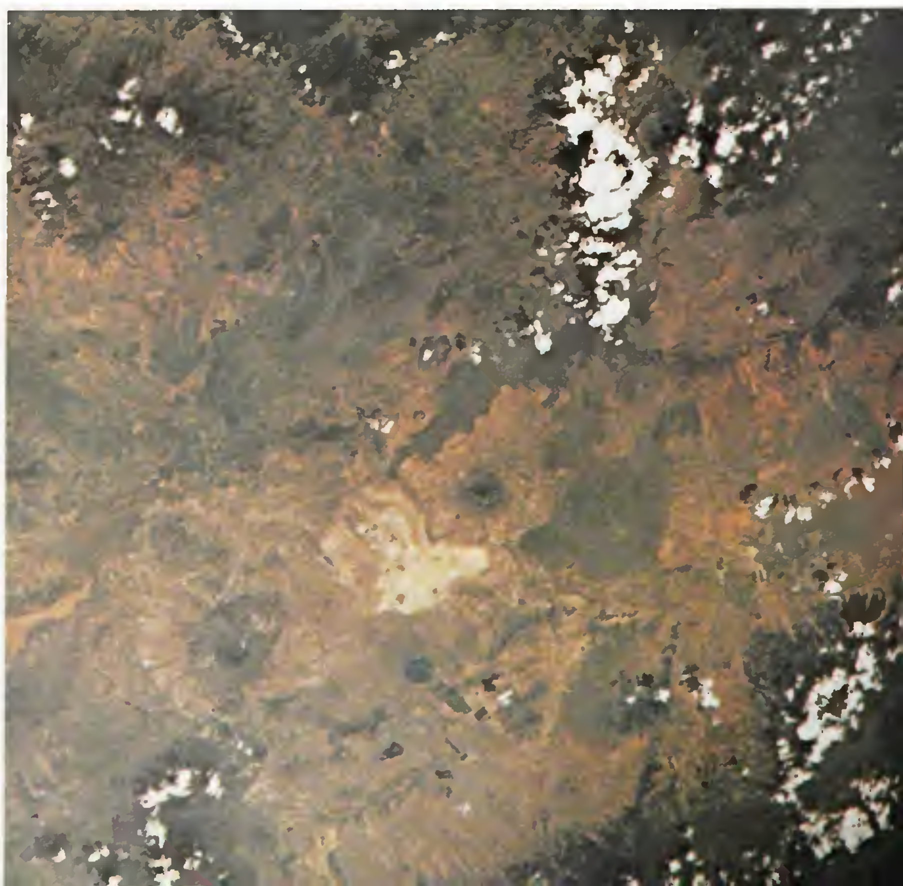
Mexico. This zone trends in an east-west direction, in contrast to the north-south trend of structures belonging to the "Ring of Fire" near the margin of the Pacific Ocean. The ASTP crew captured on film a remarkable view of the eastern end of this zone revealing a number of volcanic features east of Pueblo, Mexico (Figure 67).

Among the features revealed in this photograph are extensive lava flows, rhyolite domes, maars, diatremes, vitric ash rings and volcanic collapse features (Dietz and McHone, 1976:8). In the central part of the photograph a dry playa is present, a remnant of an extensive lake that existed when the Spanish Conquistadors arrived in North America.

One structure appearing in Figure 67, Tepexitl Crater, was recently visited (prior to the Apollo-Soyuz mission) by Dr. Robert Dietz, one of the experimenter's Co-Investigators. The visit was inspired by the suggestion that the feature is a possible meteorite impact site (Maupomé, 1974:81). The field investigation demonstrated that the crater is a rhyolitic ash ring formed by a volcanic explosion. According to Dietz and McHone (1976:9),

> . . . the ASTP photograph is detailed enough to firmly support the volcanic nature of the crater, thus making the field investigation unnecessary. Although a Landsat image of the same region was available and was used in connection with the field study, the details of the image were far inferior to the ASTP photograph, illustrating the value of

FIGURE 67.—Volcanic features east of Puebla, Mexico. Among the features revealed in this photograph are lava flows, domes, craters, ash rings, and volcanic collapse features. (NASA photograph AST-24-2003)



supplementing electronically transmitted space imagery with true photography.

On 24 July 1975, the Apollo-Soyuz astronauts photographed the 3240 m Mt. Etna in eruption. The volcano was emitting a cloud of ash that appears to have been visible for at least 200 km eastward (Figure 68); nearby cumulus clouds appear to have been generated by the action of volcanic ash particles becoming condensation nuclei (Dietz and McHone, 1976:5).

Mt. Etna, a basaltic shield volcano 30 km across at its base, is the most active in Europe; more than 75 eruptions have been recorded since Roman times. Its lava flows and ash falls have caused damage to urban areas and crops on numerous occasions. Volcanic ash layers are frequently found in sediment core samples of the floor of the Mediterranean Sea; the layers are ash deposits from volcanoes such as Mt. Etna.

It is interesting to compare the Mt. Etna volcanic plume with that observed at Sakurajima Volcano of Japan by the Skylab 4 crew (Friedman, Frank, and Heiken, 1974:8–2:8–5). The Mt. Etna plume appears somewhat more coherent, diffuses more regularly, and displays no evidence of a changing wind direction at higher altitudes. According to Dietz and McHone (1976:6), the Mt. Etna plume does not appear to break through the tropopause and carry ash into the stratosphere; hence the area of ash fall-out remains limited. The usually inferred pattern of an ash fall-out in an elliptical pattern, however, appears to be an oversimplification of what actually happens.

### *Astroblemes*

The term "astroblemes" refers to old circular features of impact origin (Dietz, 1961, p. 51). These features are of interest in comparative planetology since they constitute terrestrial analogues of impact craters on the Moon, Mars, and Mercury.

The ASTP mission photographed two circular structures, one in Libya (Figure 69) and the other, previously unknown, in Brazil. The Libyan structure (at about 24°N, 24°E) lies near the Kufra Oasis and was named "the Oasis structure" by French, Underwood, and Fisk (1974:1425). The diameter, including the outer ring of the structure, is given as 11.5 km by French, Underwood, and Fisk (1974:1425) although a study based on Landsat images by Dietz and McHone (1976:5) suggests an overall diameter of 17 km. This last figure appears to agree with the findings of ASTP where a large outer ring is barely visible.

The circular structure photographed in Brazil is 4 km in diameter and occurs at approximately 8°S, 47°W, only 45 km north-northeast of the Serra da Cangalha astrobleme (Dietz and French, 1973:561). This newly discovered structure appears to be similar in geomorphic form and structural style to Serra da Cangalha, and the two could be twin impact events. Field investigations of the newly discovered feature are presently under way. Results of these detailed investigations are planned to appear in NASA's Summary Science Report, to be published later by NASA.

From the Apollo-Soyuz photographs, however, Dietz and McHone (1976:3) believe that the circular feature confirms a domal structure for the entire ring with only a vague indication of a surrounding annular ring syncline. They believe that the dome consists of three formations: (1) a small central dome of resistant light-colored rock, possibly sandstone, with a central depressed dimple; (2) an annular ring of soft, topographically low, dark rock, possibly shale, eroded by a stream that breaches the outer ring along the northwest quadrant; and (3) an outer ring of resistant light rock that has been highly modified by agricultural activity, such as small-area farming and extensive grazing. Although topographically high, the outer ring has only moderate relief.

## Oceanography

The Apollo-Soyuz astronauts collected a plethora of information in support of studies of the world oceans (Figure 70). Also, as stated above, research vessels obtained numerous data on sea surface temperatures, salinity, water color, current directions, and types of cloud cover and cloud heights.

Some of the Apollo-Soyuz data deal with ocean currents, such as the Humboldt Current off the western coast of South America, and the Yucatán Current, particularly its exit between Cozumel Island and the Yucatán Peninsula. Other data pertain to both the warm- and cold-water eddies. Excellent photographs were obtained of cold-water eddies in the Pacific Ocean and the Caribbean Sea. The astronauts were able to identify these features and to photograph them because of the semicircular cloud

FIGURE 68.—Photograph taken on 24 July 1975 showing Mt. Etna (*right center*) on the island of Sicily in eruption. The volcano was emitting a cloud of ash that appears to have been visible for at least 200 km eastward. (NASA photograph AST–13–835)

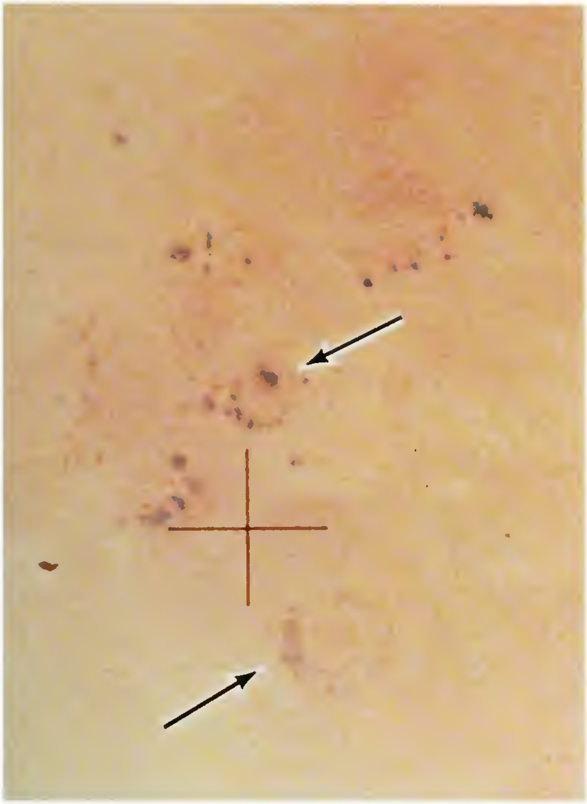


FIGURE 69.—Two oasis astroblemes (arrows) near Kufra Oasis in southeastern Libya. The main ring of the structure to the south is 17 km in diameter. (NASA protograph AST-16-1244)

patterns that delineate eddy boundaries. Eddies are important ocean features for several reasons: they act as mechanisms of energy dissipation, as productive fisheries, and as hiding places for submarines because of their effect on sound waves.

The usefulness of some of the collected data is somewhat limited by the lack of information on their exact geographic locations. Much effort is being expended to specify the location of the photographed sites. Use is made of weather satellite (SMS) images in matching cloud patterns with Apollo-Soyuz photographs. For this reason, the review of significant oceanographic findings will be limited to a brief summary of internal ocean waves and the outflow of the Orinoco River.

### *Internal Ocean Waves*

Internal waves are little-understood ocean features similar to surface waves but orders-of-magnitude larger, and they occur within the ocean. They are manifest at the surface by the accumulation of scum (slicks) above the wave crests. Because scum lines are their only manifestation from orbital altitudes, sunglint facilitates their observation; however, it was not known how and under what conditions they become visible.

The first orbital observation of scum lines associated with internal waves was accomplished in 1973 near


FIGURE 70.—Locations of major Apollo-Soyuz observation sites in the world oceans (1 = Coral Sea, 2 = Tasman Sea, 3 = South Pacific, 4 = Gulf of California, 5 = Gulf of Mexico, 6 = Caribbean Sea, 7 = northeast U.S. coast, 8 = Mediterranean Sea, 9 = Gulf of Guinea, 10 = Red Sea, 11 = Persian (Arabian) Gulf, 12 = Arabian Sea).

the New York Bight and the east and west coasts of Africa (Apel and Charnell, 1974:1309). Apel, et al. (1975:865) used Landsat imagery to measure internal wave lengths, wave pocket velocity, and bottom topography reflection effects on the waves. The same authors also detected internal waves on Landsat imagery in the middle of the Pacific Ocean (40°N, 160°W) at great depths.

The Apollo-Soyuz astronauts were asked to look for internal waves in both the Atlantic and Pacific oceans. Emphasis was placed on the coastal waters of western Spain, in which the U.S. Navy research teams were interested in locating internal waves. The waves occur at temperature or density discontinuities between water layers, and characteristically have wavelengths of several kilometers.

Apollo Commander Thomas Stafford, who was charged with the task of observing the Strait of Gibraltar, first found it difficult to distinguish any surface features on the water surface (Figure 71), but they appeared at a given sun illumination angle and viewing direction (comments by T. P. Stafford in NASA, 1975c:22):

FIGURE 71.—Oblique view looking eastward of the Strait of Gibraltar. The land mass on the left is part of Spain, and on the right, part of Morocco. The blue waters of the Atlantic Ocean and the Mediterranean Sea appear homogeneous and featureless. (NASA photograph AST–27–2362)

> I was looking for all these things and suddenly they popped out within a second right there. Just suddenly when the sun angle changed, everything was there. The waves and the boundary were all there and we just snapped a series on them. Before that, there was nothing but just solid blue water. Then they just suddenly popped. You have to be ready and the sun angle has to be just right. It's there for just a short period of time and then it's gone.

The photographs of the region clearly display the internal waves (Figure 72). The area in which they exist is very deep, although there are sea mounts that are within 40 m (20 fathoms) of the ocean surface. These mounts probably influence the waves. However, the internal wave mechanism west of Spain may be due to the density differential caused by the denser, more saline Mediterranean waters that flow under the less dense Atlantic waters. The process of flow may be expedited by the decrease of fresh water intake to the Mediterranean following the construction of the High Dam on the Nile River, south of Aswan, Egypt.

Internal waves were also observed and photographed by the Apollo-Soyuz crew west of Thailand (Figure 73). Again, the sun angle illumination and viewing directions were significant. Detailed study of the conditions under which these features were detected on the Apollo-Soyuz mission will help in the planning of internal wave observations on future space missions.

### *Outflow of the Orinoco River*

Waters of the Orinoco River carry a large amount of organic materials (including humic acids) into the Atlantic Ocean. This outflow was clearly visible near the Orinoco River delta from the Apollo-Soyuz orbit (Figure 74).

The yellow-tinted waters of the Orinoco seem to extend to the area of Barbados Island and beyond. Dr. Garry Borstad of the Bellairs Research Institute of McGill University conducted three ocean surveys during the mission in the vicinity of Barbados. The cruises, which were performed on 21, 22, and 23 July included measuring the following: (1) sea state (wave height, sea swell direction, and percent white caps); (2) Forel Scale color (Forel in a standard scale for water color measurement); (3) chlorophyll concentration (bucket samples); (4) phycobilin (pigments that occur in the cells of algae) concentration; (5) temperature (bucket sample and bathythermograph or

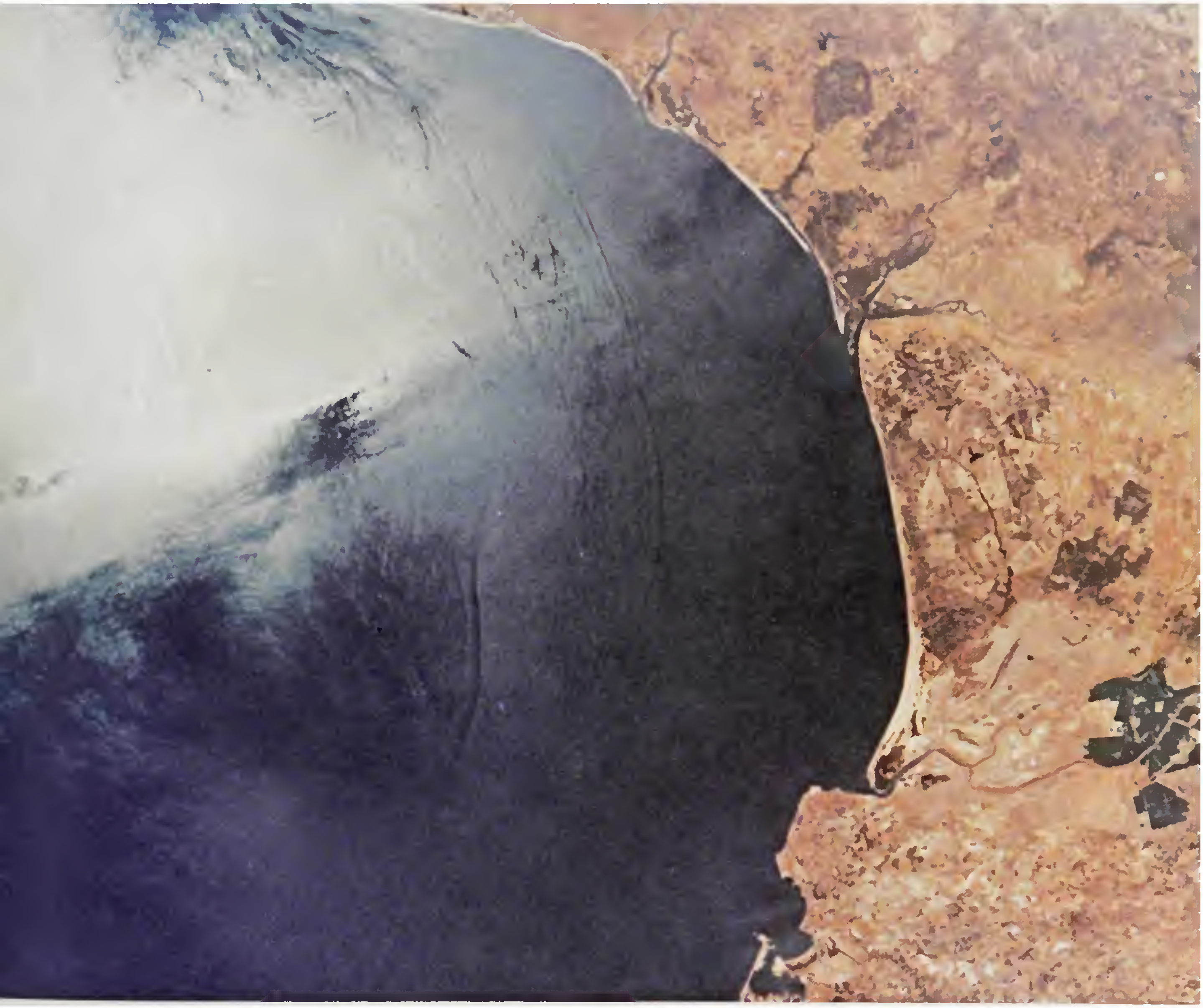


FIGURE 72.—Photograph of internal waves observed by astronaut Tom Stafford off Atlantic coast of Spain. The internal waves, which may be caused by a density differential, became visible only near sunglint and for a short period of time. (NASA photograph AST–27–2367)

BT; an instrument for obtaining a permanent, graphical record of water temperature versus depth as it is lowered and raised in the ocean) to 150 m while cruising; (6) salinity of the water; (7) cloud cover, distribution, and type; (8) plankton cell numbers (bucket samples); (9) water depth (utilizing an echo sounder); and (10) wind speed and direction. Dr. Borstad reported that the cruises were approximately 25–30 km long with samples taken at half or one kilometer intervals. The transects were performed west of the groundtrack of revolution 104 during which the observations were made from orbit. The traces of the cruises are shown in Figure 75.

During the cruises, 250 drift bottles were released,

Figure 73.—Internal waves observed and photographed by the ASTP crew in the Andaman Sea west of Thailand. (NASA photograph AST–7–427)

Figure 74.—The deep-brown, muddy water of the Orinoco River at its mouth is laden with sediments and humic compounds. As it flows northward into the Atlantic Ocean the water becomes yellowish green. The color was observed by the Apollo-Soyuz crew as far north as Barbados Island. (NASA photograph AST–21–1685)

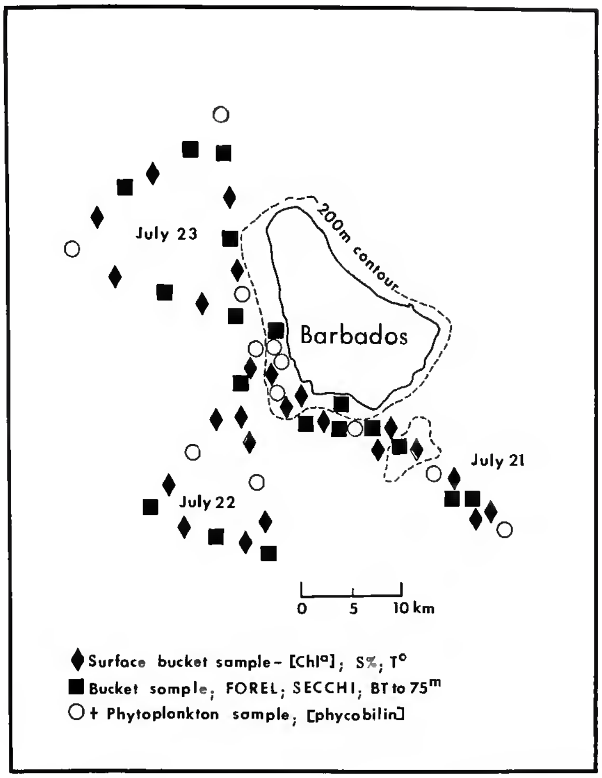



FIGURE 75.—Tracks of three ocean surveys conducted by a vessel of the Bellairs Research Institute of McGill University on 21, 22, and 23 July in the vicinity of the island of Barbados. (Courtesy of Dr. Gary Borstad)

equally spaced along the tracks. Dr. Borstad stated (1975, pers. comm.) that he "had been talking to skippers of merchant vessels plying the Barbados/Trinidad routes and will ask them to watch for the boundary of the 'green water', as they call it. They tell me it usually is seen about half way from Trinidad to Grenada."

Preliminary results of these surveys include the following observations (Borstad, 1975, pers. comm.):

1. The weather was fine and the seas calm with no white caps on 21 and 22 July. On 23 July the seas were higher. The wind was easterly at 17 to 21 km (11 to 13 mi) per hour. On 22 July the sky was clear (0–1 cloud cover) with few scattered cumulus clouds.

2. There was a definite change in color of the sea south of Barbados from Forel II off the west coast to Forel IV–V beginning about 16 km south of the island. There may have been a reduction of Secchi (a white disc, 20 cm to 2 m in diameter, which is used to determine penetration of light) depth in this region, but the correlation between higher Forel numbers and lower Secchi transparency was not good.

3. Bathythermograph (BT) profiles were taken to 75 or 100 m on alternate stations. For the most part, the isothermal (equal temperature) layer was 20–25 m thick, with some changes.

4. From drift bottle returns, the residual current was to the northwest at approximately 29 km per day. Bottles released south of Barbados apparently passed St. Lucia to the south. (Data from BT profiles will be used in conjunction with data on drift of bottles to establish current patterns.)

5. Phytoplankton members were low in the surface (bucket) samples. *Oscillatoria* cell numbers were higher in the lee of Barbados Island than elsewhere.

During the mission, astronaut Thomas Stafford reported that he could see discolored water from the Orinoco River much farther north than Barbados Island. He reported seeing that "muddy" color up to 170:06 GET, which corresponds to about 19°N, 51°W, at a distance of almost 1540 km (830 nm) from the mouth of the river. This is much farther north than expected.

The understanding of the biochemical changes introduced by the outflow of the highly colored river water into the Atlantic is important. Also, information is sought on how fresh water and ocean water mix. The photographs obtained by the Apollo-Soyuz crew are now being investigated in light of the knowledge gained from the aforementioned ocean surveys. In addition, the photographs are being quantitatively measured, by the use of a densitometer, to assess the concentration and degree of mixing of the discolored water.

## HYDROLOGY

### *Snow Cover Mapping*

The Earth's snow cover is a resource that directly or indirectly affects most of the world's population. To illustrate the importance of snow cover, the Committee on Polar Research stated in a 1970 report (Barnes, 1974a:1):

> Snow forms a transient, sedimentary veneer on much of the Earth's land surfaces. The diverse economic effects of this snow layer are incalculable. It is a major and renewable hydrologic reservoir; in many areas of North America more than half of the utilized water is derived from melted winter snow. Flood damage from spring snow melt is a recurring

hazard in many river basins. The obstacles and hazards to ground transportation alone are formidable. . . . Snow influences a broad area of geophysical phenomena simply by its presence or absence. On a large scale the winter snow cover stores water, modifies surface albedo, insulates the ground, and modifies plant and animal habitats. . . . A large-scale snow cover interacts with large-scale weather phenomena. The sharp increase in surface reflectivity (albedo) which accompanies snow deposition completely alters the radiation regime at the Earth's surface. A change in surface albedo and emissivity over widespread areas of the continents modifies both local and large-scale weather patterns.

Despite the economic and scientific implications of snow cover studies, existing data collection methods often cannot provide either the desired areal coverage or observational frequency (Barnes, 1974a:2). Except in limited areas where aerial surveys are used, the significant parameters are usually measured at ground stations or at widely scattered snow survey courses. Remote sensing from Earth-orbiting satellites now provides observations of snow that have not previously been available, and offers promise for eventually providing a more cost-effective means for snowpack monitoring. In fact, it was pointed out by Barnes (1974a:2) that "as long ago as 1960, snow could be detected in eastern Canada in the initial pictures taken by the first weather satellite, TIROS-1. Snow, therefore, can perhaps be considered as the very first water resource to be observed from space."

Since the time of the first TIROS pictures, an increasing use has been made of remote sensing from satellites to map snow extent. Of direct application were data from Landsat and the Skylab Earth Resources Experiment Package (EREP). One result of using these data was the recognition of certain problems in mapping snow from space. According to Barnes (1974a:8–9), these include the difficulties in distinguishing between snow and cloud, which may have nearly identical reflectivity, detecting snow in heavily forested areas and within mountain shadows, and estimating snow depth.

To help solve some of these problems, visual observations from Earth orbit by trained astronauts were first attempted on Skylab 4 with encouraging results (Barnes, 1974b:15–1). Additional observations were planned on ASTP, particularly of the Cascade Moun-

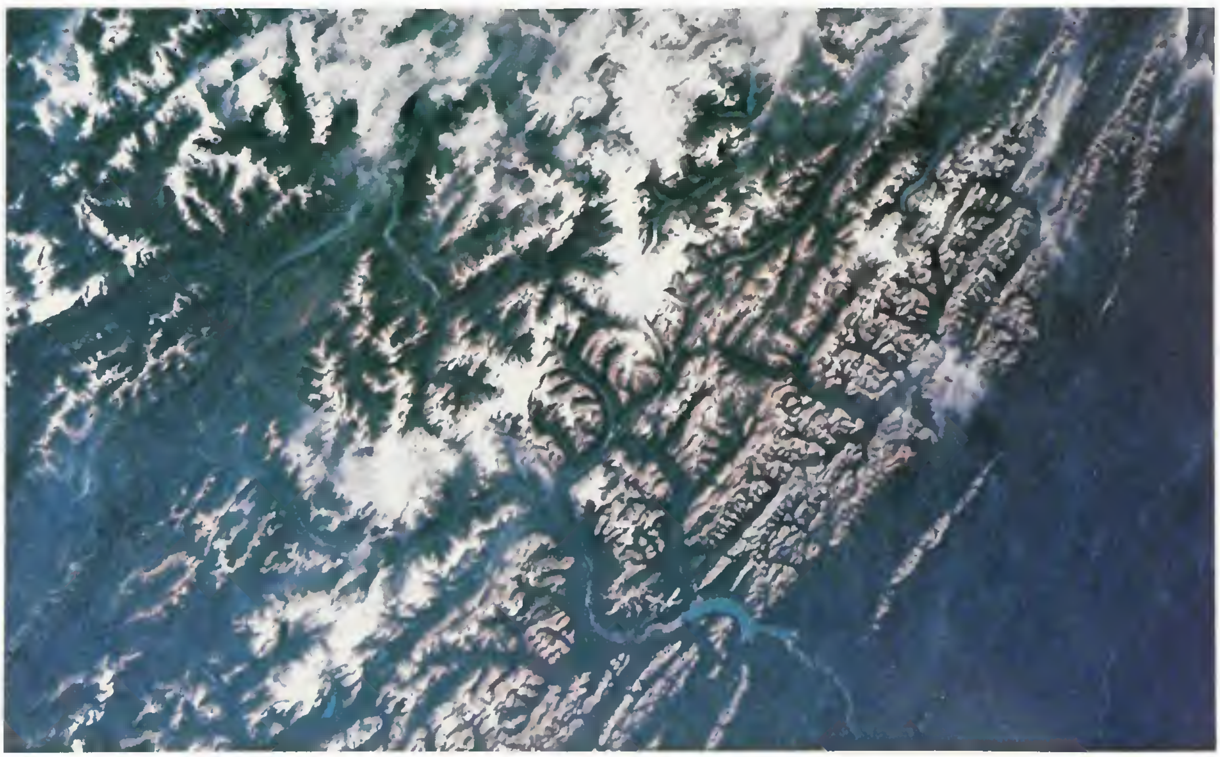


FIGURE 76.—ASTP photograph of the snow-covered Rocky Mountains in Alberta and British Columbia, Canada. (NASA photograph AST-19-1570)

tains in the northwestern United States, the Andes Mountains in South America, and the Himalaya Mountains in northern India. The Himalayan observations could not be made because of excessive cloud cover; however, excellent data were obtained of the Olympic and Cascade Mountains in Washington and the Canadian Rockies in Alberta (Figure 76).

The Apollo-Soyuz observations and photographs are being utilized to map snow extent and determine snowline elevation; to map observed changes in apparent snow cover extent; and to compare the ASTP photographs with those of Skylab, Landsat and other data for establishing seasonal variations of snow cover.

### *Major Lake Changes*

During the ASTP mission, excellent photographs were acquired of some of the world's major lakes, including Lake Chad, the Great Salt Lake, Lake Eyre (Australia), and the Caspian Sea. These photographs are being compared with previous Earth orbital data to document changes in lake size and water color, especially on Lake Chad in the Sahel region of Africa (Figure 77).

Lake Chad, once one of Africa's largest lakes, lies in the Sahel region between the savanna land to the south and the sandy desert to the north. To the northeast, it is bounded by fossile dunes, and to the south, tropical rivers flow into the lake bringing sediment and fresh water. The rapid decrease in lake size has been attributed to three factors: the influx of sand from the Sahara, the accumulation of sediments deposited by inflowing rivers to the south, and the evaporation of surface waters. The possibility that Lake Chad might eventually dry up presents a problem since the southern part of the lake is biologically productive and rich in fish. Apollo-Soyuz photographs will be compared to Skylab data to determine the rate of change to Lake Chad's size in the past few years.

FIGURE 77.—Lake Chad is the dark green area in the middle of this oblique photograph by the Apollo-Soyuz crew. Various factors, including the influx of sand from the Sahara Desert, have contributed to a significant decrease in the lake's size. Note the emergent dunes within older and larger boundaries. (NASA photograph AST-9-550)

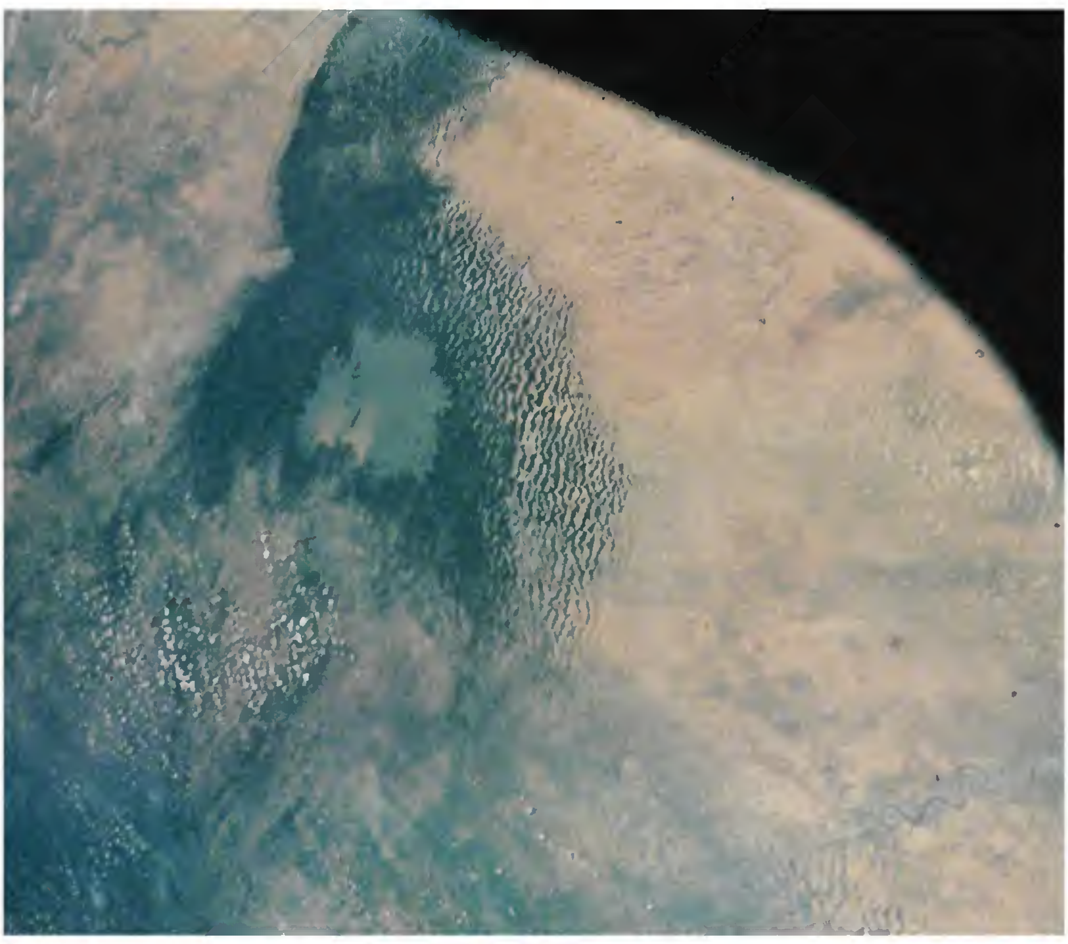


FIGURE 78.—ASTP photograph of circular irrigation patterns near Kufra Oasis, Libya. (NASA photograph AST–16–1244)

*Irrigation Patterns*

As stated before, no attempt was made on the Apollo-Soyuz mission to study irrigation and vegetation patterns. These patterns are best monitored by long-duration and repetitive-coverage satellites such as Landsat. One special example deserves mention however; that is, the pattern displayed near Kufra Oasis in southeastern Libya (Figure 78).

The photograph reveals remarkable circular patterns which are strung together to seemingly create a giant animal, or an insect complete with antennae but lacking the full complement of six legs as required for a class of arthropods. Dr. Robert Dietz (1976, pers. comm.) stated that "doubtless some future parascientific archeologist will find reason to compare this figure to the markings on the Nazca Plain of Peru and infer that there must have been astronauts flying in the 20th Century, A.D."

It is interesting to note that the development of these circular features could be traced in time through the use of Landsat imagery. Figure 79 shows successive stages of circle-addition, and illustrates the utility

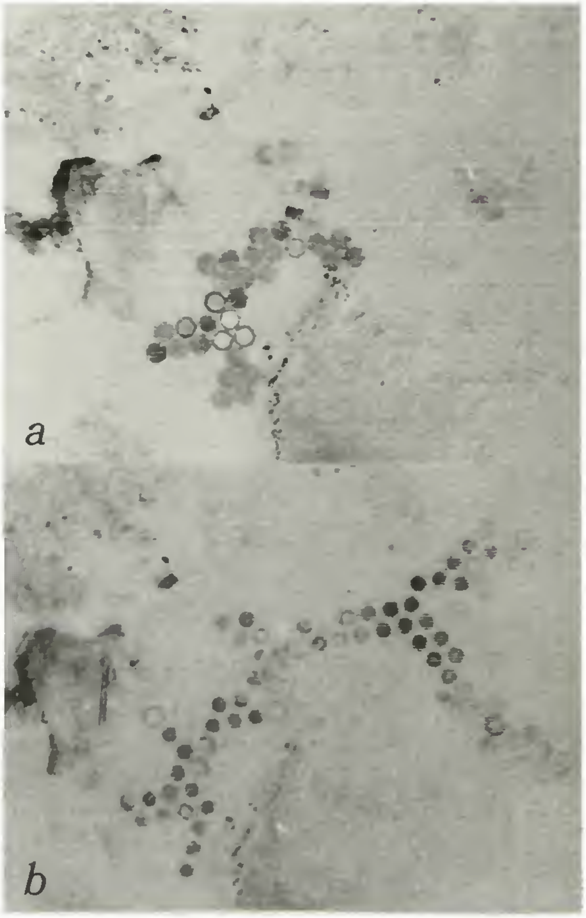



FIGURE 79.—Two Landsat images showing addition of irrigation fields at Kufra: *a*, taken in 1973 (ERTS E–1187–08250–702); *b*, taken in 1975 (ERTS E–2129–08131–701). These photos illustrate the utility of repetitive coverage.

FIGURE 80.—Photograph of Kufra area showing the circular patterns caused by huge rotating sprinklers 560 m in radius. (Photo courtesy of Derek Bayes, Aspect Picture Library Ltd, Surrey, England)

of repetitive coverage of the same area over a year's time.

Of all the features observed on the Apollo-Soyuz mission, these patterns are perhaps the most curious and unusual to anyone who does not know what they indicate. They certainly imply the existence of an intelligent tool-maker on Earth. They are, of course, vegetation patterns (Figure 80) wrought by huge rotating sprinklers 560 m in radius (Allan, 1976:98). This method of irrigation is known as center-pivot irrigation (Splinter, 1976) and has been used in many arid and semi-arid regions, including the southwestern United States.

## Meteorology

Meteorological investigations included the study of cloud features and tropical storms. Photographs of cloud features showed Bénard cells, Von Kármán vortices, mountain waves (rotor clouds), atmospheric bow waves in the lee of islands, and cumulonimbus buildups (Figure 81). The crew also obtained photographs of a developing tropical storm in the Caribbean Sea that "doesn't seem to cover so much area, but it does have a rather swirling 'V' appearance. I don't see an eye, but I can see where an eye would be" (comments by astronaut Vance Brand in NASA, 1975b:1051).

Photographs and visual observations will help meteorologists develop computer models of hurricanes and tropical storms. Stereo photographs of a dissipating storm were also taken and will be used in making a three-dimensional stereoscopic model of the storm to help decipher its topography. The stereoscopic model in turn will affect theoretical models of storm development and dissipation.

Excellent photographs of thunderstorms and convective cloud patterns were also acquired and will be used in studies of severe storm development. Figure 82 shows

> convective turrets overshooting a thunderstorm anvil near Jerevan, Soviet Armenia. . . . The photograph was taken looking southeastward with the sunset terminator in the background. West is to the right and east is to the left. The anvil is about 200 km long and about 50 km wide at its western end. Shading of the anvil top indicates that it is dome-shaped with the overshooting turrets protruding above the dome. The strong anvil outflow toward the west opposing the strong westerly flow over the anvil top apparently is responsible for the shear-induced Kelvin-Helmholtz waves which emanate from each of the turrets in the westerly and northwesterly direction. These waves are similar to the waves observed in hurricane and typhoon circular convective clouds by Arnold (1975, unpublished) and Black (1975, unpublished) using DMSP and Skylab imagery, respectively [Black, 1975, cover].

Photographs of unusual, large-scale, intersecting cloud streaks were obtained by the Apollo-Soyuz crew. During postmission debriefings, the crew reported that these features were too large to be contrails and had a wedge-shaped appearance (Figure 83):

> SLAYTON: We saw an awful lot of contrails over the North Atlantic and it's nothing like that. They just don't get that big.
>
> BRAND: Contrails were lines; these are wedges practically.

When the crew was asked: "Do you remember from Skylab, when they took a picture and they thought it was the hot air coming from a ship going through a very low scattered deck about like that, and there was a plume going across the apparent trend of the clouds. Do you think that maybe that was this same thing?" Vance Brand's answer (in NASA, 1975c:103) was: "It's a possibility, I suppose, but at the time it looked natural."

## Environmental Science

### *Red Tide*

Attempts were made to visually locate and document on film color variations in coastal waters that may be due to red tide blooms. Experts believe that these color variations can be used to determine changes in concentration of marine phytoplankton (minute floating plants) populations, especially the red tide dinoflagellate, e.g., *Gonyaulax* (Figure 84). In addition, the color may reflect the presence of suspended sediments, dissolved solids, and other water pollutants.

In the United States, red tide occurs in the coastal waters of Maine, Massachusetts, Florida, and California resulting in health and economic problems. A variety of red tide is toxic to fish, and decomposition of fish can deplete the water of much of its oxygen. Toxic particles produced by the organism can cause human eye and respiratory irritations. (At times of heavy red tide infestations, every "iron lung" in New England is occupied by people who have respiratory problems.) The toxin also affects shellfish, which may store it in their bodies. As a result,

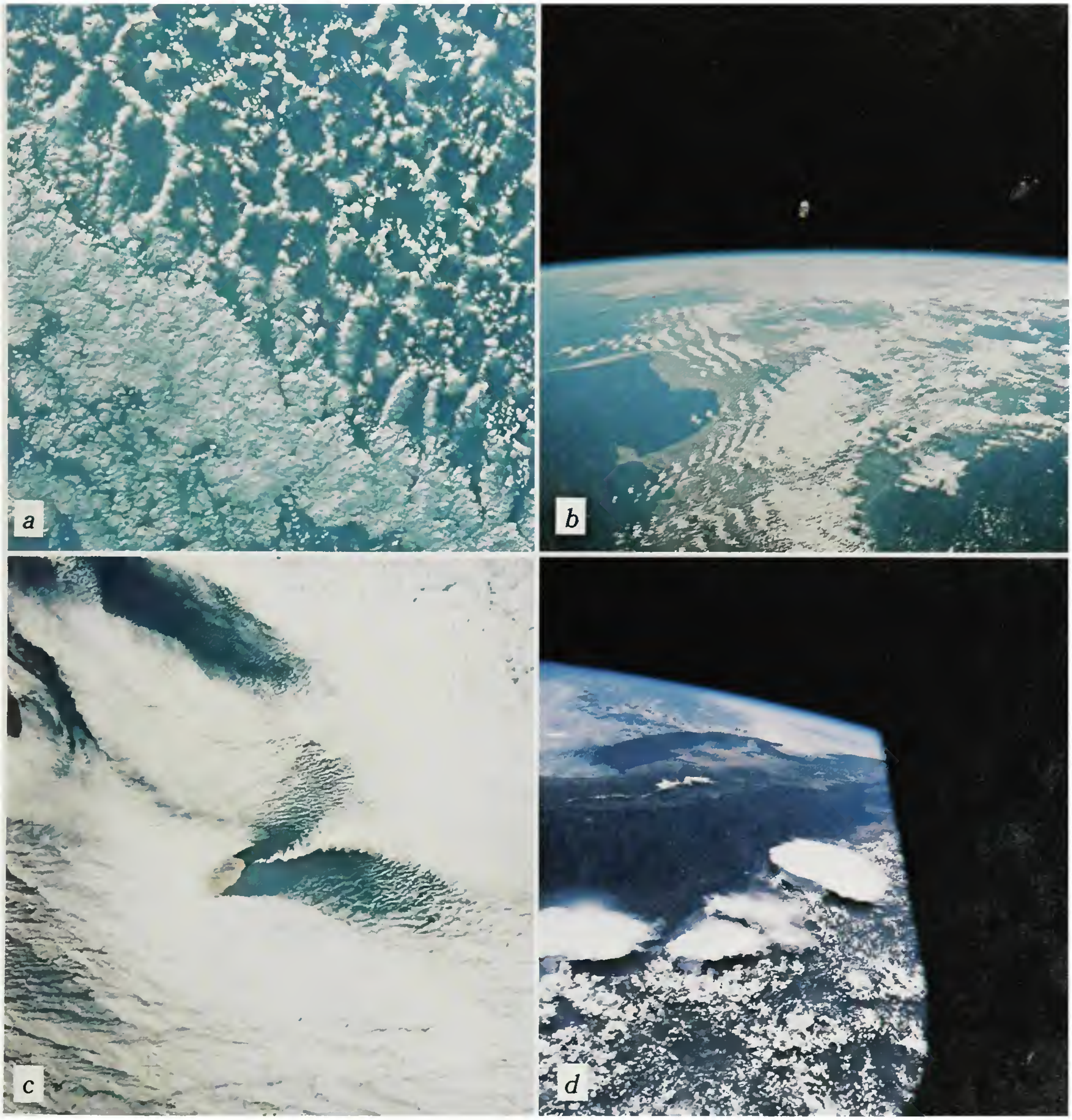



FIGURE 81.—Variety of cloud features observed by the ASTP crew: *a*, Bénard cells over the Tasman Sea (NASA photograph AST–22–1754); *b*, mountain waves (rotor clouds) over New Zealand (NASA photograph AST–1–16); *c*, atmospheric bow waves over the San Nicolas Island, west of California (NASA photograph AST–14–878); *d*, cumulonimbus near Baja, California (NASA photograph AST–9–545)

FIGURE 82.—Thunderstorms near Jerevan, Soviet Armenia (NASA photograph AST-2-95).

shellfish beds often have been closed for several months by local health authorities. A red tide outbreak in the spring and summer of 1971 was estimated to have cost Florida $20 million or more, primarily in lost tourist business when dead fish were reported littering Florida beaches.

Accurate analyses of various kinds of water coloration in the ocean depend on data collections made by different means. For this reason spacecraft observations from ASTP were simultaneously supported by aircraft flights, open ocean water surveys, and sampling of the water at the shorelines.

In New England, two research vessels of Bigelow Laboratory made a traverse of the Gulf of Maine from Portland to the Bay of Fundy and another transect, southward to Cape Cod. Data were obtained on the size, shape, and location of red water patches due to the toxic phytoplankton and included measurements of sea surface temperature, salinity, chlorophyll content, and water color. A zone of discolored water was located near the mouth of the Damariscotta River in Maine. The toxic level was low and much of the reddish coloration was attributed to sediments brought to the ocean from inland rivers.

In addition to the red tide observations off the coast of Maine, support ships and sampling stations of the Commonwealth of Massachusetts acquired water color, salinity, and bio-content data. An unusually high chlorophyll content in the coastal waters off New England was reported. This was probably the result of abnormally heavy rains carrying an increased amount of biota into the sea. High altitude metric and multispectral photography was also acquired during the mission over Cape Cod, Cape Ann, and Long Island. The photographs show the greenish color of the coastal waters (Figure 85). The data is being compiled and analyzed for the ASTP Summary Science Report.

### *Oil Slicks*

Attempts were made to observe oil slicks in the North Atlantic ship routes, but none were located due mainly to much cloud cover. An interesting story developed during the mission, however, illustrating the significance of aircraft support photography in special cases.

During the flight we had been alerted by the

FIGURE 83.—The ASTP crew obtained this photograph of unique wedge-shaped linear clouds over the Pacific Ocean west of Southern California. (NASA photograph AST–1–42)

FIGURE 84.—Scanning electron micrograph of *Gonyaulax,* a toxic dinoflagellate about 35 microns in size. (Courtesy of Alfred and Laural Loeblich, Harvard Biological Laboratory, Cambridge, Mass.)

Smithsonian's Center for Short-Lived Phenomena to an oil spill off the east coast of Florida. The astronauts were asked to photograph it if possible, but cloud cover prevented them from locating the slick. In the meantime, the NASA WB-57 plane photographed the area from an altitude of 18,400 m (60,300 ft) using a 6-inch Zeiss mapping camera with SO-397 color sensitive film and a 2A filter. Simultaneous photographs using black-and-white and infrared film also recorded the spill. The NASA plane actually photographed the slick on two separate days while filming ocean currents. Figure 86*a,* taken the afternoon of 20 July, shows the oil shimmering in the sun like a silver ribbon with a corduroy pattern. Figure 86*b,* taken 23 July, shows the slick much closer to the Keys.

Four months later, the master of an oil tanker was

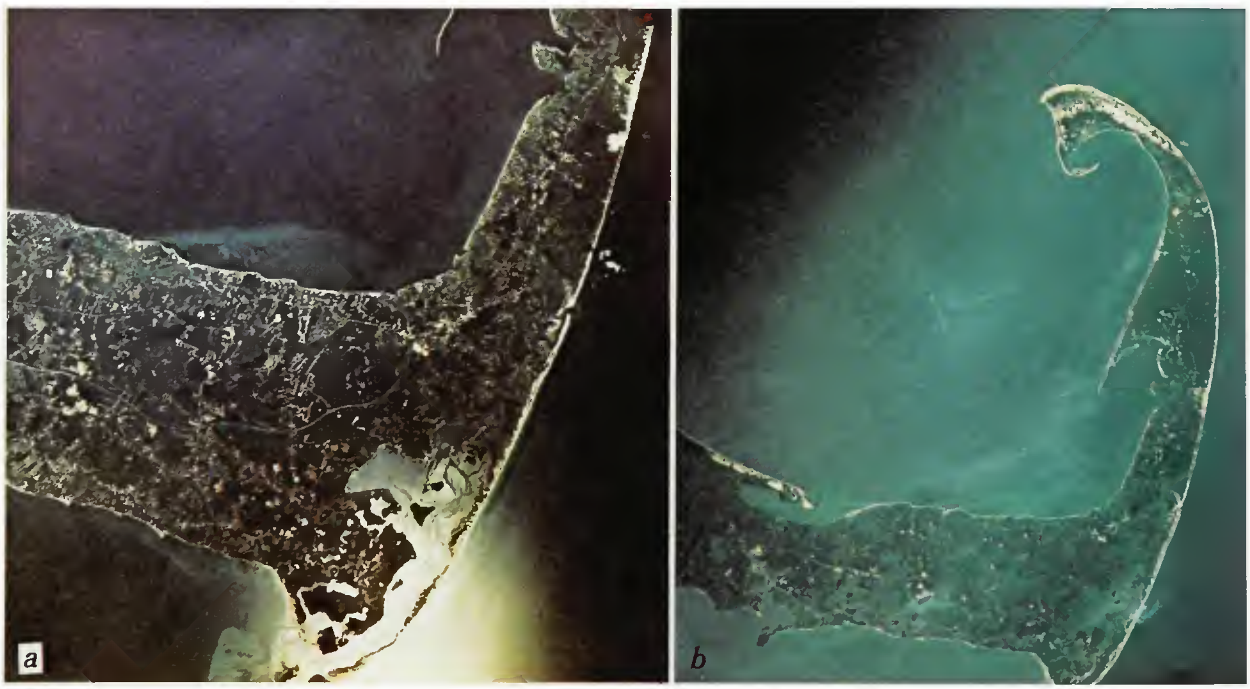



FIGURE 85.—Two photographs of Cape Cod taken in July 1975, showing the greenish color of coastal waters, probably the result of abnormally heavy rains, carrying an increased amount of biota into the sea: *a,* from an altitude of 20,000 m by WB-57 aircraft based at JSC; *b,* NASA photograph AST-1-064.

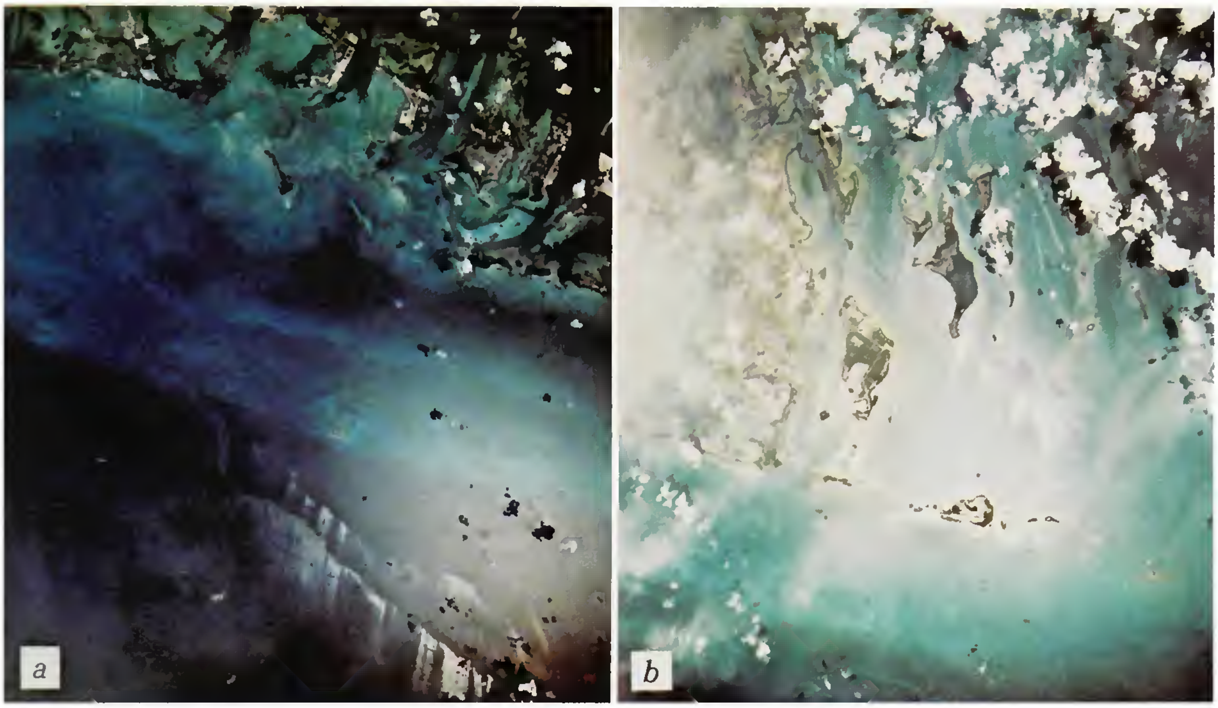



FIGURE 86.—A large, highly reflective crude oil slick is visible as a silver ribbon with a corduroy pattern. This slick was first reported on the evening of 20 July. At that time an estimated 152,000 to 228,000 liters of oil were in the water. *a*, The slick is about 5 km offshore (NASA JSC 315 July 1975, 19–054); *b*, two days later the slick has moved closer to the Keys (NASA JSC 315 July 1975, 26–061).

charged with violating the 1974 Federal Water Pollution Act by discharging 19,000 liters (5,000 gallons) of oil within 80 km (50 mi) of the United States coastline on 17 July 1975.

To help in the ensuing investigation, the aircraft photographs were sent to Rear Admiral Austin Wagner, commander of the Coast Guard's 7th District, Miami, Florida. Detailed study of the photographs will shed further light on the extent of the discharge. The direction and pattern of the spread oil may help in establishing the conditions at the start of the spill.

## VISUAL ACUITY

Of the five features that were selected for visual acuity tests on the Apollo-Soyuz mission, the astronauts were able to see the Lake Bonneville racetrack, glaciers and firn lines in Canada, and the Pyramids of Giza. They were not able to clearly discern the Nazca Plain markings or bioluminescence in the Red Sea. It must be stated, however, that the condition under which these features were observed varied significantly, as discussed below.

### *Lake Bonneville Racetrack*

During the postmission debriefings (NASA, 1975c: 11–12), astronaut Vance Brand indicated that he was able to see the racetrack at Lake Bonneville because he knew exactly where to look:

> First of all, the picture I had pointed out the area, and I compared that picture to the ground, and I saw what looked like a fairly wide linear scratch or stripe on the ground. Right at this point, after all this time and without the benefit of that same picture, I can't tell you where it is. . . . At the time, I did see it.

### *Glaciers and Firn Lines*

Visual observations of glaciers were performed under favorable conditions over the Canadian Rockies.

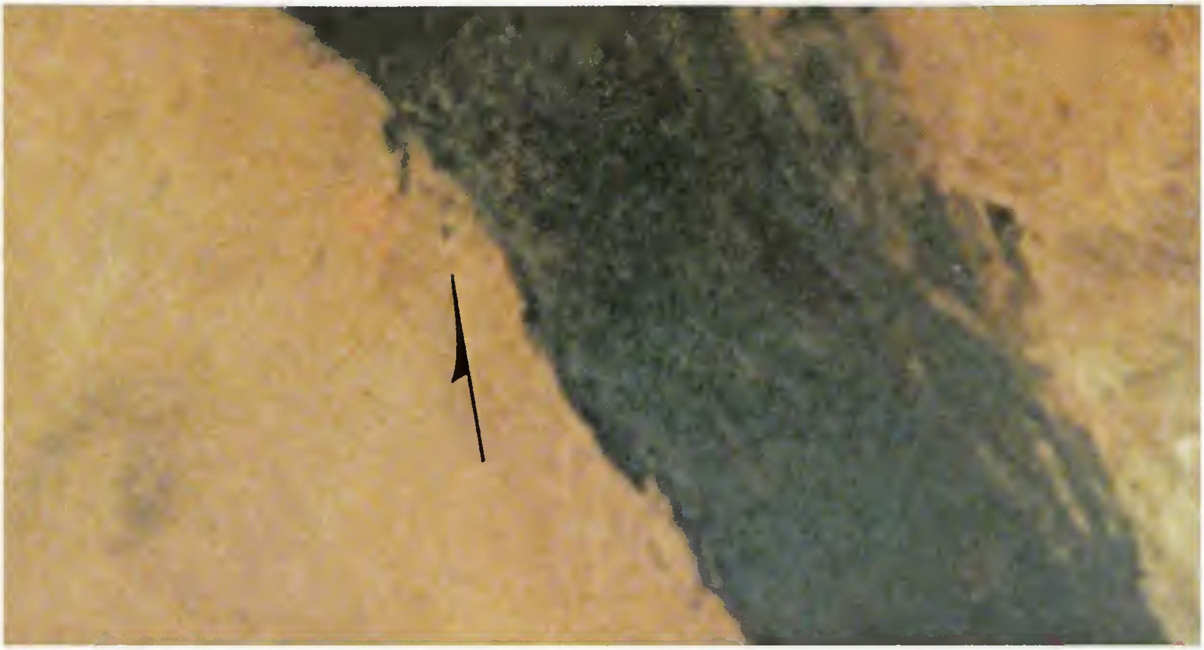


FIGURE 87.—Enlargement of an ASTP photograph of the Nile Delta. The Great Pyramids of Giza (arrow) are visible as three dark spots. (NASA photograph AST-1-49)

The crew was also successful in distinguishing firn lines and remarked that this was a function of both texture and color. The following conversation occurred during the postmission debriefings (NASA, 1975c: 15):

BRAND: The best case, I believe, was in the Alberta-British Columbia area. I very easily saw a firn line on one big glacier up there.

EL-BAZ: How did you make the distinction? Why do you think you were able to see that? Because of color or texture?

BRAND: Texture and color and even shininess, you might say. Surface texture, I guess.

EL-BAZ: The ice being more gray?

SLAYTON: Kind of a gray compared to pure white.

STAFFORD: Yes, it goes from white to gray. And the firn line wasn't just a straight line; it was kind of jagged. It wasn't a clear line.

SLAYTON: But I thought I could see texture down below it also, that sort of looked like flow patterns going parallel with the glaciers.

### *Nazca Markings*

Without the aid of an enlarging telescope, the Apollo-Soyuz astronauts were not able to see the Nazca Plain markings in the Peruvian Desert. This, however, may be due to cloud cover on revolution 74, and to unfavorable spacecraft attitude on revolution 104 as discussed in the postmission debriefing (NASA, 1975c:13-14):

EL-BAZ: All right, we had also something over the intricate patterns of the Nazca Plains. Tom, you got pictures and I don't know whether you saw anything or not.

STAFFORD: The first time the clouds went all the way to the mountains and we got nothing. This slide [not illustrated] was taken on the second pass. I can't say that I saw them. I remember this little bay in here and Vance was helping me lead in. I saw this little bay up here and I thought I saw a white streak in here, but I snapped the picture and I couldn't really say that that was it. I thought I saw something but I sure wouldn't say that was positive.

BRAND: I didn't see anything.

STAFFORD: And so, I couldn't say that I saw them. No. Now whether it was a white field or something in that area, I just don't know.

BRAND: This is one case where being upside down hurt us. The identification problem was very hard here.

STAFFORD: Can you see them on that photograph?

EL-BAZ: I couldn't, really. I know where they are, but I have not enlarged this or looked at it in detail. But this is exactly where you would expect them. This is that region.

*Pyramids of Giza*

Early in the mission and while occupied by other things, Vance Brand and Deke Slayton looked out of the spacecraft window during revolution 56 (Figure 87) and exclaimed (NASA 1975d:253):

BRAND: Boy, there's Cairo.
SLAYTON: There it is. Boy! Oh, great! . . . We got everything we want. Say, that stuff is pretty . . . right there.
BRAND: See the Pyramids?
SLAYTON: Yeah! (laughter)
BRAND: My God! I think I did. I've got to get a map though. . . . Houston, Apollo. Occasionally, we get some very good viewing because of attitude, weather, etc. We just now got a couple of visual observations, things that we haven't been able to get as well before. For example, saw the Levantine Rift and Egypt. I think I might have seen the pyramids. And now I've got to see a picture or a layout of how the pyramids are laid out when we get back, but I saw two specks that might have been pyramids.
CAPCOM: Say again what the specks might have been.
BRAND: We think they're the pyramids of Egypt, and that happens to be a visual observation (target).

Later in the mission, when the sun illumination angle was increased, it appeared that although Cairo's features were clearly visible (Figure 88), the Pyramids of Giza were no longer visible.

BRAND: Okay, Nile Delta. From the view we had today, we could not resolve the pyramids. I could see where they are. Looked like the ground was disturbed in the area where they are. But I'll have to admit that I was a little confused. There was one light area, which was disturbed, where they could be. There was another area of dark spottiness where they could have been. I'm not sure which place it was. I got three stereo photographs of Cairo.

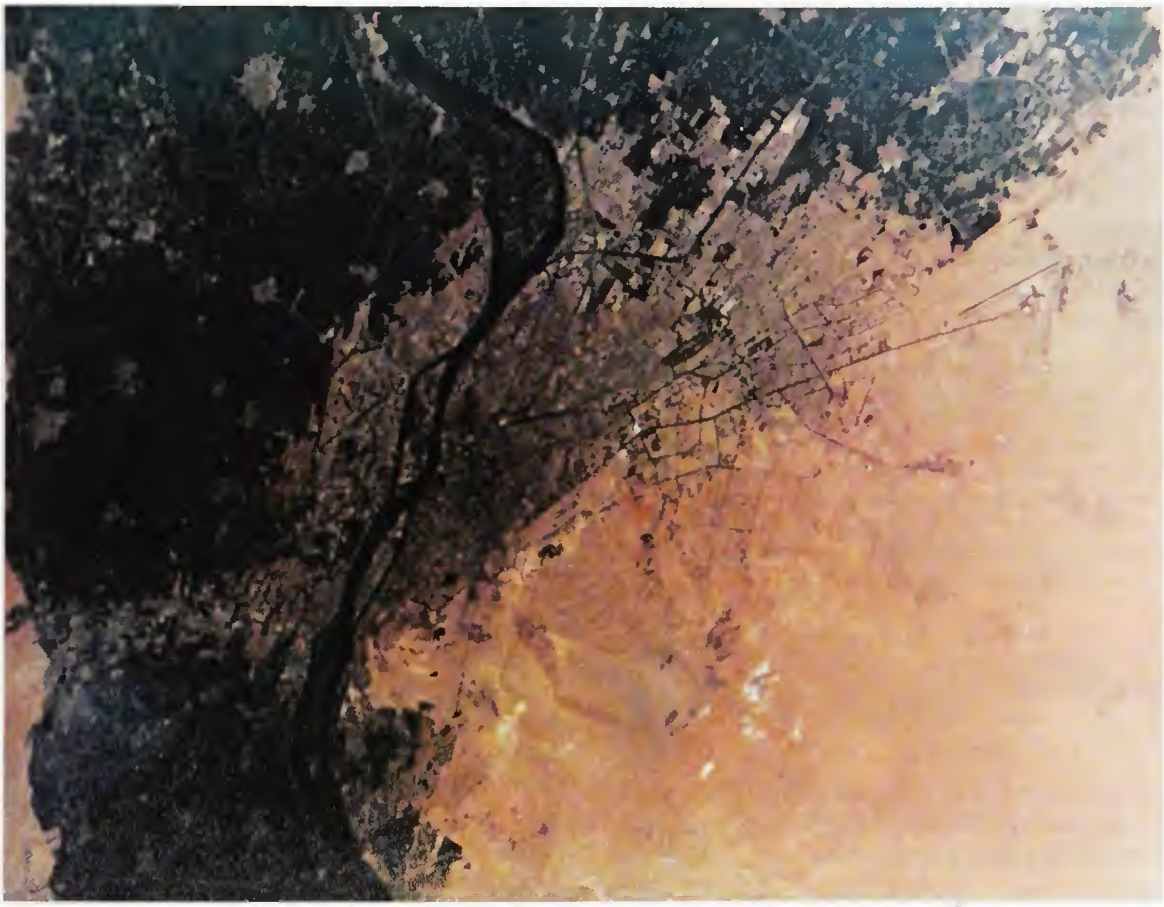


FIGURE 88.—An ASTP photograph of the region surrounding Cairo, Egypt. Note the clarity of the city's features, particularly major roads. The ASTP astronauts were able to clearly see the road leading to the airport, northeast of the city. (NASA photograph AST-2-137)

The situation of sun elevation effects was discussed during the postmission debriefings as follows (NASA, 1975c:12–13):

EL-BAZ: Okay. Very good. Next slide please [Figure 87]. We had the pyramids of Egypt as one of the targets of eye resolution because they are built from material the same color as the surrounding area, but there will be a textural difference because the pyramids are built with large stones.
BRAND: I don't believe now that I saw them. I had the benefit of two passes. The first pass, I saw two little dots that I thought possibly were pyramids. At that point, I wished I had a map of the pyramids on the ground so I could see what they're supposed to look like. I think probably what I saw were fields or something like that. So, I would say, no I didn't see them.
EL-BAZ: Okay. In one group of photographs, we can identify the pyramids and there is another batch that we cannot. So the sun angle may have a great deal to do with it. And this is the picture that you can see them on if you enlarge it very much. You can only see two big ones and a third tiny one.
SLAYTON: With a low sun angle, you might have a reasonable chance of seeing them.
BRAND: I think you should be able to see them, because we saw things in that size range.

### *Bioluminescence*

In relation to the observation of bioluminescence, the crew failed to see much, probably because target acquisition time was scheduled on revolution 91 earlier than it should have been (NASA, 1975b:722):

SLAYTON: Okay, we just passed site 9P, and unfortunately, I'm afraid the old Greek gods are getting to us today on the Earth Obs, Crip [astronaut Crippen]. I'm supposed to be over the Red Sea, which I'm sure we are, looking for bioluminescence. But unfortunately, what wasn't factored in here is that we're still in sunlight and I got the sunshine nice and bright right in the window. I'll hang in here until it sets and see if I can see anything, but I'm not optimistic.

. . . . .

Okay, Crip. Wherever we are, I've got a series of very bright lights down here. A pair to the right, a pair directly under the nose, and a set of three ahead of me. Looks like they're under a bit of cloud, but they're superbright. Must be gas fires, maybe.

In addition to this, there was some cloud cover and moonlight as indicated during the postmission debriefing (NASA, 1975c:98–99):

STEVENSON: I have one more question, which is really for the whole crew. We were hoping you were going to see some bioluminescence. I remember on that one pass when Deke said, "Hey, somebody goofed up; it's still daylight here."
SLAYTON: We were in daylight; the ground was in dark. But once we got the spacecraft into the darkness, there was a cloud cover, I'd have to guess. I could see oil fires burning up through there, but it was obvious from that that there was somewhere between five and eight-tenths cloud cover and I couldn't even tell where water was, to say nothing about where bioluminescence might have been.
STEVENSON: So you never had any during the whole flight?
SLAYTON: No, sir. If it had been clear as a bell down there and it, in fact, existed, our odds of seeing it were pretty poor, I think, because we'd just come out of that bright sunglint and suddenly you're in the dark and no dark-adaptation time at all.
BRAND: If you ever try that again, you'd really want to have a long dark-adaptation time, and you'd want to think about moonlight and things like that, too. The moonlight has quite a big effect on what you can see.
STEVENSON: You had a good moon?
BRAND: Yes.

## CONCLUSIONS

For the successful performance of Earth observation tasks, the observer must be well prepared and adequately trained. The exercise must be pursued systematically; otherwise, significant features and phenomena may be overlooked. An observer in orbit can make on-the-scene interpretations that significantly contribute to solving the problems in question; for example, the explanation of the tectonic setting of the Levantine Rift area. A trained observer is also essential to the study of features and phenomena characterized by transient visibility, such as internal waves, which are only visible under very restricted conditions. In addition, a trained observer is essential for exploring the unknown since he can scan an entire region and select targets for photography, such as the previously unknown circular feature in Brazil. The visual acuity tests performed on ASTP proved that the astronauts could see beyond the limits of theoretical eye resolution, corroborating such reports by Gordon Cooper on Mercury 9 and others.

Astronauts in orbit can help design instruments or film to be used on unmanned probes. An example is the use of the color wheel to establish the actual range of visible colors of deserts and oceans. Earth observations and photography require a flexible platform where viewing angles and interior lighting conditions can be controlled. The design of instrumentation should allow control of imaging systems by the observer.

Space observations and photographs provide excellent tools to study the global distribution of the generally inaccessible desert environment of the Earth. From the information learned about deserts on this mission, it is concluded that much more can yet be obtained from orbital surveys in this field. Desert study must also include mathematical modeling and experimental work on dune structure and sand movement. This is important for understanding the nature of terrestrial dunes and similar features on Mars. Finally, the utilization of orbital observations of all types of features can be increased if simultaneous investigations are conducted from the air, on land, or at sea.

## Experiment Performance

Data pertaining to the Earth Observations and Photography Experiment include 10 tapes of verbal comments made during the mission, one magazine of 16 mm motion picture film, 41 reels of video tape also on 16 mm film, and nearly 1400 photographs taken with the 70 mm Hasselblad cameras and the 35 mm Nikon camera. (Although over 1900 photographs were taken with the Hasselblad and Nikon cameras, about 500 of them are useless, being too oblique, underexposed, overexposed, or out of focus.)

A total of 11 mapping passes and 60 visual observation sites were scheduled. Only one mapping was canceled (on revolution 15/16) because of problems in the flight plan. Approximately 20 percent of the 100 planned visual observations of the 60 sites were not performed because of bad weather, making the overall data acquisition measure of the experiment approximately 80 percent. Summary results of the photographic mapping sites and visual observation targets are given in Tables 10 and 11, respectively.

To assist in making orthophotomaps, photographic support data were obtained for the following parameters:

ALPHA. Angle between the camera optical axis and the projection of the local vertical (principal point) into the plane formed by the vector from the principal point to the sun and local East.

ALTITUDE RATE. Time rate-of-change of the spacecraft altitude (inertial) with respect to the principal point.

COORDINATE TRANSFORMATION MATRICES. Geographic coordinate system to camera coordinate system transformation matrix, and local horizontal coordinate system to camera coordinate system transformation matrix.

EMISSION ANGLE. Angle between the camera optical axis and the local vertical at the principal point.

GEOGRAPHIC DIRECTION COSINES. Direction cosines for a vector from the vehicle to the principal point in the geographic coordinate system.

HEADING ANGLE. Angle, measured positive clockwise in the local horizontal plane, from local North to the projection of the camera x-axis into the local horizontal plane.

HORIZONTAL VELOCITY. Component of the spacecraft's velocity vector (inertial) which is colinear with the local horizontal plane.

NORTH DEVIATION ANGLE. Angle, measured positive clockwise in the camera x, y plane, from the camera x-axis to the projection of local North into the camera x, y plane.

PHASE ANGLE. Angle between the camera optical axis and the vector from the sun to the principal point.

PHI, OMEGA, KAPPA. Angles that rotate the camera coordinate system into the local horizontal coordinate system, where: phi is the primary right-hand rotation about the camera y-axis, omega is the secondary right-hand rotation about the intermediate x-axis, and kappa is the final right-hand rotation about the local vertical axis.

PHOTOGRAPH FOOTPRINT. Latitude and longitude of the field-of-view corner point projections onto the Earth's geoid.

PRINCIPAL POINT. Latitude and longitude of the intersection of the camera optical axis with the Earth's geoid.

SCALE FACTOR. Constant which relates film dimensions to surface dimensions.

SUBSOLAR POINT. Latitude and longitude of the intersection of the vector from the Earth's center of mass to the sun with the Earth's geoid.

SUN AZIMUTH AT THE PRINCIPAL POINT. Angle, measured positive clockwise, from local North to the projection of the vector from the principal point to the sun into the local horizontal plane.

SUN ELEVATION AT THE PRINCIPAL POINT. The acute angle, between the vector from the principal point to the sun and the local horizontal plane at the principal point.

SWING ANGLE. The acute angle, between the camera y-axis and the projection of the local vertical into the camera x,y plane.

TILT ANGLE. The acute angle, between the camera optical axis and the local vertical.

TILT AZIMUTH. Angle, measured clockwise, between local North and the projection of the camera optical axis into the local horizontal plane.

X-TILT. Angle from the local horizontal plane to the camera's y-axis (lateral tilt).

Y-TILT. Angle from the local horizontal plane to the camera's x-axis (longitudinal tilt).

The availability of these data has allowed the construction of semicontrolled photomaps of several regions. The Defense Mapping Agency's (DMA) Aerospace Center at St. Louis, Missouri, has produced and distributed maps (which are necessary for the data analysis program) for Los Angeles, California, the Levantine Rift in Syria and Turkey, southeastern Angloa and Zaire, the Western Desert of Egypt, and the Simpson Desert of Australia.

TABLE 10.—Photographic mapping results (from El-Baz and Mitchell, 1976)

| Mapping pass | | Description | Remarks |
|---|---|---|---|
| M4 | Himalaya Mountains | Shoreline processes at Zambezi River Delta margin<br><br>Sediment plumes in Somali Current<br><br>Ocean currents in Arabian Sea<br><br>Flood plains of the Indus River<br><br>Drainage patterns of foothills of Himalayas<br><br>Photography of snow cover | Excellent photography was acquired over the Indian Ocean and Arabian Sea; however, most of India (and particularly the Himalayas) was completely cloud covered. |
| M5 | Arabian Desert | Afar Triangle<br><br>Structures on border of Red Sea rift<br><br>Dune patterns in Ar-Rub Al-Khali<br><br>Coastal processes at Doha, Qatar | Scattered clouds covered the western part of the Afar Triangle, but the weather was clear from eastern Afar to Qatar and good photography was acquired. |
| M6 | Australia | Playas in the Lake Eyre region<br><br>Dune patterns in Simpson Desert<br><br>Great Barrier Reef<br><br>Eddies in the Coral Sea | The weather was good all along the revolution 64 groundtrack, and excellent photographs of Australia and the Coral Sea were obtained. |
| M1 | Gulf Stream | Fracture pattern of a micro-crustal plate that includes the Yucatán Peninsula<br><br>Eddies and currents in the Yucatan Channel<br><br>Red tide off western coast of Florida<br><br>Eddies and gyres of Gulf Stream | Mapping camera photography was canceled on revolution 15/16 because of Flight Plan problems. |
| M2 | New Zealand | Photography of Alpine Fault<br><br>Internal waves<br><br>Plankton blooms<br><br>Eddies in South Pacific | Alpine Fault photography was not successful because of cloud cover; however, all other objectives were achieved. |
| M3 | Southern California | Ocean water color<br><br>Red tide off coast of California<br><br>Subsystems of San Andreas Fault<br><br>Desert colors and processes in the Mohave Desert | The ocean part of the mapping strip was partly cloudy; excellent photography was obtained of the land part. |
| M7 | African drought | Guinea Current<br><br>Lake Chad region, vegetation and land use patterns<br><br>Desert colors in northeastern Africa<br><br>Sand dune patterns and their relation to vegetation and wind<br><br>Nile River Delta<br><br>Levantine Rift: structures of Golan Heights and southern Turkey | Photography of the Guinea Current was not successful because of cloud cover; however, the weather was clear from Lake Chad to the Levantine Rift and excellent photographs were obtained. |

TABLE 10.—Continued

| Mapping pass | Description | Remarks |
| --- | --- | --- |
| M8 Falkland Current | Continental-shelf waters<br><br>Falkland Current and its relationship to fisheries | The spacecraft attitude for this pass was not nominal and resulted in oblique photography with the horizon occupying much of the frames. |
| M9 Sahara | Niger River Delta: dune patterns and land use of the Inland Delta for comparison with Skylab data on the Sahel<br><br>Desert color and relation to age<br><br>Desert dunes and their relation to topography, moisture, and vegetation<br><br>Coastal processes at Tripoli<br><br>Eddies in waters between Tripoli and Sicily | South of the Niger River Delta, cloud cover obscured much of the terrain, but the weather was clear north of the delta. Photographs of the Sahara are slightly overexposed, but those over the land-water interface at Tripoli are excellent. |
| M10 Northern California | Ocean water color<br><br>Red tide occurrences<br><br>Subsystems of San Andreas Fault<br><br>Metamorphic foothills of Sierra Nevadas | Photographs of northern California are good, although some frames are slightly overexposed. |
| M11 New England | Mexican volcanoes<br><br>Sediment patterns in Gulf of Mexico waters<br><br>Eddies and gyres in Gulf of Mexico<br><br>Mississippi River Delta<br><br>Potomac River pollution<br><br>Red tide occurrences off coast of Massachusetts and Maine | Mapping pass photography on revolution 135/136 is out of focus, probably because the 80-mm lens (used for the electrophoresis experiment) was substituted for the 60-mm lens. |

TABLE 11.—Visual observation results (from El-Baz and Mitchell, 1976)

| Target designation | | Description | Remarks |
|---|---|---|---|
| 1 | New Zealand | Alpine Fault photographs<br>Internal waves between North and South Islands<br>Plankton blooms<br>Pacific water color | The Alpine Fault was cloud covered, but visual observations of ocean waters northeast of New Zealand were recorded. The color wheel was used, and the crew reported that the ocean color was close to 47-B. |
| 2A | Southern California | Current boundaries<br>Red tide off coast<br>Gran Desierto color<br>Desert varnished hills | Cloud cover obscured much of the ocean, but interesting cloud waves were observed in the lee of the Channel Islands. A color wheel reading of 16-A was given to the Gran Desierto. |
| 2B | Baja California | Pacific water color<br>Bahia Concepción Fault<br>Internal waves in Gulf of California<br>Gray rock exposures | Oblique photographs were obtained over the Baja peninsula, but there were no crew comments. |
| 2C | California Current | Pacific water color<br>Faults west of San Andreas<br>Foothill metamorphic range | There was some cloud cover over the ocean, but a color reading of 47-B was taken for the coastal waters just offshore from San Francisco. |
| 2D | Great Salt Lake | Bonneville track<br>Color boundaries and sediment plumes in lake<br>Bingham copper mine<br>Snow cover on the Wasatch Range | Excellent photographs of the Great Salt Lake were acquired. In addition, the crew reported that the Bonneville track could be easily detected. |
| 2E | Guadalajara | Major fault lines<br>Big Bend structures | No visual observations were made or photographs taken of the Guadalajara area; however, good photography was obtained of a part of the Mexican volcanic belt southeast of Guadalajara. |
| 3A | Cloud features | Photographs of convective clouds | A number of excellent photographs were obtained including Benard cells, atmospheric bow waves, rotor clouds, and severe thunderstorms. |
| 3B | Tropical storms | Storm centers<br>Texture of storms | Good data were acquired on both developing and dissipating tropical storms. |
| 3C | Hawaii | Upwellings, bow waves, island wakes<br>Kilauea Volcano | No photographs were taken of the Hawaiian islands, but excellent data were obtained of eddies and currents southeast of the islands. |
| 3D | Kuroshio Current | Ocean current boundary<br>Plankton blooms | Some photography was acquired in the South China Sea. |
| 4A | Snow peaks | Snow-peaked mountains<br>Glaciers and firn lines | Excellent photographs were obtained of glaciers and snow-peaked mountains in both the Cascade and Canadian Rocky Mountains. |
| 4B | Puget Sound | Suspended sediments<br>Gyres<br>Glaciers and firn lines | Valuable photographic and verbal data were obtained of sediments and gyres in the Puget Sound. |
| 4C | Superior iron | Color oxidation zones | No photographs were taken but visual observation comments were made on color oxidation zones in the Superior region. |

Table 11.—Continued

| Target designation | Description | Remarks |
| --- | --- | --- |
| 4D Sudbury nickel | Color oxidation zones | Photography of the Sudbury area was unsuccessful because of cloud cover. |
| 5A Gulf of Mexico | Eddies in Yucatan Channel<br>Florida Current<br>Gulf Loop Current<br>Internal waves in Gulf | Excellent data were obtained, including photography of eddies in the Yucatan Channel and current boundaries in the Gulf of Mexico. |
| 5B Gulf Stream | Ocean current boundary<br>Internal waves<br>Confluence with Labrador extension | This target was canceled on revolution 15/16 because of Flight Plan problems. |
| 5C Labrador Current | Ocean current boundary<br>Confluence with Gulf Stream | The ocean northeast of Newfoundland was cloud covered and no photographs were taken. |
| 5D Central American structures | Bartlett Fault extension<br>Graben valley structures | Central America was usually cloud covered and visual observations of fault structures could not be made. |
| 5E Florida red tide | Red tide location<br>Color and shape of bloom | The crew reported cloud cover over the Florida peninsula during every visual observation pass. |
| 5F New England red tide | Red tide location<br>Color and shape of bloom | Boothbay Harbor in Maine was always cloud covered, but excellent photographs of coastal waters of Massachusetts and Canada were taken. |
| 5G Chesapeake Bay | Sediment gyres<br>Pollution in Potomac River | Valuable photographic and verbal data were obtained of sediment gyres and pollution plumes in the Chesapeake Bay. |
| 6A Oil slicks | Oil slick extent<br>Color and location | No oil slicks were observed in the North Atlantic, but some photographs of slicks were acquired over the Persian Gulf and the Mediterranean Sea. |
| 6B London | Sediments and boundaries in English Channel<br>London Harbor area | England was usually cloud covered, but some photographs were taken along the coasts of England and France. |
| 7A Humboldt Current | Ocean current boundary<br>Gyres in water | Photography of the Humboldt Current was successful. |
| 7B Nazca Plain | Nazca Plain markings<br>Peruvian desert landforms | Some photography was obtained of the Nazca region, but the crew could not definitely confirm visual sightings of the Nazca Plain markings. |
| 7C Internal waves | Photographs of internal waves | Excellent photographs were taken of internal waves off Thailand and west of Spain. |
| 7D Peruvian desert | Dune fields<br>Nazca Plain markings | Valuable photographic data of dune fields in the Peruvian desert were acquired. |
| 7E Orinoco River Delta | Photographs of delta<br>Water color near Barbados | Photographic and verbal data of the Orinoco River Delta included excellent photography of ocean waters between the delta and Barbados as well as visual observations of the extent of "brown water" outflow from the delta. |
| 7F Galapagos Islands | Upwellings<br>Bow waves<br>Island wakes<br>Internal waves | Excellent photography was acquired of the volcanic calderas on the Galapagos and of the complex atmospheric wave patterns surrounding the islands. |

Table 11.—Continued

| Target designation | | Description | Remarks |
|---|---|---|---|
| 7G | Caribbean Sea | Eddies<br>Gulf Stream | A number of photographs were taken of the Caribbean waters and the islands of Cuba and Jamaica. |
| 8A | Falkland Current | Ocean current boundary<br>Plankton blooms<br>Confluence with Brazil Current | The spacecraft attitude was not nominal for the revolution 72 pass, and the viewing angle out window 3 was very oblique. |
| 8B | Chilean Andes | Color oxidation<br>Structures and lineaments | The Chilean Andes were cloud covered and only a few very high peaks were visible. |
| 8C | Dune field | Dune field color<br>Dune pattern and orientation<br>Relation with topography | Excellent photography was obtained of this little-known dune field and of a smaller unknown field to the east. |
| 8D | Paraná River | Photographs of dam sites | The weather over Paraguay and Brazil was amazingly clear, and excellent data were acquired of potential dam sites on the Paraná and Paraguay Rivers. Additional photographs were taken of the Amazon River. |
| 8E | Circular structures | Photographs of two structures | Excellent photography of one possible astrobleme was obtained. |
| 9A | Afar Triangle | Ethiopian Plateau scarp<br>Red Sea mountains | The Afar Triangle was mostly cloud covered. The infrared photography is out of focus. |
| 9B | Arabian Peninsula | Structures normal to Red Sea<br>Desert color<br>Dune types<br>Coastline of Qatar | Infrared photography of the Arabian Peninsula is out of focus. |
| 9C | Guinea Current | Ocean current boundary<br>Gyres in water | Currents and gyres in the Gulf of Guinea could not be observed because of cloud cover. |
| 9D | Desert colors | N'Djamena photographs<br>Desert colors<br>Dune patterns | Excellent photography was obtained of the Lake Chad area and of desert colors and dune patterns in the Libyan Desert. |
| 9E | Oweinat Mountain | Photographs of mountain<br>Structures in mountain<br>Color oxidation zones | Valuable data were obtained over the Oweinat Mountain, including excellent photography and verbal observations of structural features and color zonations. |
| 9F | Nile Delta | Observation of pyramids<br>Photographs of Cairo<br>Gulf of Suez structures | A number of photographs were acquired over the Nile Delta and included excellent near-vertical photography of the Cairo area. |
| 9G | Levantine Rift | Arcuate fault photographs<br>Terminations of faults | Excellent data were obtained on the arcuate terminations of the Levantine Rift. |
| 9H | Niger River Delta | Dune generations<br>Vegetation patterns | Photography of the Niger River Delta was not successful because of cloud cover. |

Table 11.—Continued

| Target designation | Description | Remarks |
|---|---|---|
| 9I Algerian Desert | Desert colors<br>Dune patterns<br>Interdune areas<br>Desert and vegetation relationship | Good photography was taken of the Algerian Desert; observations of color zones and sandstorms were also made. |
| 9J Tripoli | African coastline<br>Eddies, gyres, current boundaries, internal waves in Mediterranean Sea | Data for this target included good photography of the land-water interface at Tripoli and of current boundaries in the Mediterranean Sea. |
| 9K Strait of Gibraltar | Coastline at Casablanca<br>Atlas Mountains<br>Ocean current boundaries<br>Internal waves | Excellent photography of the Strait of Gibraltar was acquired, and the crew was successful in observing internal waves and current boundaries. Good photographic data were also acquired of central and southern Spain. |
| 9L Alps | Snow cover<br>Glaciers and firn lines | Photographs of snow cover on the Alps were not obtained because of cloud cover |
| 9M Danube Delta | Photographs of delta<br>Sediment plumes in Black Sea | The crew was successful in photographing the Danube Delta but reported that most of the area was very hazy |
| 9N Anatolian Fault | Photographs of fault<br>Snow cover on mountains | Good low-Sun-angle photography was acquired of fault zones in Turkey, including excellent data east of Lice (epicenter of the recent earthquake). |
| 9O Volcanics | Photographs of Vesuvius<br>Dark-colored volcanic rocks | Excellent infrared photographs were taken of igneous terrain in Italy. |
| 9P Bioluminescence | Brightening of tracks or zones in the Red Sea, Persian Gulf, and Arabian Sea that may be due to biological factors (nighttime observation) | The crew was not successful in observing bioluminescence in the Red Sea and remarked that they were still in sunglint. However, that was 2 min before the scheduled observation and they were still over the Mediterranean Sea. Earlier in the mission, the mission clocks had been updated 2 min, and the crew was probably using the old ground-elapsed time (GET). |
| 10A Great Dike | Color of Great Dike and surrounding rock | Photography and visual observations of this target were not successful. |
| 10B Somali Current | Zambezi River Delta<br>Coastal sediment plumes<br>Current boundaries<br>Internal waves | Infrared photography of the delta was out of focus, but observations were made of sediment plumes and gyres along the coast. |
| 10C Arabian Sea | Ocean current boundaries | The crew was successful in observing a current boundary, but farther north, high cirrus clouds obscured much of the Arabian Sea. |
| 10D Himalaya Mountains | Photographs of northwestern India | The Himalayas were cloud covered and photographs were out of focus. |
| 10E Takla Makan Desert | Desert colors<br>Dune patterns | The infrared photography of the Takla Makan was out of focus, but observations were made of what was probably a sandstorm over the desert. |

Table 11.—Continued

| Target designation | Description | Remarks |
|---|---|---|
| 11A Playas | Lake Eyre deposits<br>Desert erosion and dune patterns<br>Great Dividing Range | Excellent data were acquired of playas in the Lake Eyre region and included an unusual photograph of the normally dry Lake Eyre with much water. |
| 11B Coral Sea | Coastal sediment plumes<br>Great Barrier Reef<br>Water eddies | Valuable photography was obtained of ocean features in the Coral Sea, and the crew was very successful in locating and describing eddies. They also observed the Great Barrier Reef and remarked that coastal sediments did not extend as far as the reef. |
| 11C Simpson Desert | Desert colors<br>Dune fields<br>Dune types | Excellent photography was obtained that clearly illustrates the characteristic linear dune patterns and the red color of the Simpson Desert. |
| 11D ANZUS Eddy | ANZUS Eddy | Most of the area was cloud covered, but the crew did observe several eddies, one of which may have been the ANZUS Eddy. |
| 12A Icebergs | Photographs of bergs<br>Berg rotation<br>Edge of Antarctica | No icebergs were observed in the Southern Hemisphere; however, the crew did see several large bergs in the North Atlantic and attempted to photograph them. |

## Apollo Crew Comments[2]

American manned space missions have developed from Mercury through Gemini, Apollo, Skylab, and ASTP. During this same period visual observations' objectives and techniques have changed as well. Mercury and Gemini were devoted mainly to Earth photography from orbits of low inclination. Apollo emphasized description and photography of the lunar surface and the Earth. Skylab involved description of Earth's oceans, deserts, weather, vegetation, geological features, ice flows, snow cover, and cities from a higher inclination and altitude Earth orbit (450 km). Visual observations on ASTP were similar to Skylab's, except that objectives and techniques were keyed to the requirements of a relatively short mission in a low Earth orbit (225 km). Since the nine-day ASTP mission was short, crossings of the visual observation sites were preplanned, and each location was observed only once or at most a few times. In low orbit there were only seconds to view each site, generally 15 or 20 seconds at most. In order to accomplish visual observations objectives, it was necessary not only to plan but to train for each of the sites to be encountered.

When the space program resumes visual observations at the beginning of the Shuttle era, there should be a change in direction. There should be both improvements in the viewing station and the initiation of major visual observations projects. The following are detailed comments on ASTP experience and recommendations for the future.

### Viewing from Low Orbit

Our crew enjoyed visual observations' runs and was fascinated by the beauty and the detail that could be seen on the Earth below. In orbit, the blue and white ocean areas contrasted with the black sky, and continents loomed up as light brown masses. Most cities were gray. At the 225-km altitude, it was possible to see ships wakes, icebergs, current boundaries, the apparent manifestation of internal waves in the ocean, airplane contrails, thunderstorms, gas flares, lightning, eddies and gyres in the ocean, glacier firn lines, sand dunes, sediment patterns along coastlines, and man-made features such as airports. Thunderstorms looked like large toadstools. At the same time we could see a sweeping panorama. For

[2] This section, prepared by astronaut Vance Brand and reviewed and approved by his crewmates Tom Stafford and Deke Slayton, represents the views of the ASTP crew.

example, Italy really looked like a boot. Vegetation such as grass and trees effectively obscured the color of rock formations, but in the deserts where vegetation was sparse, surface colors showed up well. It was easy to see many modern cities, such as Los Angeles and Chicago, but difficult to find a city built with rock from the local countryside, such as Jerusalem. In deserts it was easier to see linear dunes than star dunes. Ocean viewing was aided by sunglint, and looking down-sun over ocean areas was generally nonproductive. Ocean wakes, currents, and internal waves were visible only momentarily when viewing conditions were just right. The human eye easily adjusted from viewing bright sunglint to viewing darker land targets.

Depending upon the complexity of the scene, sometimes it was easy and at other times difficult to comment on what one was seeing. For example, it was difficult to describe a complex network of faults on land or a pattern of gyres in the ocean. One wanted to illustrate the scene by drawing a picture. Easier description tasks were to answer "yes" or "no" questions and to explain simple features in terms of their size, shape, color, texture, and contrast. A unique human characteristic was the ability to describe large weather patterns covering a wide field of view that could not be captured on a single photograph.

Two interesting sightings that the ASTP crew unexpectedly made are not well understood or verified by ground studies at this time. The first, a vast pall of smoke or ashes, was sighted south of the Aleutian Island chain. The second phenomenon was circular cloud patterns sighted routinely over the Pacific Ocean. The patterns were not Bénard cells but were random sized, randomly spaced rings or ring segments over the ocean. The rings varied from 15 to 50 km in diameter. Most rings of clouds had clear sky inside the cloud circle, but a few of the rings were filled in. It has been speculated that the cloud rings may indicate eddies of cold or warm water in the ocean. Several photographs were taken of typical groups.

## Preflight Training

Our training prior to the mission was excellent. The foundation training consisted of basic science courses including oceanography, meteorology, tectonic geology, snow cover, environmental problems, desert features, and hydrology. We soon moved on to an advanced course which consisted of planning, learning how to identify sites, T–38 flyovers to improve observation techniques, equipment instruction, and time line simulations in mockups. Training accomplished on the photographic equipment was more than sufficient. We probably should have concentrated on camera malfunction training earlier in the equipment course.

Just prior to launch, training efforts emphasized trying to second-guess possible viewing poblems, last minute planning, and memorization of objectives to be accomplished over each site.

## Observation Techniques and Procedures

At an altitude of 225 km (120 nm) and at orbital velocity, we sensed our speed over the Earth, could see great detail below us, but felt somewhat rushed in making visual observations. As a result, we felt more comfortable using three men as a team during visual observations. When approaching a site, the entire crew worked to be ahead of the time line (if possible) so that two men could assist the primary observer. It always helped to organize the visual observations equipment well, to study charts, and to prebrief the upcoming run. We never desired to use binoculars or the spotting scope, because too much time was required to focus on and track an object on the ground and this left little or no time to look at it.

Repeated visual observation passes were helpful because sometimes one could see something on a second pass that was missed on the first. Often, there was little time for debriefing as the flight plan kept the crew moving on briskly to the next event. Some data were lost as a result.

The spacecraft attitude for viewing was heads down and nose forward along the orbital track. Before the flight all parties concerned believed that this would be a good viewing attitude, but being heads down turned out to be less than optimum for finding and identifying sites. Future observing crews should be oriented heads up, if possible. Imagine here on Earth how difficult it would be to drive down the highway in your car and identify objects along the side if you were sitting upside down. Early in the flight the spacecraft's attitude was such that the viewing windows faced slightly below the horizon. An improved attitude, adopted later in the mission, was to face the viewing windows downward so as to see less of the sky above the forward horizon and more of the Earth directly beneath the spacecraft.

Generally, there was time for a crewman to take pictures or to describe, but not to do both. If in doubt, it was best to take pictures rather than comment, because sometimes phenomena to be described were so complex that a picture was really needed for documentation.

The visual observations film budget was keyed to fairly precise and predictable film usage over each site, but actual expenditure depended so much on viewing conditions that day-to-day budgeting was best performed by the crew during flight. In the future, film should be stowed in a cassette "supply" locker; there should be a cassette "used" locker and cassettes still should be color-coded by film type. Crews should be permitted to manage their own film budgets and to pull any film cassette of the right type (not necessarily in numerical order) from the film supply side of the locker.

Before the mission it was decided to record the observer's comments and film information on the portable tape recorder and to back up this procedure by recording on the ship's tape recorder whenever possible. In addition, the last frame number of each photo series was to be noted in the "Earth Observations Book." The procedure worked well from the crew's point of view as it was convenient to depend mainly on the portable tape recorder, but the scheme required observer self discipline and consistency. In a fast moving situation, one could easily forget to call out the last frame number after a series of photos.

In the early part of a mission, a crew should (if possible) start with easy viewing sites, well spaced. Then, as on-the-job learning progresses, it could proceed to more difficult and closely spaced sites. It is helpful to use simple, short terminology whenever possible. For example, instead of calling our two Hasselblad cameras by their letter designations, we simply called them the "Silver" and "Black" cameras. Surprisingly, such simplifications help, especially in air-to-ground communications.

Moreover, if there is a procedural or hardware trap, someone will fall into it. For example, a crewman inadvertently left the ETE spacer on the Hasselblad for some out-the-window photos, which made them out-of-focus. There should have been a checklist verification that the spacer was removed or the spacer should have been an integral part of the lens for which it was required—better yet, there should have been no spacer. In the "heat of battle" there always is a chance that an error will be made if a procedural trap exists. Equipment should be easy to handle, fool-proof, and as simple as the job allows. Equipment that is to be handheld and passed around ideally should be compact and free of power and timing cables.

## Observation Aids and Photographic Equipment

The onboard cameras and viewing aids were adequate for the mission. The following are commendable features and problems that the crew encountered while operating the equipment. For a description of any of the following items, refer to pages 46–59. The convenient orbital chart (Figure 35) developed by Dr. El-Baz was ideal for use on a short mission. Useful additions to the chart would be revolution numbers at the end as well as the beginning of each revolution trace, and a representative, relative time scale to indicate minutes elapsed along a typical trajectory. The "Earth Observations Book," was complete and well suited for its purpose, but it was difficult to write on the pages in the book due to the finish of the paper. The battery-operated tape recorder was conveniently small and generally reliable, but it was inadvisable to rewind the tape in weightlessness because rewinding tended to snarl the tape. This problem should be corrected by installing weak springs to apply spring tension to the tape supply and takeup spools. An additional improvement would be to supply longer-life batteries for the tape recorder without increasing its overall size. The cardboard, handheld ground distance measuring device was handy and accurate to within a few kilometers and much used during the mission. Although suitable, the large packet of world maps was not used because it was stowed in a relatively inaccessible location and was difficult to pull out on short notice. In any case, the El-Baz orbital chart was suitable for most purposes. The color wheel used for determining the absolute color of surface features was inaccurate. Color shades on the color wheel changed as a function of lighting within the crew cabin. The lighting problem should be corrected if a similar device is to be considered for future use. The 35 mm Nikon camera was useful for visual observations as well as for indoor photography; it was convenient because of its size, reflex feature, and rather compact and reliable design. The Nikon was difficult to use with the 300 mm lens attached, however, because there was insufficient light collected in the reflex for aiming the camera. The 70 mm Hasselblad camera was acceptable except when using the 250 mm lens with the reflex attachment. In this case, the Hasselblad suffered from the same light loss problem as the Nikon. In addition, the Hasselblad extension ring attachment for the ETE experiment and the orange filter for the infrared film were traps lying in wait for the unsuspecting crewman. The extension ring, if not removed, distorted out-the-window pictures and the orange filter darkened the view through the lens. The photo cue card was very useful, but Nikon Earth photography numbers were missing. The omission was understandable since the camera was not cast in the role of an Earth observations camera until after launch. None of the above mentioned problems were "show stoppers," but they should be addressed if the same equipment is to be used for future missions.

## Technological Developments for the Future

The ideal Earth observations platform of the future would consist solely of an orbiting plexiglass sphere with an astronaut inside. A sphere concept being impractical, the next best thing would be a viewing bubble or turret on a spacecraft with the observer sitting upright and looking forward and down. The bubble or turret should contain a sensor platform, which the observer would sit on and point with a sidearm controller. The astronaut would select and point the various cameras and sensors at objects of interest on the ground. Since this concept may not materialize in the early Space Shuttle era, the following developments are proposed to improve data-taking capability on early Shuttle missions: (1) an Earth-viewing TV camera with improved spatial and color resolution for transmitting interesting features in realtime; (2) a wide angle or pan camera for use in photographing extensive features, such as hurricanes and for mapping; (3) cameras with automatic exposure meters suitable for out-the-window use (the automatic exposure meter should have a manual override for special applications such as cloud photography); (4) films with better color resolution and range, especially in the ocean colors of blues and greens (films still do not accurately record many of the colors that the eye can see); (5) a sighting device worn on the crewman's head which could be used to accurately pinpoint the latitude and longitude of something being viewed (it would be necessary to merely sight at an object and depress a "mark" button to record the object's coordinates); and (6) a handheld optical color comparator about the size of a pair of binoculars. One half of the instrument should view the Earth and the other half should contain a uniformly lighted color screen, which could be varied to obtain ground/screen color comparisons. A device of this type is needed to accurately determine absolute colors of land and water surfaces. It should be noted that if binoculars or a spotting scope are carried on a future low Earth orbit mission, magnification should not exceed $\times 10$ and the field of view should be wide to minimize acquisition time.

## Scientific Objectives for the Shuttle Era

Man's capability to perform visual observations from orbit has been shown on Apollo, Skylab, and ASTP. During past missions, astronauts selected sites, positioned instruments at specific features, operated specialized equipment, and served as observers (with a wide field of view and good acuity and color perception).

The first objective for the future should be to improve man's viewing platform and viewing instruments to take better advantage of his capabilities. The second objective for the future should be to organize visual observations to support extensive projects, as well as a multitude of limited scientific investigations. The large projects should utilize all available data including imagery from Landsat, manned mission photography, and visual observations. As a starting point, several projects could be accomplished in the relatively cloudless regions of the world: (1) Providing a complete geological and surface mapping photo service for uncharted desert areas throughout the world. There are few good maps of many of these areas at present. (2) Determining the direction of movement of the Sahara Desert. The space program has performed some work in this area in the past, but there are no definitive and complete results. (3) Conducting search for probable ground-water resevoirs by analyzing space photography and imagery of desert areas.

There is strong need for such projects. In the spring of 1976, the ASTP crew visited North Africa and was told that the Sahara Desert is "the great enigma" there. In trying to tame the Sahara, the

North Africans are looking for information to help them find water and to stop encroachment of the sands. Maps of high quality are needed to support these and other objectives. Desert projects have been emphasized here because desert areas are relatively free of obscuring clouds and well suited to monitoring from orbit. Ocean and weather projects should be organized as well. For example, a worldwide scientific study is needed to better understand the transfer of energy that occurs between the oceans and the atmosphere and the resulting effect on climate. Visual observations in the future should emphasize and contribute to such projects and, in addition, cater to a large diverse group of more limited scientific objectives.

## Recommendations for the Space Shuttle

Results of the Earth Observations and Photography Experiment on ASTP confirm the ability of orbiting astronauts to increase our knowledge of the Earth. These results show that a trained astronaut can expertly describe observed features and phenomena, can discern and interpret what is seen, and can select photographic sites or modify planned activities. The ability to perform in this manner can be beneficial in complementing data-gathering by automated satellites.

The Space Shuttle, scheduled to start operations in late 1979, will provide an excellent vehicle for similar Earth observations experiments. Earth observations from the Shuttle should be given high priority, because of the potential scientific returns. This is particularly true since present plans call for several Shuttle flights each year.

The following are this author's recommendations based on experience gained from the Apollo-Soyuz and previous manned missions. The recommendations, both short- and long-term, should be considered in planning Earth observations on the Shuttle.

### Platform Design

For Earth observations tasks, it is advisable to allocate the time of two crew members, one to perform visual observations and the other to simultaneously operate the cameras. A mechanism is necessary to let the orbiting astronauts know where they are at any given time. The transparent sliding orbital groundtrack (previously used with a map) is not practical; faster and more accurate means should be made available.

At least one frame-camera (preferably large film format) and one television camera should be mounted and readied for photography on command. Camera automation alleviates many problems during the mission. All cameras used in support of Earth observations should be equipped with time and photo-data recording mechanisms. This will assure exact location data of photographed sites and will reduce the time normally spent on photo-documentation. A high quality optical (quartz) window should be installed to alleviate the problems of distortion and reduction of light transmission due to use of normal glass windows.

If Earth observations are to be performed from the Shuttle's cockpit, enough space should be allocated for the operation. This would remedy the problem of the usual "Christmas tree" effect of accumulating camera equipment and visual observation aids around the observer. For the early Shuttle flights, the craft should be oriented to allow making the observations in a right-side-up position, and looking ahead of nadir.

For the later Shuttle flights an Earth observations platform should be designed specifically for the task. The Skylab 4 crew recommended that an "Earth observatory" be designed as a transparent "bubble" within which an astronaut could sit and direct sensors at observation sites. During the Skylab 4 crew debriefings, astronaut William Pogue suggested that the observatory might be thought of as a "Flash Gordon type thing that could look out the side of the cargo bay in the Shuttle some way and feed the imagery back into another compartment."

### Scientific Objectives

Emphasis should be placed on the ability of trained observers to complement data gathered by other means. Astronauts are able to gather new data more successfully than automated sensors. The human eye can discern more subtle color differences, such as in desert sands or sea waters; dynamic phenomena or features that are visible under very limited conditions, such as internal ocean waves; and lineaments, which can indicate the tectonic setting of large areas of the crust.

Because of the anticipated short duration of Shuttle missions (about seven days for the early flights), it will be best to concentrate on a few major objectives:

one mission might concentrate on desert color and landforms, another on ocean features, and yet another on atmospheric phenomena. Minor objectives for these "specialized missions" may be considered based on scientific requirements and opportunity.

## Astronaut Training

Classroom Instruction.—Training of the Shuttle crews should start about two years prior to the flights with briefings on the various fields of the Earth sciences. For this type of training, it would be practical to instruct several crews at the same time. Classroom instruction should continue for no less than six months and consist of one two-hour lecture every two weeks.

Training sessions should include familiarization with sites of interest along the groundtracks. This "geography" training should be done by the use of maps, space photographs, and other images. Complete familiarity with the groundtracks, which is mission-specific, requires about six training sessions spaced over a three-month period. During the last three months before a given mission, all classroom training should be site-specific. This training may be completed during, but preferably after the groundtrack familiarization period.

Ground Motion Simulations.—The Shuttle astronauts should study the motion picture films obtained during previous missions, particularly the ASTP 16 mm films and television reels. Films should also be made which simulate ground motion as seen from the Shuttle's orbit. These films would be an important complement to both classroom instruction and flyover exercises.

Flyover Exercises.—At least six training flights should be undertaken by Shuttle crews. Preceded by briefings and followed by debriefings, the exercises should include overflying features and phenomena of the Earth's atmosphere, hydrosphere, and lithosphere. The "Manual of Training Flights" included in this book as Appendix 2 could be used for these exercises.

For Shuttle crews that intend to conduct observations in one or a few subjects only, special training flights could be undertaken. In these cases, supplementary flyover books may be prepared. Training flights should also include the handling of photographic equipment and visual observation aids. This would teach the astronauts to compensate for fast image-motion while taking pictures and to become adept at obtaining stereo-photographs.

## Flight Planning

Site Selection.—Selection of observation sites should be completed at least six months before the mission to allow time for flight planning, site-specific training, and the preparation of onboard aids. The sites should be referred to in the simplest possible form, either by a name (preferably two words) or a simple letter-number combination. This facilitates reference to the sites during both the training period and mission operations.

Enough time should be allocated in the flight plan not only for discerning the target, but also for preparation for and documentation of the observations. Although all tasks should be programmed in the flight plan, flexibility should be retained to allow for real-time changes. These changes may be necessitated by uncontrollable conditions or by crew preference and on-the-job recommendations.

Observation Aids.—Several observational aids would facilitate data gathering. A separate booklet, including all the necessary information to conduct the observations, in the format of the "Earth Observations Book" used on ASTP (Appendix 3) has proven to be suitable. Although the world map package is not mandatory to the successful performance of Earth observations from orbit, its usefulness could be increased by using Landsat imagery as a map base to give a better indication of topography and vegetation.

A mechanism is necessary to obtain quantitative data on the color of observed features. Because of variable illumination, the color wheel designed for the ASTP mission and the Forel scale used on the Skylab 4 mission to determine ocean colors would not be practical for the Shuttle. It should be possible, however, to modify a low power monocular, or even a plain cylinder, by inserting miniature color wheels that are internally illuminated to overcome uncertain lighting.

A ground scale, temporarily attached to the spacecraft wall, to allow the astronauts to estimate sizes of features and distances on the ground by holding it at arms' length would also be helpful. Finally, binoculars, of magnification and an enlarging power dependent on altitude, to be used in observing small targets should be selected and carried onboard the Shuttle craft.

Photographic Equipment.—Cameras to be used in documenting visual observations should have a single-lens reflex mechanism to allow the astronauts to see the camera's field of view. Other cameras should be automated for easy start/stop operations. A television camera also should be used to convey data during the mission for realtime analysis and interpretation.

### Mission Operations

For the first Shuttle flights it is necessary for the Capcom to be familiar with the scientific objectives of Earth observations and with the details of the observation sites. This can be accomplished during classroom training. For later Shuttle missions the scientists themselves must be allowed to talk to the orbiting astronauts to significantly enhance task performance and increase scientific returns. It should also be possible for the scientists themselves to fly on the Shuttle and perform the observations.

Concurrent investigations in the air, on land, and at sea should be encouraged. Interaction between an astronaut in orbit and a "groundtruth" data-collector can yield significant results. Verbal descriptions of observation sites must be recorded in realtime. An easy-to-operate tape recorder should be supplied to the crew for use while out of communications with the ground.

Realtime weather forecasting is very important to Earth observations from orbit. A NOAA facility is needed to provide high-resolution SMS visible and/or infrared data at 30 minute intervals. The SMS data should be obtainable on a hemispheric scale as well as on one of many sectorized scales, depending on the needs of the investigation team. This type of weather support would be particularly significant when the SMS system provides world coverage, hopefully before the Shuttle is operational.

### Data Analysis

The conduct of a successful scientific analysis program requires the documentation of the data (verbal comments and photographs) and their presentation in a usable form. All photographs must be cataloged and voice tapes transcribed for the investigators. Data analysis should be considered as important as data collection. Support of postmission research is essential to the proper utilization and dissemination of the results.

The NASA requirements for internal reports should be lessened to reduce the burden on investigators. Instead of investing in NASA publications, investigators should be encouraged to publish their findings in the existing scientific media. This will assure better dissemination of the gained information.

# Literature Cited


Allan, J. A.
1976. The Kufrah Agricultural Schemes. *The Geographical Journal,* 142(1):48–56.

Anders, W. A., J. A. Lovell, and F. Borman
1969. Visual Observations. Chapter 1 in *Analysis of Apollo 8 Photography and Visual Observations.* NASA Special Publication, SP–01. Washington, D.C.: U.S. Government Printing Office.

Apel, J. R., H. M. Byrne, J. R. Proni, and R. L. Charnell
1975. Observations of Oceanic Internal and Surface Waves from the Earth Resources Technology Satellite. *Journal of Geophysical Research,* 80(6): 865–881.

Apel, J. R., and R. L. Charnell
1974. Ocean Internal Waves off the North American and African Coasts from ERTS–1. Paper M2 in *Third Earth Resources Technology Satellite–1 Symposium.* NASA Special Publication, SP–351, 1:1309–1316. Washington, D.C.: U.S. Government Printing Office.

Arvidson, R. E., and T. A. Mutch
1974. Sedimentary Patterns in and around Craters from the Pinacate Volcanic Field, Sonora, Mexico—Some Comparisons with Mars. *Geological Society of America Bulletin,* 85:99–104.

*Aviation Week . . .*
1976. Earth Resources Stressed on Soyuz-22. *Aviation Week and Space Technology,* 105(13):20.

Bagnold, R. A.
1933. A Further Journey through the Libyan Desert. *Geographical Journal,* 82:103–129, 211–235.
1941. *The Physics of Blown Sand and Desert Dunes.* 265 pages. London: Methuen and Co., Ltd.

Baker, B. H.
1970. The Structural Pattern of the Afro-Arabian Rift System in Relation to Plate Tectonics. *Royal Society of London, Philosophical Transactions,* series A, 267(1181):383–391, 399–405.

Barnes, J. C.
1974a. ASTP Earth Observations Experiment: Snow Hydrology Investigation. [Unpublished report in the files of F. El-Baz, National Air and Space Museum, Smithsonian Institution, Washington, D.C.]
1974b. Snow-Mapping Experiment. Section 15 in *Skylab 4 Visual Observations Project Report.* NASA Technical Memorandum, TM X–58142. Houston, Texas: Johnson Space Center.

Bird, P., M. N. Toksöz, and N. H. Sleep
1975. Thermal and Mechanical Models of Continent—Continent Convergence Zones. *Journal of Geophysical Research,* 80:4405–4416.

Black, P. G.
1975. [cover] *Bulletin of the American Meteorological Society,* 56(12).

Breed, C. S.
1976. Terrestrial Analogs of the Hellespontus Dunes, Mars. Pages 117–119 in *Reports of Accomplishments of Planetology Programs, 1975–1976.* NASA Technical Memorandum, TM X–3364.

Cameron, W. S.
1965. Man in Space. Pages 527–547 *in* W. N. Hess, editor, *Introduction to Space Science.* New York: Gordon and Breach Science Publishers.

Campbell, W. J., R. O. Ramseier, W. F. Weeks, and J. A. Wayenberg
1974. Preliminary Results of Lake and Sea Ice Experiment. Section 11 in *Skylab 4 Visual Observations Project Report.* NASA Technical Memorandum, TM X–58142. Houston, Texas: Johnson Space Center.

Committee on Colorimetry
1963. *The Science of Color.* 385 pages. Washington, D.C.: The Optical Society of America.

Committee on Polar Research
1970. *Polar Reseatch, A Survey.* Washington, D.C.: National Research Council, National Academy of Sciences.

Cutts, J. A., and R. S. U. Smith
1973. Eolian Deposits and Dunes on Mars. *Journal of Geophysical Research,* 78:4139–4154.

Dietz, R. S.
1961. Astroblemes. *Scientific American,* 205:51–58.

Dietz, R. S. and B. French
1973. Two Probable Astroblemes in Brazil. *Nature,* 244 (5418):561–562.

Dietz, R. S., and J. McHone
1976. Volcanic Landforms and Astroblemes. [Unpublished report in the files of F. El-Baz, National Air and Space Museum, Smithsonian Institution, Washington, D.C.]

Dubertret, L.
1953. *Carte Geologique au 1:50,000 du Liban.* Beyruth: Ministere des Traveaux Publics.

El-Baz, F.
1969. Lunar Igneous Intrusions. *Science,* 167(3914): 49–50.
1975. The Moon after Apollo. *Icarus,* 25(4):495–537.
1976. Terrestrial Sand Patterns Photographed by the Apollo-Soyuz Mission and Similar Features on Mars. *Lunat Science VII, Abstracts of Papers,* Part 1:236–238. Houston, Texas: Lunar Science Institute.
n.d.a. Mission Notes. In the files of F. El-Baz, National Museum of Air and Space, Smithsonian Institution, Washington, D.C.
n.d.b. Transcription of Visual Observation Comments. In the files of F. El-Baz, National Air and Space Museum, Smithsonian Institution, Washington, D.C.

El-Baz, F., and R. E. Evans
1973. Observations of Mare Serenitatis from Lunar Orbit and Their Interpretation. *In* Proceedings of the Fourth Lunar Science Conference. *Geochimica et Cosmochimica Acta*, supplement 4, 1:139–147.

El-Baz, F., and D. A. Mitchell
1976. Earth Observations and Photography Experiment. Chapter 10 in *ASTP Preliminary Science Report*. NASA Technical Memorandum, TM X–58173. Washington, D.C.: U.S. Government Printing Office.

El-Baz, F., and S. A. Roosa
1972. Significant Results from Apollo 14 Lunar Orbital Photography. *In* Proceedings of the Third Lunar Science Conference. *Geochimica et Cosmochimica Acta*, supplement 3, 1:63–83.

El-Baz, F., and A. M. Worden
1972. Visual Observations from Lunar Orbit. Chapter 25 in *Appolo 15 Preliminary Science Report*. NASA Special Publication, SP–289. Washington, D.C.: U.S. Government Printing Office.

El-Baz, F., A. M. Worden, and V. D. Brand
1972. Astronaut Observations from Lunar Orbit and Their Geologic Significance. *In* Proceedings of the Third Lunar Science Conference. *Geochimica et Cosmochimica Acta*, supplement 3, 1:85–104.

Evans, R. E., and F El-Baz
1973. Geological Observations from Lunar Orbit. Chapter 28 in *Apollo 17 Preliminary Science Report*. NASA Special Publication, SP–330. Washington, D.C.: U.S. Government Printing Office.

French, B., J. Underwood, and E. Fisk
1974. Shock-Metamorphic Features in Two Meteorite Impact Structures, Southeastern Libya. *Geological Society of America Bulletin*, 85(9):1425–1428.

Freund, R., I. Z. Garfunkel, M. Goldberg, T. Weissbrod, and B. Derin
1970. The Shear along the Dead Sea Rift. *Royal Society of London Philosophical Transactions*, series A, 267(1181):107–130.

Friedman, J. D., D. G. Frank, and G. Heiken
1974. Volcanoes and Volcanic Landforms. Section 8 in *Skylab 4 Visual Observations Project Report*. NASA Technical Memorandum, TM X–58142. Houston, Texas: Johnson Space Center.

Greeley, R., J. D. Iversen, J. B. Pollack, N. Udovich, and B. White
1974. Wind Tunnel Simulations of Light and Dark Streaks on Mars. *Science*, 183:847–849.

Hardee, S. N.
1976. Mission Description. Chapter 2 in *ASTP Preliminary Science Report*. NASA Technical Memorandum, TM X–58173. Washington, D.C.: U.S. Government Printing Office.

Hartmann, W., and O. Raper
1974. *The New Mars*. 179 pages. NASA Special Publication, SP–337. Washington, D.C.: U.S. Government Printing Office.

Jerlov, N. G., and E. S. Nielsen
1974. *Optical Aspects of Oceanography*. 494 pages. New York: Academic Press.

Kaltenbach, J. L., editor
1970. *Apollo 9 Multispectral Information*. 34 pages. NASA Technical Memorandum, TM X–1957. Washington, D.C.: NASA.

Kaltenbach, J. L., W. B. Lenoir, M. C. McEwen, R. A. Weitenhagen, and V. R. Wilmarth, editors
1974. *Skylab 4 Visual Observations Report*. 250 pages. NASA Technical Memorandum, TM X–58142. Houston, Texas: Johnson Space Center.

Lowman, P. D.
1966. New Knowledge of Earth from Astronauts' Photographs. *National Geographic*, 130(5):645–671.

Lowman, P. D., and H. A. Tiedemann
1971. *Terrain Photography from Gemini Spacecraft: Final Geologic Report*. 75 pages. Goddard Space Flight Center Report, X–644–71–15. Washington, D.C.: U.S. Government Printing Office.

Lucchitta, B. K., and H. H. Schmitt
1974. Orange Material in the Sulpicius Gallus Formation at the Southwestern Edge of Mare Serenitatis. *In* Proceedings of the Fifth Lunar Science Conference. *Geochimica et Cosmochimica Acta*, supplement 5, 1:223–234.

Macdonald, G. A.
1972. *Volcanoes*. 510 pages. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Mattingly, T. K., and F. El-Baz
1973. Orbital Observations of the Lunar Highlands on Apollo 16 and Their Interpretation. *In* Proceedings of the Fourth Lunar Science Conference. *Geochimica et Cosmochimica Acta*, supplement 4, 1:49–56.

Mattingly, T. K., F. El-Baz, and R. A. Laidley
1972. Observations and Impressions from Lunar Orbit. Chapter 28 in *Apollo 16 Preliminary Science Report*. NASA Special Publication, SP–315. Washington, D.C.: U.S. Government Printing Office.

Maupomé, L.
1974. Possible Meteorite Crater in Mexico. *Revista Mexicana de Astronomía y Astrofísica*, 1:81–86.

McCauley, J. F.
1973. Mariner 9 Evidence for Wind Erosion in the Equatorial and Mid-latitude Regions of Mars. *Journal of Geophysical Research*, 78:4123–4137.
1974. Pages 110–111 in *Mars as Viewed by Mariner 9*. NASA Special Publication, SP–329. Washington, D.C.: U.S. Government Printing Office.

McCauley, J. F., M. H. Carr, J. A. Cutts, W. K. Hartmann, H. Masursky, D. J. Milton, R. O. Sharp, and D. E. Wilhelms
1972. Preliminary Mariner 9 Report on the Geology of Mars. *Icarus*, 17:289–327.

McIntyre, L.
1975. Mystery of the Ancient Nazca Lines. *National Geographic*, 147(5):716–728.

McKee, E. D.
1966. Structures of Dunes at White Sands National Monument, New Mexico (and a Comparison with Structures of Dunes from Other Selected Areas). *Sedimentology*, 7(1):1–69.

McKee, E. D., and C. S. Breed
1974. Preliminary Report on Dunes. Section 9 in *Skylab Visual Observations Project Report.* NASA Technical Memorandum, TM X-58142. Houston, Texas: Johnson Space Center.
McKenzie, D. P.
1970. Plate Tectonics of the Mediterranean Region. *Nature,* 226:239–243.
Muehlberger, W. R., P. R. Gucwa, A. W. Ritchie, and E. R. Swanson
1974. Global Tectonics: Preliminary Report on Skylab 4 Observations and Handheld Photography. Section 6 in *Skylab 4 Visual Observations Project Report.* NASA Technical Memorandum, TM X-58142. Houston, Texas: Johnson Space Center.
NASA (National Aeronautics and Space Administration)
1973. *Handbook of Pilot Operational Equipment for Manned Space Flight.* Report Number CD42-A/SL-997, MSC-07210. Houston, Texas: Johnson Space Center.
1974a. *Skylab Earth Resources Data Catalog.* 359 pages. Johnson Space Center Report, JSC 09016. Washington, D.C.: U.S. Government Printing Office.
1974b. *Earth Observations and Photography Experiment (MA-136): Site List and Site Acquisition Data.* Johnson Space Center Report, JSC-09223. Houston, Texas: Johnson Space Center.
1975a. *Evaluation of Film Type QX 807, (SO-368, Kodak Ektachrome MS, Estar Thin Base, with an Equivalent Wratten 2A Filter Overcoat).* 14 pages. Johnson Space Center Report, JSC-09621. Houston, Texas: Johnson Space Center.
1975b. *ASTP Technical Air-to-Ground Voice Transcription.* 1080 pages. Johnson Space Center Report, JSC-09815. Houston, Texas: Johnson Space Center.
1975c. *ASTP Visual Observations Debriefing.* 113 pages. Johnson Space Center Report, JSC-09920. Houston, Texas: Johnson Space Center.
1975d. *ASTP Onboard Voice Transcription.* 670 pages. Johnson Space Center Report, JSC-09966. Houston, Texas: Johnson Space Center.
1975e. *ASTP Technical Crew Debriefing.* Johnson Space Center Report, JSC-09823. Houston, Texas: Johnson Space Center.
Neev, D.
1975. Tectonic Evolution of the Middle East and the Levantine Basin (Eastern-most Mediterranean). *Geology,* 3:683–685.
Norris, R. M.
1966. Barchan Dunes of Imperial Valley, California. *Journal of Geology,* 74:296–306.
1969. Dune Reddening and Time. *Journal of Sedimentary Petrology,* 39:7–11.
Norris, R. M., and K. S. Norris
1961. Algodones Dunes of Southeastern California. *Geological Society of America Bulletin,* 72:605–620.
Pirie, D. M., and D. D. Steller
1974. *California Coast Nearshore Processes Study, Final Report ERTS-1 Experiment #088.* Greenbelt, Maryland: Goddard Space Flight Center.
RMAG (Rocky Mountain Association of Geologists)
1972. *Geologic Atlas of the Rocky Mountain Region.* 331 pages. Denver, Colorado: A. B. Hirschfeld Press.
Sagan, C., J. Veverka, P. Fox, R. Dubisch, R. French, P. Gierasch, L. Quam, J. Lederberg, E. Levinthal, R. Tucker, B. Eross, and J. B. Pollack
1973. Variable Features on Mars 2, Mariner 9 Global Results. *Journal of Geophysical Research,* 78: 4163–4196.
Schmitt, H. H.
1974. Lunar Mare Color Provinces as Observed on Apollo 17. *Geology,* 2:55–56.
Shepard, F. P., and H. R. Wanless
1971. *Our Changing Coastlines.* New York: McGraw-Hill.
Splinter, W. E.
1976. Center-Pivot Irrigation. *Scientific American,* 234 (6):90–99.
Stafford, T. P., E. A. Cernan, and J. W. Young
1971. Visual Observations. Chapter 1 in *Analysis of Apollo 10 Photography and Visual Observations.* NASA Special Publication, SP-232. Washington, D.C.: U.S. Government Printing Office.
USGS (United States Geological Survey)
1968. A Descriptive Catalog of Selected Aerial Photographs of Geologic Features in the United States. *Geological Survey Professional Paper,* 590: 79 pages.
White, W. A.
1958. Some Geomorphic Features of Central Peninsular Florida. *Florida Geological Survey Bulletin,* 41.
Williams, R. S., and W. D. Carder, editors
1976. ERTS-1: A Window on Our Planet, *U.S. Geological Survey Professional Paper,* 929: 362 pages.
Wood, E. A.
1975. *Science from Your Airplane Window.* 227 pages. New York: Dover.
Yentsch, C. S.
1974. Some Aspects of the Environmental Physiology of Marine Phytoplankton: A Second Look. *Oceanography and Marine Biology: An Annual Review,* 12:41–75.

# Abbreviations and Acronyms

| | |
|---|---|
| AC | Apollo commander |
| AFB | Air Force Base |
| AG | air-to-ground voice transmission |
| ANZUS | Australia–New Zealand–United States |
| ASTP | Apollo-Soyuz Test Project |
| ATS | Applications Technology Satellite |
| BP | British Petroleum |
| BRKT | bracketmount (for cameras) |
| BT | bathythermograph |
| CDT | central daylight time |
| CI | co-investigator |
| CM | command module |
| CP | command module pilot |
| CRT | cathode ray tube (TV) |
| CSM | command-and-service module |
| DAC | data acquisition camera |
| DM | docking module |
| DMA | Defense Mapping Agency, St. Louis, Missouri |
| DP | docking module pilot |
| DSE | data storage equipment |
| DT | dump tape |
| DV | descent vehicle |
| EREP | Earth Resources Experiment Package, Skylab |
| ERTS | Earth Resources Technology Satellite, now called "Landsat" |
| ETE | Electrophoresis Technology Experiment |
| FR | frame (film exposure) |
| GET | ground elapsed time |
| GMT | Greenwich mean time |
| GSFC | Goddard Space Flight Center, Greenbelt, Maryland |
| HDC | Hasselblad data camera (black) |
| HRC | Hasselblad reflex camera (silver) |
| IF or IR | infrared (film) |
| ISRO | Indian Space Research Organization, India |
| ITC | intertropical convergence |
| IVL | intervalometer (for camera) |
| JSC | NASA Lyndon B. Johnson Space Center, Houston, Texas |
| KSC | NASA John F. Kennedy Space Center, Cape Canaveral, Florida |
| LOS | loss of signal |
| LSI | Lunar Science Institute, Houston, Texas |
| MAG | film magazine |
| MCC | Mission Control Center, JSC |
| MILA | Merrit Island, Florida |
| MOCR | mission operations control room, JSC |
| MPAD | Mission Planning and Analysis Division, JSC |
| MTF | modulation transfer function |
| NASA | National Aeronautics and Space Administration |
| NM | nautical miles |
| NOAA | National Oceanic and Atmospheric Administration |
| OBS | observation |
| OM | orbital module |
| OPS | operations |
| PAO | public affairs office |
| PCM | pulse code modulation |
| PET | phased elapsed time |
| PI | Principal Investigator |
| PTR | personal tape recorder |
| RAF | Royal Air Force (Great Britain) |
| RCS | reaction control system |
| REV | spacecraft orbital revolution around the Earth |
| RMAG | Rocky Mountain Association of Geologists |
| SAA | South Atlantic anomaly |
| SAM | stratospheric aerosol measurement |
| SIM | scientific instrument module |
| SM | service module |
| SMS | Synchronous Meteorological Satellite |
| SSR | science support room |
| STDN | Spaceflight Tracking and Data Network |
| TIROS | Television Infrared Observation Satellite |
| USGS | United States Geological Survey, Department of Interior |
| UV | ultraviolet absorption |
| VHF | very high frequency |
| VIS | visual |
| VORTAC | VHF Omnirange/Tactical Air Navigation |
| VTR | video tape recorder |
| XBT | expendable bathythermograph |
| ZFF | zone-forming fungi |

# Glossary

ALBEDO. The reflective properties of materials; the ratio of the light reflected by a surface to that received by it.

ALGAE. A major group of simple plants that usually live in water.

APOLLO. NASA manned space flight project, 1968–1975, which included twelve 3-man Earth-orbital or lunar-orbital and/or landing missions.

ASTHENOSPHERE. A region of weakness tens of kilometers below the surface of the Earth, where plastic movements take place to permit isostatic adjustments.

ASTROBLEME. A geologically ancient remnant of an impact by a meteor or a comet, usually a multiringed crater.

BÉNARD CELLS. Standard convection cells formed over oceans when surface water temperatures are evenly distributed over large areas, winds are less than 15 knots per hour, and sufficient nuclei of water vapor condensation exist.

BIOLUMINESCENCE. The emission of light by living organisms.

BIOTA. The animal and plant life of a land region or of a water mass.

BLOOM. The sudden development of masses of organisms in bodies of fresh or marine water.

BOW WAVES. Atmospheric bow waves are cloud forms occurring on the lee of an island; they are morphologically similar to waves produced by moving ships and may be gravity-generated shock waves.

CALDERA. A large basin-like depression formed by explosion or collapse following volcanic eruptions.

CAPCOM. Capsule communicator; one who relays all communications between the Mission Control Center at Houston, Texas, and the astronauts in space.

CHLOROPHYLL. The green coloring matter of plants that is essential to photosynthesis.

COMMAND MODULE. The part of the Apollo spacecraft in which the astronauts travel and from which the spacecraft is operated.

CONVECTIVE CLOUDS. Clouds developing from convection, i.e., the vertical motion of atmospheric properties.

CORIOLIS FORCE. The force which causes, as a result of the Earth's rotation, a deflection of projectiles, winds, and water to the right in the northern hemisphere and to the left in the southern hemisphere.

CUMULUS CLOUDS. Clouds exhibiting great vertical development and characterized by dense individual elements in the form of puffs, mounds, or towers with flat bases and tops that often resemble a cauliflower.

CUMULONIMBUS. A cloud that is indicative of thunderstorm conditions, similar in appearance to cumulus clouds but exhibiting a fibrous texture on top; a thundercloud.

CURRENT. Ocean water mass flowing in a certain direction.

DELTA. A nearly flat plain of alluvial deposits, often triangular in shape, occurring at the mouth of a river.

DINOFLAGELLATE. Member of an order of chiefly marine organisms characterized by a cellulose envelope and flagella.

DOCKING. The act of joining two spacecraft in orbit.

DOCKING MODULE. The instrument allowing the Apollo and Soyuz spacecraft to dock.

DRAINAGE. The streams and waterways by which a region is drained.

DUNE. A hill or ridge of sand deposited by wind.

EDDIES. Currents of air or water differing from a main current, especially those having a circular motion; small whirlpools.

ELECTROPHORESIS. The movement of colloidal particles through a fluid under the action of an electrical field.

ERG. Arabic word for a desert region deeply covered with sand and occupied by dunes.

ESCARPMENT. A long ridge or steep cliff commonly formed by faulting or erosion.

FAULT. A fracture in the Earth's crust accompanied by a displacement along the plane of the break.

FIRN LINE. The line marking the greatest retreat of snow cover on a glacier.

FLIGHT PLAN. The detailed chronological listing of all activities to be performed by the astronauts during a mission.

FLYOVER. A training exercise in which astronauts fly T–38 jets to practice observations from high altitudes.

FOREL SCALE. Scale for determining water color; water color observed against a white disk (Secchi disk) is compared to the Forel colors.

FOSSIL DUNE. A dune that was formed in the geological past and has been preserved.

GEMINI. NASA manned space flight project, 1965–1966, which included ten 2-man Earth-orbital missions.

GLACIER. Large body of ice slowly descending a slope or spreading outward on a land surface.

GREAT SAND SEA. The large expanse of sand in Libya and Egypt; it is characterized by enormous and flat-topped whaleback dunes in the northern part, and by sharp-crested, linear seif dunes in the southern part.

GROUNDTRUTH. Information derived from ground and ocean surveys to support interpretation of photography and other remotely sensed data.

GULF STREAM. Strong, narrow ocean current originating near the equator and following the eastern coast of North America.

GYRE. Large circular flow of water found in major ocean basins.

HUMIC. Relating to organic matter.

HURRICANE. Tropical cyclone with winds from 120 to about 250 km per hour usually accompanied by rain, thunder, and lightning.

HYDROSPHERE. The aqueous envelope of the Earth, including oceans, lakes, rivers, and streams.

ICEBERG. Mass of land-ice broken from a glacier at the edge of a body of water, and exhibiting only a small portion of its surface above water when afloat.

INTERNAL WAVES. Subsurface waves formed in fluids exhibiting vertical density gradients.

KELP. Any of various large brown seaweeds of the orders Laminariales and Fucales.

KILOMETER. Metric measurement equivalent to 0.62 miles or 1000 meters.

LANDSAT. One of two unmanned, NASA, Earth-orbiting, remote-sensing satellites; formerly ERTS (Earth Resources Technology Satellite).

LANGMUIR CIRCULATION. Water circulation with alternate left and right helical vortices, which have their axes in the direction of the wind.

LEE. The side sheltered from the wind.

LINEAMENT. Straight or gently curved features on the Earth's surfaces, usually the expression of fractures or faults.

LITHOSPHERE. Solid part of the Earth's surface.

MAAR. Volcanic crater produced by a violent explosion and often becoming a small lake.

MARE. Dark, relatively smooth lunar plains composed of volcanic (basaltic) rock.

MERCURY. NASA project, 1961 to 1963, including six one-man suborbital or orbital missions.

NADIR. Point on the Earth vertically beneath a satellite.

NANOMETER. One-millionth of a millimeter.

NUBIAN SANDSTONE. Refers to almost horizontal beds of coarse- to fine-grained sandstones with occasional shale and quartzite beds; these beds are widely distributed over the southern parts of Egypt and northern Sudan (Nubia).

PHYCOBILIN. Any of a class of pigments that are found in cells of algae, are active in photosynthesis, and are proteins combined with pyrrole derivatives related to the bile pigments.

PHYTOPLANKTON. Plankton that is made up of plant life.

PLANKTON. The floating or weakly swimming animals and plant life of a body of water.

PLATE TECTONICS. The branch of geology that examines the movements and interrelationships of plates thought to make up the Earth's crust.

PLATEAU. A usually extensive area of flat land raised above adjacent land on at least one side.

PLUMES. Swirling sediment-laden bands in water, often found at the mouths of rivers.

REALTIME. Time of the mission from launch to landing.

RED TIDE. Sea water discolored by large numbers of dinoflagellates.

REG. Gravel plain.

RENDEZVOUS. The meeting of two or more space vehicles in outer space.

RESEAU PLATE. Glass plate on which is etched an accurately measured grid; it is positioned immediately in front of the film plane of a camera to improve geometric accuracy.

REVOLUTION. The time it takes an orbiting satellite to pass over a specific point on the Earth and return to the same longitude.

RIFT. Network of crustal fractures.

SALINITY. Saltiness; refers to the amount of dissolved salts in a body of water.

SECCHI DISK. White disk used to obtain a rough measure of water transparency; the depth at which the disk is no longer visible from the surface is used to determine transparency.

SEIF DUNE. An elongated sand dune ridge; longitudinal dune; derived from the Arabic word for sword.

SILICA GLASS. A hard, brittle, noncrystalline substance produced by fusion and usually consisting of silica ($SiO_2$) and minor trace elements. The Libyan Desert silica glass occurs as lumps, chips, or fragments with colors ranging from greenish yellow to greenish black. It is found over an extensive area centered at about 25°25′N, 25°30′E.

SINUOSITY. The quality or state of being winding, wavy, or serpentine; a measure of river meandering.

SITE. Term used on the ASTP mission referring to any of 12 regions or features of the Earth.

SKYLAB. NASA orbiting space laboratory in which three 3-men crews spent up to 84 days during 1972 conducting various research projects.

SLIPFACE. The lee side of a dune where the slope approximates the angle of repose.

SPACE SHUTTLE. Reusable spacecraft that is launched on a rocket and lands like a glider plane. First missions are scheduled for mid-1979.

STEREO. Of or pertaining to the process by which the images of two adjacent photographs may be combined to produce a 3-dimensional effect.

STRATOSPHERE. Layer of the Earth's atmosphere between the troposphere and the ionosphere.

TARGET. Specific localities or features selected for photography and observation on the ASTP mission.

TERMINATOR. Line dividing the illuminated and unilluminated portions of a planet.

TIME LINE. Graphical and chronological document of flight operations and crew activities.

TROPICAL STORM. Tropical cyclone with winds of less intensity than comprise a hurricane.

TROPOPAUSE. Upper limit of the troposphere.

TROPOSPHERE. Layer of atmosphere next to the Earth's surface.

TYPHOON. Tropical cyclone occurring in the vicinity of the Philippines or the China Sea.

UPLIFT. A structurally raised area caused by upthrusting crustal movements.

UPWELLINGS. Areas in the sea where subsurface water moves vertically upward.

VON KÁRMÁN VORTICES. Swirling cloud patterns generally found in the lee of islands and the lee of mountains.

# Appendix 1

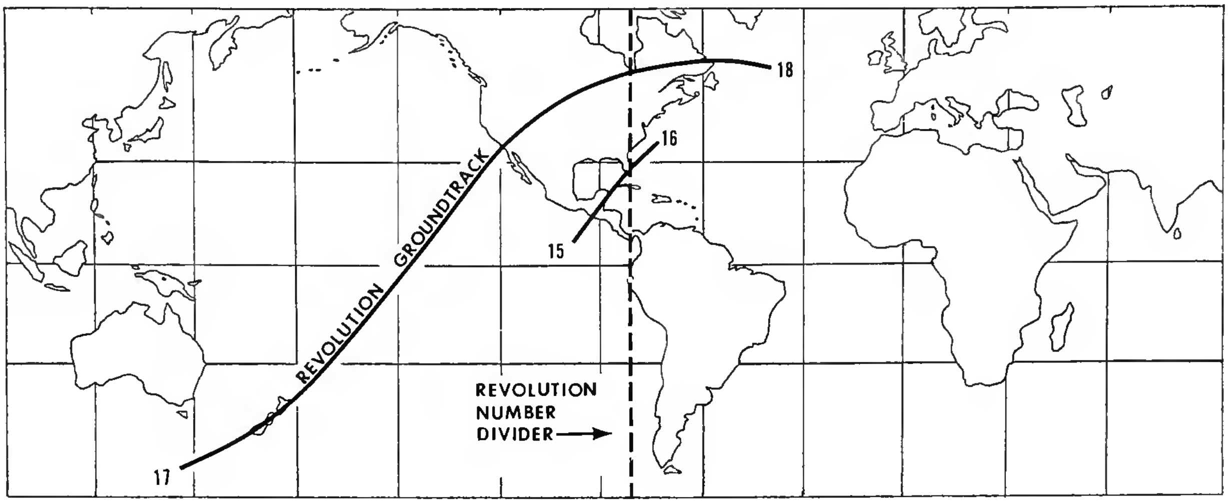
## Verbal Comments

Compiled in this appendix are all of the verbal comments by the American astronauts that relate to the Earth Observations and Photography Experiment of the Apollo-Soyuz mission. The comments are arranged chronologically and are numbered for use with the index. The numbers following each entry in the index reflect the comment (not page) number. Each comment number includes remarks that relate to the same subject. These comments were made either during the mission or immediately following it during crew debriefings.

The realtime comments are transcribed from the air-to-ground (AG) voice transcription (NASA, 1975b) and the ASTP onboard voice transcription, "dump tapes" (DT) (NASA, 1975d). Near-realtime comments are edited from the transcript of comments (El-Baz, n.d.b.) taped by the astronauts on the Sony personal tape recorder (PTR). All comments are listed under the revolution during which they were recorded and are identified by one of the following notations:

| | |
|---|---|
| AG/31:06:43+ | ground elapsed time (GET) of air-to-ground conversation in hours, minutes, seconds; + indicates comment made immediately after said time |
| DT/94:40:33 | GET of dump tape conversation |
| Onboard Recording | conversation taped on the PTR |

Throughout this appendix the revolution groundtracks where observations were made are plotted to show the general location of observation targets. At the end of the realtime and near-realtime comments, the technical crew debriefing, held 8 August 1975 (NASA, 1975e), and the visual observations debriefing, held on 12 August 1975 (NASA, 1975c), are given.




Revolutions 15/16 and 17/18

## REALTIME COMMUNICATIONS

### Revolution 15/16

1. AG/31:06:43+

Slayton: I think we're right over the Cape [Kennedy].

Capcom: You're right. You're passing right over the launch site just about now.

Slayton: Yeah, we can see it. We're in a good attitude here for Earth obs.

### Revolution 17

2. AG/33:11:13+

Capcom: Apollo, Houston. For Deke [Slayton], assuming you're going to do this mapping pass coming up, when you have the time, I've got an update on the time in the Earth Obs Book on mapping pass Mike 3 [Southern California]. The change is the stop time for mapping pass M3. The start time is okay, as is all the data for M2 [New Zealand]. The stop time for M3 should read 34:06:40.

Brand: Okay. 34:06, and you were cut out on the seconds. Please repeat seconds.

Capcom: Roger. That's really the only change. It's 40 seconds.

3. Onboard Recording

Brand: Okay recorder, we're on pass number 12, looking down at the low overcast. No sign of icebergs or pack ice just yet. Beautiful low clouds. Cannot see the edge of Antarctica, but it's sort of hard to tell. I'll take a picture anyway.

Slayton: That looks beautiful there. Just look at those clouds down there. Fantastic.

Brand: Okay recorder, took three pictures looking south toward Antarctica, just over clouds mainly. At the end, I'm on exposure 25, after three shots.

4. Onboard Recording

Brand: Coming up on next site. This will be site 1. Okay, here we are, coming up on New Zealand. New Zealand is clouded over; all you can see is the coastline.

Slayton: Look at the snow down there. You see that on those hills?

Stafford: It looks a lot closer than 100 miles [160 km], doesn't it?

Slayton: Man, those snow-covered peaks now, you can't hardly tell them from the clouds, Vance.

5. Onboard Recording

Slayton: I hear that water's rougher than hell when there's ice in it. There's all kinds of white packs in it.

6. Onboard Recording

Brand: Some of it's clouded over. I took quite a few pictures but there's too much cloud cover now. There's no chance of seeing the Alpine Fault. Stopped taking pictures. Counter number is 37.

7. Onboard Recording
BRAND: Boy, we're moving out.
SLAYTON: Here comes the coastline again.
BRAND: We're going to hit the next island in a minute. You see North Island yet, Tom?
STAFFORD: We're right near the coastline. Right there, between the clouds.
BRAND: North Island is under the clouds.
STAFFORD: There's a bunch of plankton out there to the east. I can hardly see that from under it.
SLAYTON: Yeah, sure, and you can see the tourists down there, Tom.
BRAND: I'm not sure I see plankton. I see bottom.
STAFFORD: Yeah. Only out here. Not there.
BRAND: Oh, okay. There's a lot of pretty green bottom here. But I'm not sure I see plankton. I'll take a picture of what I see.

8. Onboard Recording
BRAND: Of course, we couldn't see between the two islands, so there's no chance to look for anything in the form of internal waves.

9. Onboard Recording
BRAND: I don't think it's the time of year for plankton. It looks too cold down there.
STAFFORD: It's not there now.
BRAND: Oh, I see something. Okay, I've got one shot of some scum on the water. But it went by so fast, it looked more like trash to me. But we'll see what it is later. It could be plankton. So much for New Zealand.
SLAYTON: I'm glad we got a little Earth obs in there.
STAFFORD: We got a real good one coming up at the end of this one.

10. Onboard Recording
BRAND: Okay, recorder, the ocean northeast of New Zealand is closest to 47–B in color, very pretty light blue.

11. Onboard Recording
BRAND: Next we'll be coming up on 3A, cloud features. And I'll just be taking pictures, and report later.

12. Onboard Recording
SLAYTON: Okay, this camera's all set to continue. We may get something going here, yet.

13. Onboard Recording
BRAND: We're coming up on Baja California. See it very clearly. We've got cloud cover, I'd say from about 70 miles off the California coast solid into the coast, except there's a clear spot over Catalina. Okay, it's a very consistent blue; interesting, you see a wake behind each island in the clouds out there. Because of clouds, it's impossible to see the ocean boundary. No red tide visible.

14. Onboard Recording
BRAND: Color [wheel], I used to look at Gran Desierto, was kind of a 16–A, but it was hard to tell precisely, simply because to hold the color at all close to what I'm looking at in the window, the color chart had to be completely in the shade, with the same very bright thing out the window being contrasted. Your eye adapted to the bright thing and all the color chart colors tended to look very dark and much the same because they were in the shadow. If you happen to have the sun shining in the window, so it's shining on the color chart just right, then you're in luck.

15. Onboard Recording
BRAND: Coming up on 4C [Superior iron]. The difference between A, B, and C. Yes, there is, but let me discuss it in a minute, because we're coming up on Sudbury next. Let's talk about 4C for a minute. Looked at the three areas; areas B and C look somewhat similar. I didn't see evidence of pit mines or anything. Was more or less distinguished by a grayish, maybe purplish, color over the countryside. I don't know if that's due to vegetation or not. I did see, though, in the A region, there's nothing to distinguish until you saw the open pits, and the open pits are very reddish. Some of them are almost bright orangish red.

16. Onboard Recording
BRAND: That's all for this pass. 5C [Labrador Current] was not done because we had to change attitude.

### REVOLUTION 18

17. Onboard Recording
BRAND: Might add that just before starting this experiment activation, I had a visual obs pass over a lot of the Pacific and some of the U.S., as you know. I would say it was a partial success. We had quite a bit of cloud

cover, for example, completely over New Zealand. We were hoping to look at a fault zone there and look for some stuff on the water. There wasn't much to see around New Zealand. But at Los Angeles the water just offshore was cloudy, but it was very clear inland over the desert and so forth.

REVOLUTION 19

18. AG/35:59:18+

STAFFORD: You might pass on to Farouk [PI] there's a tremendous difference down here in this orbit we're at now compared to what we used to fly in Gemini up at 140 to 185 miles [225 to 298 km] as far as observing features.

CAPCOM: Roger. What kind of difference?

STAFFORD: Well, as far as detail.

CAPCOM: You can see a lot more from this orbit?

STAFFORD: Oh, tremendously more. Also, looks like you're a lot closer too, comparatively speaking.


Revolutions 25 and 26

REVOLUTION 25

19. AG/45:37:20+

SLAYTON: Are we just coming up on Africa, here?

CAPCOM: That's affirmative.

SLAYTON: Man, we're looking at some fantastic scenery here; weren't sure where we were. We can see fires, grass fires, and that sort of thing burning down here just like you can from 40,000 feet [12,192 m], Crip. They're all over the place.

REVOLUTION 26

20. Onboard Recording

BRAND: Okay, tape recorder, shots 50 through 53 were of the Cairo area. Stereo, three pictures, then a fourth one looking back, and finally, a last one at [Syria's] west coast.

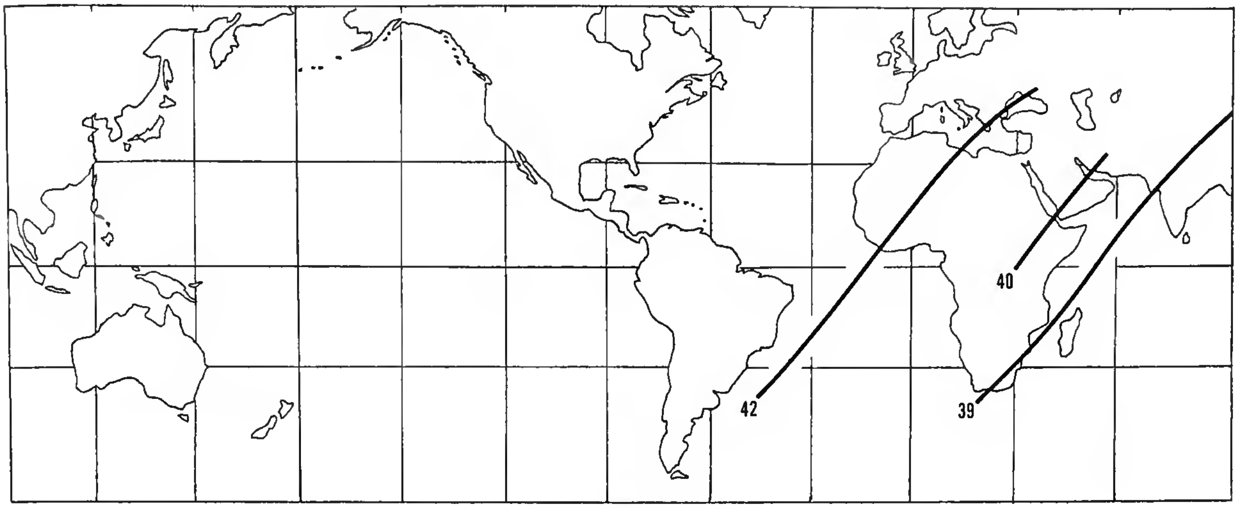
21. AG/47:30:51+

STAFFORD: Houston, are we over Russia now?

CAPCOM: That's affirm. As a matter of fact, while you were messing with the hatch, you just passed over the launch site. We saw a view of the Aral Sea and the coastline there. Reminded me of that airplane flight we took and now you're just about 52 degrees right at the highest point in latitude and west of the launch site over there by several hundred miles.

STAFFORD: Okay. They got a forest fire on top of a mountain out here that you can sure see at this point.

BRAND: See a contrail, too. It looks like pretty rugged country, this part of the world right here, a lot of mountainous country.




Revolutions 39, 40, and 42

REVOLUTION 39

22. AG/67:21:36+

CAPCOM: For that upcoming pass [Himalaya Mountains], I've got a new stop time for the camera, if somebody wants to note it down.

SLAYTON: Please stand by just a minute.

CAPCOM: Okay. The start time is the same. The stop time is now 68:04:10. And we're about 30 seconds from LOS. We'll have you again when you lock the ATS. And we should be able to get you at about 67:39.

23. AG/67:41:37+

SLAYTON: Okay, Crip. We prepared breakfast here, and I'm just coming up on the first Earth obs pass, and the mapping camera is running, and we're waiting to see something.

CAPCOM: Very good. Coming up on the tip of Africa, right now, looks like.

SLAYTON: That's affirm. We're still over the water.

24. Onboard Recording

SLAYTON: I can see sediment plumes coming out here on the African coast. I never did see the Great Dike. I think this is the Zambesi Delta right here. The sediment plumes area in the delta seem to be coming out and down the coast to the south primarily. There are a few gyres spinning off, but I'd say the predominant flow is to the south. And we've got three frames there. We did have clear weather over South Africa, but I never saw anything that looked to me like the Great Dikes I've seen in the pictures.

25. Onboard Recording

SLAYTON: We're coming up on the Arabian Sea, and it's prety well cloud covered. Possibly a cold water gyre back there; let me shoot a couple of pictures. One thing, with this orange filter, you can't see except just pointing and shooting. It looks like an obvious current boundary, based on the cloud coverage here, in the northern Arabian Sea. It's mostly cirrus, but I took three frames, so I could see some more [clouds] down below.

26. Onboard Recording

SLAYTON: I got the mapping camera on and off, per schedule. And over all of India, essentially nothing but cloud cover, so I don't think we got much there, except some good meteorology stuff.

27. Onboard Recording

SLAYTON: Now coming off the north side of the Himalayas here into the deserts region, and it is truly desert. There's a lot of lakes down there that are blue-green.

28. Onboard Recording

SLAYTON: It's pretty well cloud covered in the whole area; the same thing as far as using the HDC over India, till we broke off the north side of the Himalayas. I shot the strip anyway, in case there might be something there of value.

29. Onboard Recording
SLAYTON: And about the time we hit the Takla Makan Desert, the old tape recorder ran out of tape, and rather than rechange that out, I just looked. And as far as the dune patterns are concerned, it looked to me like there was a big sandstorm kind of laying over the whole area. It was very indistinct and hazy. If that was the ground I was looking at, I'd be hard put to define the dune patterns, other than to say it's kind of a large, rolling area. I'm more inclined to think it was an obstruction of vision. And we're coming off the northern end of the Takla Makan here. We were hoping to see something new and different, and again it is totally cloud covered, and absolutely nothing to see except interesting cloud features.

30. Onboard Recording
SLAYTON: So, other than not being able to see, I think we've got something in the Zambezi Delta, there. We simply got nothing in South Africa, and not very much anywhere else. I'll give you a frame number: got to frame number 67 on the IR film.

REVOLUTION 40

31. AG/69:00:32+
CAPCOM: On rev 40 for orbital science, the stop time is now 69:30:50.
SLAYTON: 69:30:50.
CAPCOM: Roger. That was the stop time for M5 [Arabian Desert] on rev 40.

32. Onboard Recording
SLAYTON: We're coming up on the Afar Triangle here. This isn't our day for Earth obs. Everything, again is clouded over.

33. Onboard Recording
SLAYTON: Here we are over the Empty Quarter. There are massive linear dunes. I can't see what's on them. And I don't have much luck with the color wheel because the wheel's in the shade, and what I'm looking at is in the sun, and I get absolutely no correlation at all. I hope that's not going to be true perpetually.

REVOLUTION 42

34. Onboard Recording
SLAYTON: Okay, we're in rev 42 pass. No luck at all on 8A [Falkland Current]; it was all cloud cover.

35. Onboard Recording
SLAYTON: However, in 3A [cloud features] we've got some very interesting cells here—look like Bénard cells, large-scale ones. I've got a couple of pictures, and I'll get some more. There's something screwy about the focus on this thing. No wonder we couldn't see anything through it.

36. AG/72:23:11+
SLAYTON: Hey, Bo. Can somebody there tell me quick where you got some more IR film stashed? IR film for the 70-millimeter silver camera.
CAPCOM: You're saying you want the film location for the 70-millimeter camera? Deke, the IR film is located in [stowage area] A6.

37. Onboard Recording
SLAYTON: We're coming across the Niger River Delta. I can definitely see how we already passed that. I can see the fossil dune patterns down here very neatly. Some cloud cover in the area, scattered to broken.

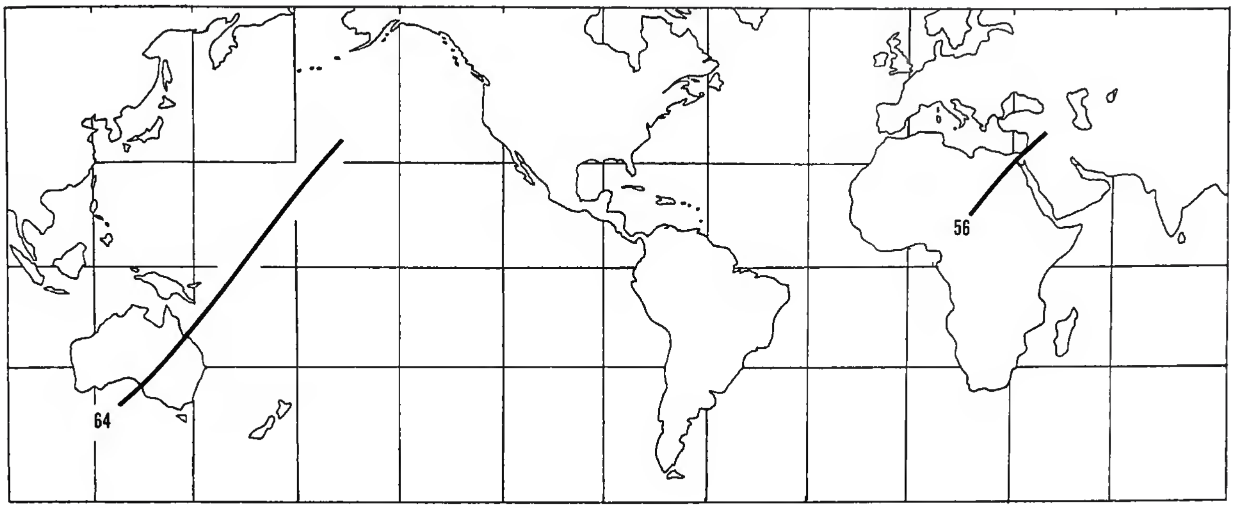
38. Onboard Recording
SLAYTON: Looks like a big sandstorm blowing down here in the [Algerian] desert that's very hazy, and it's not a cloud cover. So it must be sand blowing. It was clear back there a little ways earlier. Coming up on the coast of the Mediterranean here and south of there very large dune patterns, primarily red interdune structure and darker dunes.

39. Onboard Recording
SLAYTON: We're out over the Mediterranean now. Got a few shots of the coastline of Tripoli. Now I'm trying the water color wheel. I'm not having any luck with this color wheel to speak of. It looks like maybe a 36. We're coming up on Sicily and Italy, and I don't see any eddies. It's a completely homogeneous surface down there.

REVOLUTION 56

40. DT/94:40:33
SLAYTON: See any [cloud] buildup?
BRAND: You know, thunderstorms look a lot closer to you. Yeah. This one here?

41. DT/94:41:07




Revolutions 56 and 64

BRAND: That's what I said at first. That's one of my targets [Oweinat Mountain]. Look at them. Are they pipes or are they mountain tops?

SLAYTON: They look volcanic to me.

42. DT/94:41:07+

BRAND: We're going to come up on Cairo in a minute. Look at that country.

SLAYTON: Beautiful.

BRAND: There's Cairo.

43. DT/94:42:55

SLAYTON: Now here's the Red Sea right off to my left. . . . Unfortunately, Bo, we need about all we can get for visibility.

44. DT/94:42:55+

BRAND: Boy, there's Cairo.

SLAYTON: There it is. Boy! Oh, great! . . . We got everything we want. Say, that stuff's pretty . . . right there.

BRAND: See the pyramids?

SLAYTON: Yeah! [laughter]

BRAND: My God! I think I did. I've got to get a map though.

45. DT/94:43:26+

BRAND: Gosh, look at that! Look at that water.

SLAYTON: I know where we're supposed to be, but I'm not sure. We're going too fast.

46. DT/94:43:26+

BRAND: We're going to get a good view of the Levantine Rift here.

47. DT/94:44:15

BRAND: Houston, look. We've got some fantastic viewing and picture-taking of Africa right now.

48. DT/94:44:15+

SLAYTON: No, we're in the Middle East right now.

BRAND: I know.

SLAYTON: Hey, that's Israel right down there. There's the Sea of Galilee . . . goddam.

49. AG/94:48:54+

CAPCOM: Command module, Houston. That out-the-window camera is really giving us a good view this afternoon.

50. AG/94:56:36

BRAND: Houston, Apollo. Ocassionally, we get some very good viewing because of attitude, weather, etc. We just now got a couple of visual observations, things that we haven't been able to get as well before. For example, saw the Levantine Rift and Egypt. I think I might have seen the pyramids. And now I've got to see a picture or a layout of how the pyramids are laid out when we get back, but I saw two specks that might have been pyramids.

CAPCOM: Say again what the specks might have been.

BRAND: We think they're the pyramids of Egypt, and that happens to be a visual observation [target].

### Revolution 63

51. AG/105:42:35+

CAPCOM: Okay, Vance. This is on mapping pass M6 [Australia] and I've got a start and a stop time update for you. The start time is as follows: 107:41:30; stop time, 107:53:30.

BRAND: Rog. Rev 64, M6 mapping pass: start time, 107:41:30; stop time, 107:53:30.

### Revolution 64

52. Onboard Recording

BRAND: Rev 64 starting with the 11C over the Simpson Desert. You use the chart to define desert colors. As close as I could tell, I would say 6-A, although the desert is very reddish. It's awfully hard to compare with the color chart. The standard problem we have been having with the color chart is that you have to have it somehow in light so you can compare it with what's on the ground. It's very dark in the cabin compared to outside. It's not a very valid comparison, in general.

53. Onboard Recording

BRAND: There were distinct dune fields. As a matter of fact, they were very interesting. They showed up as lines. They were linear dunes, as near as I could tell. For the most part, they were just kind of linear scratches. Looked to me like the type was attributable to wind direction and strength more than anything else. In the short time that we went over, I could not find any probable source.

54. Onboard Recording

BRAND: Look at this atoll coming up here, Tom. I wonder what that might be. The Solomons?

STAFFORD: I don't know, Vance.

BRAND: Not atoll. I mean island.

STAFFORD: It's very rarely you can see a bunch of atolls.

55. Onboard Recording

BRAND: Very quickly we came upon Australia. Could not see any suspended sediments off the coast. I just obtained three stereo photographs of the [Great] Barrier Reef. The [film] magazine is CX12. Photos were 34, 35, and now it's on 36. I got a good clear view of the Barrier Reef.

56. Onboard Recording

BRAND: Now looking for water eddies in the Coral Sea. I have none to report yet, but I'm still looking. To finish up on the Coral Sea, found what appeared to be numerous eddies. They were cloud ring structures in various places in the Coral Sea and even across the whole southwest Pacific for that matter. I could pick these things out for some time, although there did seem to be more down in the area of the Coral Sea than farther up to the north. Continued taking several pictures of these eddies. After taking pictures, I was resting on frame 43. Took one more picture of an eddy in the central Pacific.

57. Onboard Recording

BRAND: Frame counter is on 44 now. No significant cloud formations for that particular one to get so far. I did get two shots. I am now on 50 on CX12 after getting two shots of mid-Pacific weather-tropical storms. Not tropical. Large thunderstorms.

### Revolution 71

58. AG/118:10:51+

CAPCOM: And, for your information, the weather's looking good across there. You're probably going to have little problems with the Guinea Current due to clouds, but it looks great across the desert.

59. Onboard Recording

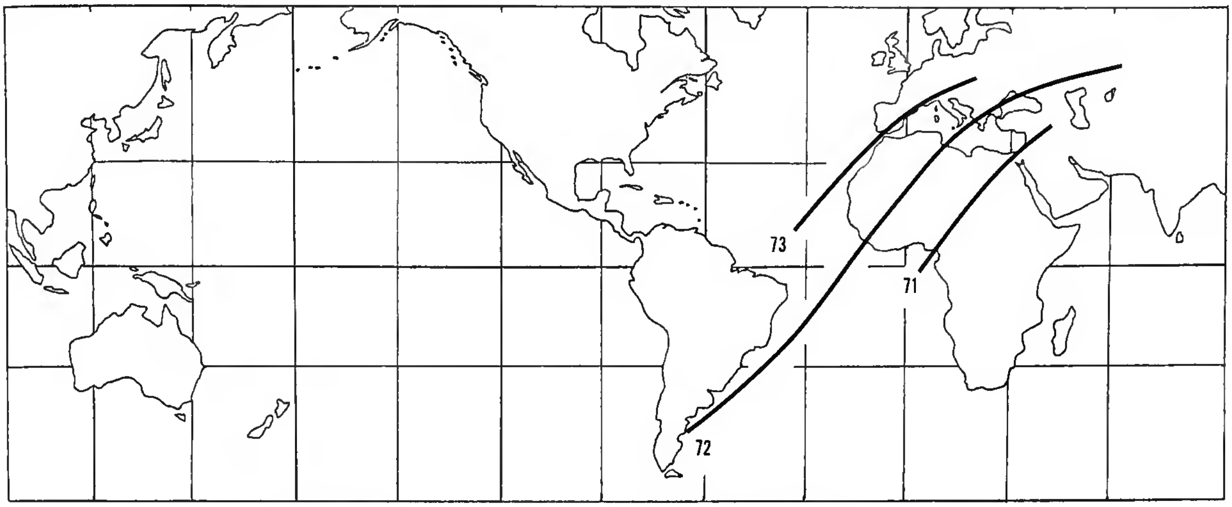
BRAND: Tape recorder, the Guinea Current area is all fogged over this morning. That's 9C, visual observation [target].

60. Onboard Recording

BRAND: We'll press along to see what we have over mainland Africa—site 9D [desert colors]. Lake Chad was—the N'djamena area was covered by about 50 percent cloud cover, although Lake Chad itself was fairly open. Unfortunately, therefore, I couldn't photograph N'djamena.

61. Onboard Recording

BRAND: I got several shots of the desert just north of Lake Chad and the dunes were long streaks. Got a color comparison; it was




Revolutions 71, 72, and 73

25-A, near as I could tell. I said the dunes were linear. As to the different colors, just a second. Tom, north of Lake Chad there, we were talking about the streak dunes. Did you see dunes on top of dunes there? I couldn't see anything but the streaks. Yeah, that's all I could see.

62. Onboard Recording

BRAND: Okay, next, 9E. Got multiphotos of Oweinat Mountain. I think the 9E photograph in our book [Appendix 3] is a good thing to refer to. The first two things you come upon on the ground track did look like vents. There was a lot of circular structure and it looked like black volcanic basaltic-like material and then it might not have been, but that's what it looked like. Later you come to the associated black territory which is a little further down the groundtrack and that, to me, didn't look like vents but looked like the top of a mountain. It did not have circular structure. I got a lot of pictures of it, so you can take a look at it and see what you think for yourself. Got some stereos too. Just seeing the vents, my guess would be that it's truly the top of a volcanic mountain with vents coming out of it in certain areas.

63. Onboard Recording

BRAND: Okay, Nile Delta. From the view we had today, we could not resolve the pyramids. I could see where they are. Looked like the ground was disturbed in the area where they are. But I'll have to admit that I was a little confused. There was one light area, which was disturbed, where they could be. There was another area of dark spottiness where they could have been. I'm not sure which place it was. I got three stereo photographs of Cairo.

64. Onboard Recording

BRAND: I got some photographs, but they were not stereo, looking south along the Gulf of Suez. And that was a very tough angle to get. I did not have a good angle on it and that's why I couldn't get three stereos.

65. AG/118:29:44+

CAPCOM: How did the pass go, coming across Africa?

BRAND: Man! It was swift. A lot to see. I had clouds up almost to Lake Chad, and then right over the Lake Chad area, I had scattered to broken. So it was poor for photography. But from then on, it was wide open. Got a lot of pictures. And of course, I got a good view of the Cairo area, Levantine Rift. We'll be talking into the tape recorder now. And as I said—have a lot of photos.

66. Onboard Recording

BRAND: Very quickly we came upon the Levantine Rift. That's an extremely interesting area that was easy to see. I guess my comments are as follows: The Levantine Rift goes into the Sea of Galilee. Beyond that, it hits the Golan Heights and then you've got a very jumbled area, somewhat reminding me of jumbled areas that we've seen in other places where you have either three tectonic lines coming together or else a turn of a bend. The one thing I noticed was that if you look at the 9G [Levantine Rift, p. 372] map, the dotted line on the left up near the end of it makes a bend to the left and follows a new tectonic line or fault which goes along parallel to the Turkish coast. In other words, the one on the left, number 1, I guess you'd call it, goes up to the end of it on 9G and then makes a left turn and parallels the Turkish coast. [Number] 2 seems to be obscured and it just ends in a lot of jumbled country up somewhere slightly beyond where the number 2 is, and it seems to end right in this jumbled area. [Number] 3, I could trace up to a river which I'll have to see a map later. But I could trace the faults out, going rather eastward. You could see them kind of through the valley silt, clear up to a river which must be well inland in either Syria or Turkey. So the overall pattern of these 1, 2, and 3, is a fan; 3 going almost eastward, and 1 bending finally to the north, and 2 going to the northeast. The terminals are hard to define, but I've defined them as best I can. And I did get three stereo photos of the area around 1 and 2 in the Levantine Rift area.

67. AG/118:30:43

SLAYTON: As far as the mapping part is concerned, we're doing it out of window 5. And that window is obviously considerably colder than number 1. And we have a continual problem with that window fogging over on us.

CAPCOM: Copy that. It's fogged up pretty good.

SLAYTON: Well, I've got it wiped down. The problem is that it keeps fogging, and you just have to keep wiping it.

REVOLUTION 72

68. Onboard Recording

SLAYTON: Okay, for the old Earth obs, we are coming up on site 12A [icebergs]. Essentially see nothing but cloud cover and have taken some pictures of some cloud streaks that look very unusual, but certainly I don't see any icebergs underneath.

69. Onboard Recording

SLAYTON: We're over the area where we should be seeing the Falkland Current and it's pretty well clouded over. In fact, I think probably that the cloud patterns I shot a couple pictures of may have been over the current. If that's typical of Gulf Stream operations, it could be the same down here. And for the record, this rev 72 attitude out of window 3 is such that I'm not sure if there weren't cloud cover we'd be able to see either icebergs or the Falkland Current in any case. It's a very oblique viewing angle.

70. Onboard Recording

SLAYTON: We're starting to shoot the 16-millimeter mapping pass over sites 9H [Niger River Delta], I [Algerian Desert], and J [Tripoli].

71. Onboard Recording

SLAYTON: The last time I came over here, at least, it's all cloud covered. We're just hitting the coastline at present. And we'll shoot away and maybe we'll get something underneath there that's worth keeping. We have some unusual cloud patterns here that should show up in the film, some low scattered cumulus and high wave patterns, high cirrus. We're coming up on site [9]I, and the cloud cover is beginning to disperse. Maybe we'll be able to see something here. It does look like a vegetated area down here. Very sparse, however. Oh, and here at 119:46 looks like some fossil dunes with a lot of red sand in the interdune area, and really red sand surrounding the area. Well I believe this is the Niger River, by golly. I thought this was Lake Faguibine. That was the old fossil dune area in the Niger River, sure enough.

72. Onboard Recording

SLAYTON: We're coming into the desert itself. And again, it looks very hazy down here to me. I don't know whether it's dust, sand in the air, or whether it's just a poorly defined landscape. And Tom agrees that it looks to him like a sandstorm too. That's really what we're seeing is sand in the air. We discovered a large expanse of fairly homogeneous sand desert. No obvious dune patterns. Oh, there's some really heavy clouds of sand blowing down there; some darker rock hills sticking out. We're now coming to the rocky volcanic hills of the northeast edge of the big sand desert. Some very red sand to the north. In fact, it looks almost like a massive parabolic sand dune, black with red sand behind it. And we're coming up on a large band of very black barren-looking hills with great red areas interspersed between them. Coloration looks volcanic, but there's something about the patterns that makes that obvious. Okay, and at 119:50:00, we're coming up into a couple of areas where the dunes are now a little better defined; they look kind of like old domes. They're certainly not stars and they're not linear here either. As we get farther into the north, there is a little linear pattern apparent, but it's mostly a bunch of dome appearances, very homogeneous.

73. Onboard Recording

SLAYTON: Coming up on another very hazy area again. Ah, that's because we're right on the coastline. Coming up on the Libyan Desert, Tripoli. Coming into the Mediterranean, there's some very light colors along the coastline. I think that's probably due to shoals rather than any current flow, it looks like to me anyway. And I believe that's the city of Tripoli down there. And after crossing the Mediterranean coast, ran into a very unusual cloud pattern in the Mediterranean, that I would say probably defines a large current. I started to say that cloud pattern probably defines a warmer water area. I'm coming up on the Greek coast here and I'll shoot a few of that until the mag runs out. Incidentally, we could see boats in the Mediterranean, due to their wakes, with no difficulty.

### REVOLUTION 73

74. Onboard Recording

STAFFORD: We're in the visual obs on rev 73–74. The last pictures that I made were on [film magazine] CX14. That's about 18, 19, 20, 21, the Volga River on over to the Aral Sea.

75. Onboard Recording

STAFFORD: Film CX08, exposure number 25, 26, and 27 over the Atlantic Ocean. There's a current boundary out here some place.

76. Onboard Recording

STAFFORD: Took a series of stereo photos of the islands off the coast of Africa, number 29, 30, and 31. Now, coming up to the African coast. I can see no wakes around the islands at this time, and no visible current.

77. Onboard Recording

STAFFORD: Now coming up to Casablanca and [Strait of] Gibraltar. Observing at Casablanca, you can see where the current has chewed out the coast there. I see notches in the area and also there's this whole series of sand dunes running parallel to the coast in the Casablanca area. Is that the Mediterranean? If so, there are no internal waves east of the Mediterranean. See no current boundaries west of Gibraltar, there.

BRAND: Now here comes Spain.

SLAYTON: We had a beautiful pass over Gibraltar yesterday.

STAFFORD: Looking at a broad area of sediment that's going into the waters out from Spain into the ocean. I can see a whole series of ships out east of Gibraltar—1, 2, 3, 4, 5, 7, 8—I can spot over 15 ships west of Gibraltar in the Atlantic Ocean.

BRAND: It's getting easy to see, isn't it?

STAFFORD: Oh, yeah. You can see the ships, see their wakes?

SLAYTON: Vision is good.

STAFFORD: Oh, now I see these internal waves; there the bastards are. Right there. All those waves and the boundary off the coastline. The sun angle changed. There they are, all of them. I couldn't see them before due to the sun angle. Just got them, a whole series of them.

78. Onboard Recording

STAFFORD: Here's the big rift leading up to Madrid. I shot a series of stereos of the great rift fault coming across to Spain. It's truncated right at the bottom by a smaller one. And the smaller one fans out at the end and disappears under the terrain.

79. Onboard Recording
STAFFORD: All right. We are coming up to the Pyrenees between France and Spain.
BRAND: Hey, would you get a shot of Marseille?
STAFFORD: Yeah, where is it, on the left?
BRAND: Yeah, it's on the left, see that bay coming up there?
STAFFORD: Yeah there's Marseille with plumes coming out in the water. I see it. We'll go right over it, Vance. See it? It's down where the Rhone River empties, isn't it Marseille?
BRAND: Yeah.
STAFFORD: That's it. Right now you can see where the Rhone River empties into the Mediterranean, the plumes out from it. Coming up to Marseille, get a series of stereos. Well, that was a good one, Vance. Got a beautiful one. Got Marseille completely. There it is. In fact, you can see the airfield.
BRAND: Hey, do you see Isthmus, or do you see this bay down here? Would you take a picture of that bay? That big lake sort of thing down there.
STAFFORD: The lake that's just inside from the ocean?
BRAND: Yeah. Just inside from the ocean.
STAFFORD: I got it. It's a stereo pair, Vance. Got it. That where you used to live?
BRAND: Yeah.
STAFFORD: That was an airfield that runs right into it, isn't there? The runways.

80. Onboard Recording
STAFFORD: Better shoot . . . now. Okay, as we're coming on up to the Alps, it looks like we're going to have cloud cover here.

81. Onboard Recording
STAFFORD: I could really see those internal waves from Gibraltar, though, right at the very last [minute] when the sun angle changed. That's fantastic out there. You couldn't see them at all from a different sun angle, though.

82. Onboard Recording
STAFFORD: Okay, going into the Alps.
BRAND: Coming up on Italy, south of us.
STAFFORD: Okay, the Alps are just completely covered with clouds; it's just not worthwhile taking any pictures there at this time. So we'll scrub the Alps on this one. The last frame that I got on rev 73, on CX08, was 52. Okay, for a comment, the first parts of rev 72 weren't recorded, that was on CX08. The first shots on CX08 was the rev 72 visual obs. And that was only three or four shots.
SLAYTON: It was all cloud cover and we didn't get anything.

## REVOLUTION 74

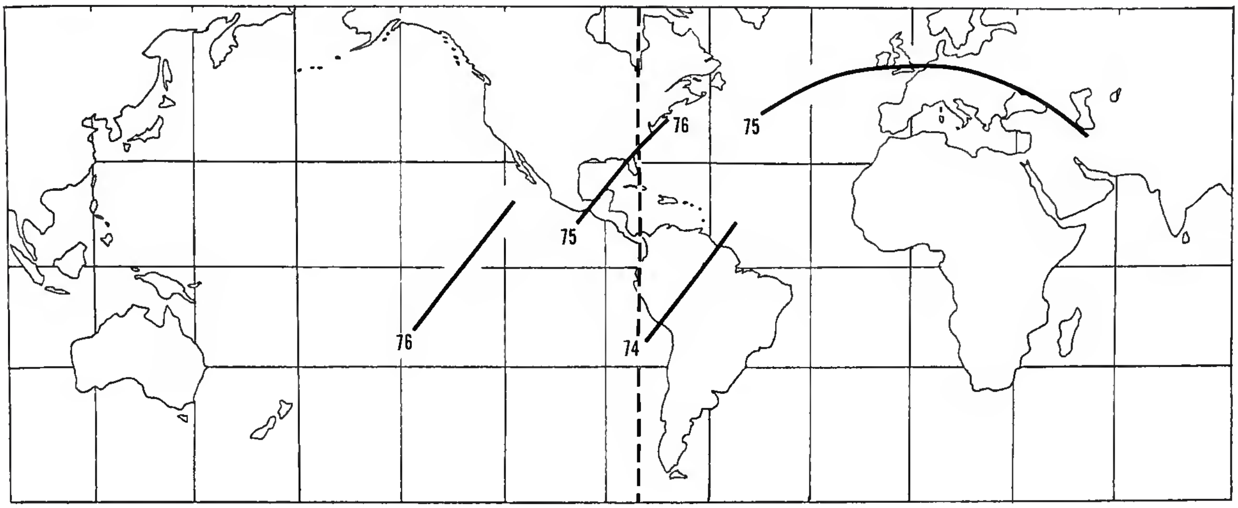
83. DT/122:28:30+
STAFFORD: Vance, you know we're upside down? If you're upside down, the Nazca Plain, should be on the right. It says to shoot it upside down. No, I'd rather have it right side up so the spacecraft is . . . .

84. DT/122:29:50+
STAFFORD: Starting with the Earth obs, revs 73 to 74. Coming up, there's a lot of clouds over the Pacific, and trying to look for the Nazca Plain markings.

85. DT/122:32:30
STAFFORD: I don't like this attitude for Earth obs. I'd rather [have] heads up and pitch down, like this. See? See if it fits; don't have enough room. Let me look at this. Can't get down there.

86. DT/122:34:06
STAFFORD: On the map, site 7 [Northern South America], rev 74, we're approaching the north coast of South America, Peruvian Desert, trying to find the Nazca Plain. The clouds go all the way up to the north of here, go all the way up to Acapulco. That's just the way a cloud system will be. We really should fire away.

87. DT/122:36:31
STAFFORD: Man, this attitude is fucked up, did you know it? It's really bad when you try to keep your head straight back like that and look right and left. I'm going to have to change this whole son of a bitch around. I want to use my headset here . . . . No, it's no problem to look ahead, just right and left. I've got to reverse this . . . first. I think if we put . . . in here, which we ought you can put those here. No, wait. You don't have enough room. Good heavens! Feeling bad




Revolutions 74, 75, 75/76, and 76

about my chair . . . . Okay, it's acquisition time.

88. DT/122:38:33

STAFFORD: How do you read, Houston? Okay. Look. Get with Farouk. This attitude for visual obs, there's no room to twist your head and look upside down, and the whole thing . . . you reverse this thing so we're heads up and pitch down . . . just makes everything about twice as easy. Can you hear me? Okay. We want to roll 180 degrees for vis obs. Not the mapping, but the vis obs.

89. DT/122:38:33+

STAFFORD: We got some clouds over. . . . It goes west and all cloud cover. Okay. The cloud cover is . . . the west coast of the Pacific Ocean . . . of the Nazca Plain, so no site 7B. 7C is also covered over.

90. AG/122:42:59+

CAPCOM: I understood that you were having some kind of problem with your vis obs attitude in the window, and I'd like to get that again, if I could.

STAFFORD: Look, I'm sure this was optimized because sometimes you do the vis obs at the mapping attitude. I'm now wings level. I've gotten a lot of cloud cover, of course, so I can't see much, so I'm not losing too much by talking to you. What we want to do is to, just the vis obs only, to roll to heads up. Because if we could sit down behind the couch, this attitude wouldn't be bad. But the trouble is there's not enough room to sit down behind the couch and look out where you're going. You can't get in there. You're too high. So we want to roll to heads up, pitch down, looking straight forward for the vis obs attitude when it's not associated with the mapping. Can you get Farouk and his troops tracking on that?

CAPCOM: Okay, Tom. I think we understand that, and we'll take a look at it for the upcoming passes.

STAFFORD: Yeah, this heads down; when you look out like that to get the view, you're straining yourself up against the instrument panel holding your feet in the struts against the tunnel, and everything in the book is left and right. Well, you can overcome that, but you just can't get the lead in. I tried sitting upside down on the couch, but the only way you can see it out is through the other side of the window. It's really a hell of an awkward situation. So we want to pitch down at least 30 or 40 degrees, nose down, and we'll take everything coming head on for the vis obs wings level.

CAPCOM: Okay. If I'm understanding, you're talking about wings level, heads up, pitch down about 30 to 40 degrees. Is that correct?

STAFFORD: Yeah, at least. Whatever it takes to get that window out good instead of this heads down. The mapping passes we'll have to leave like they are. We understand that, but when he [El-Baz] includes mapping with vis obs, there's nothing we can do about that. But as far as just pure vis obs by itself, we want heads up, pitch down to a degree. He should be able to determine that. I'm going to say, oh, at least pitch down about 30 degrees or 40 degrees.

CAPCOM: Okay. Fine, Tom. And just to make sure that we do understand that, we're talking about with docking module forward. Is that correct?

STAFFORD: Oh, yeah. Docking module forward, pitch down . . . . Looking out window 3.

CAPCOM: Apollo, Houston, for the AC. Tom, when you get a moment there, you can talk a little bit, we'd like a few clarifications on that attitude that you were requesting.

STAFFORD: Hang on. I got a target here.

CAPCOM: Okay, Tom. One of the things we want to clarify—We're assuming that you want to be with your back to the couch. Is that correct?

STAFFORD: Yeah, well, it gives your back—with my back to the couch now, looking forward. And again—you can do it, but it just seems easier if you're heads up on it looking down forward. Of course, I guess you don't get the high-gain antenna, so that's something to play off.

CAPCOM: Have you got any real preference as to whether the objects are moving from the top of the window down, or from the bottom of the window up?

STAFFORD: No, I don't think so. You talking retrograde?

CAPCOM: That's affirm.

STAFFORD: No. I think it's easier when you get a lead into it coming forward.

CAPCOM: I'm sorry. I didn't quite get all that. You said a lead into it, which you prefer coming from the top of the window down, then?

STAFFORD: Well, like for right now, I've been coming from the top of the window down, as they're going forward here. Let's just go ahead and see what we've got here for a while. Sometime later on, as we get an opportunity where it's not coupled into an antenna angle, we might just take a look at it and do it ourselves.

CAPCOM: Okay. We'll go ahead and take a look at it. One of the things we are considering was using some of the attitudes similar to the mapping pass that we used for window 5 and only to set it up for window 3. But we'll look at it down here and get back so that we can give you a new one.

### REVOLUTION 75

91. AG/124:25:59+

SLAYTON: Hey Dick [Truly]. Where are we right this minute?

CAPCOM: Oh, you're [over the] North Atlantic. You're just off the coast of Newfoundland, probably almost 1000 miles [1609 km].

SLAYTON: Must be right on the airways. I see a couple of contrails, and I can almost make out one airplane down there, going west.

CAPCOM: It's probably a pretty good [sight]. Yeah, that'd be just about the primary route between the States and Europe.

92. Onboard Recording

STAFFORD: Just to note, I shot a couple of cloud formations over Europe on [film magazine] CX14, exposure number 20, at 124:33. Okay, we're shooting some weather patterns over Europe, going on into Russia and shooting stereo pairs of semicyclonic clouds and huge thunderstorms.

### REVOLUTION 75/76

93. AG/125:46:01+

STAFFORD: We're seeing the coast of Florida go past pretty fast.

CAPCOM: Rog. You should be passing over actually the coast of Mexico there, and Florida should be coming up in just a few minutes.

STAFFORD: Okay. We thought it was out by the tip there.

CAPCOM: You just came over into the Gulf of Mexico.

94. AG/125:46:01+

BRAND: Hey, Crip. We can see you from here.

CAPCOM: See Houston?

BRAND: Can see the whole Gulf Coast there from Brownsville up around through Houston and around to New Orleans. Looks like a nice day from here. I'd say kind of high scattered [clouds].

95. AG/125:48:31

SLAYTON: If you go to the Cape [Kennedy] tonight, Crip, you got some nice big ones right over Orlando, looks like. Watch out.

CAPCOM: Big bumpers, huh? Well, I haven't got a chance to go flying through them anyhow.

96. AG/125:48:31+

BRAND: Funny thing, Crip. Looking at thunderstorms down there, they don't look that much below us. We feel like we're really in a low orbit.

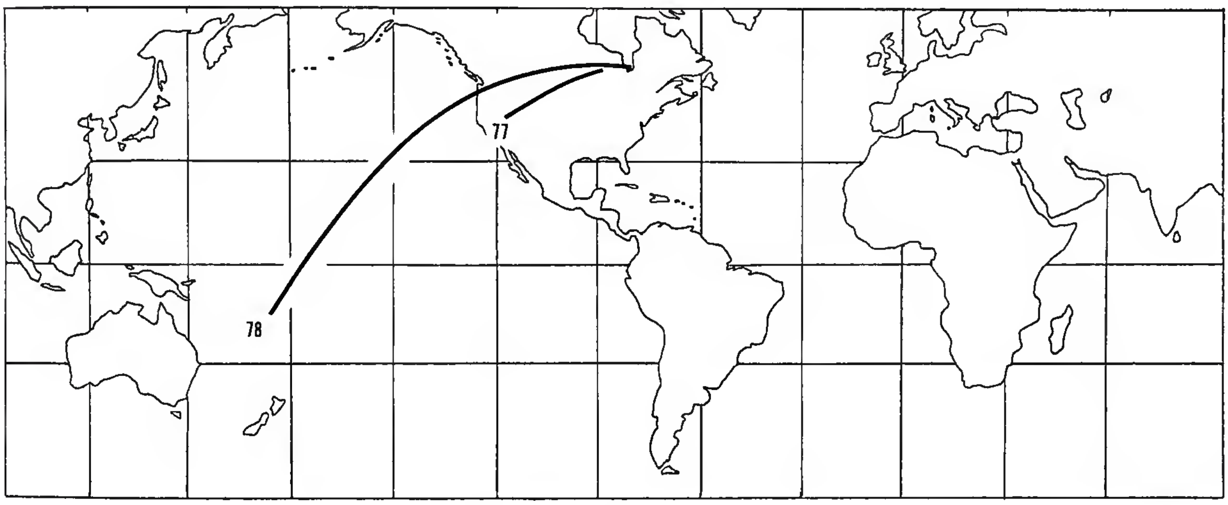
CAPCOM: I remember him making a similar comment, especially like at night when they were coming over and there was a lot of lightning and so forth going in them. I guess the appearance is that you're right with them.

BRAND: Okay, you can see the three-dimensional quality of them very well; very big mushrooms.

### REVOLUTION 76

97. Onboard Recording

BRAND: At approximately 127 hours and I picked them just because of the general interest . . . an interesting cloud pattern around. After that, we're on frame 48.




Revolutions 77 and 78

### REVOLUTION 77

98. Onboard Recording

SLAYTON: We just shot a few frames on CX14 ending with 55 of, I think, Salt Lake City; Fort Peck Reservoir; some clouds through the Midwest, hopefully Wisconsin and Michigan.

### REVOLUTION 78

99. Onboard Recording

SLAYTON: Okay, we're coming up on pass 78 over sites 3C [Hawaii] and 4A [snow peaks]. We've got the 250 lens on, set at 7, whatever it's supposed to be, F 500, [film] magazine CX14, and we're starting at frame 57. I hope we've got enough film to shoot it all.

100. Onboard Recording

SLAYTON: We just passed site 3C, and unfortunately got nothing because there's cloud cover over the islands and, secondly we were off track from window 3 from what we thought was the island of Hawaii, which was our main target island. So we'd have been unable to do much on two counts.

101. AG/130:13:04+

BRAND: Just for general interest, it looks like the Pacific is just full of eddies. Great big eddies. We see them a lot. And we think they're eddies because there are giant cloud-ringed areas that sort of make you think the water there is either hotter or colder than the rest.

CAPCOM: Rog, Vance. Any estimate on size or diameter?

BRAND: Well, we'll give you some. They're all many sizes. We'll try to give you some maximums and minimums here shortly.

102. AG/130:13:48

CAPCOM: Also, we would be interested in some further comments regarding the attitude that you've got right now for this vis obs pass. I know Tom commented on it this morning, and we were looking at trying to do something different. However, it doesn't appear to be too easy right now, and we were wondering if maybe it's just a matter of getting used to it a little bit.

SLAYTON: Well, I'll tell you. We just passed Hawaii, and I got zero for two reasons. Number one, it's cloud covered over the island that we're looking for, and secondly, it was too far to the north. This attitude is probably not the greatest. But I hesitate to recommend a better one right at this point.

CAPCOM: We're still looking at it. A little bit reluctant to come up with an attitude because a different attitude that we haven't really wrung out like we have what we got. But if we're not getting the data with what we got, well, we'll press on and continue to look at it.

SLAYTON: Well, this is a good attitude to acquire things ahead. You know, you see them coming up, which is good. The problem is we're really rotating along here, and once it [the target] gets into view where you can shoot it with a camera, you go by it in about 5 seconds.

103. Onboard Recording

SLAYTON: Okay. We just passed site 4A [snow peaks] and site 4C [Superior iron], the Olympic Peninsula was clouded over, some clouds over the Cascades. We were almost right on top before I finally saw any snow-covered peaks, which I could differentiate from the clouds. Shot three quick shots, but I could not detect firn lines on any glaciers because I didn't see any glaciers. Vance thought he saw a firn line on a glacier. And I didn't see any volcanic activity anywhere; of course I'm not sure I was looking at Mount Baker either.

104. Onboard Recording

SLAYTON: Since we're going to use this magazine anyway, we're continuing through, and we've got some pictures in western Montana, eastern Washington, and also in southern Canada. We shot a couple of pictures of a very large lake, which was we think maybe Lake Winnipeg, but we're not sure. And, of course, at this stage we're out of attitude for good Earth obs viewing.

105. Onboard Recording

SLAYTON: The only other comment is that Vance has adjusted our pitch 10 degrees and we think another 20 would be advisable. And I think we'll just pass that onto the ground now while we've got them.

106. Onboard Recording

SLAYTON: Okay, we finished the rev 78 Earth obs with frame 69 reading on the mag, so we're going to change to a new mag before we go any further in this world.

### REVOLUTION 78/79

107. AG/130:30:49+

SLAYTON: Okay, Dick. We just finished an Earth obs pass here, and talked to Crip about the Hawaii one. We hit the Washington coastline, and we did get a few pictures of that area and partly accomplished our effort there. We've been doing a little experimenting since then. Vance has striked a 10 degree pitch down towards the horizon, and we think we can tolerate about another 20 to get us into better viewing attitude for Earth obs. The problem we've got here is that we're seeing way too much stuff above the horizon and out to the horizon, which is of no value to us at all. And when we get over the target, we don't even get above it, and it's already disappeared through the window. So, we're having a real tough time here with this Earth obs and this attitude.

CAPCOM: Okay, Deke. Copy. I did copy your conversation with Crip a while ago. I've been here for about the last hour. Now, do you mean a total of 20 or a total of 30?

SLAYTON: We took 10, it didn't seem too much; it was just obviously an improvement.

CAPCOM: Deke, Houston. The only confusion I have on what you said is that I thought you said that Vance had already tried about another 10 degrees down, and then you mentioned the 20 degrees. And I was wondering if you thought that a total of 20 degrees further pitch down or a total of 30 degrees pitch down would be about as much as you could stand?

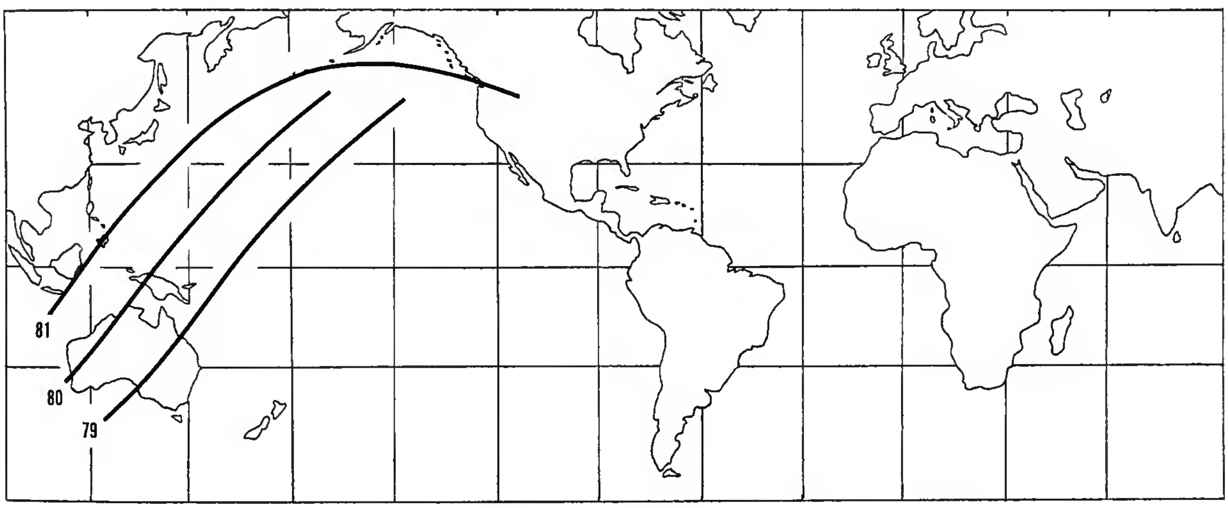
SLAYTON: I'm talking a total of 30. We tried 10, and we're still looking at a lot of stuff above the horizon. So we think another 20 on top of that might be about right.

CAPCOM: Okay. Why don't you let our guys think about that, Deke, and we'll get back to you?

SLAYTON: Thank you.

CAPCOM: We have another Earth obs pass coming up down here in just a minute, and if we can gin up a new number for you before this Ascension pass, maybe we can update this upcoming P20 [a spacecraft maneuver] and you can give that a whirl and let us know how it turns out. For your information, it's printed in the flight plan, but we have no ATS coverage this pass and due to the attitude constraints.

SLAYTON: Yes. We would have cranked in the 10-degree adjustment, but we only have 10 minutes of Hawaii to the West Coast and we didn't think that was enough to start experimenting.




Revolutions 79, 80, and 81

REVOLUTION 79

108. Onboard Recording

SLAYTON: We've got to get a picture of those.

STAFFORD: It's just like off Gibraltar. Certain sun angles you couldn't see a damn thing.

SLAYTON: Okay, we're coming up on rev 79 over Australia and, although it's not called for, we've got some beautiful internal waves right off the coastline here. And we're shooting them, using [film] magazine CX16, a new magazine, and we'll probably overuse our budget here.

109. Onboard Recording

SLAYTON: We've got the new viewing attitude at this point. I should hope it gives us better capability to find things. And we're coming up to Lake Eyre area, looks just like the photograph we see here. That's great. Let me shoot a stereo series right here.

110. Onboard Recording

SLAYTON: Here comes the old fossil ridges

[Simpson Desert]. Hey, those do look just like those in the doggone . . Nile [Niger River Delta].

BRAND: Where do you see them?

SLAYTON: Right down here to your right, straight ahead of you, see right there.

STAFFORD: Go ahead, Houston. And hey, this attitude is lots better.

BRAND: Why do they call them fossil ridges?

SLAYTON: Because they're real old emergent stuff, Vance.

111. Onboard Recording

SLAYTON: Okay, those are real dark. I don't see any light stuff indicated on them. We're shooting at them. It looks very much like the Nile [Niger]—oh, man, that is amazing.

STAFFORD: Oh, look at this!

SLAYTON: Man, this is impressive stuff, isn't it? Yeah, there's no way you cannot shoot up some film on something like this, you know? It has that red desert down there. It's really red and it's got this dark erosion pattern running through it.

STAFFORD: We're shooting pictures like mad, day and night.

SLAYTON: Okay, passing over what looks like large stream beds. Looks like a red baseline with real black stuff in it. Real red sand. Did you see any dunes to speak of in that area? Just one dune patch. Very red. Very interesting mixture of dark reds and black material; the red seeming to be the base and the dark feeding through it.

112. Onboard Recording

SLAYTON: The Great Dividing Range. Okay. Here comes the Great Dividing Range, and I'm going to shoot some pictures and we'll talk about it later. Coming up on the coastline here; and the Great Dividing Range isn't all that obvious a range to me. There's some fairly rugged looking hills just off the coastline. And I see a road . . . I think I got it on the film, but I guess I couldn't detect it as a real range. Must be very low hills. I got it on film anyway.

113. Onboard Recording

SLAYTON: I just shot a couple pictures of an island off here with coral atolls all around it. It's just plenty too beautiful not to shoot. I guess we didn't have the tape recorder on when we talked about eddies over the Coral Sea. I could see one through window 3. Vance saw a couple through window 2 yesterday, 10 kilometers in diameter. Already gone up through frame 24 here; we just plain didn't allow enough film for this. Okay. There's the Solomon Islands. I shot atoll pictures around.

114. Onboard Recording

SLAYTON: I think we're coming up on Marshalls here now. I just shot three frames here in area 3A [cloud features], a line of three very distinct buildups and two smaller ones. I don't know what you mean by interesting convective patterns, but they sure looked interesting to me, so I shot them.

115. Onboard Recording

SLAYTON: Okay, here again I'm passing a very distinctive cloud line laying off across the water which probably marks the edge of a current or an eddy, it's so distinct. However, it's not a convective cloud feature, I guess, and since we're short on film, well, I won't take any pictures of it. I hate to do this!

### REVOLUTION 80

116. AG/132:06:34

SLAYTON: And, Dick, as far as the last Earth obs is concerned, I think that attitude is much better than the previous one. We're going to keep running with it.

CAPCOM: Okay, real good, Deke. We'll take that input and crank that into our planning for all the other pads that are coming up. I mean all the other passes that are coming up.

SLAYTON: Things are still moving mighty fast, but it gives you a chance to look at them fast in nadir, which we could not do before.

CAPCOM: Okay, well, why don't we try that approach for a while? And if you have any other suggestions, just give them to us, and we'll try to help you out.

117. AG/132:06:58+

SLAYTON: Well, we got to wish we had more film. It's very discouraging to have to stay within a film budget; there's so many interesting things to shoot.

CAPCOM: Roger. Understand. Record them in your mind.

SLAYTON: Unfortunately, we have no other choice.

118. AG/132:27:55+

CAPCOM: Hey, if Deke is listening, I had a comment on his comment about the film.

STAFFORD: Dick, he's inventorying the film. We'll just wait a couple of minutes on it, and then we can talk to you, and you can talk to him.

CAPCOM: Well, I tell you what, Tom, it wasn't that big a deal, and I can just pass it on to you. He was commenting about the frustrations of having to live within the film budget, when you saw so many things out the window on good passes that you'd like to record. I'd just wanted to remind you and make sure you hadn't forgotten, that there's four film magazines listed in the Earth Obs Book [Appendix 3] under film budget on page [319]. There are four; they're listed as Hasselblad PAO magazines. They're your choice as to what to use them on. The numbers are CX06, 7, 8, and 9, located in [stowage area] B5.

STAFFORD: We've already used those. [laughter]

CAPCOM: Roger.

STAFFORD: One thing we do have as a reserve, and we are getting quite a bit of things on targets-of-opportunity, is the little Nikon.

119. AG/132:46:53+

CAPCOM: And, Apollo, Houston. Vance, when you get a minute to listen, I had a comment to you about what you told us about the eddies that you saw out on the Pacific awhile ago.

BRAND: Okay . . . go ahead.

CAPCOM: Farouk is here and we were talking to him. The question that he had that you might notice on future passes over the Pacific, if you see the same thing, was the color and the texture of the ocean down between the clouds, and he's interested there mainly in the sea surface conditions and not just the clouds.

120. AG/132:46:53+

CAPCOM: I have some news sometime later on this evening that I'll have available if you'd like to hear it. There's one item in here that I thought I'd read to you. It says an earthquake which struck an area of the western Pacific today prompted a tidal wave alert for parts of Hawaii but was later cancelled. The University of California Seismographic Laboratory at Berkeley reported an earthquake registering a 7.7 on the Richter Scale occurring at 7:50 am Pacific daylight time, and it was centered in the region of the Solomon Islands. For your information, the Solomons are about 2000 miles [3218 km] to the southwest of Hawaii. We did check with our recovery weather people just a minute ago, and it turns out that they have not seen any tidal wave action as a result of the earthquake, either at Hawaii or at Kwajalein.

BRAND: That is interesting. We've been flying repeatedly over that area, of course. I don't know if you can see something like that from up here or not.

CAPCOM: You're not going to be flying over that direct area here in the next pass or so. I just thought you might be interested in that one.

121. AG/132:49:16+

BRAND: Yeah, that is very interesting. After our last conversation, I took size measurements on a few of the eddies we've seen, and seems like a typical size is 10 to 15 kilometers in diameter. But we have seen some giant ones that would be tens of kilometers, so we'll try to look at them more closely in the future, though, and see what the sea state looks like.

122. AG/132:52:35+

STAFFORD: Dick, where are we at now? Are we heading across Africa?

CAPCOM: No, you're on ascending pass; you're just crossing the coast of southwestern Australia. And then you'll be, of course, crossing Indonesia. Then you'll get another long pass over the western Pacific.

123. AG/132:56:35

BRAND: Hey, we're going over the Simpson Desert right now. And it's just fantastic. It's got dunes in it. It looks like they are very long, and they look like road tracks, there are so many of them—like hundreds of parallel road tracks. And we'll comment on it in our usual fashion with the onboard tape recorder, but it's just plain spectacular!

124. AG/132:56:35+

STAFFORD: Yeah, and the long red streaks are matching about color 10, I would say, on Farouk's [color] wheel.

CAPCOM: Thanks a lot for the input; wish I could see it myself. Beano and I are whipping out our color chart and seeing what color it is ourselves.

BRAND: This is one of those cases where there was light coming in the window, falling on the color chart. And that made it easy to use. Sometimes when it's in the shadow, it's hard.

CAPCOM: Roger. Understand. Incidentally if you ever do have a question about the chart or any comment on it, we've got one here at the console that's just about identical to yours, I think.

STAFFORD: And some of those long streaks, those long sand streaks, could have either gone between 9 and 10.

CAPCOM: Okay, thanks, Tom. Could you differentiate 9 or 10-A or B? Are they dark or light?

STAFFORD: Now that the sun gets on the wheel where I can see it, it was more like 9. Oh, I'm sorry. Okay. Be about like 9-A.

125. AG/133:03:44

STAFFORD: Okay, Dick. And right over this area, you can mark the GET's a whole series of eddies—maybe 15 to 18 kilometers in diameter, just clumps of them. We're using the Nikon to shoot it.

## REVOLUTION 81

126. AG/134:20:54+

CAPCOM: Okay, and here's one last note, back again on the vis obs film. I think you already are quite aware of this, but I'm going to tell you anyway. There are three black camera magazines that, according to our records, because of past cancellations in Earth obs, that have extra frames if you haven't already used them. They are CT05, CT06, and CX13.

STAFFORD: We were more concerned, Dick, about the silver camera film. And we've [counted] that since the last time we talked to you, and we got about 5½ mags of that left. So we need four by our records. We're still in good shape, I think.

CAPCOM: Okay; real fine. We won't worry about it.

STAFFORD: Say Dick, one thing I want to do, too. We don't want to bring back one frame unexposed, so we're going to shoot up all that bank—a lot of it will be on outside—and just check, if there's anything that they've got in there that couldn't be used for outside using the light meters onboard the camera, over.

CAPCOM: Tom, I'm not sure I understand the question, and I'd like to make sure I pass it on properly. I realize you are going to try to shoot it all up, but say again the question, please.

STAFFORD: Okay. We're going to shoot up all that Nikon film, and a lot of it's going to be used for outside viewing. And I just wondered if—you might check—no, nothing time critical—just check tomorrow for it. And we're going to be using the light meter onboard and the Nikon.

CAPCOM: Yes, I understand now, and we'll get our camera people to take a look. And if they have any advice in the morning, we'll get it up to you.

STAFFORD: We've got the camera here right now, for example, with the CI18 with ASA 500 film in it, which is for the crystal growth of the ZFF. And we're using that also for Earth obs whenever we see something interesting.

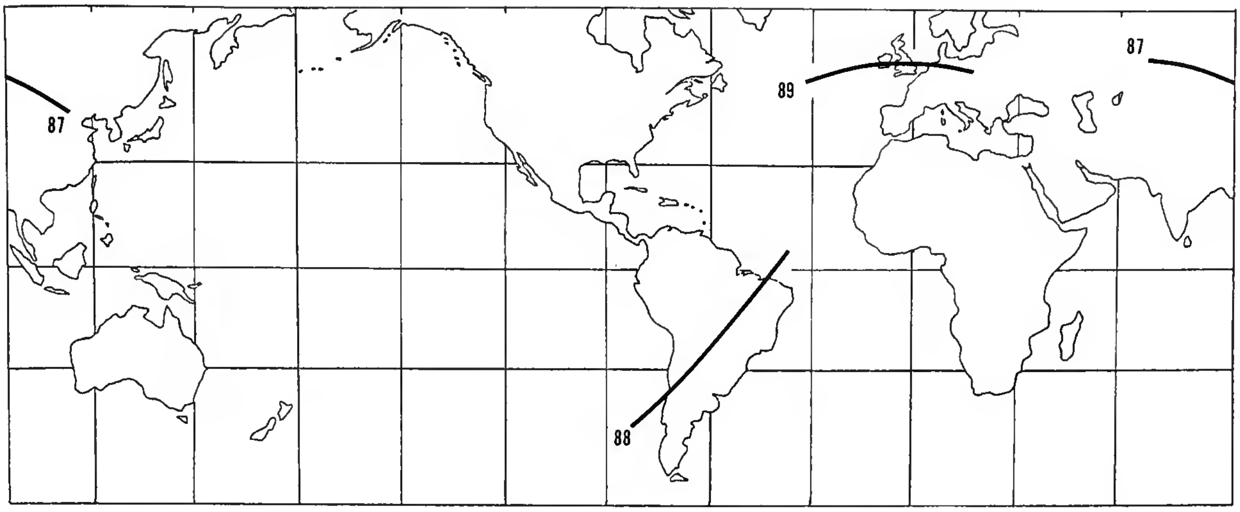
127. AG/134:29:18

STAFFORD: What terrain are we crossing over right now?

CAPCOM: You're on an ascending pass at about 10 degrees south, and you're getting ready to cross the islands out in Indonesia.

STAFFORD: Oh, okay.

CAPCOM: And the pass after you cross all those islands chains out there, Tom, you're going to be out over the Pacific all the way out, and then you'll start a descending pass and cross over the western United States over Oregon, the State of Washington. And as a matter of fact, you're going to come fairly close to Houston on your descending pass coming down this way.




Revolutions 87, 88, and 89

REVOLUTION 87

128. AG/143:49:08+

STAFFORD: Okay, Bo. I've got the Earth Obs Book here.

CAPCOM: This is for rev 88, site 8D [Paraná River]. Dam site 2 nearest the center of the window at 144:44:48. And that approximately 15 degrees south of nadir. And on site 8E [circular structure] number 1 time, 144:49:36, and that also is 20 degrees south of nadir. And structure number 2 time is 144:49:15, and that also is 20 degrees south of nadir.

129. AG/143:52:13

STAFFORD: Hey, Bo. Tell Farouk right now, wherever our position is, we're passing over some tremendous sand dunes [Gobi Desert]. They've got long ridge dunes, and on top of them are little bitty—are big stars. I mean, they are big babies. It's like in a nearly sedimentary basin. I don't know where we're at, but I just wanted to report that at this time.

CAPCOM: Roger. And it looks like you're over North China.

130. AG/143:53:15

CAPCOM: And, Apollo, Houston. Just a little weather report. It's a little cloudy at the start, rather clear over South America. It should cloud up across the inner ITC, and then it should clear up again until you get up into Europe just south of the Alps.

REVOLUTION 88

131. DT/144:31:13+

STAFFORD: Okay. This is rev 88. Starting the Earth obs at 144:30. Sites 8B [Chilean Andes], C [dune field], D [Paraná River], and E [circular structures].

132. DT/144:34:30+

BRAND: They got this dune field?

STAFFORD: Here's this dune site at 144:28. What rev?

BRAND: What rev? We're just starting 88.

133. AG/144:39:57+

STAFFORD: Okay, Bo. I'm starting this Earth obs pass. Okay, we're off a couple of minutes on the GET from what they've lined up, but I'll talk to you later. I'm busy now.

BRAND: Just crossed over the Andes and the Amazon [River]. Amazingly clear day over the Amazon.

CAPCOM: Great. Sounds like a pretty view.

134. DT/144:40:16+

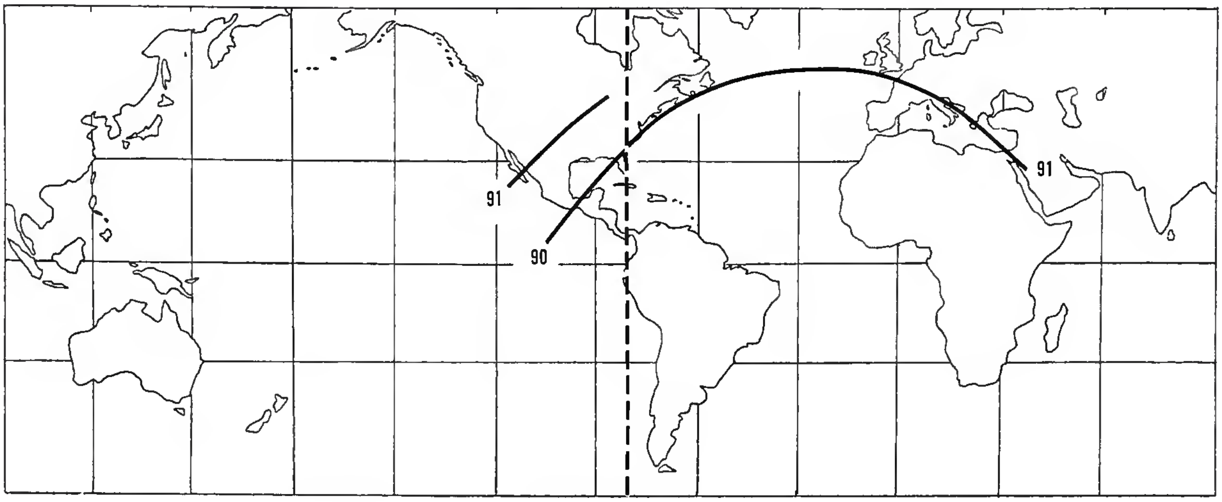
SLAYTON: Here's the long river running north to south. It comes up around in here. What direction are we going in?

STAFFORD: There's the river site. Okay. 44 [minutes] and 48 [seconds, GET].

SLAYTON: 44 and 48.

STAFFORD: No, that isn't it yet.

SLAYTON: 44 and 48 . . . Look at that highway down there. All I can see. . . .




Revolutions 90/91 and 91

REVOLUTION 89

135. AG/146:41:42

SLAYTON: Hey, Crip, would you say we were about over the Straits of Dover now?

CAPCOM: That's affirmative.

SLAYTON: Okay. Great. We got a picture of it, then.

REVOLUTION 90

136. AG/148:13:10+

CAPCOM: Vance, were you the gent that requested some information regarding 35-millimeter film and how to use the Nikon for targets-of-opportunity?

BRAND: I think Tom asked that last night. He was essentially wondering if we needed a special—oh, sort of additions to the photo ops cue card on light settings, f-stops, etc., or if we could just use the light meter in the Nikon, as is?

137. AG/148:14:44+

CAPCOM: I think you had talked to Farouk, pre-mission, regarding some of Cousteau's sea-farming sites. And I was going to tell him where one was in the Adriatic Sea, so that he might be able to get it. We're going to be doing some vis obs, anyhow, so he might be able to get a shot of it.

BRAND: Oh, hey! That'd be nice. Glad to hear we can do something in that area. Deke'll—when he comes up, then he can copy the location.

138. AG/148:16:41

CAPCOM: Great. Really glad to hear that. We had a couple of items of interest, that you might be able to do something about, on this upcoming pass that you're going to have. One of them is that we've had a rather large oil slick, about 40 miles long [64 km] and 5 miles wide [8 km], reported about 50 miles east [80 km] of Key West. And we think that that probably should be visible from the number 1 window in the command module, when you come across there on the next rev.

SLAYTON: Okay. That's 50 west of Key West.

CAPCOM: East. East of Key West.

SLAYTON: Okay. 50 east.

CAPCOM: Okay. And it's going to be available to you just about—oh, part of that red tide area, when you come across—about the same area, there. Just a little before it.

139. AG/148:17:15+

CAPCOM: Okay. The other one was that I think Vance had asked Farouk to look into talking with Captain Cousteau regarding some sea-farming sites. And we got some data back that one of them that he's considering is on the eastern edge of the Adriatic Sea. And you're going to be coming across it. And it should be visible from number 3 window, on rev 91, at about 149:44 GET. And you can take a look at your book at target 9J [Tripoli] and at least get an idea of the area by the Adriatic.

SLAYTON: Okay. Rev 91, 149:44, to 9J—and what was the window number?

CAPCOM: Window number 3, the big one there.

140. AG/148:18:24+

CAPCOM: The other item was that—because Tom had talked to the ground yesterday, regarding use of the Nikon, since you guys were getting a little bit short on film there—for targets-of-opportunity. Basically, we're telling you that you need to use the photo cue card, but I've got some recommendations, if you want to copy them down.

SLAYTON: Okay. Go ahead.

CAPCOM: Recommend using the 300-millimeter lens, although some of the problems we've had from Skylab indicates you might end up blurring a little bit, but we can try it. We recommend a shutter speed of 1/1000. And for your CI film—your interior film—use your exterior photo cue card, table Bravo, but increase each setting by one f-stop. For example, if it calls for f/8, we want you to use f/11. And for CS film, Charlie Sierra, we want you to use table B directly . . . .

141. AG/148:19:52

CAPCOM: Okay. And if you have a chance to record any of your photos on your voice record, we would appreciate it, also.

STAFFORD: Okay, we've been doing that.

CAPCOM: I thought you probably were. And that's all I was holding for you right now; let you get back to observing the world.

## REVOLUTION 90/91

142. Onboard Recording

SLAYTON: Have rev 91. Coming up on site 5D [Central American structures]. And it's about a third cloud cover down there. I'm having trouble picking anything out, I'm afraid. Decided that spotting scope was of minimal value because we're moving a little too fast. Unless you can track, you're not going to get much. I'm looking for the extension of the Bartlett [Fault] into the coastal plain which is just south of our orbit. And I see absolutely nothing. Should have some volcanoes to the south. There they are, and I'll shoot that. Okay, got a stereo set of what appears to be volcanic stuff. Got a new mag on it, it's an IFO2 with infrared filter.

143. Onboard Recording

SLAYTON: And we're already past that site; we're on into site 5A [Gulf of Mexico]. I guess headed southward to the right—or to the left. I'm confused about this attitude. The south should be to the right. North should be to the left. It's got to be; we're traveling east.

BRAND: We're traveling east. We're upside down.

SLAYTON: Seems like to me it's got to be that way. I could be wrong; I've been wrong before.

144. Onboard Recording

SLAYTON: We're looking for eddies in the Yucatán [Channel]. Coming in ahead of us. We got a lot of eddy pictures yesterday in the Pacific, but here's a fairly good one coming up. Looks like there's a series of eddies there. Relatively small. We'd have to try to get this thing centered to get a good stereo and maybe we can figure out exactly what it is in retrospect. They estimate it to be 12 kilometers across, and that seems to be typical of the other eddies we see. So, since we're short on film, I won't shoot up a whole bunch on that. We're also looking for internal waves in the Gulf [of Mexico] waters, and see if we can see the Gulf Loop Current on this. Here's a very large eddy off here to the north. I don't see any evidence of the Gulf Loop Current. There are a number of eddies that seem to run about three times as large as the one Vance estimated the size of, and we got a fair amount of cloud cover, and it doesn't seem to be any particular pattern that would define a current. Now we're coming up on a solid overcast. You can't see anything.

145. Onboard Recording

SLAYTON: We're about ready to come up over the Florida Peninsula. The whole west coast of Florida was under heavy clouds so we didn't see any evidences of red tide on this pass. We're now crossing Florida, and in traveling on up the Florida Peninsula . . . . I believe I can see the Cape [Kennedy], here, to the left. See, we're traveling northeast, Vance. And, actually, to the left is east; to the right is west, is one way to look at this and we're traveling north. Right?

REVOLUTION 91

146. Onboard Recording

SLAYTON: We're coming up over the Chesapeake Bay area here. And again, we got about 50 percent cloud cover. This is coming up over what I think is Norfolk, the James River, Cape Charles, Potomac [River], and all that stuff. And I got some pictures of that area. There is a lot of sediment; actually it's much like muddy water. I do see lots of mud, and there isn't anything out there on gyres, I guess. We're coming over Dover, Delaware. The Potomac is awful muddy and loaded with sediment, but I don't see any gyres. Well, let me try it right here. That was there at the Potomac.

147. Onboard Recording

SLAYTON: Okay, great. We're right over Cape Cod at the present time; straight overhead. I've got to get a stereo pair of that. Man, that's great. One of the best things I've been able to see here so far. The rest of the coastline from here on is completely clouded in. We're totally cloud covered over here north of Cape Cod. As far as Boothbay, in that area, haven't been able to see any bloom or anything else. Can't even see it. We're right on the coastline. And as far as the Cape Cod area is concerned, I haven't had enough time to . . . .

BRAND: Look at that below you; just coming, see?

SLAYTON: What is it,

BRAND: I don't know.

SLAYTON: Yeah, but that's not Cape Cod, that's Nova Scotia. We've already gone by.

148. Onboard Recording

SLAYTON: Okay, looking across the Atlantic for oil slicks. Tape recorder off, here.

149. Onboard Recording

SLAYTON: Okay, next site is 5C, the Labrador Current, Newfoundland, Nova Scotia. Looking for the confluence of the Labrador Current and the Gulf Stream. And we got so much cloud cover here that I think we're not going to see the confluence or nothing. There's some interesting cloud patterns down there. In fact, there's a beauty right there, and since I haven't seen anything else to shoot . . . . See that flow pattern coming over the tip of that island there?

BRAND: Yeah. Cloud patterns may give a clue to the current.

SLAYTON: Might give a clue, that's right. I'm going to shoot it. Okay, that was a stereo strip . . . see some cloud bow wave running around that island. I think we are over Newfoundland right now; should be. I think we're just departing the east coast of Newfoundland. And I should be able to see the Labrador Current right up through here, if we're ever going to see it.

150. AG/149:37:01

BRAND: Just one question about the Adriatic that's going to come up here later on this visual obs. Understand which side of the Adriatic and both north and south and east and west way.

CAPCOM: Okay. The word that we're getting, it's on the eastern edge of the Adriatic and, basically, it's the whole eastern edge along Italy there.

BRAND: Eastern edge is not mentioned.

CAPCOM: I'm sorry. Yes, on the opposite side along Yugoslavia, across through there.

SLAYTON: What, specifically, are we looking for?

CAPCOM: That's just an edge of the sea that is considered a high potential for sea-farming.

SLAYTON: I see.

151. AG/149:39:07+

SLAYTON: Okay. And the Earth obs guys may be interested in knowing that we've just seen some icebergs here in the Labrador Current north of Newfoundland.

CAPCOM: I copied about seeing some icebergs and I didn't get the rest of it.

SLAYTON: Yeah. They're in what we think is the Labrador Current, north of Newfoundland. Whether they're bergs or ice cakes, I guess we'd be hard put to say, but they're very visible at least from this altitude.

152. AG/149:39:56+

SLAYTON: Crip, I forgot to tell you that we did not see the oil slicks you talked about, east of Key West. I think we're too far north for one thing; and secondly, there's a cloud cover all over the west coast of Florida and pretty much over the state.

CAPCOM: Okay, I was afraid that was too much of an oblique angle for you to get a shot at it. We thought we'd take a look at it anyhow. It was reported to be a pretty good size.

153. AG/149:42:00+

SLAYTON: You might also pass on to Farouk that we have not seen any red tide west of Florida because of cloud cover, and the same up in the New England area. Cape Cod was clear and we got some good pictures there, but everything north of that, from our angle, was cloud covered and so we've seen nothing in those other sites.

CAPCOM: Copy. Too bad.

SLAYTON: We should have some beautiful coverage of Cape Cod, however.

154. AG/149:43:58

SLAYTON: And also for the Earth obs guys, the North Atlantic is also mostly cloud covered. We see a lot of interesting cloud features and practically nine different current and eddy patterns, but we just didn't want to waste film on that. We have not seen any oil slicks. Lots of airplane contrails, however.

STAFFORD: This Earth obs is nearly a two-man job, I'll clue you.

155. AG/149:48:08+

SLAYTON: I say, if you're still reading, we just went down the Adriatic coast there, and getting into problems. One, what we can see is cloud covered and we can't see very well on account of the oblique angle. It's clear, but it's such an oblique angle we weren't able to tell anything.

156. AG/149:53:21

SLAYTON: Okay, we just passed site 9P [bioluminescense] and unfortunately, I'm afraid the old Greek gods are getting to us today on the Earth obs, Crip. I'm supposed to be over the Red Sea, which I'm sure we are, looking for bioluminescence. But unfortunately, what wasn't factored in here is that we're still in sunglint and I got the sunshine nice and bright right in the window. I'll hang in here until it sets and see if I can see anything, but I'm not optimistic.

157. AG/149:54:12

SLAYTON: Okay, Crip. Wherever we are, I've got a series of very bright lights down here. A pair to the right, a pair directly under the nose, and a set of three ahead of me. Looks like they're under a bit of cloud, but they're superbright. Must be gas fires, maybe.

CAPCOM: Probably. You're coming just about over the Suez area at this time.

SLAYTON: I see. And it's clear off to the left, and we can see forest fires off there. But these probably are gas fires.

158. AG/150:15:07

BRAND: Be nice if you'd remind us, sometime in the future, when we're to come over the Adriatic area again in the daytime. We might have a little better viewing condition.

CAPCOM: Okay. We'll look ahead in your flight plan there and see if we can pick out a good one for you, Vance.

159. DT/151:00:39+

STAFFORD: We're going across the Midwest.

BRAND: We've gone too far.

STAFFORD: We're on the Midwest . . . interstate highway. See that interstate highway right down below?

BRAND: It may even be Oklahoma.

STAFFORD: Yeah, that's Oklahoma City.

BRAND: I think it is. See that's the lake . . . . It looks like Oklahoma City. I think it is. [laughter]

### REVOLUTION 92

160. AG/151:21:09+

SLAYTON: Hey, Crip, I wonder if you could have your Earth obs guys do me a favor?

CAPCOM: Try it. Go ahead.

SLAYTON: Next time we got a pass through the middle of Wisconsin, then give me a little bit of warning. We came over there yesterday. I was evaluating the high power scope that messed up that day. I saw it in time, but sitting there with a 300-millimeter lens, so I didn't get much of it.

CAPCOM: It looked like we just had a pass over there this last rev around. We'll try to look at that for tomorrow and warn you.

SLAYTON: Yeah. We got some pictures with a 300, but that's kind of a lousy lens for the kind of photography we're trying to take.

### REVOLUTION 97

161. AG/159:15:52+

CAPCOM: One thing that's kind of interesting —that you guys might have an opportunity to look down tomorrow when you're in the right place and see—around Key West, an unbelievable oil slick, a hundred miles long [161 km] and up to 15 miles wide [24 km], was reported today in the Atlantic Ocean off the lower Florida Keys. The origin of the mass was not known. After incoming pilots reported sighting the huge oil patches in the water off the lower Keys, the Coast Guard sent up planes to investigate. They found the slick stretched from Marathon in the middle Keys to the Tortugas Islands about 65 miles [105 km] west of here, a distance of about 100 miles [161 km]. A Coast Guard spokesman said the slick was formed of an estimated 40,000 to 60,000 gallons of what appeared to be crude oil.

162. AG/159:18:21

SLAYTON: Dick, I was just going to comment on that oil slick. We did have one pass where we might have had an opportunity to see it, but that whole area was cloud covered and at quite an oblique to us. If we get a better position tomorrow, you might give us a little lead time and maybe some pointing directions.

163. AG/159:41:55+

BRAND: Just a kind of a little item for the visual observations people, in particular oceanographic. We've talked a lot with them about gyres and eddies and that sort of thing. And something that I saw yesterday that I didn't think to report until just now, although I did report on tape, I think, was the fact that just south of Hawaii, there was a line of circles, you might say, running east to west. And it looked like a line of circles—like a chain, you might say. And if you looked at one of those, and you could see them only because of the clouds, and it just made us wonder if maybe that was perhaps the boundary of a current.

CAPCOM: Okay, Vance. I copied that, and we'll pass it to those guys and see what they think.

BRAND: Must have been 100 miles long [161 km], or maybe 200 [322 km].

### REVOLUTION 104

164. Onboard Recording

STAFFORD: This Earth obs pass will be for rev 103, 104; targets 7A [Humboldt Current], D [Peruvian Desert], and F [Orinoco River Delta]. Okay. Approaching target 7A.

BRAND: I can see the coast. I can see the coastline and I can see that little hook a little bit to the left.

STAFFORD: Can you? Good.

BRAND: I think. At least I can see something looks kind of like it.

SLAYTON: I think the clouds get in right up to the edge.

STAFFORD: There's the Peruvian Desert. There's the Peruvian Desert and there's dunes in it. That's what I got to shoot, too. In fact, we got crescents and some linear dunes right there.

165. Onboard Recording

STAFFORD: Okay, can we see the hook on the coastline by Nazca? I think I see something there. I'm going to shoot it. Triangle, right? Straight line. Going so darn fast. Okay, there's crescent dunes and linear dunes. The first break we've had on any of those. Right?

SLAYTON: Yeah, . . . clouds here. I'm surprised it's not more snow.

BRAND: I couldn't see it there.

STAFFORD: I saw one thing that might have been. I shot a picture of it.

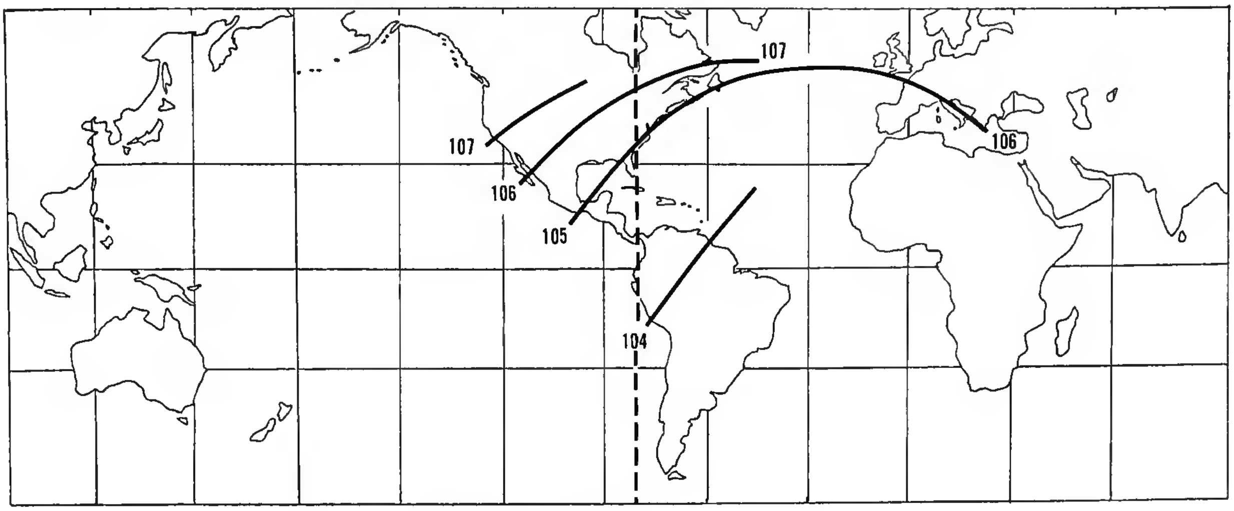
166. Onboard Recording

STAFFORD: The Humboldt Current, I got a straight line on the clouds that looked like the clouds were shifting, so I took a picture of the clouds offshore.

167. Onboard Recording

STAFFORD: I got the Peruvian Desert in 7D.

168. Onboard Recording




Revolutions 104, 105/106, 106/107, and 107

SLAYTON: That's the headwaters of the Amazon there.

STAFFORD: I'll just shoot one here. Look at that, right over there. A tropical rain forest.

BRAND: Kind of like around Houston I guess. Real flat and . . . .

STAFFORD: We shot quite a few sequences of the Amazon and tributaries running into the Amazon.

169. Onboard Recording

STAFFORD: Now coming up to cloud cover as we approach the eastern coast. I'd like to get the Orinoco Delta.

170. AG/170:04:35+

BRAND: Just passing over the Orinoco River Delta.

CAPCOM: I'm glad you pronounced that. I looked at it a while ago, and didn't want to try.

BRAND: Oh, I'm not positive. Farouk's the final judge, I guess.

171. Onboard Recording

STAFFORD: Up to 17 exposures on CX10. Targets 7A [Humboldt Current], D [Peruvian Desert], Amazon tributaries, and E [Orinoco River Delta].

172. Onboard Recording

STAFFORD: What was the number on the Nikon?

SLAYTON: 44.

STAFFORD: 44 on the Nikon. And that was CI—

SLAYTON: CI20.

STAFFORD: CI20 on the Nikon.

173. AG/170:08:06

STAFFORD: Crip, I marked the spot at 10—170:06:06 is when the muddy water from the Orinoco Delta suddenly stops; you got the blue water of the Atlantic, it goes out this far, over.

CAPCOM: Copy that 170:06:06.

STAFFORD: You can just give that to Farouk and it's on a trajectory, where the mud comes out this far into the Atlantic.

CAPCOM: That stretches out a pretty good distance across there, then?

STAFFORD: Roger.

### REVOLUTION 105

174. AG/171:45:13

CAPCOM: And a couple items for both Vance and Deke. I'm standing by with items for crossing the Adriatic, that sea-farming area we talked about a little bit yesterday. And, also, for Deke, I'm going to have a time for the crossing of Wisconsin. It'll probably be easier for me just to call those a little bit ahead of time—give you 10 or 15 minutes warning about it. Okay. We should be crossing the Adriatic at about 173:26. Not sure of the attitude; the viewing is going to be much better than it was yesterday, though. For Deke, should be going across Wisconsin at about 174:40, somewhere on that order—41.

175. AG/171:46:35+

CAPCOM: Incidentally, talking about the DAC film for entry, we've currently got CX05, which should be in F–2, scheduled for entry. We're assuming that's still available.

BRAND: Okay, we'll have to get back with you on that, Crip. Right now, Tom's taking an inventory of the DAC film.

176. AG/171:49:13+

CAPCOM: Another little item I'm going to be coming to you a little bit later is that we got word that the red tide has been spotted off the East Coast there, and I'm going to give you a time and camera and so forth a little bit later to be picking that up. Incidentally, Deke, on our upcoming pass across the States, we are going to have an opportunity to look at the red tide. And I was going to get you some information about that whenever it's convenient for you to copy it.

SLAYTON: Okay. Stand by for it.

CAPCOM: What might be convenient for you, Deke, is if you can just get out your Earth Obs Book [Appendix 3] on target 5 Foxtrot, and I can just relate it to you on there. To describe to you where the ship spotted it if you're looking at 5 Foxtrot, right above where we've got the words "Boothbay" written in, you can see there's a river that looks like it's flowing south there that comes out. Well, it was right at the mouth of that river that the red tide was spotted. And our recommendation on the camera is—well, for the window, it should be visible out of CM–3. Want you to use the silver camera, of course. And use 50, with an f-stop of 9½ and a speed of 1/500. Frame intervals should be about 6 seconds—every 6. And we should be passing over that, if you want to note it, at about 173:09 to 13. And we can give you a call just before that if you'd like a reminder.

SLAYTON: Okay. 173:09. And you want to shoot a mapping strip through there, essentially, huh?

CAPCOM: Negative. You can go ahead and just use it and take a shot about every 6 seconds or as you see fit.

177. AG/173:06:22+

STAFFORD: Are we near Houston, right now? Over.

CAPCOM: Well, you just crossed over into the Gulf of Mexico, coming across the coast of Mexico. Houston and the Texas coast should be coming up pretty shortly.

178. AG/173:06:22+

SLAYTON: Hey, Crip. Give me a reconfirmation on the window for the New England area. Looks to me like it's going to end up being window 5. We don't see anything out of anywhere else to speak of.

CAPCOM: Okay. The one we'd been given earlier was out of 3, and we'll reverify that for you, Deke.

SLAYTON: Maybe by the time we get up there, there, that'll be right. It's not right from here, anyway.

### REVOLUTION 105/106

179. AG/173:09:55+

CAPCOM: Regarding Deke's question on the red tide, we anticipate that's going to come visible first in window 5, come across window 3, and then through 1. And we thought 3 would be the best total viewing.

180. AG/173:09:55+

SLAYTON: Okay. We're over Cape Cod right now. I think we got her.

CAPCOM: Very good. Outstanding.

181. AG/173:14:07

SLAYTON: We're having trouble telling sunglint from red tide, however, in this area.

CAPCOM: Appreciate the problem.

182. AG/173:14:07+

SLAYTON: We got some pictures up through that area and we see some water that's obviously sedimented up pretty good. And we're trying to differentiate if it's really red tide or red sediment. It's difficult for me to evaluate, frankly.

CAPCOM: Very good. If you got the photos, we should be able to make a determination once we get them back. Thank you.

SLAYTON: Rog. And the other complicating factor is that we got sunglint in here, which kind of drowns them out.

183. Onboard Recording

SLAYTON: Per ground request we just shot a few frames here up through the New England area ending on magazine CX10 with frame 35. Trying to pick up the red tide around Boothbay, and we did see a lot of red coloration in the water there. However, some of it looked to me like it was coming out of the river mouths and is really river sediment. And I hesitate to term it red tide. We shot some pictures; maybe we can psych it out later. We also shot a few along the Connecticut coast, and the Long Island Sound area, because based on the time, we thought we were there. Our timing was off about 3 minutes. And three or four "gee whiz" ones earlier over the Gulf of Mexico around the north Gulf Coast arc.

### REVOLUTION 106

184. Onboard Recording

BRAND: Okay, tape recorder, just took a bunch of pictures of the Adriatic. Basically I started as soon as I got out of a cloud cover which is up near Venice. And took about three stereos around Ravenna.

STAFFORD: Okay at 174:26 about 30, there's a tremendous [current?]

BRAND: . . . starting about two-thirds of the way down the boot, almost to the heel. Much of the stereo is over the water, and finally the last photo on CX10 in this series is 45.

185. AG/174:36:04+

CAPCOM: And might remind Deke again that this is his pass over Wisconsin, coming up at about 41 after the hour.

186. AG/174:36:04+

STAFFORD: Roger. And we're right over the Rio Grande River now. Yeah, I wish the girls could see this site up here that we're seeing, Crip. We're right over El Paso. You can look down and see Biggs Air Force Base and the International Airport. Okay, Crip. Looks like we're approaching Amarillo now.

187. AG/174:46:10+

SLAYTON: Super fast up through the Midwest there.

CAPCOM: Came over pretty fast?

SLAYTON: Kansas City, Madison, Milwaukee, Chicago, Detroit, and the whole business.

CAPCOM: Rog. Was it pretty clear?

SLAYTON: Could see the cows down there on the farm.

188. AG/174:47:44+

BRAND: Incidentally, we did get to see the Adriatic. Got quite a few pictures of the lower half of Italy, from the boot up to—oh, I'd say about halfway up. But there was a cloud cover over Venice.

### REVOLUTION 106/107

189. AG/174:50:05

STAFFORD: Hey, Crip, we just had a big iceberg out here in the North Atlantic, and it has a trailing wake behind it.

CAPCOM: Copied. A large iceberg with a trailing wake, is that correct?

STAFFORD: You see, it's like a, you know, like a bow wave on it.

190. AG/174:50:33

STAFFORD: I said, I wish they could enjoy this view we're having up here today, looking down at the Earth.

CAPCOM: Rog. I imagine that's quite a sight.

BRAND: Even seen Chicago a couple of times up here.

191. AG/174:51:43

CAPCOM: Incidentally, the flight plan calls for me to give you an update for the mapping pass you got on—mapping pass number 10—you've got on the next rev. And that time is nominal. We do not need to change that.

192. AG/174:51:43+

BRAND: Okay. Before we go into that, Crip, we haven't seen any icebergs in the southern ocean. Been very hard to see the Antarctic area due to cloud cover. Haven't seen any stray icebergs down there. This is the first iceberg we've seen. Might just mention that, up here north, it was traveling through what looked like a fog layer—and leaving a wake. Or else it was stationary, and the wind was blowing the fog a little bit and leaving a wake. No evidence of rotation, which is one of the questions they've asked about icebergs in general.

CAPCOM: Okay. Sure that we'd be happy to get that data.

STAFFORD: It's a beautiful view the way the whole ground is just kind of grayish down below, just like a haze or fog.

REVOLUTION 107

193. AG/175:16:39

STAFFORD: You said that the mapping pass M10 [Northern California] was nominal for times?

CAPCOM: That's affirmative. Your time on M10 is nominal.

194. AG/175:49:08

CAPCOM: Apollo, Houston. Deke, regarding the camera conflict you mentioned, there is one—if we look in the pad for that—or in the time line in the book. We want to use, in this case, the silver camera for mapping, and we want to delete the targets that we've got called out for vis obs—at 2 Charlie [California Current] and 2 Delta [Great Salt Lake]. We do not want to do both. So we want to use the silver camera for mapping, and we go ahead and we can use the black one for the ETE.

SLAYTON: I think we could do both, Crip, if they really want it. We'll try to work that in.

CAPCOM: And, in case it wasn't clear on my last call regarding those vis obs sites, 2 Charlie and 2 Delta, those are visual only, and we don't have to use the camera. So that would relieve any camera conflict that we had. Silver camera for mapping, and the black one would be free for use with the ETE.

195. DT/176:07:39+

BRAND: There yet?

STAFFORD: Yeah. Here's the California coast. There's San Francisco [and] the Golden Gate.

196. DT/176:08:19

BRAND: And the color I can get from the Pacific Ocean is 47–B just offshore from San Francisco. No evidence of current boundaries yet. Little bit of cloud cover up to 2 miles [3 km] offshore.

197. DT/176:10:34

BRAND: Okay; the Bingham copper mine—looks to me like there's definitely an area of gray over there, or has a grayish cast. Now it could have been a false fault. All I can say is the area around the Bingham copper mine was once quite pronounced and very gray.

REVOLUTION 110

198: AG/179:43:30+

CAPCOM: One note from Farouk and that has to do with film usage. If you want us to get into the act on planning film usage, if you would let us—sometime, anytime you have the chance—if you'd go through the unused and partially used mags for both the silver and black cameras and tell us how many frames are available per mag, we'll be glad to help you. If you think you've got a handle on it, don't worry about that.

SLAYTON: As far as the film, pretty good inventory on that, but I think we know where we're at pretty much on that subject. So, thank you.

199. AG/180:24:30+

SLAYTON: I believe we've got everybody in position here for a good old Earth obs.

REVOLUTION 112

200. AG/183:23:15

CAPCOM: You're on an ascending pass and looking at our big 10 by 20 [screen at Mission Control Center], looks like you're just about very shortly going to be crossing over Thailand, North Vietnam, and China. You're going to cross the Korean Peninsula here in a few minutes and then top out up there by the Aleutians.

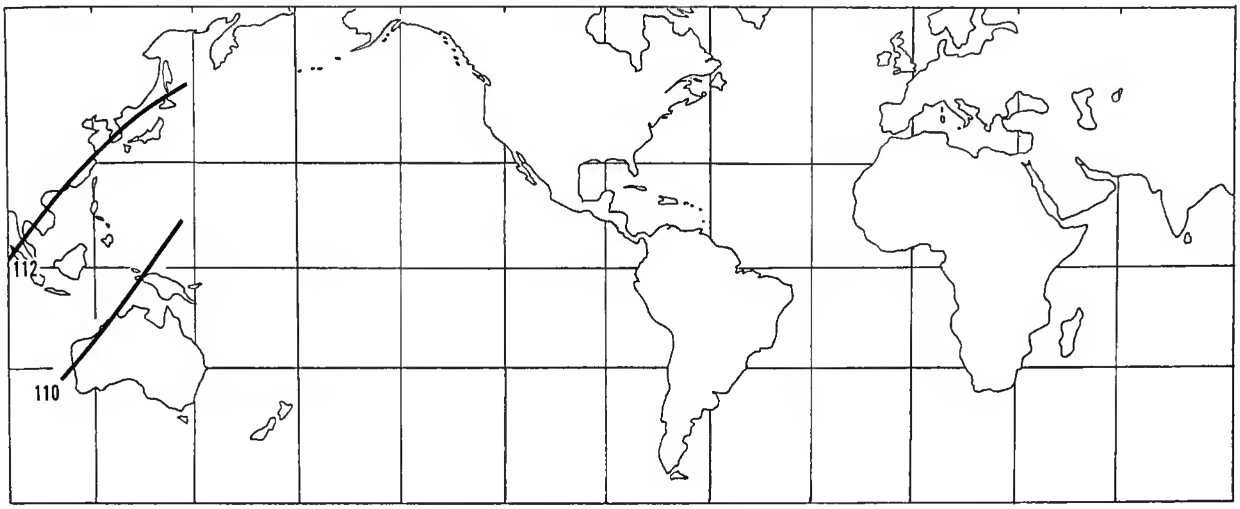
STAFFORD: Okay, Deke just got some good targets-of-opportunity for Farouk there.

201. Onboard Recording

SLAYTON: We were crossing somewhere in the Southeast Asia area right up apparently towards China, Korea, and out across the Pacific, and saw some beautiful outstanding waves off an island there, which we shot a few pictures of.

202. Onboard Recording

SLAYTON: And we came right up across eastern China. Shot a couple there. And what I think is the mouth of the Yangtze. And




Revolutions 110 and 112

the sediment plumes going way out into the sea and very visible, very pretty. And I think they showed pretty much how the current flows—rather, the coastal area or the area offshore. And that was on [film] magazine CX10, and we ended up on frame 69.

### Revolution 119

203. AG/194:04:07+

CAPCOM: Well, did that match the strawberry you'd had earlier in the mission?

STAFFORD: Yeah, that makes a beautiful view over the window here.

CAPCOM: Rog. Helps out the vis obs stuff, too.

STAFFORD: Right. Like looking at the world through rose-colored glasses.

CAPCOM: You mentioned the color or the hues on the window there; we're going to ask you to try a little bit more of the red tide when we come over it today. I was going to give you an update on that a little bit later; think we might be able to get some photos of that area again.

STAFFORD: Okay. They all look red today.

### Revolution 120

204. AG/196:01:52

CAPCOM: The next time we come across the States, we are going to be back in a position to get the red tide, basically same area we talked about yesterday. And all we're going to do is just ask you to photograph a strip starting by Cape Cod going up the east coast, and if you can go ahead and do that up to about Nova Scotia, well, that's all we're after. And I can talk to you about it when we get there.

SLAYTON: Sure. Hey, that's easy; we'll do her. I think that'll need a different lens.

### Revolution 120/121

205. AG/196:50:20

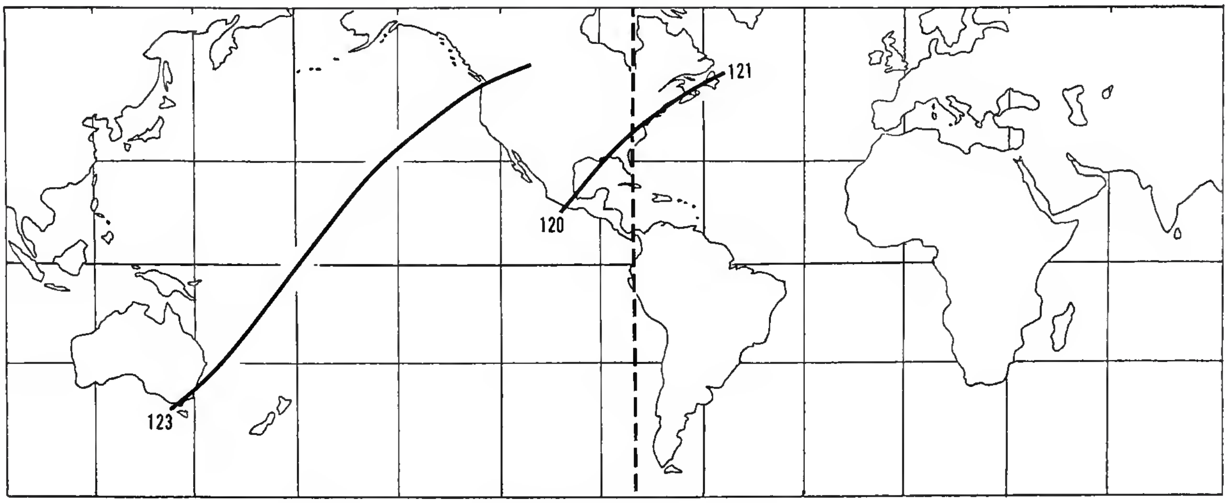
CAPCOM: I had talked to Deke briefly awhile ago about coming up on the red tide, which we're going to do here about this time. And it's kind of close. They don't know whether you guys are going to be set up for it or try to get the photos or not. Whatever y'all wanted via data window 3.

SLAYTON: Okay, how much time we got?

CAPCOM: Oh, you're about 3 minutes away from an initiation of it. That's pretty quick.

STAFFORD: Okay, use the 50 mm lens? And if they give me a couple of quick settings, we'll get a new mag and try it.

CAPCOM: Recommend a 50 mm lens and f-stop of 6.7, speed 1/250. And recommend the orange filter, if you got time to get it on.




Revolutions 120/121 and 123

206. AG/196:51:39
STAFFORD: Okay, ready to go, Crip.
CAPCOM: You should be coming up on it shortly here. If you could just photograph coming up along Cape Cod here all the way to the bay there, coming in on Nova Scotia.

207. AG/196:51:39+
STAFFORD: Roger, Crip. Check your windows again. I think window 3's looking at the sun right now.
SLAYTON: Yeah, the only place I can see the ground at all is out of window 5 right this minute.
CAPCOM: Okay, we had thought window 3 was going to be down. Whatever one you think looks best.

208. AG/196:53:00
STAFFORD: Crip, what time do you want us to start the sequence?
CAPCOM: You can go ahead and start it up on the upcoming 52 [spacecraft maneuver]. I told you orange filter awhile ago; that filter's only applicable if we've got an IF mag in.

209. AG/196:53:53+
SLAYTON: Yeah, we read, Crip. I'll tell you the problem here; can see it out the bottom of window 3 coming right across Cape Cod, right up the coast there through Boston and the whole works. The problem is that we're so close on top of it that there's no way to get a camera in the window to shoot it.
CAPCOM: Rog. Understand.

210. AG/196:55:27
SLAYTON: And we're already by it. As far as visual's concerned, I didn't see anything any different there than yesterday. There's a lot of sediment all along the coastline there. And, I'd sure hesitate to call anything red tide in there that I've seen. It looks to me like it's all sediment coming out of those rivers because it's the same color as the flow out of the river.
CAPCOM: Okay, that's a good comment. Some of the support ships that we've got out there that've been sampling have been reporting a high chlorophyll content in the water and they've been suspecting that's coming out due to heavy rains they've had up there.

211. Onboard Recording
SLAYTON: We had a realtime readout. This is the rev before we started suiting up for DM jet up over the New England red tide area. But, unfortunately, our flight path was right over the top of it, and window 5 was the only window you could see it through, and only by leaning way over and looking down at a very slant angle. Unable to get any photography of it. Did shoot a couple of long-range shots out of window 4. So we may have a little something there.

### Revolution 123

212. AG/200:03:50

Capcom: Farouk was real impressed by some of the TV stuff that you got out of the window while we were doing docking scenes earlier. And we don't know if it's going to be possible—depends on how long it takes to get out of your suits, but you've got a vis obs pass upcoming at about 200:50–200:52, and if we can, we'd like to get the TV set . . . . And I could read that to you, or however you want to do it. And so we can have TV out the window when you're doing it. And that is kind of your option, whether you think it's possible.

Slayton: Okay. We'll try her. Tell you, I think we've got all of our cameras stowed for entry right now, as a matter of fact . . . . When we cleaned out the DM this morning, we went through that whole exercise. We might be able to dig something out again in time. We'll work on it.

213. AG/200:25:54+

Capcom: Do you think you've got time to try to find a TV camera to put in the window?

Slayton: Well, I'm going to try to take time to do it. If you can just tell me what you want, I'll do the best I can on it.

Capcom: Okay. We're recommending that if you can find your cue card there. . . . The only modification to that camera does have to be in MASTER, not SLAVE as called for. We're also going to have to get the INTERLEAVER POWER ON, down on 400, for the VTR. And we'll have to take the CM 2 TV STATION POWER to ON also.

Slayton: Okay, got that.

214. AG/200:26:55+

Capcom: One item I might also tell you, since this target down there is of the ANZUS Eddy. We've had a ship spot it recently, and it's reported that there is a large cumulus cloud just about over the center of the eddy, and it's slightly southwest of where it's indicated in your book there.

215. AG/200:33:38+

Brand: Okay, Crip. Looks like we're going to get the TV camera set up and I think we're proceeding very well.

216. AG/200:33:38+

Capcom: Great. If you do, we're going to also not only look at that eddy area, but when you come across Hawaii, we're going to be looking at that one. I was going to give you some words at Orroral, Vance, reregarding eddies. We've had a lot of them reported southwest of Hawaii, and we were going to get you to look at them and try to give us a size, number, and extent, and that kind of stuff.

217. Onboard Recording

Slayton: We are getting prepared to come up on site 11D, the ANZUS Eddy. We have [film] magazine CX09 on at the present time. That's the same magazine we shot that last stuff with over New England. The settings are per flight plan. And we have the TV camera running in window 2. Okay; we are coming up on ANZUS Eddy here. We're coming down the coastline of Australia, according to the flight plan. Unfortunately, we're getting up where, I think, Sydney is, and it's totally cloud covered. I'm not seeing nothing, except clouds.

218. AG/200:53:09+

Slayton: Okay, Crip. We're over where we think we ought to be, about Sydney, and we're in solid cloud cover here right now.

Capcom: Yeah. Kind of hard to pick a cumulus cloud out amongst all the clouds then, huh?

219. AG/200:54:54

Capcom: Like to give you this quick blurb regarding the eddies I mentioned earlier south of Hawaii. It's known to have a series of eddies southwest of the islands due to the current flow being broken by the islands. And the size, and the number, and the extent of them are unknown. We'd like you to attempt to observe the orientation, the sizes, and how many you can see. You should have a chance to look at them on this upcoming pass across there at about 201:09. And we think it should be visible out of window 1.

220. AG/200:55:28

Capcom: We're also going to be, again, not beaming down this TV to Hawaii when we come across there. So we can look at it later.

We are 1 minute from LOS, and our next station contact will be at Hawaii in 14 minutes.

221. Onboarding Recording

STAFFORD: I got a huge eddy over here on the right.

SLAYTON: Did you just shoot something out there?

STAFFORD: Yeah, I got a . . .

SLAYTON: Shoot it with that camera. Shoot it with this one if you can. I don't see nothing from here, Tom. Go ahead and shoot it, the same way, about three of them if you see something.

BRAND: Here's an eddy coming up straight ahead.

SLAYTON: Yeah, it is. But I'm not going to be able to get it out this window. Get a couple of quickies, Tom, then pass yours back to me. We may be over one here right now. I think it might be! Let me have the camera quick. I think we might be over one here. It's a cloud pattern.

STAFFORD: I think you're too far off.

SLAYTON: Yeah, okay. We shot a few frames there up through 62. And I think the ANZUS Eddy is all cloud covered. But Tom shot a ring out the right window, and I shot a cloud pattern that could have defined an eddy, since they said it was a cloud-covered eddy. It was right directly in our flight path. And I doubt if it was the ANZUS Eddy.

222. Onboard Recording

SLAYTON: We just shot a frame right over New Caledonia. It's a beautiful island with coral reefs all around it. We're coming up on the New Hebrides.

223. Onboard Recording

BRAND: Believe I had 139 of an eddy on the roll CX19.

SLAYTON: Okay. We just got a picture of a pretty good eddy at 201:05 and 45 seconds, approximately. Magazine CX09, camera frame 65. I think I ran out of film on this.

224. AG/201:08:55+

SLAYTON: We're cruising along here looking for eddies, and we shot a few pictures of some of the same kind we've been seeing right along.

225. AG/201:09:15

CAPCOM: Roger. Is the weather up there any better than it was down around Australia?

SLAYTON: Yeah, it's pretty clear over most of this area, and scattered clouds that just outline the eddies. In fact, we've got a couple of super ones coming up on our right, right now at 201:07:25.

226. AG/201:09:15+

SLAYTON: Are you guys getting TV of this, incidentally, Dick?

CAPCOM: We're not getting it live, Deke. I think we are dumping it down to the Hawaii tracking station, and the station reports that they are receiving it.

227. AG/201:10:53

BRAND: This eddy Deke just called out's about 50 kilometers across.

228. AG/201:10:53+

SLAYTON: Okay; a question for Farouk on the eddies. Do they want stereos of that? We're kind of getting a little short on film, but if they need stereos fine, we'll shoot it up. But if the stereo doesn't do much for them, we might as well save the film.

CAPCOM: Let me check real quick. Hang on.

229. Onboard Recording

BRAND: There's one coming up in the center. I think there's one over there. There's another one right beside it. This side.

SLAYTON: Yeah. Actually, it's kind of a pair. There's three of them the way I see it. There's two of them in the center and one off to the left a little bit. I'm not going to get stereos on this thing. I don't think it's worth it.

BRAND: Let me try these with the Hasselblad, Tom. I wish you could get them out your window.

STAFFORD: I'm going to shoot them.

BRAND: Okay, tape recorder. On the black camera, roll CX19 was taken.

230. AG/201:12:45

CAPCOM: Deke, Houston. We did talk to Farouk in the backroom, and he says he would like some stereo photography of the eddies.

SLAYTON: Okay. I've got a million eddies out here.

231. Onboard Recording

BRAND: Taking three stereo pictures near

Hawaii. Three pictures—rather, one stereo of eddies near Hawaii. 140 is the last frame.

232. AG/201:12:45+

CAPCOM: He gives the advice to pick out one good-looking site and get good stereo of that and not try to document the whole area, Deke.

SLAYTON: Okay.

233. Onboard Recording

SLAYTON: Now, here's the edge of a current, goddam it. Are there any eddies?

BRAND: I'll get a stereo here.

SLAYTON: Yeah. Get a stereo of the edge of this current. You can get it out your side.

BRAND: And those are—What are they called?

STAFFORD: G-Y-R-E.

SLAYTON: Gyres. Gyres.

STAFFORD: We're about out of film. You got any film there?

SLAYTON: He says he wants to home in on the specific ones without just shooting a bunch of them, so I guess you wait. See that one, Vance, right under your nose. Shoot that one. Did you get it? It's a small one with a [cloud] up in the middle. It's a funny looking thing.

BRAND: This sure as heck is the edge of the current.

SLAYTON: Yeah, it is. And it looks to us, for Farouk's information, like we're almost running parallel with a large ocean current here. The cloud banners on both sides and the clouds within it look a good deal like a Gulf Stream type current.

BRAND: And it's running east to west.

SLAYTON: I'll tell you, Tom, we're about out on this mag, and Vance has got an Earth obs coming up here in an hour or so.

BRAND: Okay, tape recorder. On CX19, I shot three more. It comes up to 143. It was a stereo group of three—of what appeared to me to be an ocean current running east to west, outlined by clouds upon the edge of the current. Located slightly south and probably 200 miles [322 km] east of Hawaii.

234. Onboard Recording

SLAYTON: Okay. I ended up on frame 73 here on mag CX09 after going through that Pacific eddy pass. We're about out. I'll shoot a couple more just to finish the magazine.

235. Onboard Recording

SLAYTON: Again, just for the record, we've been going to the color wheel to find something that matches the Pacific Ocean, which seems to be very homogeneous. And the lighting is never right in the cockpit to match what's outside. So you got to look out there and come back in. So maybe that's supposed to look, I think, like a 47–B. Vance likes a 43 a little better.

BRAND: I didn't look closely.

SLAYTON: Okay. Well, I wouldn't argue with you too much about 43 either, but 47 looks a little closer to me. You can look at that water out there, and you can see some of those colors. Well, they all look the same, to me. Let's pick the color that looks the closest to it. It may be the altitude, I don't know. It's awfully tough to get. I'd better pull the wheel back in and look at it. Wouldn't you, Tom?

STAFFORD: It's darker at times. Like over there, it's darker to me than over here.

SLAYTON: Is that right?

STAFFORD: Yeah. Like I get about a 38 here.

SLAYTON: Oh, you do, huh?

STAFFORD: Yeah. And over here I would get more towards a 35 or 36. What do you get?

SLAYTON: I get me a 37. I tried to hold it like that, and I didn't get nothing. I've got to look out the window and then come back in.

BRAND: It looks like 37 here.

STAFFORD: 48 is closer here, but over here 47 is closer.

236. Onboard Recording

STAFFORD: Let's get this cockpit cleaned up here.

SLAYTON: Okay. Let me get this magazine shot.

BRAND: Yeah. We've got to reconfigure. We've got a lot to do in the next hour or so.

STAFFORD: Okay. We ended the pass on CX09. There may be a couple of frames left.

237. Onboard Recording

BRAND: We just ended up running over Seattle. And it was clear as a bell. Totally unexpectedly, since we decided we were supposed to stop looking at the ground and get on with eating and so forth. And I hope we got a few good shots of Puget Sound and the city area there, at the right settings. I'm not sure we have. But it was on a new magazine. We just switched over to CX07, and we're reading frame 9 on it right now. So the first nine frames of that are of that area. We shot on into the mountains just to get a strip.

238. AG/201:34:46

STAFFORD: Yeah, hey, if this TV comes out—I was wondering, you know, we used so much film that you can budget to shoot. As far as what it looks like, you know, from space, looking down on the Earth— and most of the time, like Skylab, those guys very seldom had, you know, a local horizontal attitude. But if you put on a tape recorder, you got some good passes coming up, like the United States. Why don't we put it on TV, on the VTR, then you can dump it? I think it'd be pretty fantastic what you see. Over. Just something for you to think about.

239. AG/201:35:23

SLAYTON: Yeah, you know, just as a "for instance," we just came off this Pacific pass and kind of all climbed back in the cockpit, and all of a sudden looked out the window, and man, we're dead center over Seattle and the the most clear day I've ever seen there. And nothing running. The TV was running, but it didn't go anywhere, I don't think. Incidentally, I did scramble and get a camera and got a few shots of that area. But it wasn't planned very well.

240. AG/201:37:06

CAPCOM: Okay. Well, I tell you what. Your next couple of revs are going to pass right over that same general area again. So, as you come across it, you probably can get another chance.

SLAYTON: Yeah, right. We noticed that.

241. AG/201:47:25

CAPCOM: Vance, when you get a chance, if you could get out the Earth Obs Book [Appendix 3] and look at site number 4, I've got a note here I wanted to pass up to you from Farouk about this upcoming Earth obs pass. I've also got a suggestion from Farouk that you ought to take just . . . for this TV out the window, ground TV for the VTR. If you've got a pencil, Deke, I can give you some on/off times for the VTR, which would get a daylight pass starting at Australia, going up to cover the area where the eddies are, and then turn it off over the clouds over the Pacific, and start it again over around Seattle, and then let it run to completion. If you see a better way to run it, or something out the window you'd rather take, anything would be fine with us.

242. AG/201:59:49+

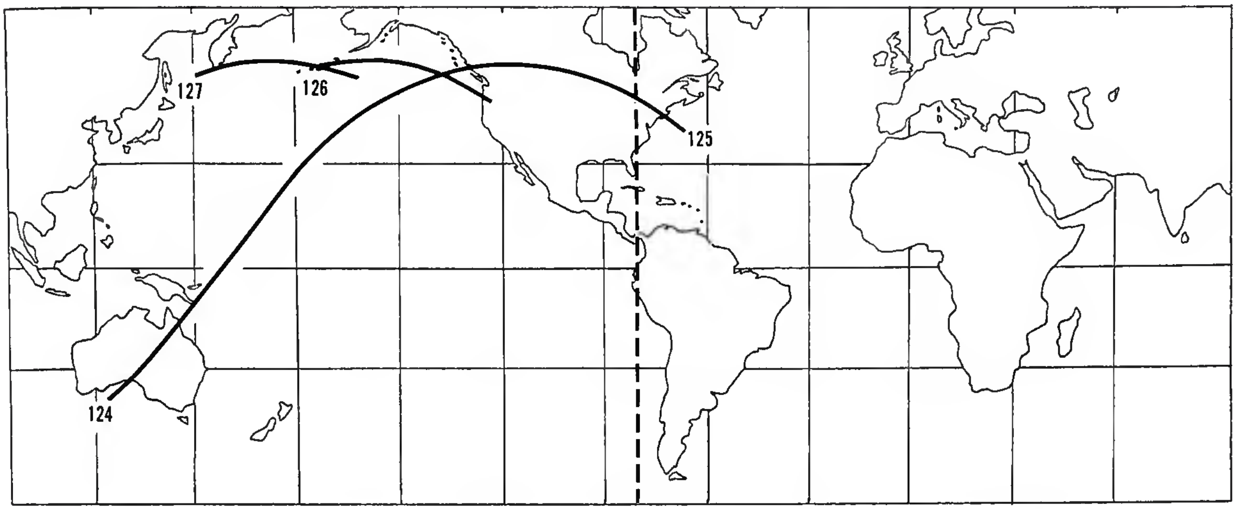
CAPCOM: Okay, Vance. I wanted to pass up a note to you from Farouk, and it might help if you were looking in the Earth Obs Book at the site 4 [snow peaks] page in there. It turns out that we have another candidate site for sea-farming from Captain Cousteau. And it's the body of water north of Puget Sound there. And if you look on that little map, it's generally that body of water to the west of Vancouver. And you'll be passing on rev 124 to the north of it. And when looking at site 4A, you'll be looking right down the Sound there, or right down the body of water looking at site 4A. It's the water that separates Canada from Vancouver Island, and it should be visible from command module window 1 at the same time as site 4A is visible. And if you have a chance, he'd like to get a color-wheel reading of that water and some photos, if you have the film to do it. The reason it's a good site for farming is that the current there runs adjacent to the coastline but does not run through that inland water there. So the water's fairly still, and the texture of it should be fairly smooth. Over.

BRAND: Is that known as the Strait of Georgia?

CAPCOM: I'm not sure it is the Strait of Georgia in that area . . . . Yes. That's affirmative, I'm told, Vance. That body of water there is the Strait of Georgia.

BRAND: Okay, and more or less along the whole length of it, or would you suggest the south end more than the north, or what?

CAPCOM: I think the whole length, because the water generally in there is still and doesn't have a current running through it. I think just about anywhere in there would be good. I think probably your best chance at getting a color-wheel reading, though, might be where you have a little more water down towards the south end. But, at any rate, there




Revolutions 124/125, 126, and 127

won't be much time to look down there; and so, do the best you can.

BRAND: So photos, not necessarily stereo, but more or less to cover the Strait of Georgia series, and a color-wheel reading of the water there.

REVOLUTION 124/125

243. Onboard Recording

BRAND: We shot three shots of Australia and the Simpson Desert area.

STAFFORD: Oh, look at the dunes down there! Did you see them?

BRAND: Yeah. We're on 12 of CX07 after that. And I'm going to get three more shots of dunes in Australia. They're beautiful linear dunes.

STAFFORD: Look at those dunes! Man, those are fantastic.

244. Onboard Recording

SLAYTON: We're on rev 124. You're right up through the middle. You're just about over the Coral Sea and the tip of New Guinea [Zealand].

245. Onboard Recording

BRAND: Hey, look at that stuff coming up on— Let's try and get that.

SLAYTON: Look at that stream kind of coming down. I think I got that the other day. But see it running off to your left there.

246. Onboard Recording

BRAND: Okay. Let's see if we can get those shoals offshore now and the Great Barrier Reef. It's going to take a while to get to it. Okay, tape recorder. We just finished crossing Australia. We crossed the Great Barrier Reef. There's no evidence that sediments along the shore of Australia get out and get between the passages of the Great Barrier Reef. In every case that I've seen sediment, it always seems fairly close into shore. There's nothing from the shore going in between, suspended sediments.

247. Onboard Recording

BRAND: I took one more shot of the central desert after the Simpson Desert. That put me one more. Then I took three stereo pairs of the Great Barrier Reef—three stereo sequences, rather. I ended up on 20, CX07.

248. Onboard Recording

BRAND: I got Wake and an island at 202:29:20. Just general interest to show waterflow around the island. Look at that boundary there, too, near that island.

STAFFORD: Maybe you ought to take one more. See if you can get the whole thing. Yeah, you can get it. Can you get it?

SLAYTON: Yeah, I can get it.

STAFFORD: See that whole thing— how the color of that water changes there?

249. Onboard Recording

STAFFORD: Are you using the black one [camera], Deke?

SLAYTON: No. I can't get anything out here, Tom.

STAFFORD: Why don't you just toss me the black one. I'm getting some great views over here.

SLAYTON: Really? I got a bad window.

STAFFORD: Just slide it over.

SLAYTON: This damn TV blocks this window pretty good.

STAFFORD: That what?

SLAYTON: This TV's got this window blocked so I can't do anything.

250. Onboard Recording

BRAND: Just to let you know, when we go over the Seattle area, we're to get photographs of snow capped peaks, three stereo frames per target. Can you see glaciers and firn lines? Sediments—describe sediments in the waters of Puget Sound. Can you see gyres there? Can you see mountain glaciers and firn lines again? That's just to give you an idea of all the things that are of interest there.

SLAYTON: Okay. We had some pretty good pictures on this last pass over there. You can take a look at it.

BRAND: I've looked at it, and I've decided that if I see sediments, I can't describe them too well. And I've just got to take more pictures in the right light.

251. Onboard Recording

BRAND: Stereo pair of thunderstorms over the mid-Pacific at 202:32:20. CX07, frames 23 and 24.

SLAYTON: I'll give you another time there. 47, I guess it was. That's about 15 minutes.

BRAND: Got another big thunderstorm in the mid-Pacific at 202:33:36. I forgot in what rev it is.

252. Onboard Recording

BRAND: Rev 123–124. Just got an eddy in the Pacific at 202:38:00. In fact, I got it in sunglint. Tried to show you the texture of it. I see a slight textural change in sun[glint], but it's so slight I can't hardly describe it. One other thing I've noticed is out of the gyre I just took a picture of, there were cumulus clouds emanating out of the side and sort of the interior of it. I found that with— I said gyre; I meant eddies, several eddies, several eddies in this area.

253. Onboard Recording

BRAND: Great big storm in the middle of the Pacific here coming up at 202:38:10.

SLAYTON: I missed the storm. I passed a bunch of thundershowers.

BRAND: Look at that swell! Okay. Got the center of a tremendously large thunderstorm. I don't know, it might be 100 kilometers across. I can't even see the extent of it. It's more than that. I got a stereo pair of the center. Okay; counter is now reading 30 on CX10.

254. Onboard Recording

BRAND: Got a picture of an island at 202:41:10. A lot of good sunglint around it. Just an interesting, beautiful island with the sunglint around it. You may be able to see some current pattern . . . . That's [frames] 32 and 33.

255. Onboard Recording

BRAND: Typical, rather linear cloud pattern in the mid-Pacific oriented east and west. I see this quite a bit. Makes you think it might be associated with the water current. It flows east-west. These cloud patterns go for sometimes hundreds of miles.

256. Onboard Recording

SLAYTON: I just shot four pictures, sort of a panorama of a very large hurricane-type-looking structure. It's a real large circular cloud pattern. And that's on magazine CX19 on the black camera, ending at frame 150—about as close as I can read it.

BRAND: Okay. Looks like it might be a "mega-eddy," huh? Deke's picture was taken at 202:48:45 above.

257. Onboard Recording

BRAND: Took a picture at 202:52:45 of the Canadian Rockies. Snowy-area, stereo pair—beautiful. We were looking for glaciers; couldn't see any. We got more Canadian Rockies coming up here. God, aren't they beautiful? Can you see a glacier anywhere?

STAFFORD: I was looking for one, but I didn't.

BRAND: Okay. I see a glacier. I see a glacier.

SLAYTON: I do too, now. There's the firn line. See that?

STAFFORD: You can see the firn line real clear.

BRAND: Yeah. We saw a firn line, and this was about 202:40—I mean, 202:54:00. Over the Canadian Rockies we saw a big glacier. Just came down over a town, a big farming area. Suppose that's Banff?

STAFFORD: No, that's Calgary right there.

BRAND: This area that we shot the glacier of was just west of Calgary. Impressive.

258. AG/203:04:06

SLAYTON: For Farouk's info, we saw a super circulation pattern off the West Coast. Got a kind of panorama. It was so big you couldn't get it into two camera frames. I wouldn't have any idea of how big an area it covers, but it looks like a super big hurricane, except it wasn't all that dense.

BRAND: It was sort of a ring of clouds, I guess you'd say, rather than a hurricane. When we got to Seattle, we were too far north of Seattle to see it. And there were clouds over Canada, but we did pick up some glaciers, see some firn lines on Canadian Rockies—glaciers. And Lake Superior was clouded over completely.

259. Onboard Recording

STAFFORD: I'm all out of film. I'm going to kill this one.

BRAND: Okay; 39 and 40 were a cloud pattern and thunderstorm out over the Atlantic just offshore from New York. Stereo pair. Near sunset.

260. Onboard Recording

SLAYTON: We shot a series of Earth obs stuff along with Vance on the 35 millimeter, magazine CI15, ending with frame 32, I guess it is. Last few frames are a combination of a weather pattern with some thunderstorms. The sunset's shining on them and the Moon's in one corner of the frame.

## REVOLUTION 126

261. AG/204:53:41+

SLAYTON: Dick, if things are quiet down there, I can give you a quick film inventory.

CAPCOM: Okay, Deke. Can you stand by just a second? We're getting ready to change dump modes, and I'm going to drop out. I'll call you when we're back up.

SLAYTON: Okay; here it goes. We got about 320 frames of 35 millimeter left, 140 of 70 for the silver camera, and about 180 for the black over and above our mapping requirement. We have one mapping pass left, which we figure it will take 90 frames. And we only have one mag of 16 left, and that's an interior. We've already talked to you about that one. And that is it.

CAPCOM: Okay. Let me read them back: 320 frames of 35 millimeter left, 140 frames of the silver 70, 180 frames of the black camera over and above the mapping requirements, and one mag of 16 millimeter.

262. DT/205:58:47

STAFFORD: You suspect that's a cyclone?

BRAND: Yeah. I'll bet from real up high it looks like a cyclone . . . . I'll bet it's that same thing we saw earlier. It looks like a possible hurricane . . . . We ought to find out—at this point, 205:56.

STAFFORD: All right, Vance. Take a couple of it—about 100 miles [161 km] across, I think . . . . It's building up on the outer edges. The whole thing narrows— weather satellite in the Pacific.

BRAND: I don't know, it appears to be a typhoon area?

263. AG/206:01:15

STAFFORD: Dick, we saw a huge weather cycle out in the Pacific at a GET of 205 plus 56. It's built up on the edges . . . . It tapers down in the center; it's got a really open center. But it looks— and it's circulating. You can see the whole circulation. It's probably 150 miles [241 km] in diameter. You might want to check it with Farouk and the weather people.

CAPCOM: We got weather up in recovery to show us the satellite picture of the cloud formation that you saw. For your information there's a big low located right in the center of the circulating pattern, and on the eastern edge—the leading edge of the cloud pattern that's close to the western coast of the United States is a cold front. So the cloud characteristics— it just turns out that the cloud characteristics of the weather pattern look like a tropical storm, but, of course, that's not what it is.

BRAND: Okay. Well, I'm glad it isn't. It's just that it would be in kind of an odd place for a tropical storm anyway, I guess.

CAPCOM: Well, we do have a satellite picture of it, and it certainly looks like one, and it covers a tremendous area.

BRAND: Yeah, we were impressed by the spiral arms on it.

### REVOLUTION 127

264. DT/207:34:00+

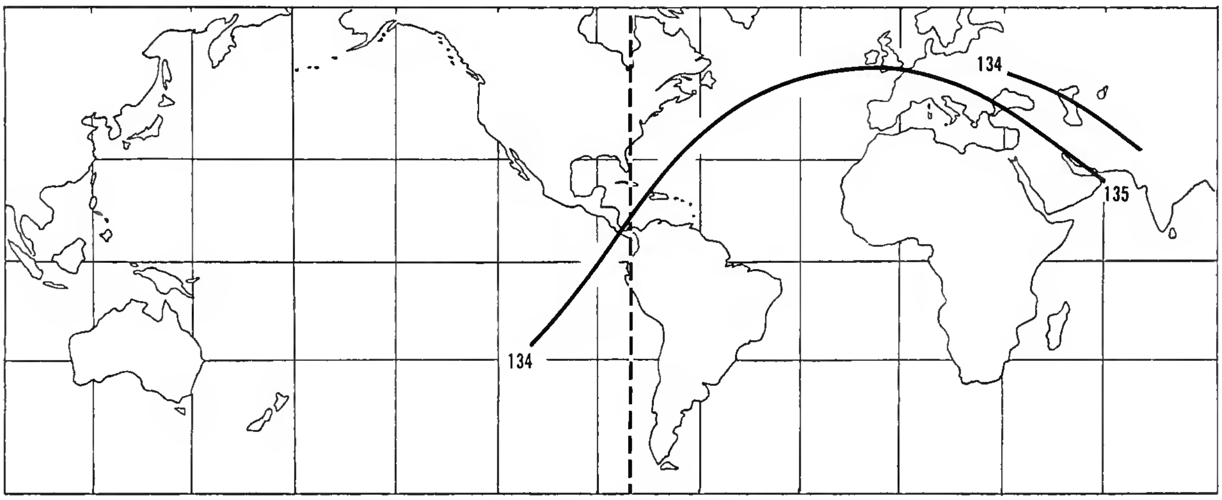
SLAYTON: We just saw what we think is a possible volcano. I don't know . . . down there or not . . . 207:19:20— a very large kind of mushroom type thunderstorm-looking thing with a large stream of gray-brown smoke going downstream, mixed with white . . . volcano . . . horrendous oil fire . . . track that one for us?

CAPCOM: We'll correlate that time and see if we can check it out.

### REVOLUTION 128

265. AG/208:04:11

CAPCOM: Incidentally, while I'm getting an answer for you guys, it turns out that that latitude and longitude when Deke reported the possible volcano, was directly over head the Aleutian Islands, and we're going to be checking it out over night. But that's more likely exactly what you saw.




Revolutions 134 and 134/135

### REVOLUTION 134

266. AG/217:28:11

SLAYTON: Crip, anybody got any word yet on our Aleutian volcano.

CAPCOM: You get me completely at a blank here. Let me see if I can get an update on that.

267. Onboard Recording

SLAYTON: DAC 7; we've got film left there, and we've searched through our film library and recovered all the open frames. And, unfortunately, we couldn't find our tape recorder so we haven't kept a very good log on what we've shot. We did finish off a CT02 this morning with a few frames. And let me see if I can remember what we shot those of. Oh, yes, that was across South America—some stuff in the upper Amazon area and the Andes. And then I think we finished it off, with what I thought was the mouth of the Andes—the Amazon rather—big sediment flows up and down the coastline and so forth.

268. Onboard Recording

SLAYTON: We now have a mag CX13, which has about right now 80 frames left. I just shot about 10 off on that. And just before we went into darkness; and we're at 93:41 PET if that helps you backtrack. Just before we went into darkness, there was a big desert dune area, very large, super large crescent dunes. And from there to some fairly rugged mountainous terrain, which we shot a few pictures of, and I don't really know where that was. So that might help you a little.

269. AG/218:06:45+

CAPCOM: At about 94:36, we'd appreciate it if you could give us a colorwheel reading on what color the water looks to you at that particular point. And also, north of the Caribbean Islands, just a couple of minutes later about 94:38, we expect you to pass over a developing tropical storm. It'll be about the latitude of Cape Kennedy, directly under the groundtrack scan. So if you could try to get some stereo photos. If you've got any film left, you can use the camera settings that are noted down for site 3 Bravo [tropical storms].

STAFFORD: Okay, real good. And at what time is it to look for the tropical storm?

CAPCOM: About 94:38.

STAFFORD: 36 for the color of water at 94:36 and 38 is the tropical storm?

270. AG/218:07:15+

CAPCOM: That's affirm. And incidentally, the whole vis obs team would like to give you several "atta-boys" for the performance you guys have been doing on this vis obs stuff. You've been doing a super job, and they can't wait to hear your efforts recorded on the VTR and also to see the photos when you get back.

STAFFORD: Okay, good. We're trying like mad. The only thing that's gotten to us— there's just been so many clouds up here that its gotten to us occasionally. Thank you, and tell "hi" to Farouk and all his team there.

## REVOLUTION 134/135

271. Onboard Recording

STAFFORD: Okay, this pass is visual obs, rev 134/135. We'll be using color exterior CX07 to start with, and we'll start on frame 42–43. Okay, we shot the Galapagos Islands; we got stereos. You could see the swirls of clouds around in the calderas looking down on top of the volcanoes. However, due to the cloud covers, we could not see any internal waves around or any upwellings.

272. AG/218:50:57+

STAFFORD: Okay, Crip. And we just shot the Galapagos.

CAPCOM: Any turtles down there?

STAFFORD: Only big ones.

273. Onboard Recording

STAFFORD: As we come up to Central America, the problem is we have clouds all over the Pacific coming up to it. Oh, now we can get it. And over to the right is an active volcano—supposed to be, Deke, that's your side.

SLAYTON: North?

STAFFORD: To the north.

BRAND: I'm going to map this.

SLAYTON: Sure is funny; I didn't see any.

274. Onboard Recording

SLAYTON: There is a lot of sediment and stuff down there . . . .

STAFFORD: It's to the right. See, we crossed right across from here to the Atlantic Ocean. Beautiful, beautiful. Just what I was looking for. And Farouk, we got a boundary layer right off the east coast into the Atlantic. You got some internal waves and could even be some big upwellings right there.

BRAND: Where do you see an upwelling?

STAFFORD: I see it—I see an upwelling—I've got it right here, right off the coast. See it? See that baby?

BRAND: Yes. There is a thing that looks like an upwelling.

STAFFORD: Yep, it sure does look like a big upwelling. Right there, about 20 miles [32 km] off the shore.

275. Onboard Recording

BRAND: And CX30, frames 87 through 91.

276. Onboard Recording

STAFFORD: Hey, let's look at 35. In 1 minute we need a color of the water.

277. Onboard Recording

BRAND: Okay, but I got a Central American stereo on there. Four shots.

278. Onboard Recording

STAFFORD: This is the Caribbean. See, it comes right over Jamaica and Cuba on this pass.

279. Onboard Recording

BRAND: CX13. Ended up 91.

280. Onboard Recording

SLAYTON: Okay, you want colors here?

STAFFORD: No. At 36.

281. Onboard Recording

SLAYTON: I'm shooting on a magazine CX16, color exterior, 35 millimeter, and everything on this roll is going on this pass, which is pass—rev 134/135.

282. Onboard Recording

STAFFORD: See if we can see the Gulf Stream down there. Okay. Let's look up here for the boundary between now and— in fact, in another couple of minutes we should see a big boundary. In fact, you guys could probably pick it up better . . . .

283. Onboard Recording

BRAND: 42 Alfa in the color is the closest.

STAFFORD: 42 Alfa.

284. Onboard Recording

BRAND: What's this? Jamaica?

SLAYTON: Jamaica.

285. Onboard Recording

STAFFORD: Oh, here's the Gulf Stream boundary.

SLAYTON: No, no. That's just the shoals.

STAFFORD: The shoals. The Gulf Stream boundary should have been back there someplace, but I couldn't see it.

286. Onboard Recording

STAFFORD: Coming up over Jamaica. There's Kingston. Bauxite. Yeah, on the bauxite.

SLAYTON: What? Is Cuba coming up then or [what]?

STAFFORD: You can very easily see all the bauxite that's mining there, on Jamaica.

287. Onboard Recording

SLAYTON: Cuba.

STAFFORD: Fidel Land.

SLAYTON: It isn't too big, is it?

STAFFORD: What do we see around Cuba? All we got there are some internal waves off the coast. Off the southern coast. Look at those big things just suddenly popped up; see those internal waves?

SLAYTON: Did you get them?

BRAND: Yeah. I sure did.

288. Onboard Recording

STAFFORD: Now we're going into the Caribbean. Okay. I just couldn't see a Gulf Stream boundary down there at all or the Caribbean Current there. There's no differentiation in colors.

289. Onboard Recording

SLAYTON: Oh, that is pretty. Then we're going to hit Bermuda, I understand. Right over Bermuda.

290. Onboard Recording

BRAND: Okay. I'm up to frame 105; that was all stereos over Cuba and beyond. And I also got the area where Tom reported internal waves.

291. Onboard Recording

STAFFORD: Okay at 38 we—look out—Deke, look out for a tropical storm. This is—well hell, we're on top of it.

BRAND: There it is. Okay, I'm going to get it.

STAFFORD: And, Crip, we're on top of the tropical storm right now.

SLAYTON: We're on top of some clouds.

BRAND: I don't think it is a tropical storm.

SLAYTON: It doesn't look any different to me than a whole bunch of clouds . . . .

STAFFORD: We said a possible.

BRAND: There's the eye right in front of you. If you call this an eye. Get the eye. Get pictures if you can.

STAFFORD: See how it curls around to the left here and curls into it?

SLAYTON: Maybe not. That looks to me like— It's hard to tell over here. I just don't think so. It could be.

BRAND: Are we over the area where you reported there may be a tropical storm?

CAPCOM: That's affirm. You should be just about in that position.

BRAND: It doesn't seem to cover so much area, but it does have a rather swirling appearance. I don't see an eye, but I can see where an eye would be.

CAPCOM: Okay. I think that it's just developing, yet. I don't even believe it's to the area where they're calling it a storm, yet.

SLAYTON: It looks just like the bunches of thunderstorm patches we've seen around the Pacific area the last couple of days.

BRAND: Tape recorder. A tropical storm was reported—and in the same rev, in the Caribbean-Atlantic area just after passing Cuba. Got some more shots. I'm up to frame, about 107, now. Had to get some short sequences of stereo over that storm. Could not see an eye.

292. Onboard Recording

STAFFORD: Here's a boundary right in the Atlantic Ocean. And Farouk, we have a boundary of current from light blue to dark; where's the color wheel?

BRAND: It's right up there above you.

STAFFORD: It goes from 37 on the other side, to about a 41. The time is 95:35:45. And it went from forty—about 45, 46, down to 37. Down 1 point. Now we're covered by clouds. And on the silver Hasselblad, I've changed to CX17.

293. Onboard Recording

SLAYTON: That's right up through 24 on magazine CX18 and the 35 through Central America, Cuba, Jamaica, and Bermuda. On 35-millimeter mag CX18 shot 1 through 24 over Central America, Cuba, Jamaica, and Bermuda.

294. AG/219:05:56+

BRAND: Ireland really is green.

CAPCOM: Really is what?

BRAND: Said, Ireland really is green.

CAPCOM: How's the percentage that— Does most of the world look green up there? Or most of it—well, I know most of it's blue.

BRAND: Not as green as it looks on the ground, generally.

SLAYTON: But Ireland is really supergreen. We got a couple of pictures of that, and we're over the south end of England here, now.

STAFFORD: Yeah, England—was looking great, except it just has these broken clouds all over it. That's the problem. Yeah, Crip, you can tell the BBC [British Broadcasting Company] and all our good friends in England "hello" for us.

CAPCOM: I'm sure they'll appreciate that greeting.

SLAYTON: We're sitting high over London at present.

BRAND: Unfortunately, quite a bit of cloud cover over England.

295. Onboard Recording

BRAND: In roll CX13, exposure 108 is coming over the coast of England, lot of cloud cover. 109 was the coast of Holland, lot of cloud cover, also.

STAFFORD: You can see the Zuider Zee loud and clear. Wait a minute. Down in the center window, using CX17, I got pictures of Rotterdam and England was obscured.

296. Onboard Recording

STAFFORD: Deke is using the Nikon in the right seat, using the color exterior. Vance is in the left, using CX13.

297. Onboard Recording

STAFFORD: And Germany is pretty much socked in. But we're starting to get a break in the clouds. However, it looks a little hazy up ahead. Next data point will be the Danube Delta. We'll be shooting on frame 12 on CX17. Okay. Coming up to the Danube Delta, there's tremendous sediment plumes there.

SLAYTON: If that's the Danube coming down through there, which I think it is, that's the the delta running right out into there right in here. Man, that's really flooding out into the Black Sea; turning it brown.

STAFFORD: Taking a series of stereo [photographs] running right out into the Danube Delta.

BRAND: I got some shots of the delta.

SLAYTON: So did I. Okay, Tom. We just crossed here. I need to get out of your way. I think we got mixed up back over here. It looks like the Danube's . . . water running right across the Black Sea.

298. Onboard Recording

SLAYTON: You better get over here.

STAFFORD: Yeah. Okay. Just let me [move] over here.

BRAND: Got the camera?

SLAYTON: That's Turkey. Either [window] 5 or 1 . . . . Better get there quick, because we're there.

STAFFORD: The Caucasus. Okay. I'm over here, Deke. You want to take the center seat and shoot? You take the center seat and shoot like mad, because that's better.

299. Onboard Recording

STAFFORD: We're still over the Black Sea.

BRAND: Look at that circle of clouds on your side there, Tom.

STAFFORD: Yeah. There's a tremendous circle of clouds on the north side of the Black Sea.

BRAND: Probably be the south side.

STAFFORD: Should be looking south or north.

300. Onboard Recording

SLAYTON: We're looking south . . . there's Turkey. Good ole Turkey. Well this is— it's just a big fault to me running right dead center down there. That is a fault. Did you get it out your window? That's a fault running almost parallel to our flight path. Looks like a . . . fault. Right over Turkey.

STAFFORD: You guys see the Caucasus yet?

SLAYTON: I don't know, but there are mountains. But I don't know which ones they are, Tom.

STAFFORD: They must be Caucasus.

BRAND: Damn clouds again.

SLAYTON: There's that little lake. That's got to be the Caucasus; we're right over them. Right there.

BRAND: There's a peak right there beside that lake; it's a beauty.

STAFFORD: Well, here's the Anatolian Fault clear down here . . . . Look at that right out there, Deke. Look straight ahead; you shoot her.

SLAYTON: Oh yeah. That's not as impressive a fault as that other one we had. We got it. You guys should probably be opened up. I'm continually open on this . . . .

STAFFORD: You've really got to open her up.

301. Onboard Recording

SLAYTON: There's a goddam small patch of desert down there [Iran], with some weird looking dunes. That's a big sandstorm out there to the south. Look at the fires out there.

302. Onboard Recording

STAFFORD: Okay. Finished on the Anatolian Fault, number 55 on CX17. That does it. Man that stuff was covered with clouds and haze.

303. Onboard Recording

BRAND: Okay, tape recorder. Just took a long mapping stereo strip. First, I got just a few shots over the Danube Delta and ended up Danube Delta frame number 115. And then ended up at 95:04:45 PET on something, which you'll see the Anatolian Fault.

304. Onboard Recording

SLAYTON: I shot up on again magazine CX18, the 35 millimeter, through frames. God, I can never read those fucking frames.

BRAND: We must have gotten out of Russia pretty fast.

STAFFORD: We got up to 52, Deke.

SLAYTON: 52. Okay. We shot those over Ireland, England, Rotterdam, and down through the— Romania, the Black Sea, Danube Delta, and on into Turkey and a few faults down there.

### REVOLUTION 135/136

305. AG/219:35:33

CAPCOM: Okay. What we wanted to tell you was we got some ships collecting some data on this 5 Alfa [Gulf of Mexico], that you're going to be coming across next time, and we'd like you to attempt to get a color wheel reading of the coastal water that'll be visible . . . . out of CM3 and they'll be between the Mississippi Delta and the Gulf Coast around Mobile. Just in that general area there.

306. Onboard Recording

SLAYTON: We're coming up on the final Earth obs pass here, rev 135/136. And we've got two things out of configuration coming into it. For the mapping camera, we've got the 80-millimeter lens on instead of the 60, because we started the entry stowage and we haven't been able to find the 60. I've got the same problem with the orange filter for the 250. We have got the orange filter for the 50, so we'll just switch over to the 50 lens and shoot that with the IF film for the last two sites.

307. Onboard Recording

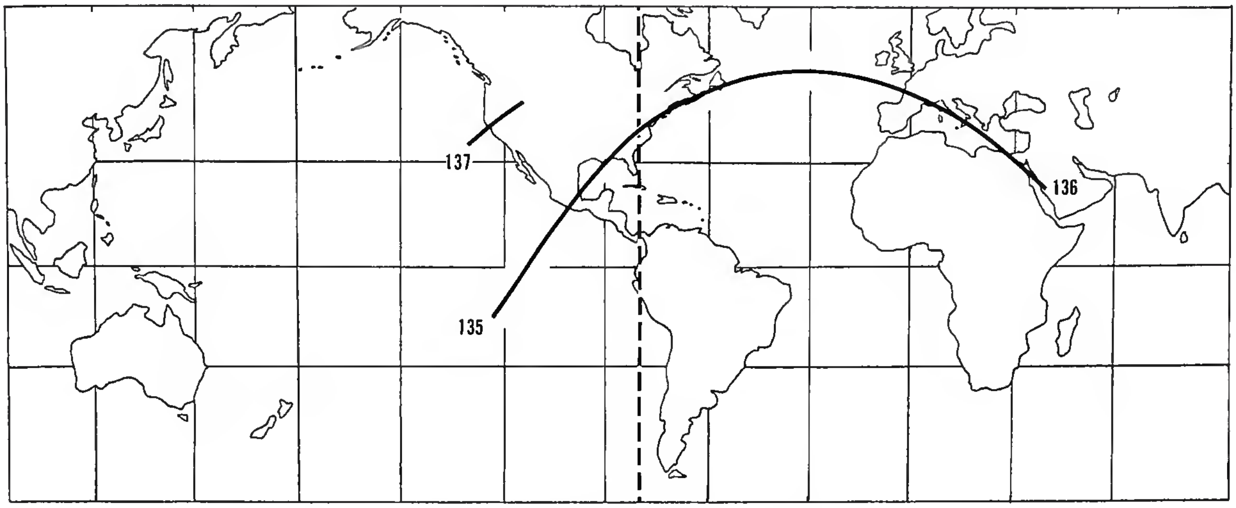
SLAYTON: Got three frames out in the area 3A [cloud features] – 3B [tropical storms], rather. It's a circular area, I don't think it's a tropical disturbance, but it's got the characteristics of a small one, so I shot it anyway.

308. Onboard Recording

SLAYTON: And it looks like coming up on 5B [Gulf Stream] – 5A [Gulf of Mexico], rather, that it's getting a little clouded over. However, we'll break through there somewhere. Okay. The whole West Coast is clouded over.

STAFFORD: Here comes the coastline, Deke.

SLAYTON: It may be getting a little clearer as we approach the coastline. Okay. We're crossing Mexico and the area looks pretty




Revolutions 135/136 and 137

reasonably clear, so the mapping camera should be getting good data through here. So unless I see something unusual to shoot, I won't do it with the silver camera.

309. Onboard Recording

SLAYTON: Okay, we're crossing the east coast of Mexico and then out in the Gulf. And I'll start watching for the Gulf Loop Current and internal waves. And there's some interesting stuff on the ground down there. The boundary. I'll shoot that one. I've got enough film, I think. Never going to get a better chance to get it. Okay. Shot three frames for each, we're using magazine CX17 until we come to the end of it.

310. Onboard Recording

SLAYTON: We're now out over the western part of the Gulf, trying to see whether we could see the Gulf Loop Current and/or internal waves. Man, that is pretty down there toward Monterrey. There's some pretty clear green water on the north shore of the Monterrey Peninsula. And that's where the Gulf Loop Current is supposed to be coming, is right up around here.

STAFFORD: You've got an eddy out here in the Gulf.

SLAYTON: I think this may be it right here, as a matter of fact; it looks that way to me. It's a total change in cloud pattern right here. It's right up around here. Almost following the coastline. Okay. What I've got is a line of clouds that come around the Monterrey Peninsula. That area down there is all clouded over right off Monterrey. But there's then a line of clouds that come up right on around—almost follow the contour of the coast. I would guess it might very well be the Gulf Loop Current we're looking at. The problem is I can't see it off to the north.

311. Onboard Recording

STAFFORD: Deke, right down below here, do you see it? There's an eddy and the color changes right in here. See that eddy right there?

SLAYTON: Right there, that's probably part of it right there, I'm sure.

STAFFORD: See it. See, there's one, two, three eddies right there.

SLAYTON: Vance, if you can get a color in—right in here somewhere . . . . Man, I don't know why they wouldn't use this big lens here. It's worthless for this kind of photography.

312. Onboard Recording

STAFFORD: Here's the coast of U.S. . . . . color changing . . . .

SLAYTON: We should be crossing Mobile and New Orleans, which is what they wanted. Look at those boats down there. I'm going to get one of that.

313. Onboard Recording

BRAND: Okay, it changes from 47–B to 45–B. As you get from the shoreline over to the Gulf Stream.

STAFFORD: Hey, look at that change in color.

SLAYTON: That's what they're looking for. There's a color change right through here. Oh, hey, we're coming up in the Mississippi Delta right here. This is— we aren't there yet, Vance.

BRAND: Yeah, I see it coming.

SLAYTON: Good. Well I couldn't.

STAFFORD: It's right here on the left. Right here is the Mississippi Delta. It'll be over you in about 5 seconds . . . right down to your left.

SLAYTON: Great. And they'll want pictures of that in particular, I guess. I should have gotten one more. You know you can't see at all what you're shooting through this goddam lens. Okay. This lens, in my opinion, is lousy for what we're trying to do. Okay. Where they want this water color now. There we go. Between the Mississippi Delta and New Orleans. Our time is off . . . 96:09 or 07. Here we are, Vance; let me take a quick— exactly where we're looking. Right between, right in there. There's no way I can match this except by taking it away from the window. I give that about a 46 in here, before I get into sunglint. Why don't you try it, and see what you get. And I tell you what, we'll shoot some—well, we're getting into sunglint enough, so it probably won't show up on the film. Okay. I got a shot on the film anyway. And while we're at it, I'll get Mobile and Mobile Bay. Well, I guess it's too late to worry about it, changing things, but in my opinion, we'd be much better off on this pass with a 50-millimeter lens instead of a 250. Okay, . . . Let me pass it over to you. Well, I think they heard the ones I gave it.

BRAND: Just for interest's sake, after coming into the Gulf of Mexico over from Mexico, first we had color 47–B and then after we got out into what seemed to be the Gulf Loop Current, it was 45–B. Your recorder's still on.

314. Onboard Recording

SLAYTON: Yeah. Here's the slide out of this one. The next magazine's got a few frames on it, too. We're back in business. Well, we're coming up on site 5G [Chesapeake Bay]. How's our tape recorder doing? I've still got tape. Got to switch that over here in a minute, too. Coming up on 5G. We just switched magazines to CX06, starting with frame 60. I finished up the last magazine with the Gulf business. I can now see the East Coast of the U.S. coming up. And it looks like it's going to be clear today, hopefully. There's Cape Hatteras. That's clear. And I can see Cape Charles coming up. Suspended sediments and gyres in the bay and pollution in the Potomac. And talk about pollution, man, there's Chesapeake Bay. And it's sort of a cloud cover and haze over this area.

STAFFORD. It looks darn near purple the way . . . .

SLAYTON: It does, doesn't it? There's the Potomac, the York River there and that's full of muddy water. Well, shoot. There's plenty of mud and sediments there. There's plumes or gyres in the bay. Well, we're going to get a good shot. Jesus Christ, I can't shoot them with this goddam reflex . . . . I'll just point out the window and shoot and hope I got it. It was right down the Chesapeake Bay. Should have been a beautiful shot. There is all kinds of sediment down there in that thing, but I don't see any gyres in the bay.

315. Onboard Recording

BRAND: Now we're coming up on New England, New York.

SLAYTON: Yeah. We're right over the center of New York City right now, which is hazy. Long Island. Tom would you keep an eye on how that tape is doing and switch it quick when it runs out? And I got to get a map here. No changes . . . 96:12. These times are all off today. Just switch that one over, I think.

STAFFORD: All right.

316. Onboard Recording

SLAYTON: There's a beautiful picture of Cape Cod. I've just got to shoot that, because it's —this lens is lousy for what we're doing here.

BRAND: You see the red tide?

SLAYTON: We're just crossing Boston. And there is Cape Ann. So, we're coming up to Boothbay and I don't think we're going to be able to bend— son-of-a-gun. Good idea.

317. Onboard Recording

STAFFORD: There's Boothbay.

SLAYTON: Man, I can't see it, Tom.

BRAND: You want to cut it off. And we just crossed good old Boothbay again and as usual it's under clouds here from our angle. We got some beautiful pictures, however, of the Cape Cod area. And we did get some color prints or measurements between New Orleans and Mobile there. Get back to you in a little bit. Let me see if I can get that. I'll check this out . . . too, Tom.

SLAYTON: I shot some pictures of sediment stuff coming out of the river here north of Boothbay; I think we got it a couple of days early. It's really red muddy water.

318. Onboard Recording

SLAYTON: And now we're about to head off across the North Atlantic over Newfoundland.

319. Onboard Recording

SLAYTON: And I've still yet to see what I consider red tide. I see red coloration here in spots. In the angle we're in right now, however, we're looking in sunglint when we get to see it. And I didn't see anything that looks like that red tide we saw on the West Coast in the airplane.

BRAND: Probably too far north here.

SLAYTON: I think so. We need to get back down over that other area. So I guess if anybody asks me if I saw any red tide . . . .

320. Onboard Recording

SLAYTON: Okay. That should be a change [of camera] setting for crossing the North Atlantic here. I've yet to see the oil slicks, however, in the North Atlantic. And I think we probably wouldn't, generally, without having some sunglint. Totally cloud covered.

321. Onboard Recording

SLAYTON: I'm going to change—man, I'm way out on this timing. Something's different about our orbit.

STAFFORD: Why don't you keep shooting? You need some more film?

BRAND: I need it.

322. Onboard Recording

BRAND: Look at the black clouds.

323. Onboard Recording

SLAYTON: I've got to change magazines right now. Okay, Tom. Here's another shot-up magazine. I've got five frames to go on this camera. I need another one . . . . I'm just going to shoot up the rest of this magazine.

STAFFORD: Go right ahead.

SLAYTON: I forgot to mention it. I've switched magazines again on the silver camera and we're now on CX07, which has 5 frames left, and we'll shoot these off before we switch over to the IR. There's that great big, what I thought it was a circular thing, there again; saw it the last time. I can't see nothing through this goddam lens.

BRAND: This attitude is especially tough.

SLAYTON: Yeah. Well, see, you're getting with that camera. You're getting about the same stuff, I can shoot anyway.

324. Onboard Recording

SLAYTON: There's very little I can cover that you can get with that. How many frames you got left on that dude? We'll be coming over the North Atlantic right—

BRAND: Well, we've got . . . left of 135. We may cover the whole North Atlantic . . . it's mostly clouds.

SLAYTON: Well, at least it's pretty clouds, anyhow.

325. Onboard Recording

SLAYTON: There was an eddy in the Atlantic . . . . if I could just see it through the goddam reflex. I think I got it.

326. Onboard Recording

SLAYTON: You know, the combination of the cloud cover and the sun angle, we could have oil all over and we'd never know the difference.

327. Onboard Recording

SLAYTON: We switched over to the IF film magazine IF02 and we got a 50-millimeter lens with an orange filter. And we're at frame 30. We're now crossing southern Europe. And, man, is there sediment down there.

BRAND: What is that?

STAFFORD: That's Italy.

328. Onboard Recording

BRAND: If you get a chance to, get me an

Adriatic shot.

SLAYTON: Well, we go right down the coast there.

329. Onboard Recording

SLAYTON: We'll get the goddam Alps here. I'm supposed to be getting some Alps stuff. But, hell, I don't think we're going to see any Alps.

BRAND: Here comes something.

SLAYTON: Maybe that's the Alps right there.

STAFFORD: No way. They're too close to the water.

SLAYTON: Glaciers and firn line. According to this, we should be coming right over the Alps. But, by golly. I don't see any Alps at all.

STAFFORD: Here they are down on the left. Right there, Deke.

SLAYTON: They're underneath us. No way to go—oh yeah. Yeah. Christ. No way we can get a photo of those.

BRAND: Let me get the Nikon.

SLAYTON: See if you can get any out that window, because I can't get anything here. I'll shoot a couple. I can see some Alps.

STAFFORD: Oh, here's Sardinia and Sicily coming up—Sardinia and Corsica.

SLAYTON: We got some pictures right over the Alps, what little we could see of them.

330. Onboard Recording

SLAYTON: You can see both of those islands . . . just like a map.

STAFFORD: Here's Africa coming up.

SLAYTON: Let me get that.

BRAND: This Africa right coming up?

STAFFORD: No. Way on the horizon over there.

SLAYTON: No. That's Corsica right there we just saw.

STAFFORD: Right here on the horizon. Right here is Corsica and Sardinia.

331. Onboard Recording

SLAYTON: Okay. Then we're coming down.

STAFFORD: The coast of Italy.

SLAYTON: 6th, 125th. [camera settings]

STAFFORD: East of coast of Italy—the west coast.

SLAYTON: The west coast. Oh, man. This is super.

332. Onboard Recording

SLAYTON: There's Corsica, we're right over Naples. No, we're not, either. We're too far north. Is that the Isle of Capri right there? Hey, it is. And that's [Mount] Vesuvius. We just went over Naples, Bay of Villa Sorrento. That's all the volcanics down there, no question about it. That really shows up like a sore thumb.

333. Onboard Recording

SLAYTON: And we've got a good picture now in Corsica. And we should have gotten a picture of my good old airbase down there by God, while . . . still that lava.

334. Onboard Recording

SLAYTON: Let me get a picture right here of the Italian coast.

STAFFORD: Yeah. Here's the boot and here's Sicily.

SLAYTON: Now, I'm looking for Mount Etna down in here. There's a toe going down there. There's Sicily over there. That's Sardinia. So, I should be able to see—hey, there it is right there, Stromboli . . . . God I wish I could see out this frigging lens. There's no indication of any activity on the part of those volcanoes. But, you can sure see them. Hey, that's super. Tell you what, let me just continue to shoot down through here. That's going to be just like a map. Get the whole toe of Italy—I got Malta, Sicily on the horizon. Okay, and here's the heel of Italy right underneath us here. There's [the Gulf of] Taranto . . . and there's Bari Harbor. Ah-hah, we got it all.

335. Onboard Recording

SLAYTON: Now. We're coming up on the—this should be the Greek islands, I guess.

336. Onboard Recording

SLAYTON: Since this is our last chance to shoot film, we might as well shoot some. It's getting dark down there.

337. Onboard Recording

SLAYTON: There's the coast of North Africa. And if I had my map I could tell exactly where that is.

STAFFORD: Got to be in Egypt.

SLAYTON: See the hook? I think that's Bizerte. No, I think that's Libya. Yep. See, that's got to be Bizerte, isn't it?

338. Onboard Recording

SLAYTON: Coming right down the coast of Greece here. Vance probably can get better pictures of that than we are . . . anything else.

339. Onboard Recording

SLAYTON: Well, I tell you, let me get one picture of desert area down there toward Bizerte and the Mediterranean coast and the desert, all of that . . . . We shot up through frame 57 here, so far, in this pass. And about to run into darkness. It's a weird angle.

STAFFORD: Okay. We're coming into nighttime and we've got to get with it. Stow Earth obs for entry. Stow box over here, could we get this box over here?

SLAYTON: Well we didn't have many frames left. I've got 10 left on this camera. I'm going to shoot some more down here in the desert. This North Africa desert coming along the south shore of the Mediterranean. Yeah, let's keep it out. We may get a chance to shoot some more pictures later here, too. I think we've really got a lot of time here from now on as I recollect it. But, we don't want any . . . . where we can't afford to be behind, obviously. I'm going to shoot up what I can shoot here.

BRAND: We used CT06 for the mapping revs 135, 136.

SLAYTON: Well, that killed that magazine through the end. And last one was getting fairly dark. We probably didn't get much, but they might be able to push it.

### REVOLUTION 137

340. AG/223:26:45

SLAYTON: Okay, coming up the California coastline here.

BRAND: One more rev. Okay, what part of California?

SLAYTON: Don't know. I'm not sure.

BRAND: San—what do you call it—Valley [San Joaquin Valley].

SLAYTON: Oh, there's the Salton Sea down there. We're right up above San Francisco, must be?

BRAND: Yeah. San Joaquin, that's what. Roger, Crip. Coming right up over the San Joaquin Valley.

### TECHNICAL CREW DEBRIEFING

341. SLAYTON: We slipped on over to day 4 and the second transfer, and, let's see, you guys did that, I know. Let me just comment before I get into it. I think we started that day a little early, also. We made it a point to because we had that Earth obs pass. I had two Earth obs passes earlier that day and in the middle of the transfer, and the first one was site 10 [Africa and India], which was our only chance to get it. Then the process was trying to get back to stowing and get started. We weren't too well set up to do that. That was an IF mag and orange filter, and I did see the Johannesburg area. I never did see what I thought was the Great Dike up through there. We'll talk about that more on Earth obs. The mapping part of that, I think, we got going good and, far as I know, went well.

342. SLAYTON: However, for the photography with the orange filter, I was looking through that lens and I wasn't seeing much. I kept shooting pictures and figured that was due to the orange filter and discovered later that we were out-of-focus on that lens, and I doubt whether we got anything too great with the silver camera on that pass.

343. SLAYTON: Most of India was clouded over, and I doubt if we got much of anything on either camera over that area . . . .

344. SLAYTON: Okay. Let's see, we didn't have too much over there really. We had the microbial samples we did on each guy and then that's when Vance picked up for the U.S. tour. And I was again supposed to be doing another job out of window 1 in parallel with that. We had the same kind of a problem in that everybody in there was trying to do different things; it just wasn't very effective Earth obs, plus some cloud cover . . . .

345. BRAND: Briefly my TV excursion went pretty normal. We got a good lock on MILA over the Gulf of Mexico in a timely fashion. Valeriy introduced me and we got off on sort of what had been prethought out on the way of a tour and only two comments. One is, we had overcast over the Central Eastern States, which gave me a little bit of a hard

time. I had to explain that away somewhat. Also, if I had it to do over again, I would have had Deke and myself reversed. He was looking out the commander's rendezvous window, I was looking out the center hatch window. My vision was displaced from my TV camera's view by some number of degrees. And, I wasn't always sure what the camera was looking at because it was looking at things before I was. I thought the [word garbled] preparation was a tremendous help in getting me ready for this. That's all.

346. SLAYTON: First thing is cameras. And we had three cameras that we used for Earth obs. Let's talk about them independently. We had the silver camera, 70 millimeter.

BRAND: It was the 50-millimeter lens that was great. With the 250 we had light loss that gave you problems.

STAFFORD: Yeah. There's a lot of selective targets we wanted, and we could see them with our eye but, when we looked through the reflex, the light loss was so much that you couldn't even get on target. And, we had to take the pictures too far back from the window. It would have been simpler if we had just a regular 50-millimeter lens with a ring site.

SLAYTON: Yeah, the reflex thing most of the time didn't do much for me at all.

BRAND: I liked the reflex if I had the 50 lens on. It's with that 250 lens on that gives the problem that you are talking about.

347. SLAYTON: Well, the other problem I had with it, too, is with the orange filter on it. I had the same problem with that; I couldn't get the resolution through it. And I know I screwed up one pass because I thought it was the orange filter that was giving me distortion and I was really out-of-focus on it. You still have to play the mechanical game just like you do with the black camera. I just think that you can't depend on what you are seeing through there.

348. SLAYTON: A lot of things that you can see with your eyeballs, you just couldn't see through that reflex.

BRAND: I still think that a reflex, if it is done right, gives you something in addition. It lets you frame the picture that you are taking and really see it.

SLAYTON: When you are moving as fast as we are moving, you didn't have that option too many times anyway. You are looking, through the window and all of a sudden here comes something and you got to get it. All you are going to do is hold the camera up there and point at it and time it out for your 5 seconds, approximately, and shoot.

BRAND: So for the Shuttle, I guess a lot would depend on cabin geometry.

SLAYTON: We used up all the film we had available using that camera.

349. SLAYTON: I screwed up that camera once for the SAM experiment, where I didn't get the 250 lens on all the way. I thought the camera was firing and it wasn't.

350. SLAYTON: Now then, the 70-millimeter black camera is a mapping camera. Everytime I used that, it worked perfectly. I stuck it in the window and set it fine, and then all I had to do is turn it on and let it run. And it did great. We used that for a lot of miscellaneous out-the-window stuff, too.

351. BRAND: In the end, we had film left and decided to use it in the silver camera.

SLAYTON: Yeah. And I think we used up all the film we had left for that camera. I guess I got some questions whether we are using the setting on that camera one of the times during the latter part. We couldn't find that cue card once in a while, and I think we could use the same settings we used on the silver one. I am not sure if that is really right. Well, hopefully they weren't too far off anyway.

352. SLAYTON: The 35 [Nikon] was not designed to use for Earth obs. And we shot one hell of a lot of Earth obs with that thing using the light meter, at least I did.

353. SLAYTON: I think we made one mistake there. We called the ground and talked to them about using it, and they recommended going to the 300 lens. And I put the 300 lens on there for one pass, and that was useless in my opinion, totally useless. Your field of view is so small. The relative rate of motion over the Earth is so fast that you're trying to get rid of the motion in that thing—I think is almost impossible. And you couldn't tell what

you are shooting. It was just a blind-type operation. I think we took that off after—that really torqued me, that one good pass right through the middle of Wisconsin. And when I had that lens on, I don't think I got anything.

BRAND: I think that whoever gave us that advice was thinking in terms of purely Earth obs objectives. And what we were wanting was a general purpose out-the-window.

SLAYTON: I think the lens we had on here was pretty good for that. Might have been a little bit too—too broad a lens. It might have been better if we had a tighter lens with that much.

354. BRAND: It is a very convenient camera. If there is a difference out-the-window, such as you can't use the light meter, it would have been nice to have had a bias or something.

SLAYTON: It would be interesting to compare some of the film we get with that, because you and I ran one strip along the Anatolian Fault. You were using the black camera and I was using that one. I kept changing settings in accordance with the light meter. I think you were running with a canned setting.

BRAND: I was changing as we approached the terminator.

SLAYTON: That was the advantage I could see to the 35, assuming that the light meter is working about right. Seems like you ought to have a lot better chance of having the right exposure with it. It might be worth looking at for other cameras in the future. Postflight evaluation will tell.

BRAND: The flash operation of that camera was nominal. It is a convenient camera to have onboard.

355. SLAYTON: Okay. Then we used the 16 [mm camera] for one strip of Earth obs. You just held it and turned it on and let it run. The intervalometer worked every time we used it, I think. Cables and mounts, those all worked fine.

356. SLAYTON: Tape recorders, handheld. I think that's a good little tape recorder.

STAFFORD: One night we forgot the switch and the batteries ran down.

BRAND: We needed every battery that we had onboard. We were always conservative. We didn't want to have the thing running out of battery power in midtask. When we thought the battery was getting a little weak, we changed it out; I think we used more there.

SLAYTON: We have to be careful about rewinding. In fact, I think you should kind of have the kind that you don't rewind. We tried it a couple of times and we always ended up with a scrambled reel in there. Those little things are not really designed to rewind in zero g. So we should program so you don't ever do that, I think.

357. STAFFORD: Let's see, the Earth obs logs. Sometimes we were so damn busy, we didn't get a chance to log what we were doing. But we always put it on the tape. The logs were great; we just didn't have enough time to do them all the time.

358. SLAYTON: The other thing is, we didn't use the same mags in the period they had us programmed for anyway, so the log didn't even fit. We got it on tape and that is the important thing. They'll find the right frames to go with the right pass on the right magazines.

BRAND: That's all we attempted to do, but we attempted to do that. I would log them on pages 4 [318] and 5 [319, Appendix 3] but I think I missed one or two.

STAFFORD: Yeah. I know I missed a bunch of them.

359. SLAYTON: The "Earth Observations Book" [Appendix 3]. I only have one recommendation, and that is we need something different to write in it with. The pages were glossy, and everytime I wanted to make a note in it somewhere, like time of acquisition of a site or whatever, I had to go find a felt-tip pen. And even that I could hardly read.

STAFFORD: Yeah. Yeah, a regular ballpoint wouldn't write on it.

SLAYTON: You need some kind of pages that you can write on and make notes.

360. BRAND: Well, in one or two cases, you need sort of little drawings where you can fill in with pencil. Now I will give you an example. I came up on Puget Sound and I was supposed to make comments on the currents and gyres I saw. I saw some. And I saw pollution and everything. You know, that

is something that is hard to describe verbally. It is just almost impossible, in a way, because you have to reference it to a certain point. Puget Sound is not a square tank, it is rather a complex sort of thing. And I wanted to draw a picture of what I saw. So I took a pen and, as Deke said, I couldn't draw on the picture, and it was too dark anyway. And I feel that I lost some data there. And after it was all over I cussed myself because I even tried to describe it. I should have just tried to take a picture.

361. SLAYTON: That is what I kind of concluded, in general, if given a choice. The best thing is to try to get some good pictures and then, if we have time later, to put it on tape. Like Tom says, most of the time when you got through the pass you were in the middle of something else. And you [don't] even have time to backtrack to pick that up. Early in the mission, things were happening too fast. We got very little good data out of it. I know I didn't anyway.

362. BRAND: Yeah. I remember exactly thinking what you are talking about. I think, well I'll have time right after this task to quickly get it on tape. And then, I didn't. The next site would come up and you would get five or six sites stacked up, and then it was all over. And then you would say that I'll debrief the whole thing. By that time, you have forgotten some pertinent parts, and then there wasn't time often to debrief the whole thing.

SLAYTON: We were always against the time constraint, too.

363. BRAND: We had only the photo cue cards, and I used them a little. We needed Nikon film on it, but that was our fault. We should have asked for it ahead of the mission. We sort of had that camera ruled out for out-the-window.

364. SLAYTON: Okay, the map pack. We used the one map that they had in there. And I thought that was pretty good. There were lots of times we pulled that out to navigate with.

365. BRAND: But I tell you, I needed the map pack two or three times, and I wanted it but I couldn't get to it. There were three or four places where I wanted to get it, and it was so inaccessible that I didn't bother. I didn't have time to get it.

366. BRAND: I recommend against using a color wheel on any future missions.

SLAYTON: There's got to be some better device.

BRAND: It has the same problems that we talked about before it was ever built.

SLAYTON: But it worked pretty good in the airplane where you get lighting behind it which corresponds with the lighting you're seeing on the ground. And in the spacecraft, you're always in the shade with the color wheel, but you are looking at in the sunshine and trying to compare the two is like comparing apples with oranges. And the only way I could come up with anything even close, I'd look out the window and then I'd come back in the cockpit and get the color wheel in the light, and look at that and say, I think that was close to what I was looking at.

BRAND: My technique was to hold the color wheel sideways in the window and hope some light would shine on it.

SLAYTON: But then you would get a totally different color appearance also. So I think that color wheel was a dead loss.

BRAND: If you get any results from it, the best results will be from the ocean. Because somehow or another those yellows and reds seem to change an awful lot, depending on how much light was shining on it.

SLAYTON: I guess our best chance is going to be to go over it and hope we got some good film, and compare the film against the color in debriefing. And maybe we can, in retrospect, say yeah, we think that was pretty close or it wasn't.

BRAND: There should be an attempt made, that if this thing is ever important in the future, to get this device that we have all talked about, some sort of an optical device. Color is always a dead loss.

367. SLAYTON: Film management stowage went pretty well.

STAFFORD: Yeah, we spent an awful lot of time on it.

SLAYTON: We kept F-1 and F-2 pretty full of film. I think it worked all right, we ended up using different magazines at different times. But that wasn't any big deal.

BRAND: We'll find out.

SLAYTON: We inventoried there once and we were concerned about running out of film. We were shooting pretty fast at one stage of the game, then we began to worry we weren't going to be able to use it. So we figured out how much you can use it and not overdo it. I think in the end we came out using everything except about three rolls of 35, didn't we?

STAFFORD: Yeah, I think everything was shot.

SLAYTON: Yeah, and we'd have used a lot more 35 if we had thought about it earlier.

BRAND: We had enough film onboard, no doubt about it.

368. STAFFORD: We ran out early on the color exterior 16-mm DAC because I used some extra when Deke was stationkeeping.

SLAYTON: That's right, we could have used some more DAC, couldn't we? In fact, we had to use that color interior for entry. I hope that came out all right.

369. BRAND: You know, in the future, I don't think we should budget film for PAO versus Earth obs as we did on this mission. I think you should have a film cabinet with a certain kind of film and you just start using it. These allocation problems should be solved on the ground. It may be a hard ground problem, but I think it should still be solved on the ground.

STAFFORD: I agree with that.

370. BRAND: You know, we had both onboard and we were mainly using the spotting scope, but we sort of had the binoculars onboard as a passenger to be used for evaluation. I made a comparison looking at the Moon one night with both and I found that both worked pretty well, but I had a steady target. I probably slightly preferred the spotting scope. The thing of looking at the ground was something else. If I had the most perfect pair of binoculars or spotting scope, either one, in that low orbit I wouldn't have used them, because you never had time enough to use them.

STAFFORD: You have to preplan one specific point on one rev and look at that only.

BRAND: And you lose all the other data around it.

STAFFORD: And also, from that low orbit, 20 power is too much.

SLAYTON: I would have gone right back to 10 power.

STAFFORD: 20 power might have been all right for Skylab, but Skylab is twice as far away.

371. SLAYTON: We were seeing much detail with eyeballs, anyway. For example, at El Paso, I could see the runways, taxiways, and hangars faster with the naked eye.

372. BRAND: Thunderstorms appeared to come a fourth or a fifth of the way up to us.

STAFFORD: At least 25 percent of the way. You thought maybe only 200 or 300 thousand [feet].

STAFFORD: To me, as I mentioned before and I'll mention again, about my Gemini flights. From both 160 to 170 miles [257–274 km] down to 120 [193 km] and below, there is a noticeable difference in the resolution of the ground, and also a noticeable difference as far as tracking a target . . . .

373. SLAYTON: Photography and camera training. I think we had probably more than enough in my opinion. The kind of mistakes I made with a camera up there are the same kind I make down here, forgetting to take off the lens cap and simple things like that. There isn't any amount of training that will prevent that.

BRAND: I think we should have gotten to camera malfunctions and things like that a lot sooner.

SLAYTON: We could have, but that wouldn't have made any difference.

BRAND: It seemed like we had a 2-hour briefing regularly on cameras and I'm not sure we needed that much.

374. SLAYTON: Okay. Charts and maps? We talked about that earlier.

BRAND: Only one thing that might be added. We said the most useful map was that map of Farouk's that showed every orbit and where it went [Figure 35]. I would say that, in the future, such a map for a similar mission is a useful thing. But you might add a couple of things. The rev number should be put at the end of the rev as well as at the beginning. You had to trace clear across, and it was hard to trace. Also, it might have been nice to have had a minute scale so that you could more or less see how many minutes it took to go from Hawaii to Seattle, for example. I know that it wouldn't be something you'd want on each rev, but maybe in a couple of representative places.

## VISUAL OBSERVATIONS DEBRIEFING

375. EL-BAZ: Good morning, everybody. Tom Stafford will be here shortly. We have Deke Slayton and Vance Brand and would like to ask a few questions about both the silver camera and the black camera, following the comments made in the crew debriefing. Vance was of the opinion that the Hasselblad reflex [silver] camera does give you something, because you can see through it, provided you use the 50-millimeter lens. With the 250-millimeter lens, they thought there was too much loss of light, because of the transmission characteristics of the lens, and you don't see the target. So, in general, would you still think the reflex camera does something for you, Vance?

BRAND: I think it's best with the 50-millimeter lens. When you put on a 250-millimeter lens, you're hamstrung by the light loss and the length of the camera when you're trying to get close to the window. I don't know that we had complete agreement on that, but that's the way I felt. Tom and Deke probably have their own ideas.

SLAYTON: I agree with you, generally. I never was able to see anything through that lens; it was just kind of a blur. I didn't feel that I was gaining much by looking through it. What we're saying here is that we probably could have done about as well without the reflex system on it. I understand you did get some good pictures despite what we thought we were seeing.

EL-BAZ: That's the point. Yes.

SLAYTON: Whether they were good because we were looking through versus alongside, I'd hesitate to say.

EL-BAZ: Yes, you couldn't really see well, but the pictures came out very nicely. So it's a matter of your not seeing the scene as you get the photograph.

SLAYTON: I still think it's comforting to be able to see your picture outlined through a reflex if you don't have too many of these accompanying disadvantages.

376. EL-BAZ: That's correct. And you used the 35 millimeter [Nikon] quite a bit and the photographs from the 35 millimeter are excellent, even though we weren't really prepared for either the film or the lenses to be used for exterior photography.

377. SLAYTON: There again, I had the same feeling with the 300-millimeter lens, though, on the 35-millimeter camera. Maybe this again is a function of our particular orbit. We were traveling quite fast and trying to track anything through that lens was almost impossible. I always had the feeling that I was going to get image-motion blur. Whether we did or not, I don't know.

EL-BAZ: You had excellent photography and the camera people really said that the 300-millimeter lens is the only one that you can use with the 35-millimeter camera for outside photography.

SLAYTON: Well, we took it off because we weren't getting anything, from the way it looked to us. We just couldn't track a thing. We finally went back to the other lens [135 mm]; that's what we shot most of our stuff with.

378. EL-BAZ: A couple questions related to the attitude of the spacecraft. You remember we had worked on this attitude and you told us it wasn't really a very good one. And Tom figured out a new attitude for us. Why was the first one bad, really? And how was the second attitude?

STAFFORD: Using the first one, we were pointed toward the horizon too much and that doesn't do any good.

EL-BAZ: Were you able to see the horizon? You couldn't see the horizon, though, could you?

BRAND: Oh, yes. We could.

SLAYTON: We could see about that much black sky above it. That was the problem on the first attitude.

STAFFORD: When we got right down to the

nadir, we couldn't get down there that close.

SLAYTON: So we took that first 10-degree increment, thinking that might correct it, and we still were seeing black sky. So we took the next 20-degrees and that put us in real good shape.

EL-BAZ: In the new attitude, were you looking straight down or just ahead a little bit?

SLAYTON: You could still see way out ahead.

379. STAFFORD: You could still see way out ahead for what you can resolve with the eye as far as your lead-in. But this brings us to another problem on which we got a lot of discussion. When you look at a specific target in a lead-in, upside down, this makes it extremely difficult to think. To lead in, you should be right side up, pitched down.

BRAND: Especially for identification. If you're upside down, all these years of training and living down here are certainly thrown out the window. You're saying, well, let's see, is north to the left or right? Let's see, I followed that little river and if I go north is it left or right or back this way? You have to think everything out.

SLAYTON: You've got a 50-50 chance of being right, but you're usually wrong.

BRAND: And you have 15 seconds or 20 seconds to do everything.

380. EL-BAZ: Okay. And was this problem of not being able to see from the window very well something new because of something in the couches or the fact that you were too far down from the windows in the old attitude, or is it because you had to get up too far to look at it?

STAFFORD: You couldn't get the nadir.

EL-BAZ: Oh, I see. Okay.

STAFFORD: First, we were pitched up like that, we had a view out here, but what you're really interested in is shooting closest down here. And it was hard to get to.

SLAYTON: By the time you got in where you could kind of shoot to the nadir, the target was almost gone. And we were effectively losing 30 degrees of sweep underneath us, which would have been the optimum angle for shooting pictures.

EL-BAZ: That's correct.

381. EL-BAZ: How about the mapping camera attitude? Was this also bothersome?

STAFFORD: It wasn't the best.

BRAND: It wasn't optimized at all for visual observations

382. EL BAZ: Okay. Very good. We have your comments on the color wheel and we think we agree with you on this business of the lighting inside the spacecraft, the comments on the "Visual [Earth] Observations Book" [Appendix 3] in the technical crew debriefing, so we'll not go over this.

383. EL BAZ: There are problems with some of the focus on the film magazines and we think that some of this is due to leaving the extension ring that we used for electrophoresis on the camera. Could this be the case? Because everytime we used the electrophoresis and then shot out the window, this happened. Every single time.

SLAYTON: You mentioned that yesterday and I haven't had a chance to track back through the flight plan and find out. It's embarrassing if that happened. I guess it could have.

EL BAZ: It could happen, especially since we had nothing in the procedures to tell you to remove that ring after the electrophoresis run.

BRAND: Did somebody check the camera when it came home?

EL BAZ: No, I don't think we did. The camera people are not here yet.

OTHER PARTICIPANT: It wasn't all the way through, Vance. We noticed that at the end of the electrophoresis roll, for example. The few frames there looked like they were out-of-focus like it was probably left on, but it wasn't all of them.

SLAYTON: The only reason I hesitate to think that happened is because, if we had done that, we really wouldn't have had any reason to take that thing off later, either. And it seems to me like everything we shot from then on would have been poorly resolved.

OTHER PARTICIPANT: Each time at the end of electrophoresis, the dark side went in and and there was a blank at that point, so you had reconfigured the camera some way probably.

SLAYTON: My only point is, if we'd made the mistake that Farouk is anticipating here, it seems to me we never would have corrected it through the whole flight because we never had any reason to correct it. We'd have been exchanging lenses and left that spacer in there forever.

EL BAZ: That's correct; we used the photography of electrophoresis several times during the mission and this happened with the film also, several times.

SLAYTON: But there was only one split in there, where we switched that camera out and did mapping and back in for electrophoresis. We did all the electrophoresis in two days.

EL BAZ: Right. There are several handheld shots also with the black camera that were taken right after the electrophoresis experiment and these are out-of-focus.

384. EL BAZ: And the only other one that is out-of-focus is Rev 39 that you said something about, Deke. You said that you thought that this was orange filter. So we had no out-of-focus photography with the silver camera. So the reflex can help in that you can see that something is wrong. And you mentioned that on the tapes, also, that there was something wrong with the focus and you looked at it and it wasn't the orange filter but the focus.

SLAYTON: That's right.

385. EL BAZ: Yeah. Very good. Do we have any more hardware or camera questions?

OTHER PARTICIPANT: Let me ask one. You had some comments in the technical crew debriefing concerning the binoculars versus the spotting scope. We'd had a couple of questions like that. Would you elaborate on your comments there in terms of what your preferences were?

SLAYTON: It's my opinion that we should have left everything alone and stayed with our good old 10-power glasses, probably. That was more than adequate. On the other hand, I can completely understand the Skylab guys in the orbit that they were in arriving at the conclusions they did. But I think that the altitude we were in and as fast as we were traveling, I had zero success tracking anything with the spotting scope and never could have seen anything through it at any power.

STAFFORD: I could track, but it's really meaningless unless you had a specific target that you wanted to see and lead into; then it's going to be very difficult to find it because the field-of-view is so narrow.

SLAYTON: Things are just going too fast.

386. STAFFORD: Let me tell you something that was noticeably different. Did you hear my air-to-ground comments on the difference between the Gemini altitudes and this? These thunderbumpers look like they're coming about a quarter of a way up versus being about that big from the Gemini altitude. And the lead-ins and the angular bearing rates are fantastic compared to Gemini.

387. BRAND: I'd go a little further than that. If I had the most optimized perfect pair of binoculars or spotting scope available, I never would have used it, because I never had time to search around and get it on. Even assuming the focus was okay and everything was perfectly run by a computer in the spotting scope, I never would have used it, not once. We could see pretty well with the eyeball, first of all.

SLAYTON: That's right. We had a real good definition with the bare eye.

BRAND: And it was just too hard, too little time.

388. OTHER PARTICIPANT: Okay. Thank you. Let's press on then with the discussions in the various disciplines and, Farouk, will you introduce your co-investigators there?

389. EL BAZ: Yeah. I want to get on with this resolution of the eye and we'll get all the things that we had there for eye resolution out of the way first. We'll do this with slides, and then we'll have each of the co-investigators run through some of the slides and ask questions about the visual observation sites. May we have the first slide, please? For everyone's benefit, we had a few targets that were scheduled in the flight plan just to set the limits of eye resolution on the mission.

390. EL BAZ: Vance, you had the chance to look at the Bonneville area. Were you able to see the racetrack?

BRAND: Yes.

EL BAZ: And is it the one that we thought it was? The Wasatch are on the right side there and the Great Salt Lake with the two halves and the Bonneville Lake is the white patch. Did you mark it on the book or something?

BRAND: First of all, the picture I had pointed out the area, and I compared that picture to the ground, and I saw what looked like a fairly wide linear scratch or stripe on the ground. Right at this point, after all this time and without the benefit of that same picture, I can't tell you where it is on that slide. At the time, I did see it.

EL BAZ: Was it darker in color? Do you think you saw it because it was a different color?

BRAND: Well, I would say it was more of a textural difference.

391. EL-BAZ: Okay. Very good. Next slide please. We had the pyramids of Egypt as one of the targets of resolution because they are built from material the same color as the surrounding area, but there will be a textural difference because the pyramids are built with large stones.

BRAND: I don't believe now that I saw them. I had the benefit of two passes. The first pass, I saw two little dots that I thought possibly were pyramids. At that point, I wished I had a map of the pyramids on the ground so I could see what they're supposed to look like. I think probably what I saw were fields or something like that. So, I would say, no, I didn't see them.

EL-BAZ: Okay. In one group of photographs, we can identify the pyramids and there is another batch that we cannot. So the sun angle may have a great deal to do with it. And this is the picture that you can see them on if you enlarge it very much. You can only see two big ones and a third tiny one.

SLAYTON: With a low sun angle, you might have a reasonable chance of seeing them.

BRAND: I think you should be able to see them, because we saw things in that size range.

392. BRAND: Tom very easily saw the taxiway at El Paso Airport and a hangar, I believe.

STAFFORD: A hangar. There was a couple of buildings.

BRAND: The whole question for the pyramids is: How good is the contrast?

EL-BAZ: Yes. Also, whether you know what you are looking at; for instance, Tom knew that airport and knew where the hangars were on the runway and such.

STAFFORD: I looked down and there was kind of a desert area with a green river running through it that I thought looked like the Rio Grande. I looked down and there was White Sands over there, Biggs Air Force Base with its runway, and the two runways at El Paso, the taxiway, and these two buildings over here.

393. EL-BAZ: Very good. Next slide please. All right, we had also something over the intricate patterns of the Nazca Plains. Tom, you got pictures and I don't know whether you saw anything or not.

STAFFORD: The first time the clouds went all the way to the mountains and we got nothing. This slide was taken on the second pass. I can't say that I saw them. I remember this little bay in here and Vance was helping me lead in. I saw this little bay up here and I thought I saw a white streak in here, but I snapped the picture and I couldn't really say that that was it. I thought I saw something but I sure wouldn't say that was positive.

BRAND: I didn't see anything.

STAFFORD: And so, I couldn't say that I saw them. No. Now whether it was a white field or something in that area, I just don't know.

BRAND: This is one case where being upside down hurt us. The identification problem was very hard here.

STAFFORD: Can you see them on that photograph?

EL-BAZ: I couldn't, really. I know where they are, but I have not enlarged this or looked at it in detail. But this is exactly where you would expect them. This is that region.

394. EL-BAZ: Next slide please. Okay. And you did say something about being able to see, first of all, glaciers and then firn lines on glaciers. Did you see that over the northwest as well as over the Alps?

STAFFORD: I had the Alps and it was cloud cover; we got nothing on it. It was hazy. I couldn't see anything, but Vance saw something.

395. BRAND: The best case, I believe, was in the

Alberta, British Columbia, area. I very easily saw a firn line on one big glacier up there.

SLAYTON: So did I.

EL-BAZ: How did you make that distinction? Why do you think you were able to see that? Because of a color or texture?

BRAND: Textural and—

SLAYTON: Color gradation—

BRAND: Color and even shininess, you might say. Surface texture, I guess.

EL-BAZ: The ice being more—

SLAYTON: Kind of a gray compared to pure white.

STAFFORD: Yes, it goes from white to gray. And the firn line wasn't just a straight line; it was kind of jagged. It wasn't a clear line.

BRAND: It was fairly clear. Crescent.

STAFFORD: Well, it had kind of a little curve in it.

EL-BAZ: Okay. Thank you.

SLAYTON: But I thought I could see texture down below it also, that sort of looked like flow patterns going parallel with the glaciers.

BRAND: You could, very definitely. It looked like old ice down below.

396. EL-BAZ: Okay. Very good. Now before we start talking about the disciplines, we want to summarize some of the results of the ocean groundtruth collection. Dr. Robert Stevenson will start this by talking about the groundtruth collection in the Mediterranean and Tasman Sea and so on.

STEVENSON: Too bad we didn't have other chances to look at that. That's what we thought about everything. It really helps to have repeat assurances.

BRAND: The day before, it was bright and clear.

397. STEVENSON: Well, I think before you took off you had some indication of the kind of groundtruth backup that was going to take place. I made a list of those that have come in to date, and I keep finding everyday that some other ship was involved that had received the message before the flight and had not indicated that he was going to do anything until after the flight was over. So the data are piling up in my office about 3 feet high. But I think you can see from that list, that certainly the U.S. Navy and the fleets and air forces of New Zealand, Australia, and Great Britain were interested enough to become involved. To refresh your mind as to where they are located and where they are planned, I'll go over them.

398. STEVENSON: The first one was on revolution 17, and we sure appreciated that fact that you left that in the flight plan, running north from East Cape in New Zealand. In that area, the Royal New Zealand Air Force had a P3 they flew the day before. They flew the day you launched and then the day after you launched, which was your visual observation and photographic day. Then they flew the third day, and the day after that. During the same time, the New Zealand Navy also had a research vessel along that line and I'll show you some of those data. They're rather interesting, because not only did they run water temperatures, but they also did some sound-velocity measurements and they caught an eddy and you can see the change in sound velocities in that eddy as we talked about before you went up. Vance, that was one area where you said you thought you saw a scum line, but it went by so fast. We'll look later and chat about that later, maybe.

399. STEVENSON: The second area was along the east coast of the United States; along several of these revolutions that you eventually made. In that case, *Preserver* (one of the ships standing by in an event of an immediate abort after launch) went farther north and released four drifting buoys with transmitters that transmitted to Nimbus-F. The Nimbus-F was positioning the buoys about once a day with the precision of a kilometer. And those buoys drifted throughout your entire mission. They worked beautifully, by the way. Hopefully we can tie some of the photography in with that area. I don't know what they got of that area, but I think they did get some.

400. STEVENSON: In coming around the world, the next line was running southwest from the bight of Spain and in that line we had the U.S. Navy research vessel *Caine,* and they ran that line from July 15 through July 22; so they started the day of the launch and they continued to run back and forth along that line for six days getting some detailed

temperatures and other data.

401. STEVENSON: Then again, the day before, the day of, and the day after, your revolution 73, the Navy flew a P3 along that line dropping expendable bathythermographs [XBTs]. That was the greatest success from my point of view because that's when Tom suddenly began to see the internal waves [west of Spain] and the boundary; and the photographs are beautiful. They're really spectacular, and that boundary was precisely where we had hoped it was. It's right across the flight line and the data looked great. I've seen some of the data and they really look good; so that was a spectacular success.

402. STEVENSON: The next planned line was the Royal Air Force [British] line that ran more or less east and west from southwestern England, although they didn't start dropping XBTs until they got just off the tip of Ireland; and that was revolution 160 [?]. They again flew a three-day sequence. On the day before the revolution, they had really fine weather, they got good observations, and the data looked pretty good. The day of your pass, it was pretty cloud covered. They noticed 10/10ths for two-thirds of the line and 25 percent and 75 percent for the rest. Again, it was the type of situation where operations in one shot over the area is going to hurt if the weather's going to move in.

403. STEVENSON: Then we had two groups come into the picture that came in on their own more or less; but we certainly welcomed the data. The carrier *Roosevelt* was on the return from their final deployment—*Roosevelt* henceforth will be used for a training carrier along the East Coast—from the Mediterranean to the U.S., so they made a complete transect of the Atlantic Ocean dropping XBTs all the way and making weather observations right across.

404. OTHER PARTICIPANT: What's an XBT?

STEVENSON: Expendable bathythermograph. It's a probe which is dropped into the water and it makes a record of the temperature of the water versus depth to a depth of 1500 feet [457 m]. They're expendable because, when the probe comes to the end of its very fine copper line that attaches it to the recorder on deck, then the probe breaks the line. They're fairly cheap devices, so you don't worry about throwing them over. In that way you can throw them from an aircraft, too. You don't have to lower something and pull it back up.

405. STEVENSON: Anyway in two cases, *Roosevelt* happened to cross at times when there were visual observations. And I haven't seen the *Roosevelt* data yet, but I'm sure they will be useful.

406. STEVENSON: Also the carrier *Kennedy,* which is now on deployment in the Mediterranean, is sending a mass of data that they took during the redocking. I don't know whether you were looking at Soyuz or at the Mediterranean when you were redocking, but there was a beautiful shot of the Mediterranean behind Soyuz and there were two good fronts that showed up well in the videotape. Now I don't know what the photography looks like. I haven't seen it, but in the video there were two good fronts that showed up very beautifully. Did you have a movie camera going at that time here?

STAFFORD: I had the DAC going at the right window for the redocking.

STEVENSON: That's what we saw yesterday, I guess. *Kennedy* is our most sophisticated weather ship, oddly enough, even though it's an attack carrier. So, we have some good data coming from that.

407. STEVENSON: We also have data from three of our defense meteorological satellites, both visual and IR. The point of that is to try to relate the photography and your observations to the kind of degraded information we were getting from those meteorological satellites.

408. STEVENSON: As I mentioned, New Zealand had P3's out three days, and they had a ship out.

409. STEVENSON: The Australians had Her Majesty's Australian Ship *Bombard* sitting right in the middle of an [ANZUS] eddy for four days. You remember we did give you information of the approximate location of the eddy. We got good solid data. The report was that it was the most intense warm-water eddy they had yet surveyed. It's 80 miles [129 km] in diameter, nearly circular, and

the first two days the ship was there, it was clear sky with a beautiful formation of cumulus over the eddy; and sitting right in the center were about a dozen Japanese long-line tuna vessels, which created a navigation hazard for the guys trying to get across and make some temperature transects. It was a very good exercise even though the front moved by and you couldn't see through those clouds.

410. STEVENSON: And then, of course, the Royal Air Force [British] were flying Nimrods, which are converted Comets. At cruising speed with all four engines going, they can attain 400 knots. And you can't drop an XBT at 400 knots, so they shut down two engines and put down third flaps and they flew the whole line, 600 miles [965 km] at 240 knots and got some very fine data. Unfortunately again, as I say, the day was cloud covered. Well, as you can imagine from that, much of what you reported is of real value. Not having been able to go through the data yet, I can't comment on all of it.

411. STEVENSON: But the spectacular one was the Spanish coast.

STAFFORD: That's the value of these flyovers. When you fly up and down the channel between Los Angeles and San Clemente, you'd go one way and you could see some of the waves and some gyres. If you turn around and fly down the other way with a different sun angle, there would be nothing but blue. I was looking for all these things and suddenly they popped out within a second right there. Just suddenly when the sun angle changed, everything was there, the waves and the boundary were all there and we just snapped a series on them. But before that, there was nothing but just solid blue water and then they just suddenly popped.

SLAYTON: They don't last long, either.

STAFFORD: No, they don't last long.

SLAYTON: You told me to look about 10 seconds later and they were gone.

412. STEVENSON: So you have to be ready.

STAFFORD: You have to be ready and the sun angle has to be just right. And it's there for just a short period of time and then it's gone.

413. STEVENSON: I suppose if you're in the right attitude and you can look at the glitter as you're moving along, as long as it maintains itself in your field-of-view, then you can probably pick up features a little better. In this particular case, the glitter came upon you all of a sudden?

STAFFORD: Yes. It was just instantaneous.

SLAYTON: But you lose it the same way, as soon as the sun angle changes.

STAFFORD: The sun angle gets lower and lower and then it's gone.

OTHER PARTICIPANT: We never got around to computing sun angle.

BRAND: We might add that, because of this fast change that we come across so often, that was one reason why we finally shifted to trying to get three crewmen looking at once. When I went over Seattle once, I had sunglitter great on Puget Sound. I could see it all with my eyes. After it was all over, there was little time to debrief and I felt like I wanted to paint a picture. I thought, why didn't I use the camera instead of my eyes? You always had to make a choice ahead of time. So finally got in the mode where we tried to keep both going at once. Somebody using his eyes and somebody shooting the camera.

EL-BAZ: Very good. Now we have Dr. Charlie Yentsch from Bigelow Laboratory to summarize the studies of the New England Coast.

YENTSCH: We can summarize by saying there was a lot of fog. Bob sounds like he mobilized all the navies of the world to help you fellows out. The best I could do was to get two of our research vessels out; and we roamed the ocean essentially from Cape Cod to Grand Manan Island at the entrance to the Bay of Fundy. Most of the time we found ourselves in a considerable amount of fog and overcast. However, about halfway through the mission, we did come on a band of discolored water and our mission was essentially to try to find where large accumulations of discolored water were occurring in this area, partially with reference to red tide, partially with reference to the general problem of water discoloration in the oceans. I phoned Farouk, who got in touch with you. Later I heard that this sighting was confirmed. Is that true? We have no photography of it.

SLAYTON: I guess I got mixed emotions about how we confirmed it, because what I saw was obviously discolored water, but it was fairly close into the coast; what I would be positive of is that there were sedimentary patterns coming out of some of those rivers onto the oceans. So as far as trying to make a flat statement that that was the sedimentary boundary versus something else, I wouldn't do it. There was obviously a discoloration difference there and I hope we got a few pictures of it, I don't know whether we did or not.

STAFFORD: We shot a lot of pictures of that area.

414. YENTSCH: As you pointed out, the whole problem with water color is complicated by the fact that sediments, biology, and actually a group of organic compounds that flow into the ocean also discolor the water. If we did get some record of what we call wall-to-wall dinoflagellates, red tide, then I think in your mission, you'll have examples of all three phenomena of color, which is quite nice. I'll just sum up by saying that I think that, if we do have all three of these examples from high altitude, this will be a contribution to oceanography.

415. EL-BAZ: We have also a note from George Maul. He's not here today yet, but he had a NOAA ship . . . the *Virginia Key*, from Miami going all the way to the Yucatán. They did find that all the Gulf Stream was squeezed between the Yucatán Peninsula and Cozumel. They did scan the waters of the Gulf from this area all the way to the Gulf and they also had some twenty NOAA ships working around the Mississippi River Delta and the coastal waters. So whatever information you had, plus the pictures in the Gulf waters, will be also helpful; the moral of all that is that, from the oceanographic point of view, there was really a lot of good ground support and people who are very enthuiastic about what you were doing and I'm sure the photography will be very helpful to all these parties later.

416. EL-BAZ: I want to go through some of the disciplines, discuss some of the photographs, and show you some material you may have not seen and would like to ask you for more additional comments on what you actually saw in flight. We'll start with Bill Muehlberger, who will treat structural geology in a couple of areas.

417. MUEHLBERGER: One thing I would be interested in has nothing to do with structure, but that is the glitter. As you come across the ocean onto land, did your eye have to readjust to be able to discern textural features on land from the glitter all the time?

BRAND: No.

MUEHLBERGER: You do it all right. Good. I didn't want those oceanographers to beat us out of our land targets.

418. MUEHLBERGER: What I'd like to do is work through the Dead Sea/Red Sea strip first and then move into the southwestern U.S. Lee Silver couldn't be here, so I have to play him for a minute. Those I thought were some of the really spectacular pictures that you picked up through this mission. Some of the other targets that we had told you were clouded over too much to show a lot of neat features. But if we are smart enough, we could ask you questions that might increase our knowledge.

419. MUEHLBERGER: Let me start down in the Afar Triangle, which is the southern point, but I think it was mainly cloud covered for you. What could you discern there in terms of the big fault scarps? They are the ones that are of particular interest, their linearities or bends. Are there any features beyond what we tried to show you before the mission that come to mind? It was a bad day. The only cloud in all of central Africa went over the area at that moment and it was very solid.

SLAYTON: I don't remember seeing anything in there.

420. MUEHLBERGER: The Skylab crew had filled in much of the Sinai Peninsula and on up into the Dead Sea; the part of particular interest is farther north. You took a suite of pictures there that is just gorgeous, makes a perfect fill-in. When someone wants to give a lecture on the whole region, he can just run along here and look at these pictures and illustrate all these.

421. MUEHLBERGER: That's the Levantine Rift and

I have two slides that I'd like to show you and I'd like to ask Vance about his three faults. This is one of the suite that doesn't show all the northern end, but it does illustrate the three major faults that were illustrated in the Visual [Earth] Observations Book [Appendix 3]. Then in the debriefing Vance mentioned one going almost due east that worries me a little bit and maybe that's that upside-down position that gives you a little problem with compass direction.

BRAND: Because it's been about three weeks, I'd like to review my comments and then try to reconstruct it.

MUEHLBERGER: You said 1 and 2 were very prominent. One stayed parallel to the coast as I remember. I concluded you were talking about that one.

BRAND: That one stood out very clearly; one that I'd never heard mentioned before, that headed up the Turkish coast.

MUEHLBERGER: At right angles to the direction that we're looking now? East? West?

EL-BAZ: Do you really mean the Turkish coastline or is it Syria? Do you mean the Turkish coast or the northern end of the Mediterranean?

MUEHLBERGER: Let me sketch it for you. Turkey comes around like that and then the eastern Mediterranean coast goes down here; Cyprus would be in here. Is it part of the north-south . . .

BRAND: I guess I didn't know how far south the boundary of Turkey extended. Continues up the Mediterranean coast toward Turkey.

MUEHLBERGER: Presumably that would be the continuation this way; it's trying to make another left kink way up there.

BRAND: That was very prominent.

422. EL-BAZ: The way you described this is that you had a fan-shaped— number 1 went all along the coast, number 2 got lost in the middle somewhere, and number 3 headed east-northeast until it joined a river.

BRAND: Let me talk about number 3 first. It looked like a sort of a sedimentary plain down there and it sort of got lost in that plain. I couldn't really see where it ended. The river cut it off completely as I recall, but it kind of disappeared before it got to that river.

MUEHLBERGER: Was that the Euphrates, that main river with all of its vegetables down the middle of the floodplain that would make it dark and green?

BRAND: As to which river, it was off this picture. What I should do is refer to a larger map to reconstruct.

MUEHLBERGER: Unfortunately, I don't have any pictures that look the other way to show you that sort of thing.

BRAND: But I did not see a sharp end to this and it sort of went into a sedimentary area. I could not determine a precise ending for it.

423. MUEHLBERGER: The other one we have mounted is the closer view of this one. Here's a small lake; the Dead Sea; the Sea of Galilee; and this one's name I can't remember; but you took a beauty of this area which I'd like to have you look at.

BRAND: My overall impression, remembering now, is that, in general, you could not see the ends of these things.

424. MUEHLBERGER: You also talked about the twists and turns. One of these other frames shows it very prominently, and, because of the look angle you had, accentuates the bends a little bit. This one, that one, and that one make the bends look very angular. I'm wondering whether they're really angular or whether they're long arcing things within the bend. Do you have any remembrances along those lines?

BRAND: I'd have to say no, that my overall impression of the first bend was that it was a very jumbled, beat-up area.

MUEHLBERGER: A mass of arcs trying to be but they were—

BRAND: They were having a hard time making the corner sort of.

MUEHLBERGER: That's a reasonable answer. If your strike slip fails, you have trouble going around corners.

BRAND: I can't answer the question the way it was framed in the beginning.

425. MUEHLBERGER: Well, here's a high oblique looking southward into the southwestern U.S. One of the questions that was asked was, where is the southwest end of the metamorphic belts in the Sierra Nevada? Which means looking down along this strip of coun-

try and all this picture is supposed to do is jog your memory.

BRAND: We had a good pass over that. I had a good chance to look at it and I must say it's from an airplane. The vegetation overrides so you do not see the gray except in areas where there are roads, perhaps quarries, where something has disturbed the vegetation.

MUEHLBERGER: Vegetation overrides the color differences of the ground underneath it?

BRAND: Yes. Where the vegetation was cut away, in the northern area of where that was supposed to be, I could see some gray. At the northern end of the San Joaquin Valley is where I could see this gray cut away. But as you looked south to what we're really trying to see, the vegetation isn't cut away anyplace and you just can't tell, because the area was covered by golden grass and purplish trees. I will say, though, that as soon as we crossed the Sierras and got into the desert where there wasn't very much vegetation, I wished to myself that the Sierras on the western side had been like this, because I could see all kinds of colors.

426. EL-BAZ: Before we leave this slide, there are two things that will interest many people here. First of all, were you able to see these sets of fractures west of the San Andreas from the estuary? Were they clear? Did you see the San Andreas escarpment itself?

BRAND: Yes, very definitely. It was very easy to see. I forgot just how I reported it, but I did see other fractures. Basically, I think you can see that from an airplane as well.

427. MUEHLBERGER: There's an alignment in this picture that really intrigues my eye and I suspect that's the one that Lee has been working on for quite a while. It cuts across the east part of the world in there. The San Andreas is over here. And I think that's his old fault zone because all the mountain ranges just completely change their orientation and shape in there. I remember he's been worrying about where it is some of these bands of rocks go. The gray polonna [?] schists and things that were supposed to be down in that area are completely missing.

EL-BAZ: It's the one that's supposed to lead into the desert-varnished hills, also. Vance, were you able to do anything about these desert-varnished hills? Were you able to see any more in the Mojave or the desert in general?

BRAND: I saw some more hills that looked just like varnished hills.

EL-BAZ: In addition to the four you already knew about?

BRAND: Yes. And I think I called out their locations.

EL-BAZ: Fine, because we did not hear this on any of the tapes.

428. MUEHLBERGER: Lee was also interested in the Bahía Concepcíon Fault which is on Baja Peninsula. Next slide, please. Here we are looking north up through the Gulf [of California] and here's where the fault zone exists. Naturally, we have a cloud on it. Any thoughts concerning this fault zone? It may be one of those old dead spreading centers that presumably is out in the bottom of the ocean now.

BRAND: I tried to get the pictures. It was one of those cases where I think pictures overrode viewing. And the cloud cover was a little bit bad and I was—

429. MUEHLBERGER: Another good example of two people really being needed to do the job.

STAFFORD: I think that's generally true all the way through. If you're going to try to get a stereo set of anything, you can forget looking at it. There's absolutely no way to do both.

MUEHLBERGER: Well, I had that feeling before we went and you guys have really clearly demonstrated it. One of the recommendations had better be a two-man team then.

BRAND: And this was early in the mission, before we got into that two- or three-man mode.

MUEHLBERGER: We should have thought of that beforehand.

430. MUEHLBERGER: The strip you took across Los Angeles is gorgeous, incidentally. It's probably the best set of photographs that we've had and I don't remember that we mounted one of those. I think those were the main points I wanted to cover.

431. EL-BAZ: Now Carol Breed will talk to us a little bit about some of the deserts, both in North Africa and Australia.

BREED: First, I want to thank you for always being willing to look out the window one more time to try to get one more picture. I know that time was of the essence and yet you always seemed very willing to go on with the Earth observations. I'm also very happy that you made as many observations over the deserts as you did. I was really surprised, considering the brevity of your mission, that you could make as many as you did. I have some slides showing the variety of features which you saw and then there are some pictures which I believe are on the rolls here that I'd like to, if I could later, spend a little time going over with you, because pictures that I don't have are very small features that are of particular interest to our project but may not be of general interest to the whole audience.

432. BREED: First slide, please. We'll start with something to take you back to where you were and get you thinking about what you could see in terms of resolution. This is the southern part of the Simpson Desert. This is where you remarked that the dunes looked like straight lines drawn across the landscape. Actually you can only see parts of the dunes here and the ones that are really quite straight occur farther to the north. Can you tell me anything more about the dunes in this area other than what you said at the time?

STAFFORD: We all looked at it. You can see the long lines. I couldn't remember anything like the crescents such as we saw on the east side of the Andes or over in China Mongolia.

SLAYTON: They tended to be linear.

STAFFORD: These were all linears.

BRAND: The overall structure was linear and, when you looked at the detailed structure, it was linear, too.

BREED: I'm glad that that's the case because that's what we know about so far and if you had found something different, I would have been a little concerned. That confirms the classification of that area.

433. BREED: Now there is a picture on one of these rolls of some dunes that look very much like this in South Africa and Angola. This would be north of the Namib Desert. There were some very narrow linear features there that appeared to be taking off from some dry river beds. To me, looking at the pictures, it looked very similar to the ones in the Simpson Desert. So far as I know, these dunes have not been described and I'd like to know if you remember seeing them and, if you do remember seeing them, do you remember noticing any similarity between those dunes and the ones in the Simpson Desert?

EL-BAZ: We can look at this later. The strip of photographs was taken with the mapping camera [black] so nobody was really looking at this terrain at the time, unless Deke was. On revolution 40, when you turned the camera on, it was good weather in Southwest Africa all through. I don't know if he was looking in that direction or not, but we can look at these pictures later.

BREED: Well, the reason that this is of interest is because the more southerly parts of the African continent are well known. But this particular place is not, and I didn't know that these dunes were there; I didn't expect anybody to see, report, or map them.

434. EL-BAZ: How about a comment on the Simpson Desert? Do you think any of this color is real?

BRAND: It is red!

EL-BAZ: Is this the way it looks? Is it dark red, this red? Dark-brownish red?

BRAND: We might have done fairly well with the color wheel on that.

435. BRAND: The usefulness of the color wheel was a function of how much light we could get on it from outside. I know that I tried once or twice and might have come up with a fairly good representation of the color.

SLAYTON: I think the fidelity of the color in those photographs is pretty good. I wouldn't be uncomfortable about taking a color wheel and matching it against the photograph and saying that's pretty good.

436. EL-BAZ: Was there any other desert that looked as red as this one?

BRAND: Not as red; there were other red deserts but not as red.

BREED: I feel a little bit handicapped in this regard, because we don't have all the transcripts and nine of the deserts you observed were later on in the mission, and we don't have transcripts of the recordings yet.

437. BRAND: I must say that I expected the African deserts to be redder than they were, just from hearing people talk. They struck me as being more yellow than I expected.

438. BREED: Okay, the next slide is the African deserts, and I wanted to use it as a contrast.

SLAYTON: That's fossil dunes there?

BREED: Yes, these are fixed dunes, stabilized by vegetation, all but their crests, which are still active. That's quite far south in the Simpson Desert.

SLAYTON: Yes, that's down in the south; it's the first thing we'd run into actually crossing the coastline. I remember we ran into this kind of structure, then you get into the red material.

BREED: And the material in the center part of the desert and towards the north is considerably redder than all of this, is it not?

SLAYTON: Oh yes.

439. BREED: Now this slide is what I think Farouk is talking about. Notice the color difference here in the Egyptian Desert. Here you can see some linear dunes. I am not sure that you can see it, but there is a different dune pattern up there. It doesn't show up too well in projection. It's an entirely different pattern than these large seif dunes right down here. The seif dunes themselves are rather atypical linear dunes because they are a branching, sort of bifurcated feature. I noticed right away looking at this that there is a very distinct color difference between these big dunes and the background. I wanted to ask you if that's real, do you remember?

BRAND: This is once again a case where I was concentrating on photography or looking for pyramids. I don't recall that the dunes over in that area stood out all that much. That photograph was a view taken by the mapping [black] camera out window 5.

BREED: This is an area in which you were making visual observations, but you did not notice that the dunes stood out in any way?

BRAND: I wasn't really looking for them over in that area. But it's not something that attracted my attention.

440. BREED: You can see this area in the center of the desert is considerably redder than the area up here. As you know, within a desert where the dunes are all derived more or less from the same source of sand and presumably by the same processes, we think relative color differences like that can be used to determine a sequence of events; because the longer the dunes sit in a subareal environment, the redder they get. So this kind of color difference is interesting, and I just wanted to know if you had actually observed this kind of thing in the African deserts as a general rule.

441. BREED: Are they redder in the southern part and lighter as you get closer to the Mediterranean?

SLAYTON: I think there is little doubt that close to the Mediterranean they seem to be fairly light. But some of the material we saw down there in the central part was like this, some of it was more reddish. Of course, around the dark hills down here, you see some little darker material.

BRAND: I couldn't draw that conclusion that there is more red in the southern part at all. In the area of the Oweinat Mountains down to Lake Chad, it's rather yellowish as I recall.

442. EL-BAZ: Actually, Carol, these dunes are a lot more weird than you would expect. I flew over these and there are star dunes on top of the seif dunes.

STAFFORD: On top of the big long linear ones?

EL-BAZ: Yes. The ones that go north-south.

BREED: These are much bigger than the ones in the Simpson Desert.

443. EL-BAZ: While we're talking about the linear dunes with star dunes on top, Tom, didn't you say something about this in real time? You said you were looking at dunes, long linear dunes with star dunes on top, maybe over the Gobi?

STAFFORD: Yes, there was one you could see. There were huge long dunes with something superimposed on the linear dunes, but I don't remember exactly where.

BREED: You were somewhere in China; you were right over this area west of the Hwang Ho River, the Yellow River, right in the Chinese part of the Gobi Desert. Did you take any photographs of the area?

BRAND: We sure took a multitude of that area, probably on the 35-millimeter film.

STAFFORD: I think this was late in the afternoon. Due to the sun angles, I could probably see it well. That was why. With a high sun angle, I couldn't have seen anything. The sun angle means everything in certain features.

444. BREED: Next slide, please. This is the Lake Chad area; I wanted you to look at this because here we have the other major classification of dunes, the crescentic features, which you did observe. Here they are stabilized, they are fixed, and the curvature is not particularly pronounced, but it's pronounced enough that you recognized them as being crescentic dunes.

445. BREED: If we could go to the next slide, you could see this one in a little more detail. These are the crescentic dunes regions here. Next slide.

STAFFORD: Yes, I remember that.

BREED: That's just super. This is a dune field in Argentina. What can you tell me about it?

STAFFORD: Okay, it's right over the edge of the Andes Mountains. Where the mountains end, there is a little area in between and those [dunes] start. And you could really see how they were crescents; it looked like occasionally maybe the head of the crescent would wash out, and it would tend to be a linear one with lineations on the side. There are all those other little crescents up on the left. That was the area that you wanted me to look at?

EL-BAZ: Yes, that's the only one that we thought existed. We didn't know that there were two dune fields.

STAFFORD: We were really taking photographs of that.

EL-BAZ: Tom, to remind you, this is the shot with the 250-millimeter lens and it's beautifully centered.

BREED: This is really a super picture for many reasons. This dune field is not well known at all.

STAFFORD: I'd remembered that there was some type of linear feature. There were two rays. One was on this edge down here, which is nearly a linear. But the big thing was those huge crescents; then something else linear caught my eye. I see what it is now, those very minor ones in the center left part of the picture.

BREED: This is a particular variety that I haven't seen anywhere else; I have seen a lot of varieties of this generally crescentic dune pattern, but nothing where you have these linear dunes superimposed right on the crescent and they're oriented in this way. That's totally unlike anything I have ever seen anywhere else, so this really is the prize picture as far as desert dune observations went.

STAFFORD: On that little field up there, it's just the way the boundary was very well defined, as opposed to the other where this kind of fades out into like a dry lake bed.

BREED: One of the things that is very obvious is the relationship between the edge of the alluvial fan and the beginning of the dune fields; it's very, very sharp. That's not a very red dune field, is it?

STAFFORD: No, it's not.

BREED: Does it look about like the ones you see in the southwestern United States in terms of color?

SLAYTON: I would say so. We had a fairly early morning light.

STAFFORD: I think it's close. We had early morning light there and low sun angles. It didn't have the redness like the Simpson does or anything like that.

BREED: Well, that was what I was getting at. The reason I asked that is that this is in a latitude where you might expect redder dunes.

446. BREED: We don't have any pictures or any record yet in the transcript of any area with any star dunes, but you did mention the ones that you saw in the Chinese region. Did you see any other star dunes anywhere?

STAFFORD: I didn't. Again, I said stars; I saw something superimposed, and I made a guess that it was stars.

BRAND: In general, I think it's a lot easier to see linear dunes than anything else, because your eye picks them up. Star dunes are rather hard to see at that altitude. Crescentic dunes are somewhere in-between.

447. EL-BAZ: Now, Deke was describing some stars or domes.

SLAYTON: Yes, there were some interesting features in what I thought was China or

Mongolia. We weren't too sure where we were, but there was something peculiar about that whole area; it just had a different appearance about it.

BREED: In the transcript, it says, "They look kind of like old domes; they're not stars and they're not linear either." I presumed that what you were talking about here was Africa, but you did see this sort of thing in China also? Something that looked like domes?

SLAYTON: Yes, but I would have to go back and refresh my memory on that subject. I remember every time we came over there I was fairly sure that was where we were, because the mountains had a real black look about them and had a totally different overall appearance than anything we saw anywhere else. I think that was in the area where I saw what I would term more of a dome-type pattern as opposed to the pure linears. I hope we've got some pictures in there; I don't know if we did or not.

EL-BAZ: I think this mention of the domes was while you were running the DAC, between hills in Algeria.

448. BREED: I wanted to ask you about one other phenomenon, and that is the sand and dust storms that you saw.

SLAYTON: The first pass we made over that area, I just had the feeling I was looking through a haze layer. So all I could conclude was it was either a very high thin cirrus (which I don't think it was) or it was a dust storm. It was definitely a fuzzy-looking phenomenon.

BREED: You mentioned that it had a rolling appearance, a layered appearance. Could you see anything that looked like a regular pattern of rollers, a cellular sort of structure?

SLAYTON: Not that I recollect. I just had a very positive conclusion in my mind, that was what I was looking at. I couldn't draw any other conclusion from it.

BREED: Well, Bill Muehlberger brought along a copy of *Science* magazine and inside there is a picture of part of the Chinese Desert, the Takla Makan Desert, with a dust storm in progress.

MUEHLBERGER: Now that's a storm pattern.

BREED: I was wondering if you could see any of that pattern.

SLAYTON: I don't recollect it.

BREED: At your altitude then, it doesn't show up?

BRAND: The only place I remember dust storms is around Aral Sea, Kazakhstan [USSR].

BREED: Did you get any pictures of those dunes?

BRAND: They were really obscured by the haziness.

STAFFORD: It was late afternoon, but you could see the storm was really blowing; the wind was really blowing.

449. BRAND: You asked about the color of the desert in the more southern parts of Africa, south of Egypt, mid-Africa. I think that last shot showing the Oweinat Mountains was fairly representative of south of Egypt.

EL-BAZ: Vance, are you talking about the strip of sand between the two hills?

BRAND: It has some reddish tint to it but, by and large, it's fairly yellow.

EL-BAZ: That strip of sand between the two hills is rather light colored, very light. So this was the color of the desert from Lake Chad all the way to Egypt?

SLAYTON: It has that real light color track there, a river; then you have that darker stuff which you would expect around those mountains.

BREED: Then there is a streak of windblown sand, here and there are some dunes associated with it that you can't see too well.

BRAND: Well, you have a fair amount of variation in the deserts down there, but I would say if you would take the lower right-hand one-fourth of that photograph, the colors there are fairly representative.

BREED: Well, you can easily pick out the contrast here between the gravel plains and the windblown sand, because you don't get the oxidation.

BRAND: I might say that the black mountains in that picture look much blacker in real life.

STAFFORD: Yes, they sure did.

BRAND: You just couldn't miss them. They really showed up.

BREED: This illustrates very nicely, too, the barrier effect that you get between an outcrop of this sort and the beginning of a major sand deposit of that sort.

450. EL-BAZ: One more question here. Vance, we thought that these things were igneous intrusions. What did you think? I know that you said something about volcanic nature.

BRAND: Well, I know that it's always unsafe to draw big conclusions like this in geology, but they looked igneous to me. It looked to me like a big volcanic pile under the sand that had intrusions, many of which were circular and some were not. But it looked like the top of a mountain under the sand, and these were just some of the things coming up. I know that that's just an impression, but it looks like a lot bigger area of black rock than just what you see here. You think igneous because it's black, and you see structure.

BREED: Okay, that's all I had, and thank you very much again. I think it was quite successful. You brought back a lot of good material.

451. EL-BAZ: Dr. Robert Dietz has a few items on several structures and a few things that we have not seen yet.

DIETZ: I want to cover both impact structures and some volcanic features. Regarding impact structures, there are two known types and these give very close contrast with lunar features. Among impact features are meteorite craters, the "type" example being the Arizona crater, Lonore in India, and some others; and I assume none of these were observed. They are all very small and probably outside your resolution unless you knew exactly where they were. The other type of feature is the astrobleme; these are the ancient impact scars, and you did obtain two of these. There is a third type which we think may exist; I'll mention it briefly. In 1908, there was the Tungusky event in Siberia caused by a comet head or possibly a carbonaceous chondrite, a friable meteorite that exploded in the upper atmosphere and blew down trees over a radius of 25 kilometers. Of course, you didn't see this; it's too far north. But it has occurred to some of us that in desert areas, particularly in the gravel plains or regs, that someday we might hope to find—we never have—a bleached stellate spot caused by some sort of upper atmospheric event of this type in one of the regs. These would turn over the gravels, which are desert varnished; you should have a bleached stellate spot. Did you see anything like that at all?

452. DIETZ: Let's go into the astroblemes. One of the targets on the mission was the Sudbury Basin. This was not acquired.

453. DIETZ: Another was of two features in Brazil, and one of these is in the first slide.

STAFFORD: I could see it with my naked eye, but when I went again to the reflex, I couldn't see; so I just aimed down the barrel of the camera and shot; I'm glad we got it.

DIETZ: I assume this wasn't adventitious, but you did see it and photograph it. Is that correct?

STAFFORD: Yes, you could see it.

DIETZ: This is in Goias; it's the Serra de Canghala feature, or Packsaddle Mountain if we translate, a Mesozoic impact site. It's about 12 to 15 kilometers across the central dome and a ringed depression. I think it's remarkable that you were able to acquire it and to get this remarkable photograph of it.

STAFFORD: From the spacecraft, I couldn't tell you that that was an impact. You could see the round structure; but as far as definition goes, I couldn't tell whether it was a volcano or something else. There was a circular structure, and I was scanning and I could see a kind of high cirrus in there. And I suddenly picked it out and shot it. I had the 250-millimeter lens. I could see it with my naked eye, and I just aimed down the barrel and shot.

454. DIETZ: Congratulations on it. A few minutes before this, over at Mato Grosso, there is even a larger feature which has more of a series of concentric rings, 40 kilometers across, the Araguania Dome. Did you see that?

STAFFORD: Yes, I saw the two circular structures, and I think I shot at both of them. I'm not sure whether I got them.

EL-BAZ: There is one picture that we have right after this, but I could not see the circular structure in it. So this is the only one that we have identified yet.

STAFFORD: I saw the other one. The other one was bigger than this, isn't it?

DIETZ: It would be prior to this; it s to the southwest of this.

STAFFORD: I remember I saw two; one was bigger than the other one.

EL-BAZ: Was the big one not perfectly circular? Was it a little oval or ellipsoidal?

STAFFORD: There was something about the rings that was more defined. The rings looked harder to me. I can't say whether it was oblong, but it was bigger. Again, I tried to hit it with the 250-millimeter lens and I probably missed it. I was lucky to get this one. It was really frustrating to look through that lens and see nothing out there.

EL-BAZ: It's amazing that we get a picture like this of a very small feature that's still centered.

DIETZ: It's amazing and it's very difficult because generally there's a very high haze in the area, in the Chapada region just south of the Amazon (lens). We really got a remarkable day in having a cloudfree day. As far as I know, I have this on ERTS, but I don't have any cloud-free images on ERTS, which is most remarkable.

455. DIETZ: Next slide. This is the Kufra Oasis, and the circular spots are caused by a large pipe moving around once a week irrigating the ground. Near this, we have what is called the BP structure, which is a known impact site with shock metamorphic effects. And that is located right there, you see. These features typically have a central dome and a ghost ring. You see, here is the central dome, and there is the ghost ring. This is also about 15 kilometers across. Right here, there is another part of a ring that looks like a twin site, which if it is, would be a new discovery. This hasn't been described. This is 130 kilometers or so up to there. You see the central site, and you see the ghost ring. I haven't ever seen that ghost ring before in my ERTS images, so this is much better resolution. Further north is an even smaller circular ring, which is unnamed. Did you see that? It's another 50 kilometers further north.

EL-BAZ: I don't think they would see this, Bob. This is mapping camera photography.

DIETZ: This was not acquired for the circular structure?

EL-BAZ: No, this was a continuous strip through the desert. Vance was looking through window 3, and this is from window 5.

456. SLAYTON: In terms of resolution, though, that irrigated area down there and those circular things show up with no problem at all.

EL-BAZ: Oh, you have seen that in flight?

SLAYTON: Oh, yes. It's very easy to differentiate.

EL-BAZ: I see.

457. DIETZ: Well, this is a very fine slide and remarkable resolution of that feature, so it certainly is a plus to the mission. These are both two examples to be obtained of these astroblemes, these ancient impact sites which are domic scars or roof structures which have been etched out by erosion. But they are very important. There are very few in the world, and they are very important to tie in with lunar geology.

458. DIETZ: Next slide. Let's look now briefly at some volcanic features. This is Mexico in the area west of Puebla, and it shows a great many volcanic features. There are dike rings [?] and cinder cones, all acidic volcanism. You can see this little ash ring here; this is Tepexitl Crater; I studied this last February. But this is a remarkable sequence of volcanic features, in the Mexican central volcanic zone. I have no questions, but if there are further comments, we can take those.

SLAYTON: I think that is all very visible, again, very easy to see.

STAFFORD: Yes.

EL-BAZ: Who took this batch of pictures? They are very nice stereopair of this site. Do you remember who took these pictures, to put them in sequence?

SLAYTON: I think I took some through here, but I would have to go back and review.

BRAND: I think, in this sequence, we had a couple of cameras going. We had the Nikon and we had a Hasselblad going.

EL-BAZ: Okay.

DIETZ: This is a fine view of the east end of the central volcanic zone of Mexico.

459. DIETZ: Next slide. This is the Galapagos Islands. We see in here four or five large calderas. It's a most remarkable photograph, cloud-wise and also geologically. Now I take

it that when you're looking at Santa Isabela here—

STAFFORD: You could look down and because of the sun angle, you can see the shadows down in the calderas. You can see the depth.

DIETZ: There's one, two, three, four calderas here. And this is a separate island nested in against Isabela; this is Fernandina, using the Spanish names, Ecuadorian names. Fernandina is probably the third most active region in the world after Hawaii and Iceland. Fernandina was seen to be in eruption on an earlier space mission. In 1968, it had a caldera collapse, the only one in history where the central parts subsided about 200 meters.

460. DIETZ: My question is, did you see any activity here or any transients elsewhere in the world except Mount Etna, which you have and which is excellent, of course.

461. DIETZ: Do you see any volcanic activity anywhere in the world?

SLAYTON: I did as a matter of fact. We were flying over cloud cover, and we didn't know where we were as usual. But we saw something coming up out of those clouds that looked like an A-bomb to me. That was my first impression of it.

DIETZ: Where was that now?

SLAYTON: It was just a big mushroom thing. Well, we called the ground and gave them a GET; and a couple of hours later, they came back and said, we think you were about on the Aleutian chain. But this was an obvious big billowing cloud coming up through a lower cloud deck, and there was a big stream of gray-black smoke running downstream from it. And it had to be covering 150 or 200 miles [241 or 322 km], probably more than that at least. We reported it on the ground, and I hope we got some pictures of it; we tried to anyway. Whether they came out, I don't know. I have been very curious because I can't figure out what else it could possibly have been but a volcano.

STAFFORD: We never saw anything else on the flight that compared with that, as far as smoke.

EL-BAZ: We assume that it may have been an explosion, anyway, because this is a Soviet military testing site or range.

DIETZ: We have not run this down. Volcanoes have neither fire nor smoke. They have ash and they have iridescent lava.

SLAYTON: They do have smoke that goes with them.

DIETZ: Not really smoke unless they're burning a log or something. What they have is ash clouds.

SLAYTON: Right. That's what I assumed it was, an ash cloud. But it looked to me like it was a split cloud, actually. One part of it was gray-black and there was another stream running parallel to it, coming out that was more white.

BRAND: My impression was of the world's biggest grass fire, smoke cloud or something. It was a tremendous smoke cloud.

SLAYTON: Would it be some classified event or something?

EL-BAZ: It could very well be.

462. EL-BAZ: Bill has suggested that he saw . . . .

DIETZ: There's a strip at the end of the terminator and there was some gorgeous— I just thought they were thunderheads piling up in the background. Maybe that's why you took them. The things came right out of the stratus and made a great big mushroom.

SLAYTON: We took those, I think, down across Southeast Asia.

STAFFORD: This was blackish.

SLAYTON: It stood out by itself.

463. DIETZ: This area is uninhabited. It's a good example of what we can do from space because when something happens here, no one knows; it may be for two or three weeks or even months. So a place like this can be monitored from space.

464. DIETZ: It's very important to know that, and I'm sorry you didn't get the Sudbury structure. I can understand why, but if we find another Sudbury structure from space, we can hopefully justify the space mission economically because this dominates the world's nickel mines.

BRAND: Just a comment; the first time we passed over Sudbury, there was too much cloud cover. The next time, it was a very oblique angle; we just couldn't see it, as I recall.

DIETZ: I have no further comments.

465. El-Baz: Very good, thank you. Bob? Now we'll go back to the ocean observations and we have Dr. Yentsch talk about the New England waters.

466. Slayton: This goes with volcanics. We did have the three targets and I didn't see any of them. Mauna Loa was one of them that was clouded over.

467. Slayton: Mount Baker we did see and we didn't see anything.

El-Baz: There was nothing at all on Mount Baker?

Slayton: No.

468. Stafford: In Guatemala there is supposed to be an active one, and it was clouded over. We couldn't see a thing.

469. El-Baz: We are going to show some slides of the waters of the northeast coast of the U.S.

Yentsch: These are mostly on revolutions that paralleled the coast. The first revolution starts when coming up the east coast of North America; it's a very conspicuous feature being the sunken river mouth and the coastal plain area where it enters Chesapeake Bay. It's a good example of a situation where the interaction of the fresh water outflow and the sea water inflow creates all the sedimentary patterns that are suspended in water, and I think that's the first slide. It's a very excellent . . . slide. ERTS photography also has some very good slides of this sort.

470. Yentsch: So let's move right on up the coast. The next conspicuous feature is the world's most famous sandspit, I guess, Cape Cod.

471. Yentsch: Next slide, please. And that's a very excellent photograph of Cape Cod, Martha's Vineyard, Elizabeth Islands, coming off here, and Buzzards Bay in this area, Cape Cod Bay on the other side. The general problem of red tide in New England starts essentially from this bay and extends up to the Gulf of Maine, into Canada.

472. Yentsch: The next slide is a little bit better, or that's a better outline of the Cape. Provincetown is in this region. The very shallow area is here; here are the deeper waters of Massachusetts Bay and you can see some of those little entrance channels and places of that sort. The next slide is a little bit broader shot of the entire coast. This is Cape Ann, which is the northern cape in Massachusetts, and the New Hampshire border is right there.

473. El-Baz: Excuse me, Charlie. I would like to ask Deke a question. We have a report from the results of the 14 stations that were set up by the Commissioner of Public Health in the Commonwealth along the Massachusetts coast from Cape Cod to the south part of the Boston Harbor, through Gloucester and Cape Ann. They had a very high percentage of chlorophyll in the water near the coastline, and that area in particular, because there has been a lot of rain and the rivers brought in nutrients and chlorophyll and so on. Did you see any indications of that at all, Deke?

Slayton: Well, it was obvious that there had been a lot of rain and had all that sedimentary stuff floating along the coast. I guess I'm not sure what you mean by chlorophyll.

El-Baz: I mean it would have given the water near the coast a green tint. That comment never was sent up to you but it was supposed to have been. Along with the sediments you would have seen a greenish tint to the water at the coastline. You did not notice that?

Slayton: Would it have been a greenish-tint boundary between the muddy water and the clear ocean water?

El-Baz: That is right, yeah.

Slayton: Well, thinking back on it, there probably was a little bit of that but I kind of assumed that that was just a phasing thing rather than having a clear-cut boundary where you have a little mixing going on between the fresh muddy water and the salt water.

El-Baz: It could be mixing, but did you have the feeling that there was a greenish tint to that muddy water or the fresh water coming out?

Slayton: I'd have to say I think so.

Yentsch: Low-level haze almost rules out that kind of visual identification. Even from an airplane you have difficulty.

Slayton: We certainly didn't get it on this pass. There was a couple of passes where we were a little oblique and we had a fairly good view in that area. I don't think we got any good pictures at that time.

474. EL-BAZ: The ones that were taken of Cape Cod with the 250-millimeter lens. Those were the runs that you were supposed to take of Cape Cod and Cape Ann and so on. I bet that was the run that was good for viewing.

SLAYTON: That run, as I remember, was clear around the Cape Cod area and then got cloudy as you got farther north. I think that's where we got the good Cape Cod pictures. I think it was a later pass where we got the stuff farther north.

475. YENTSCH: Yes, I think that's in the next slide, the shots of the Bay of Fundy. Next slide, please.

SLAYTON: That's quite a bit farther north. I hope we got some in between there.

YENTSCH: This is Prince Edward Island. All of these red discolorations are really due to red clay. There are lots of deposits there and the high tidal activity keeps the water stirred up. It's kind of interesting to be able to follow these and see where the water clears up.

STAFFORD: I didn't get much chance but it seems like those little things came out a little redder than what that photographed. It seems like the redness of that stuff near there was more likely a clay. Deke, what do you and Vance think?

BRAND: There was a lot more contrast.

YENTSCH: I think maybe the next slide is a little bit better. Perhaps not.

SLAYTON: That covers the area pretty good all right, but that's hazy too. It was a lot clearer eyeballed than that shows.

476. YENTSCH: The next slide gives a good example of the sort of organic outflows that I was telling you about. Now this is a totally different material. This is organic acid that's made by the heavy vegetation in these delta areas. This is the Orinoco River outflow and that is really a beautiful, beautiful section.

477. YENTSCH: I personally have been interested to know how far out you can detect this material.

STAFFORD: We gave you a mark. It goes way out in the Atlantic.

BRAND: Let me qualify one thing. You know we were talking about it all the way out there, to where the end of the brown water was; but later I kept watching and I decided that maybe we said it was a little too far out because you can detect a little bit of brown in sunglint.

EL-BAZ: Tom, if we go by this we didn't know whether you were giving us the old GET or the new one. Do you remember? We were two minutes off, or whatever, because when we plotted that on the map it was way out in the Atlantic. Now can you remember, where was Barbados in relation?

STAFFORD: Oh, it was past Barbados, because Deke got a stereopair of Barbados.

SLAYTON: I took a whole series clear across here. On that run I think we went across Cuba and Bermuda. That pictures that whole area I hope.

EL-BAZ: We have very good pictures of Jamaica, Cuba, and so on but we are talking about this discoloration in the water from the Orinoco River delta, whether it actually did go beyond Barbados.

SLAYTON: Oh, yes. Barbados was in fairly close but I sure agree with Vance, because in the sunglint it does have a tendency to look a little tan or something. In any place, the Pacific or the Atlantic. But you could look out to the side and it even went way past Barbados.

EL-BAZ: That's the question.

478. YENTSCH: To the oceanographer, this is a very interesting situation because this is like doing a huge dye experiment and putting it into the water and being able to trace it. It doesn't decompose very rapidly so that it takes on the characteristics of the water motion along the coast.

BRAND: I think it was one of the most dramatic ocean effects we saw. It was really something.

479. SLAYTON: Another one similar to that was off the coast of China there where a river, that is the Yangtze, drains into the China Sea there. That was the same kind of a thing.

480. YENTSCH: Bob, one of the Chinese rivers had one of the highest loads, you were mentioning?

STEVENSON: Yes, the Ganges has the highest sediment load, I think. But the Yangtze is way up there, and so is the Orinoco. But the Amazon is quite clear.

481. YENTSCH: It's kind of interesting as sort of a sidelight that this yellow water going by Barbados is a signal to the fisherman out there to start up their fly fishing industry. It's kind of correlated, indicating that that does have some sort of a biological significance.

482. EL-BAZ: Thank you very much. Now, Deke, getting back to your comments about the New England coastline. I don't think we have seen any pictures from about Cape Ann until you come to the northeast part of Maine. Unless it is in a magazine that has not been processed yet, we have not seen photographs of Boothbay Harbor.

SLAYTON: The whole particular area was just about all clouded over. The one pass when we got the Cape Cod area was clouded over just north of there. But that's what I was thinking; maybe my geography is off a little bit. I thought we were getting Boothbay there in that area, that last one with all that coastal outline.

EL-BAZ: It's farther north than that. That's the Bay of Fundy.

SLAYTON: My geography was off and we never did get any good stuff done around the Cape.

483. EL-BAZ: The comment that we wanted fed up to you was "on this particular pass, try to get a continuous strip all the way from Boston to New Brunswick." I think it was Crip that read the note and he emphasized the Boothbay Harbor, and you picked up the Boothbay Harbor or you thought it was at the Bay of Fundy because of all the sediment in the water.

SLAYTON: I thought that we were in the Boothbay area there; we must have been farther north.

EL-BAZ: It was a poor attitude.

SLAYTON: We were kind of at an odd angle and I remember looking over it like this to see it.

EL-BAZ: The attitude was not optimized for visual observations. We were piggybacking on some other attitude.

SLAYTON: It was okay for looking. I could see fairly well, but I couldn't get any photography because it was a very oblique angle down through the window.

EL-BAZ: But you don't recall whether you were looking down at Boothbay Harbor or not?

SLAYTON: I thought I was, but I probably wasn't. That whole area up there was usually clouded over or at least large enough portions of it so that it was pretty hard to differentiate. I remember that one pass when I picked up Long Island; I thought I was already at Cape Cod and I shot some shots. I think we were really right on the edge of Long Island. We got a few pictures before we got to Cape Cod that should be on that same strip.

484. EL-BAZ: Very good. Now, Bob Stevenson will continue with the additional ocean scenes.

STEVENSON: I don't have a lot of specifics. I do have a couple, but I am more interested in your telling us the constraints that you felt in trying to find these features in the ocean and describe them in real time. We already heard from Tom, where he pointed out that the sun glitter comes in a hurry and disappears in a hurry.

485. STEVENSON: But in a more general way, you remember my point was if you're up there and you're trying to describe the scene to either a tactical force on the surface or maybe even a fishing fleet on the surface, what were the constraints that you felt in trying to do this?

486. STAFFORD: Well, the sun angle, to start with, on certain features is really the dominant factor; say, if there were no clouds as far as obscuring it, I think you can work it out. You know it really correlated with those fly-overs you did over the West Coast. Those flyovers up and down that channel really helped.

487. STAFFORD: As far as the eddies and gyres, the big thing that outlined those to me, and I think to everybody else, were those little clouds right around the edges of them. You can really see that. And a current boundary, too. The clouds define it often. And I couldn't see any difference in the coloration—at least at sun angles I looked down at those eddies. Did you see any difference in the color? I couldn't see any difference in color.

BRAND: Generally, you had a cloud rim which precluded you from doing that, but if you tried and if you looked at gaps in the cloud rim you couldn't see a difference.

488. SLAYTON: If you're asking how do you optimize Earth observations for the kind of things you are talking about, in my opinion we could talk about this among ourselves, too. I think we're at a very good altitude to do it but the penalty you pay for that altitude is a fast motion over the surface. The only way I know to beat that is to build yourself a nice big bubble off the side of your satellite here, so you can sit right here in the bubble and you can look ahead and pick up what you want; and once you've got it, just track that thing right through until it's gone by. If you could do something like that you could get some phenomenal stuff. Even with all three of us working on things, we still had problems. Things just go so fast, there's no way you can sit and look at it and think about it and still take pictures. It's just impossible to do those two things in parallel.

489. BRAND: And to go on further, suppose you have another problem, that of pinpointing where an eddy is. I always felt very uncomfortable because I'd see an eddy and I'd say, "Farouk and Bob want to know where that is, I'll just give them the GET." But we can see for hundreds of miles all the way around. So while you're sitting in that bubble Deke's talking about, you need one of those eyeball gunsights or something so that you can look over there and say "Mark," and so you can get the azimuth off the guy's mask devices or something. You also need to know the spacecraft attitude.

490. BRAND: You could, of course, give him a little sighting device to use, but he'd have to spend all his time getting that thing lined up and he would have wasted good viewing time.

STEVENSON: I've gathered from what all of you have said that sighting devices at that altitude are really pretty useless and even maybe binoculars are not all that useful. You've got a good view, you can recognize thoroughly.

491. STEVENSON: Tom mentioned he saw 15 ships coming out of Gibraltar, at least.

STAFFORD: Oh, you could see them down there.

STEVENSON: So with the visual acuity of even fairly small objects, there's no problem that I can see there.

492. BRAND: In mid-ocean, you can plan on getting most of your data from clouds and only once in a while getting it from sunglint when you are especially lucky.

493. STEVENSON: I also gather that you felt much more comfortable in observing and trying to describe the scene rather than trying to photograph or point at the same time. Is that right?

SLAYTON: Say you've got an objective of taking a stereo trio of an object. If you do that right, that takes you 15 seconds. By the time you get into to where you can really shoot that thing and use 15 seconds, it's gone. And you haven't looked at it.

BRAND: They're starting to do one or the other.

SLAYTON: They asked to comment on a lot of these pictures. There isn't any way to do it because, if we got you good pictures, we didn't really see it.

STEVENSON: That's right.

494. BRAND: And comments may come easily one time and hard the next. For example, you may see something that you can describe very well. You may say, "I see a circular cloud structure and I can see that it's 20 kilometers across the mark, the time I see it is such and such." And you can describe the color maybe. The next time you may come up on sunglitter, you'll see a pattern, you'll see a gyre perhaps in there. And there's no way you can describe that, and you wish you had taken a picture or you'll wish that you had a pad that you could draw on to fill in.

495. BRAND: For instance, if you had an outline of Puget showing Seattle and two or three prominent landmarks and a pencil in your hand, you could draw in what you see. You need something like that.

STEVENSON: You also need the Maine coastline already predrawn.

BRAND: Yes.

OTHER PARTICIPANT: What you need is outline maps?

496. BRAND: Yes. Because there are times when the flight planners have you hitting several sites in a row, too, and you don't have time

to do that sketch and so you say to yourself, "I don't have time to debrief this one; I'll debrief all five of them when I finish." And then you get to the end of that, and you're coming up on the next event, and you don't have time to spend 10 minutes debriefing things that you've partially already forgotten. These are all problems.

497. EL-BAZ: We should have kept you up there for a couple of months so you would get a couple of chances?

BRAND: You need repeated passes over things, too, because if you have one pass, there's a good chance that something will be bad. But if you have three or four passes, you've got a very good chance of getting a lot of data on it, or if you have two passes even. And you shouldn't be very oblique. If you're oblique, that's tough.

STEVENSON: Unless it's a major feature.

BRAND: Well, yes. Maybe a series of gyres going off to the horizon. That's okay, but if you're wanting to get Puget Sound, you'd best be right over it.

498. STEVENSON: But now, the first observation pass was the day after launch, about 26 hours or something like this, coming up across New Zealand. With New Zealand's cloud cover, you didn't see Cook Strait?

BRAND: That's right.

499. STEVENSON: Okay. But it was the first time that you really seriously looked out other than to maybe occasionally say, "There's the passing scene." Can you think back through all of the events and then think ahead maybe after the undocking when you then began to do visual observations again. Did you feel more confident as this mission went on?

BRAND: There's a learning curve.

500. SLAYTON: I think, again, it was the time constraint. Speaking for myself, I had a couple of passes early during the joint operations period which was our only chance to get it (that one rev) and we knew we were going to be busy through there but as usual we were about four times busier than we really expected to be. We just felt like we didn't really have time to properly prepare for it; we didn't do it right, we were just up against the stops all the way on these early ones. I don't think we did very well on them at all. Once we got through the joint activity period, where we could all three work the problem together, help the guy that had the primary task by looking out the window and we changed our attitude, I think we got reasonably good results from then on. But I frankly think that anything we did prior to that was not very good. If it was, we were just lucky.

501. SLAYTON: I think, on the other hand, if we are talking about five years from now and you want to do Earth observations from a space station; if that was one of your objectives, we could build a beautiful Earth observation module that you could do a super job with. You could couple in this great visibility along with a couple of hand controllers. You could tie all your bank of cameras in and a couple of push buttons here to select a 250 [lens] there and an IR here, and get some beautiful stuff. That's what the Shuttle's all about, isn't it?

502. BRAND: Man's greatest utility up there is as an identifier of sights and the way his eyeball can be used to describe things, but he can be very useful in pointing things. And then describe them, maybe in addition.

SLAYTON: You can discriminate and you can pick the right thing to do the right job for you in realtime and do it fast. I think that's the big thing.

503. STAFFORD: You'd also like to have this observation device in a heads-up reference, too. I think that's been pointed out before.

SLAYTON: If a person is out there in a big bubble, so he can pick his own attitude, he can't go wrong.

504. STEVENSON: Now do you think it's useful to consider some kind of device that instantaneously tells you where you are, or what part of the Earth you are over? Many times you say, "Where am I?"

STAFFORD: You could have a data printout.

SLAYTON: We had this thing onboard which we never got around to using. We thought about it a few times but it's one of those things you have to update to be valuable. We had the other map that we did pull out and stuck up here; we kept referring to that and that was very helpful once we got it out and used it. You'd be surprised how many times you'd come up over a coastline and you wouldn't have the vaguest notion whether you were over Africa or Australia or the U.S.

STEVENSON: Mainly because you haven't been doing visual turns all along.

SLAYTON: You're wrapped around the axle with crystal growth, or something.

505. EL-BAZ: Is this the map [Figure 35] that you are referring to?

BRAND: That's a good map.

STAFFORD: That's a good one. The only thing you might do, though; all the numbers are down at the bottom. They need to be up at the top, too, because you have to start way down here and turn the map over and thumb over to here.

SLAYTON: That's why I think this would be good if we'd ever had a chance to get it updated and use it. Also, we got the time ticks on it.

BRAND: Deke mentioned the time ticks. I think it might have been good enough to put just some representative curve on there showing representative time ticks that you could translate to any one of those curves. You could take your finger and say, "Well this is 6 minutes."

SLAYTON: You could look at that quick and say "Well, I got 10 minutes from Hawaii to the West Coast."

BRAND: Something like that if it were kind of automated so you had a quick visual reference without manhandling anything.

506. STEVENSON: Well, you're talking now about the Soyuz ball or the Mercury ball.

SLAYTON: We had one on Mercury that did exactly that. It was an old clock globe. All you did was wind it and turn it on and put in the right cooordinates at the right time. It was a little gross, but it pretty well did the same thing. You could refine that.

507. STAFFORD: Well, with the data displays that you're going to have on the Shuttle, the CRT's that we have now, you could have them read out a latitude and longitude in just continuous strip on the thing.

508. BRAND: I must say though, that a ball is much quicker. There are some times when I think of 159 west. That doesn't mean much to me.

STAFFORD: You don't need it in the basic cockpit, but for the Earth observations it would really be handy to have that.

509. STEVENSON: So inside the bubbles or on the bulkhead of the bubble where the guy is going to be sitting, you've got this ready reference, right?

BRAND: And we talked also about how do you mechanize the bubbles. Tom suggested a big mirror, and Deke and I were also thinking of perhaps, instead of a mirror, a tracking arrangement where the whole seat would move like a turret or something. If you really wanted to get exotic, you could just go to the end of the world on fancy devices.

SLAYTON: You put the bubbles on an arm and you got a hand controller. Just fly the thing around and you're tracking through the whole arc.

BRAND: It might be done either way.

SLAYTON: Work it like a turret.

BRAND: Like a ball turret.

EL-BAZ: Are you guys going to write a note on this?

BRAND: I think Bill Pogue is working on something like that, as a matter of fact, right now. Perhaps he could incorporate some of our ideas.

510. STEVENSON: In some of the observations, and I guess I'm now thinking of the ones that you made, Tom, of the front off Spain as you were coming up. All of a sudden it comes up. There it is and this is great. At least we know it's there. If you were placed in a position of having to give some sort of ready reference as to where it was physically located, that would not have been a problem. In other words, here you saw this front and all the internal waves. The only place for this kind of reference of magnitude or location would be when you're well away from any coastline or any island or anything of this sort, where you're really not sure where you are.

511. SLAYTON: Not quite. I was looking out at some islands down here in the south; we weren't sure where we were, just shooting "gee whiz" pictures and all of a sudden I'm in sunglint, and there were some internal

waves right along these islands and we didn't have the vaguest notion where we were. And it turned out we were down around New Guinea, somewhere in there. But we had to call the ground and ask them. We didn't know. I didn't know whether those pictures came out or not either.

EL-BAZ: Yes, they came out.

STEVENSON: Yes, those were spectacular. Those are the ones with the 35-millimeter [Nikon] camera.

512. STEVENSON: Yes, I think Dick Underwood needs to sit down with you gentlemen. Where were you when you took this picture? Or what were you doing other than taking pictures? Okay, I need one more thing before we look at some pictures. Again, I would rather have your opinions right now, as you recall, of the problems and the constraints in some detail.

513. STEVENSON: But this one early in the mission, revolution 17 again, and Vance saw a scum line. Do you want to discourse some on that scum line? Can you remember it?

BRAND: Let's see, am I right in thinking that I'd just passed over New Zealand?

STEVENSON: That's right.

BRAND: There were a lot of clouds over New Zealand, I remember the mountains sticking up through the clouds, and I guess what I was looking for was a red tide, or plankton blooms.

STEVENSON: Yes, you said, "I don't think it's the time of year for plankton; looks too cold down there." Real objective.

BRAND: All I can say is that I was looking for plankton blooms, and I saw a line beyond the island that did not look like it was vegetation. I mean it did not look like it was biological, and I think that is why I asked. You do see occasionally, especially from airplanes, trash lines on the water. And it was kind of a dark, wavy line, and that's about all I can give you.

514. STEVENSON: The thing that's making me wonder are data of the New Zealand air crew on that day. Here's their cloud-line flight-line plot from New Zealand going northeast. They plotted the cloud types and roughly their heights, every few minutes. So this is about two-thirds of the way out the line; the line was 400 miles [644 km] long, so let's say this is like 250 miles [402 km] north of East Cape. So you're beyond the islands; and the clouds, presumably, are reasonably broken out there, very scattered, and they got this very distinct discontinuity in the water. Distinct change in wave heights; so the appearance of the sea should have changed.

BRAND: It should have changed in color or texture on either side of this line?

STEVENSON: Texture. But, you see, if it did change, also in the motion of the water, this could have been a scum line.

BRAND: All I can say, Bob, is that I don't recall so much a textural or a color difference in the sea, but I do remember seeing this line.

STEVENSON: And it was beyond the islands, clearly?

BRAND: Yes.

STEVENSON: Not immediately adjacent?

BRAND: That's correct. And at our altitude we didn't really see texture and color differences unless the light was just right.

STEVENSON: But if you're going to see a scum line, it's going to be a fairly sizeable feature.

BRAND: Yes. I agree.

STEVENSON: It's not going to be one of these Galveston Bay scum lines. Or something maybe that's isn't too wide but it's long. So thinking back, that's kind of what you think you saw, long linear features?

SLAYTON: It would not have to be too wide because we could differentiate roads.

BRAND: That's right. It wouldn't have to be very wide.

STAFFORD: Was that the area we looked down and it looked like something like plankton but it was probably sedimentary out east or northeast of New Zealand, or some place? We were describing and said, "Is that plankton or is that sediment?"

EL-BAZ: "Or is that bottom?" I remember that. You were talking about that maybe you were seeing bottom because it was a little greenish, and maybe that's not plankton bloom because you were seeing bottom.

BRAND: We did see bottom, we're pretty sure.

515. EL-BAZ: But then this is farther off the island; there are pictures of something that looks like plankton bloom. I think we have the slides.

OTHER PARTICIPANT: Frame 37. About the

time you were talking about the scum, you got this nice big bloom.

STEVENSON: But again that's reasonably close to shore, if that's the one I'm thinking about. Right? Because the frame immediately before showed the shoreline and then you could see part of that feature.

BRAND: Later on it might be helpful to look at the pictures. That would trigger our memory.

EL-BAZ: We do have some pictures.

516. STEVENSON: Right in that area, here's the sound-velocity profile. You can see the low velocities jammed up toward the surface there. Sometime later we'll go through the photographs and we can go back through this. That's the kind of features we like.

517 STEVENSON: Deke, you mentioned that you, north of Hawaii, came past Hawaii and one day saw all the eddies standing out about 200 miles long [322 km], you thought, south of Hawaii. Just a minute or so later, you saw linear cloud lines and you mentioned what you thought looked like a big front in the ocean. Can you describe that a little bit?

EL-BAZ: We have the pictures of that, Bob, at the end. We have the pictures of the front. The mapping camera was photographing at this time, and we do have the slides.

STEVENSON: I don't think it was contrast.

SLAYTON: I don't have any more comment on it.

BRAND: I took the pictures and remember it fairly well. It was just weird. I'd never seen anything like it before, it was a tic-tac-toe type pattern.

EL-BAZ: We're talking about two different things now. You're talking about the highways? I was talking about the bunch of eddies, or Bénard cells, or whatever they may be, and then a very solid front of clouds. Right?

SLAYTON: Yes, I remember that when we discussed that, and I saw it. The cloud pattern was unusual; one was one way and one was another coming into it or something.

EL-BAZ: We have the pictures.

BRAND: Oh, I remember now. Part of it was circular and it had a linear thing coming into it.

SLAYTON: Yes, there was something linear going into it.

BRAND: I think you would have to rely on the tape, whatever we said.

STEVENSON: We don't have that part of the tape yet.

EL-BAZ: We don't have the tapes of the latter part of the mission; we're still looking for them.

518. STEVENSON: This was a realtime transmission you made, Deke. You said, "Hey, gee, there's a big front down there." And you mentioned that it looked as if there were turbulent eddies along the boundaries. And that's all we got so far. I don't know if there's a picture; I haven't seen a picture.

EL-BAZ: As we go through the pictures, maybe that will remind them.

SLAYTON: I can't tell you any more off the top of my head. We saw so many interesting cloud features over that ocean, you can't believe it. If we had about another 500 frames of 70-millimeter film, we'd have shot her up over there; but we thought we were running short and we were holding our horses. There were all kinds of interesting clouds.

BRAND: Infinite variety of patterns.

519. STEVENSON: Okay, one last general question. I have already talked to Vance about it, but maybe Tom and Deke can remember the last day. Was it revolution 136, the one across the North Atlantic? At the end of that revolution you all looked out and saw the green Ireland. You mentoned Ireland really is green, that you could see it through the breaks. Okay, that was the RAF pass; on most of that pass, the Nimrod [airplane] crew had 100 percent cloud cover out to 400 miles [644 km] west, and then they got into some broken scattered clouds. And they did see some distinct changes in water color. So my main question is this: Looking through that kind of cloud cover, what sort of comments can you make about looking at the ocean through that kind of stuff? Do you remember seeing anything other than the fact that there were breaks in the clouds?

SLAYTON: As I recollect that particular pass, we were pretty much over cloud cover for an extended period of time and all of a sudden we found this break, and there was that green down there and we figured, trajectory-wise, that would be about where Ireland was. And as a matter of fact, we then saw southern England, and on into France and then we picked up some more cloud cover through Middle Europe again. I think it was pretty solid overcast before that.

STEVENSON: So when the clouds do open up, even reasonably good, then are you not prepared, or are you saying, "It's pretty solid?"

SLAYTON: I think you can tell pretty well, when you are looking out, when you are getting enough breaks in it so you expect to see something. But when you have something like five-tenths cloud cover, you don't see very much obliquely. If you're looking straight down through them, you can pick up some definition.

BRAND: The shadows don't help the situation at all, in the clouds.

STEVENSON: White caps.

STAFFORD: You don't really see white caps too much.

BRAND: No.

OTHER PARTICIPANT: When you've got that many clouds, your geographic orientation is going to be poor, too.

BRAND: That's right.

520. STAFFORD: We sure saw some icebergs though, up in the North Atlantic.

SLAYTON: Did you ever get a picture of that?

EL-BAZ: In the 35 millimeter [Nikon], yes, there are some pictures.

SLAYTON: There was that one iceberg sticking right up through that cloud deck, or fog deck, that was leaving that wake right behind it. Spectacular.

EL-BAZ: There was a picture of some icebergs, one big one and maybe a few small ones, with not a speck of clouds.

STAFFORD: There was one you could see the tip of the iceberg, and it looked like a shockwave behind it. There were clouds flowing behind it. It was just a "V," like this. And here's the iceberg sticking up through it and the clouds were flowing like that.

EL-BAZ: Okay, I haven't seen that.

STAFFORD: I hope it came out.

521. STEVENSON: No white caps though? You don't remember seeing any white caps?

SLAYTON: I don't know, maybe around some—

522. STAFFORD: You could sure see the wakes of ships, though. Those will really stand out.

523. SLAYTON: Maybe on some shorelines you might have seen the stuff.

STAFFORD: Yes, possibly, but I can't remember identifying it. The main things are the wakes of ships.

SLAYTON: At least, that's where it ought to be, but whether we're actually seeing it or not—

BRAND: I think you would have to see it as textural difference, rather than white caps.

SLAYTON: Yes, right.

524. STEVENSON: Let's quickly run through these slides. Now, I think that this is the one that everyone is talking about off New Zealand.

SLAYTON: Yes, that's it. That light material is what we're talking about. Is it sediment or is it plankton or bottom?

STEVENSON: Let's go to the next one, because that's the same feature. Now that's not your scum line. That must have been a different camera or different lens.

OTHER PARTICIPANT: No, this is taken I think about 4 minutes later. He was almost to Cook Island when he took this.

STEVENSON: But that's the same feature there, or something. Can you back that one up? There it is.

SLAYTON: That's the same feature.

OTHER PACTICIPANT: There's four frames in between, though.

SLAYTON: Okay, you had to change lenses to get that difference.

EL-BAZ: You have to change lenses and we had one mapping camera busy, and we could not have been using two cameras either.

SLAYTON: But there was stuff like this out to the northeast of New Zealand.

OTHER PARTICIPANT: This camera doesn't have a Reseau plate on it.

STEVENSON: Okay, let's go to the next one then.

SLAYTON: Has that got a Reseau on it?

EL-BAZ: It's the same pattern, but it cannot be the same feature, because we had one camera going. And there are several frames between the one we saw and this one.

SLAYTON: That has to be 250-millimeter lens there to have the same scale effect.

BRAND: We didn't change lenses.

SLAYTON: We sure didn't change lenses that fast.

525. STEVENSON: Okay, the next slide, please.

STAFFORD: Hey, there's some with internal waves.

STEVENSON: And I'm guessing that these are the internal waves you saw.

SLAYTON: Yes, sir.

EL-BAZ: Very nice. Is this the same view? Do you remember it?

SLAYTON: Yes, exactly. I may be wrong, but that was my immediate impression, that those were internal waves, and I shot them. I don't know if you guys agree if that's what they are or not.

STEVENSON: I think there's no doubt about that.

SLAYTON: They're certainly very big structures.

STEVENSON: So as you came across this field of view, you got a glitter pattern and there's the internal waves.

SLAYTON: That's what I mean about them just springing out of you all of a sudden. We were just kind of cruising along there enjoying the scenery and all of a sudden, there they were.

STEVENSON: So you have, about 5 seconds, you think?

SLAYTON: Probably.

STEVENSON: So if you're going to say anything about it, you're not going to shoot a picture?

SLAYTON: That's right

526. STEVENSON: Okay, the next slide.

STAFFORD: That's the Mediterranean. There it is.

STEVENSON: Now, if you can remember before the mission, there was a Skylab shot, and in that shot that front was lying right opposite that river mouth. Now you were coming up on a path roughly about so.

STAFFORD: Yes, up to the north, because we were right by a big flightline that runs from Spain.

STEVENSON: And you also looked over here. Now is this where you saw the ships' wakes?

STAFFORD: Right in that area, right there.

BRAND: I saw those, too.

STEVENSON: So the glitter pattern then came moving this way toward you, is that right?

STAFFORD: No, this way.

STEVENSON: So you saw this feature first?

STAFFORD: At first, it was just a solid shade of blue, nothing there. Suddenly it just popped like that.

527. EL-BAZ: And you noticed that we have not seen these ships or the ship wakes in the pictures.

OTHER PARTICIPANT: There's no glitter pictures down in there.

STAFFORD: But you can see ship wakes if you don't have glitter, too.

BRAND: You can, yes.

SLAYTON: You're right.

EL-BAZ: They were looking at ship wakes before they got the glitter there.

STAFFORD: And these ships are like little white dots all down in there.

528. STEVENSON: Yes, that's a beauty; there's no question about that.

EL-BAZ: Bob, what's this dark water, or is this the boundary between the two currents?

STEVENSON: There's a distinct difference in the motion of the water on either side of the boundary. You see rougher water on one side than you have on the other, and it makes a difference in the reflective pattern.

529. STEVENSON: You can see the slicks, Tom; that's the first thing that struck your eye, I guess.

STAFFORD: Yes. The whole contrast looked like it had a gyre spinning off of something out there, too. I shot a bunch of them right in this whole area. There were also some internal waves that were coming out someway. We have a couple of other shots that we could look at individually, later.

STEVENSON: Boy, that scene comes pretty fast for you to describe all the features you saw, right?

STAFFORD: Yes, it does.

530. STEVENSON: Next slide, please.

STAFFORD: That's Sicily. You can see those waves. That's the southeast coast.

STEVENSON: Now you mentioned the cloud

line several times, and I'm guessing that this is it.

STAFFORD: That's what it is. You can see it's superimposed on top of a wave right there.

STEVENSON: So that was fairly easy to see, I guess.

EL-BAZ: This was very clear on the TV that we saw during the undocking. That was a beautiful line right there.

STEVENSON: Yes, at the undocking and the redocking, there was a fantastic cloud line. Are those cloud lines helpful as you come up on them and as you get into a glitter pattern and then begin to see the features behind?

STAFFORD: You can do a lot with clouds as far as giving some clue.

531. STEVENSON: The Mediterranean was mainly clear from all I remember during the flight. And you did look at it several times, and there weren't a lot of clouds, but still the features stood out, did they?

SLAYTON: We were coming down across the other way through, it seemed to me.

532. SLAYTON: Of course, that's most of the Adriatic, but that was pretty well clouded over, in the eastern Mediterranean.

STAFFORD: That was a descending pass where this was kind of ascending.

533. SLAYTON: Ascending passes seemed to be clear, when you're trying to get that stuff.

534. BRAND: When we were trying to [get] that Adriatic Sea stuff, we had a lot of clouds over the Alps. It seems to me we had them over the Balkans, and down to Venice and then it would clear out over the water.

535. STAFFORD: The Alps also had a lot of haze up in the air, haze and clouds. We got some of the surroundings, you could see some of the snowline, but it was just very hazy there.

EL-BAZ: Was it air pollution in little areas and valleys and so on, or the whole thing?

STAFFORD: No, the whole thing was pretty hazy.

536. OTHER PARTICIPANT: Was there any more, or was that all the slides?

STAFFORD: Here are some cells. We used to see those every once in a while.

STEVENSON: That's in the mid-Pacific, right?

BRAND: Generally, you didn't see so many cells.

STAFFORD: They were bigger and fewer, weren't they?

BRAND: Yes, in all different sizes.

OTHER PARTICIPANT: Was that all clouds?

STEVENSON: It's cloud, these are convective cells over the Pacific. It's a fairly consistent feature of the tropical ocean, at least in that area.

537. OTHER PARTICIPANT: Bob, about your internal waves off New Zealand. Now, the internal wave has to be normal to wind direction at speeds less than about 11 miles [18 km] per hour, or 13 miles [21 km] per hour, otherwise you have Langmuir circulation and your slicks run parallel to wind direction.

STEVENSON: That's right.

OTHER PARTICIPANT: Off Brazil, which is it, internal waves, or Langmuir circulation or do you know?

STEVENSON: In that photograph we saw, I think there's no question that it was internal waves. I can show you some Langmuir circulation and it doesn't have anywhere near that appearance, from that altitude.

OTHER PARTICIPANT: But it was off New Guinea.

538. STEVENSON: I think the next slide has another cell. And that's a 35-millimeter [Nikon] shot and my guess is that, Deke, you took that. You mentioned that you didn't usually see so many cells together and here's one that's pretty isolated. So I guess my question is: Is this fairly common?

SLAYTON: Yes, very common. And many of them were exactly like that, they have a fairly large cloud structure on one side and then there was kind of lower clouds around the rest of the rim.

STEVENSON: Are those easy to pick up?

SLAYTON: Yes.

BRAND: No problem.

539. STEVENSON: I have one more question, which is really for the whole crew. We were hoping you were going to see some bioluminesence. I remember on that one pass when Deke said, "Hey, somebody goofed up; it's still daylight here."

SLAYTON: We were in daylight; the ground was in dark. But once we got the spacecraft into the darkness, there was a cloud cover, I'd have to guess. I could see oil fires burning up through there, but it was obvious from that that there was somewhere between 5–8/10 cloud cover and I couldn't even tell where water was, to say nothing about where bioluminescence might have been.

STEVENSON: So you never had any during the whole flight?

SLAYTON: No, sir. If it had been clear as a bell down there and it, in fact, existed, our odds of seeing it were pretty poor, I think, because we'd just come out of that bright sunglint and suddenly you're in the dark and no dark-adaptation time at all.

BRAND: If you ever try that again, you'd really want to have a long dark-adaptation time, and you'd want to think about moonlight and things like that, too. The moonlight has quite a big effect on what you can see.

STEVENSON: You had a good moon?

BRAND: Yes.

540. STEVENSON: I have one more thing to say. As you remember, the Chief of Naval Research, Admiral Dick VanOrden, came down here prior to the mission, and you guys were all on simulation that day, so he didn't get to see you. The Office of Naval Research considers this whole effort to be of extreme significance to their research program, as well as to future Navy operations. The Admiral has since retired, as of August 1, and he wanted me to extend his best wishes to all of you and thank you for your efforts. He has had put together some certificates which on his behalf I'd like to present to you now.

541. EL-BAZ: We have maybe 5 to 10 minutes more with a few more pictures of the clouds and meteorology. Unfortunately, Pete Black cannot be here today, but we'll show some of the slides that he wanted to talk about. Look at a couple of cloud patterns and here, Bob, this is one of those places where you have in the Pacific these tremendous Bénard cells or the cells of clouds; then you get to that edge of the cloud front. I think Vance also commented about that and so did Deke; that is in the Pacific and for miles ahead of these you had these separate patterns.

BRAND: We ought to really sort out Bénard cells from what we're calling eddies. I guess those look like Bénard cells. But the things that we're calling eddies are bigger features, not all of the same diameter, and sometimes scattered.

EL-BAZ: Can you see a few of them? There are not as many as what you see right here?

BRAND: Sometimes you'll see only one. Or you may see three, but in kind of random groupings.

STAFFORD: I remember one time, we looked obliquely and these were great big things, but they went practically all the way to the horizon, like one, and here's another one, and here's another one, and disappeared. We're talking about maybe four cells, eddies total.

EL-BAZ: So the stuff that you were describing, Vance, near Hawaii, was it like this, or like what you think the eddies may be, the fewer?

BRAND: It was not like this because this is an area of cells. What I saw was a line of circular structures going to the horizon. And it occurred to me that perhaps it was the edge of a current, but then I couldn't justify that idea, because it didn't look like gyres, or spinoffs. It looked like pure circular cells, more or less in a line.

STAFFORD: But it did look like you were following a meandering current that was going off across the ocean, didn't it? If you were going to try to establish a pattern to it.

BRAND: It looked like it followed a boundary.

STAFFORD: Yes.

542. EL-BAZ: Okay, good. Next slide please. Okay, here's your highways in the sky, a very fantastic picture. Some people have said that these may be contrails, and you said they are a little too big to be this way. And I think we had comments coming from some of the Skylab guys, that they had seen these linear patterns in the clouds before, but this is a very dramatic one.

SLAYTON: We saw an awful lot of contrails over the North Atlantic, and it's nothing like that. They just don't get that big.

STAFFORD: That's right. They were lots thinner than that.

BRAND: When you look at this in a picture, you say, "Obviously that's contrails," but when you remember back to how wide they were, at the bases—

STAFFORD: You see that little thing right there? That's more like the size of a contrail, at the maximum. That would be a big contrail right there.

BRAND: Contrails were lines; these are wedges practically.

STAFFORD: Also, it was interesting in the way this pattern stopped.

543. EL-BAZ: That's very good, next slide.

OTHER PARTICIPANT: Remember from Skylab, when they took a picture and they thought it was the hot air coming from a ship going through a very low scattered deck about like that, and there was a plume going right across the apparent trend of the clouds. Do you think that maybe that was this same thing?

BRAND: It's a possibility, I suppose, but at the time it looked natural.

OTHER PARTICIPANT: Did you get any perception of depth on it? Or did it look like it was all of the same depth?

BRAND: More or less the same depth.

OTHER PARTICIPANT: Especially the two that crossed?

EL-BAZ: Can we get that slide back for a picture?

OTHER PARTICIPANT: They didn't look as wide.

BRAND: Let me say this, the base of the wedge was extremely wide, I'd say miles and miles. Now do you think there's anything natural that would give that width of, I don't know how many, miles?

SLAYTON: You could put a scaling factor on that.

BRAND: It could be determined. Perhaps 10 or 20 miles [16 or 32 km]. Would a contrail or ship's wake do that?

STAFFORD: Here's something else. Is it because of sun heating that down below this is all blue and the discontinuity?

EL-BAZ: Okay, I think we'll have to leave this to meteorologists, and we'll see what comes out.

544. EL-BAZ: This is one very good picture of the convective thunderstorms or thunderclouds. You were aware of these things as they went by, the difference, the distinctive difference?

STAFFORD: We got a bunch of those in various places, too, but I don't know how they came out.

BRAND: That's very typical.

EL-BAZ: This is a typical view, is it? Very good.

BRAND: We've seen just scads of those.

EL-BAZ: And this is just the right exposure for the meteorologists because they can see the texture in all the cloud here. This is what they would like to see in cloud pictures.

STAFFORD: We lucked out, this is going into sunset.

EL-BAZ: So, to me, I thought it would be a very underexposed picture, but this is the way they like it so that they can start seeing the texture in the cloud. Next slide, please.

SLAYTON: Most of them that we shot intentionally were probably overexposed.

545. EL-BAZ: What's this one, Vance?

BRAND: I believe that was an attempt to show an eddy.

546. EL-BAZ: This is not the developing storm?

BRAND: No. The one that was developing was so big that if we had taken a picture of the center of it, all you'd see was white on that frame.

EL-BAZ: The developing one, the one that you got at the very end of the mission?

BRAND: Yes, it took minutes to cross it.

STAFFORD: Yes, hundreds of miles across.

SLAYTON: We had to shoot a panorama through almost 180 degrees to cover that whole thing.

STAFFORD: That's it, that's the one.

EL-BAZ: And why did they call this developing? That has a very good movement to it.

BRAND: It looked like a hurricane, it really did; it had spiral arms. The only thing is you didn't see the eye in the center, but you saw things that could have been the eye covered over, or you saw something that you could imagine that's where the eye was.

STAFFORD: Yes, out-of-focus.

547. CO-INVESTIGATOR: Do you remember where that previous slide was taken, Vance?

BRAND: I think I called down a mark; I tried to on all these; tried to give a GET. All I can say is that I'm sure it was the Pacific; and can we switch back to it?

EL-BAZ: You had five very nice pictures in that sequence of it; we have magnificient stereo.

BRAND: I think that's a very good picture of what we call an "eddy."

EL-BAZ: Okay.

STAFFORD: The earlier one.

BRAND: This one before this.

STAFFORD: Yes. That's what we term an "eddy."

BRAND: Now you can see on the bottom of that structure a continuation around, and clouds on the edge that are normally cumulus-type buildups, but not going very high. Sometimes in the center there are clouds, like you see; and sometimes in the center, no clouds at all.

STAFFORD: Often I'd say at least 50 percent of the time, the center had no clouds at all.

SLAYTON: I thought that was the difference between a cold- and warm-water eddy and the clear ones were cold-water eddies. I don't know if that's right or not.

OTHER PARTICIPANT: I think you're right.

OTHER PARTICIPANT: I'm convinced that's warm water; and if it is where I think it is, it's a perfect representation.

SLAYTON: That was what I said about all those.

548. EL-BAZ: Okay, very good. Next slide. We have a couple of pictures here. Is this a ship wake or an oil slick? This I think is in the Gulf. We may go through this sequence in detail and see.

STAFFORD: Often you would see stuff like this over here, and I don't remember seeing that. Does somebody remember seeing it? We just lucked out and got it.

SLAYTON: I remember, once coming across the Gulf, that we did see what I thought was a pretty clear boundary line there; but whether that's it or not, I frankly don't remember.

STAFFORD: That's right in the Gulf of Mexico. There was a boundary line. Down here.

549. EL-BAZ: Okay, the next one please.

STAFFORD: That looks like part of the Amazon Basin. See that river? That's the Amazon Basin.

EL-BAZ: Okay.

STAFFORD: That's interesting, because we haven't brought that out before, but in part of that Amazon Basin, what I thought was the main Amazon River, was real brown muddy water; it stood out just like a brown line running through the green jungle. Then there were some rivers to the north of there, and this is one of them, I think, that was clear bright blue, nice clean looking water.

EL-BAZ: North of the Amazon?

STAFFORD: I never was sure whether it fed into the Amazon as a tributary or not.

OTHER PARTICIPANT: The part which is dirty comes from the Andes and you have clear water coming in north and south. The dirt from the south is very black because it's high in humic acid. The Río Negro is called Negro, not because it's muddy, but because it's high in humic acids. It's very black.

BRAND: Where we saw those two rivers come together, it was jungle; and it looks strange to see the water look clear, going through jungle terrain.

550. EL-BAZ: Okay, very good. Here are a couple more pictures that we don't know the location of. Next slide, please. This one we have an idea about, but we're not really sure. You see, this is snow cover on top of the mountains, and see the solid cloud?

STAFFORD: That could be the Andes but I don't remember anything detached like that in this other thing.

SLAYTON: It could be the Himalayas. One pass we made over there. It was all cloud covered and I just remember we had a few sticking out the top there once.

EL-BAZ: You could see things sticking out through the clouds?

SLAYTON: Whether that's it or not, I don't remember.

EL-BAZ: We'll come back to this, maybe. This one is the same little detached piece. And that's low sun angle and most likely it is the Andes, because of the geometry. Do you remember, Tom, when you had two revolutions at the southwest over South America (one of them revolution 88 and the other about 120)? Maybe one of the revolutions was where the clouds came all the way up to the mountain, where you did not see a coastline, where you could not see the Nazca

Plains.

STAFFORD: That could be it. It would be on the earlier pass. On the second pass, the clouds were not as—

EL-BAZ: Did not keep to the mountain. This is very low sun, so that's why I'm saying it is the Andes.

OTHER PARTICIPANT: Between Concepcíon and Santiago is this detached mountain range that goes up almost 9000 feet [2743 m] off the main Andes. At the lower right corner, Santiago would be under those clouds.

STAFFORD: You think the last one was over that same area, too?

EL-BAZ: It's the same area. Go back to the last slide.

OTHER PARTICIPANT: You can see those Argentine sand dunes in the background.

STAFFORD: Okay, there they are. So the Pacific Ocean is down here at the bottom? That's the Andes. They have a kind of peculiar characteristic of their own.

551. EL-BAZ: Very good, and then the last slide, please. That's about the only one that I recall with an iceberg in it. I don't know whether these white pieces are also ice pieces or not.

STAFFORD: Is that with a 35 [mm Nikon lens]?

EL-BAZ: Yes. And there are no clouds.

STAFFORD: That was in the North Atlantic.

EL-BAZ: Yes.

STAFFORD: There's the one with the cloud pattern, but also we saw some that weren't that big, kind of in groups of threes. They were more something like that. There were three and then three one time that we shot.

EL-BAZ: So you did see icebergs on two or three revolutions?

STAFFORD: Yes.

552. EL-BAZ: Very good. Is this the last slide? In conclusion, I want to thank you very much for a terrific job. I want to thank you first for spending the time for the training required for this experiment, and also for your help in getting most of that stuff in the flight plan, and certainly for your tremendous effort in trying to get most of the stuff. I'm sure we will put it to good use. On behalf of everybody here, I'd like to thank you. Do you have something to say?

553. STAFFORD: I've got a question. I don't know whether anybody's seen another two or three pictures I hope we got, of some structure which I think is in China or Mongolia. I don't know whether I mentioned that to you or not. It looked like a great big riverbed coming out of the north and fanning out over a very large area. It just looked like a sandy, dry riverbed coming down and spreading out this way. It was quite a bit north of our orbit and, considering the distance, it had to be a very mammoth structure of some kind. I shot three or four pictures of it, I think. Did you see anything that looked like that?

OTHER PARTICIPANT: It may be on that one roll we have left.

BREED: Was this in the northern part of China?

STAFFORD: That would be my guess as to where it was. Yes.

BREED: I think I know what you mean. I hope you did get a picture of it.

STAFFORD: It was a very unusual looking thing. Considering the size of it, if I was looking at it from 10,000 feet [3048 m] I'd have said, "That's a mammoth old dry riverbed." But from that altitude, it would really have to be mammoth. It just kind of fanned out. It just looked like a sandy river bottom.

BREED: That's exactly it. I have an ERTS image over that area. I can't quite pick out what those things are. So if you got a picture, that would be really a picture we could use.

# Index to Appendix 1

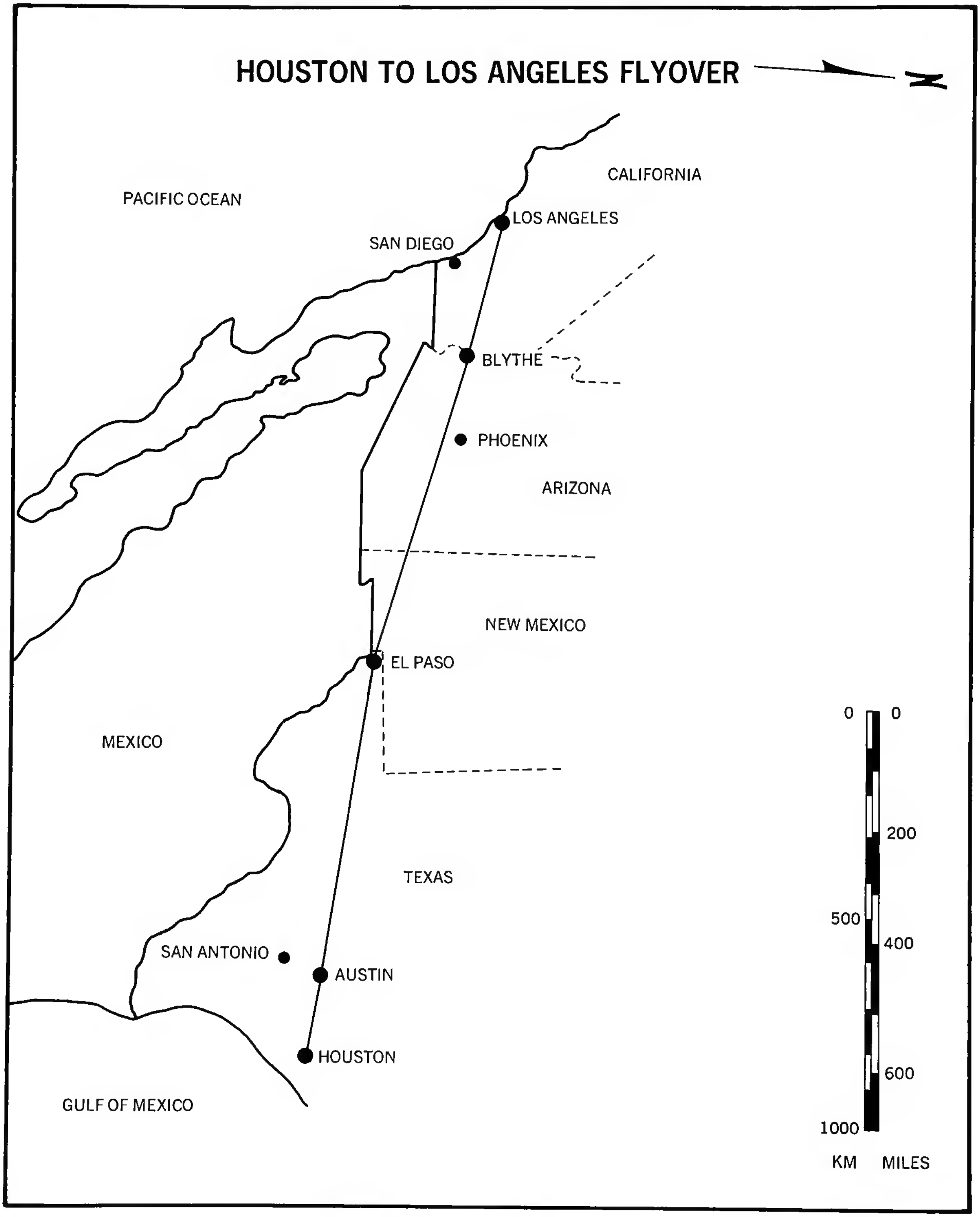
Notations in parentheses indicate either a site number or a mapping pass. Each entry is followed by the comment numbers assigned in Appendix 1 that relate to it; italicized comment numbers identify the most significant item relating to an entry. Where applicable, figure numbers are given in brackets after the entry numbers.

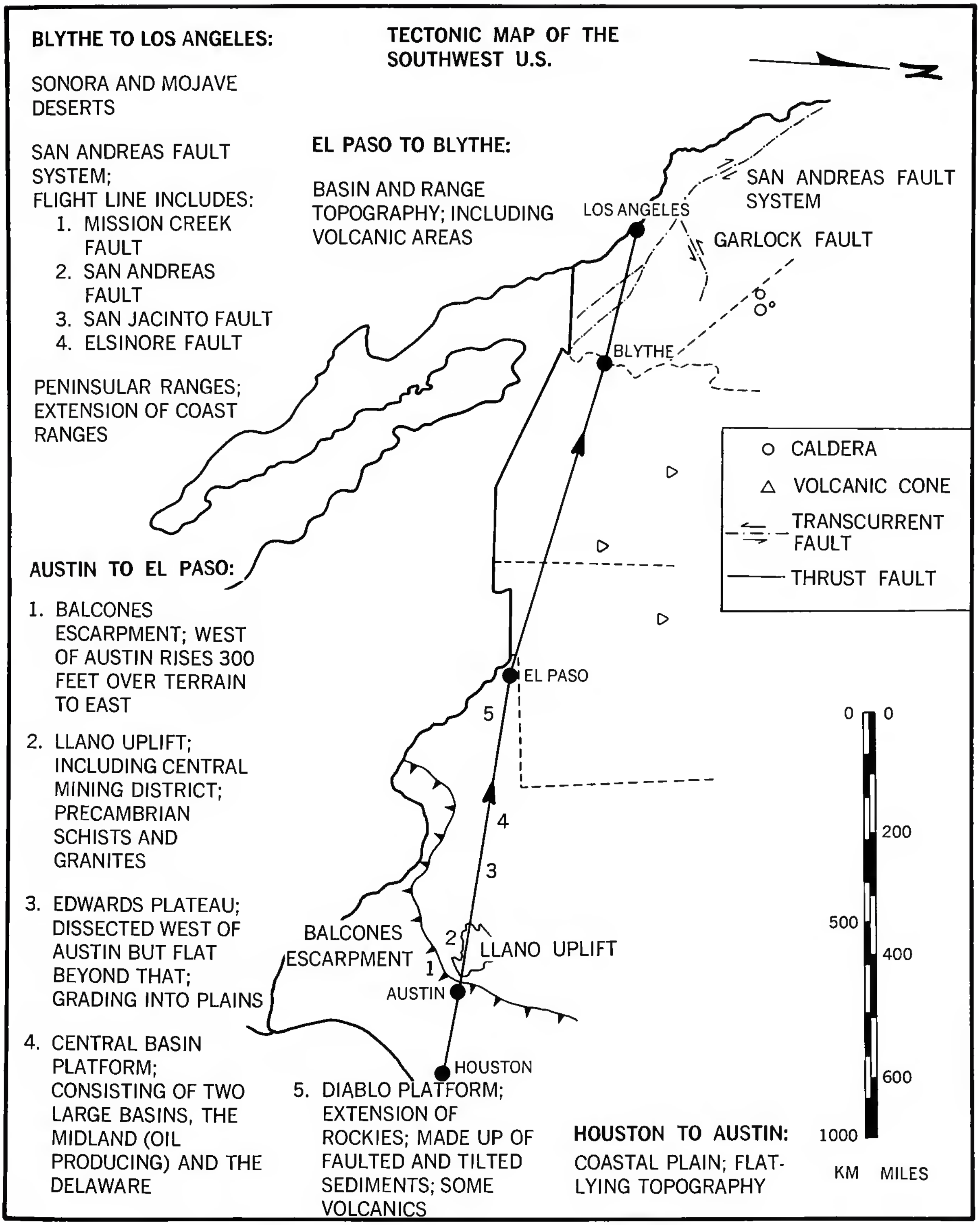
# Appendix 2

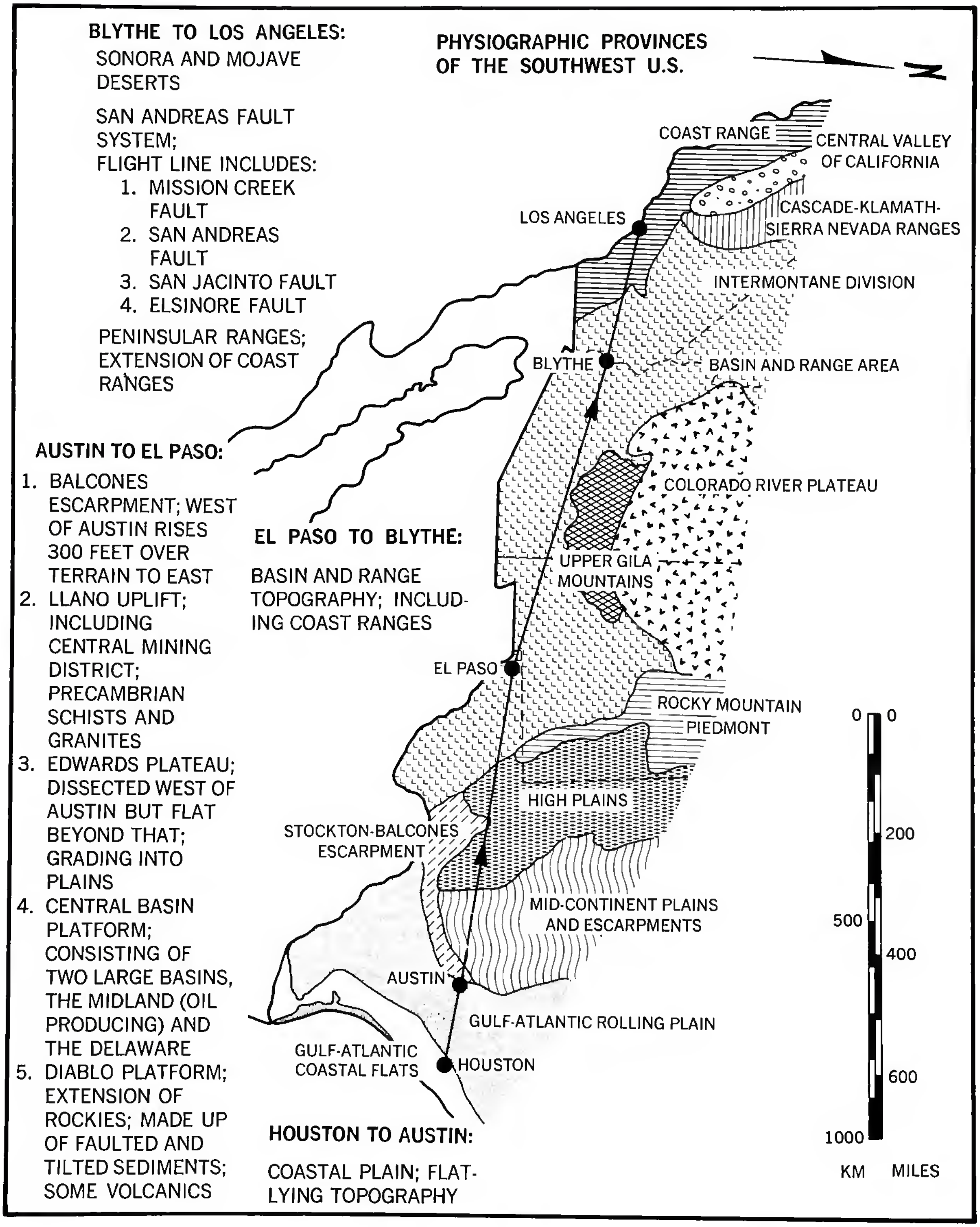
## "Manual of Training Flights"

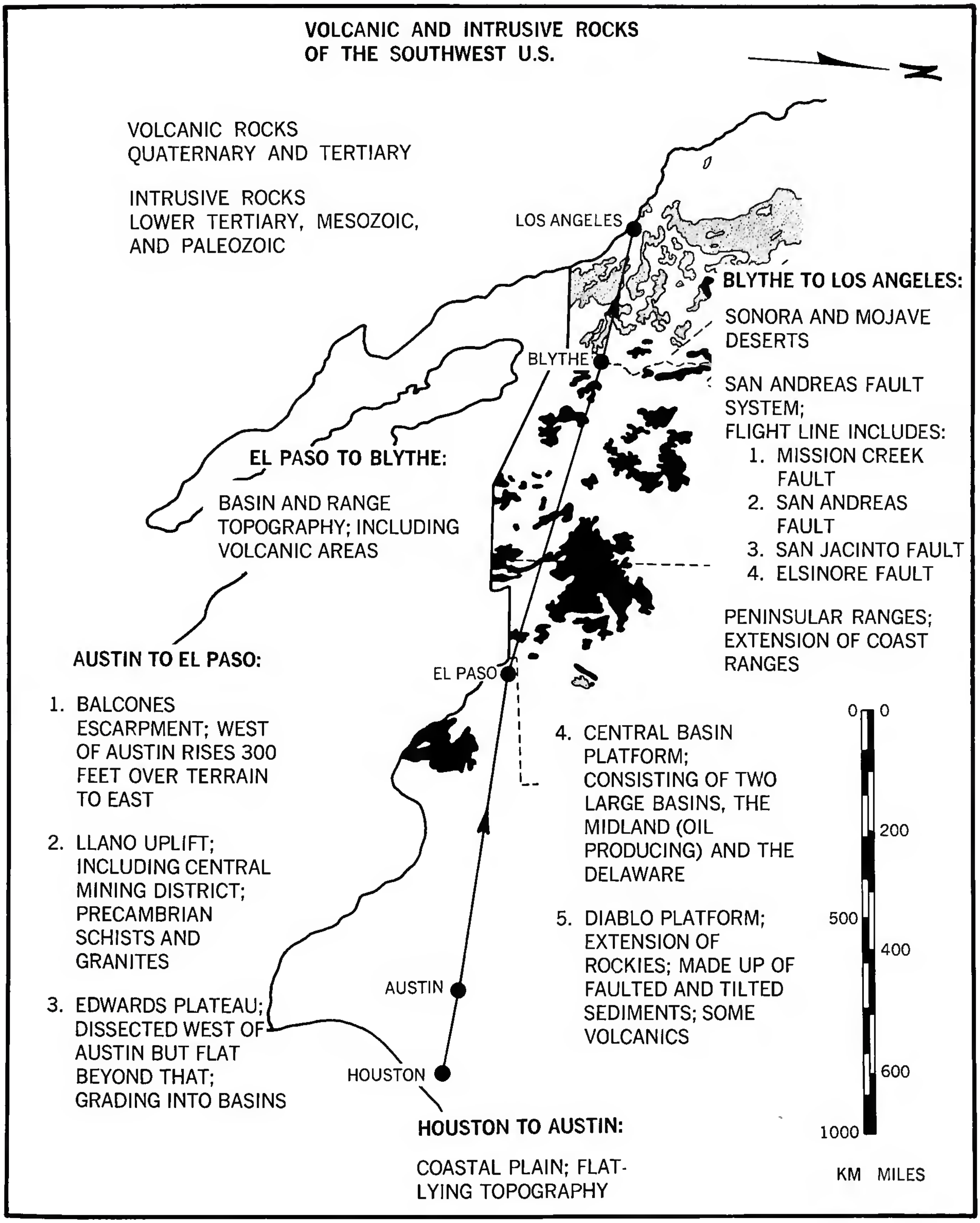
Training flights or flyovers were undertaken by the Apollo-Soyuz astronauts to (1) observe examples of land and ocean features, (2) become familiar with a number of sites planned for observation during the mission, (3) gain experience in observing sites at various sun-illumination conditions and viewing angles, (4) practice verbal description of observed features and phenomena, and (5) gain experience in handling visual observation aids and photographic equipment.

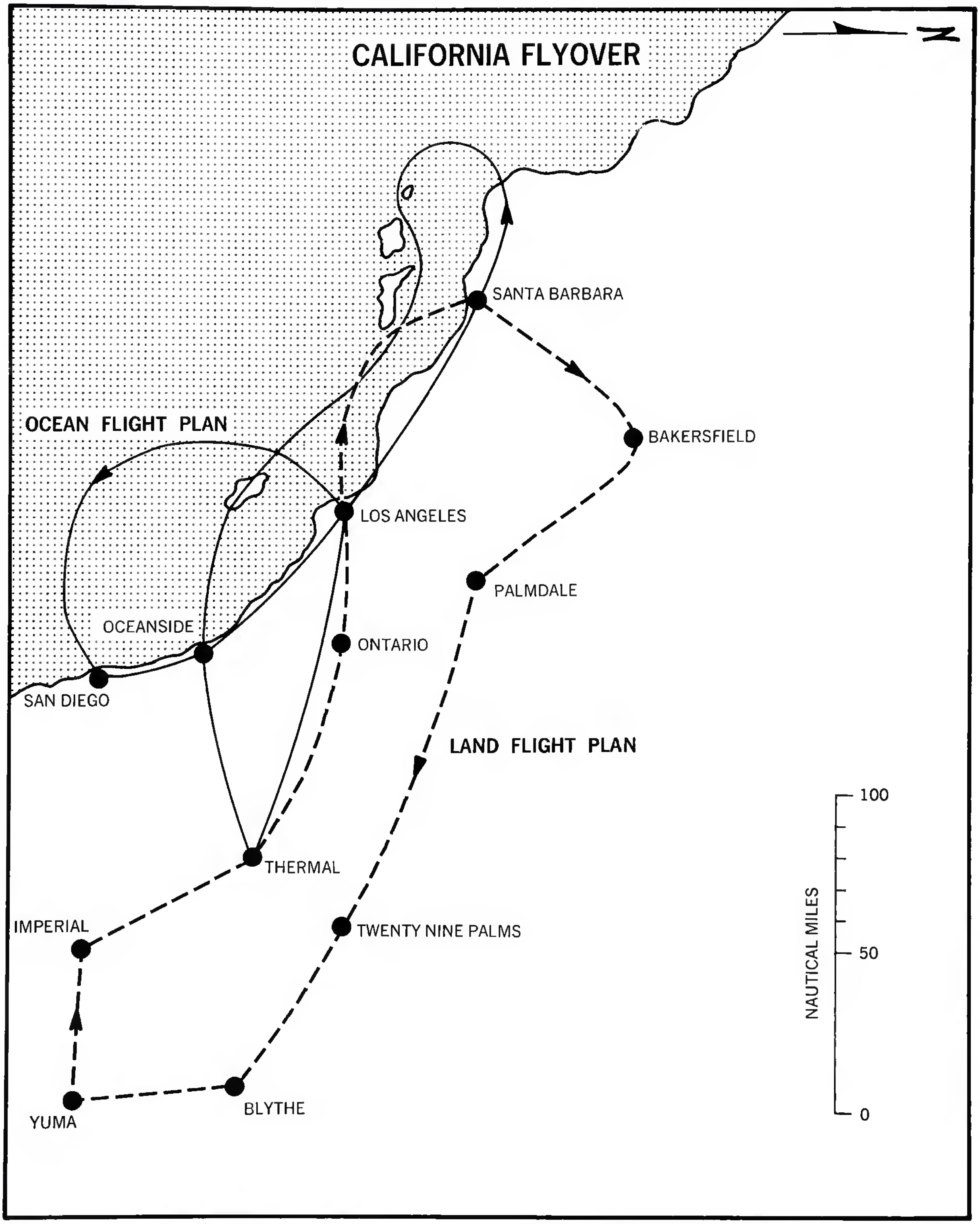
The flyovers were usually preceded by a briefing on the various tasks, and followed by a debriefing on the results. These flyovers were undertaken with the use of booklets, reproduced here in the same order as they are discussed in the text (see "Astronaut Training," pp. 30–42). The seven flyovers were as follows: Houston to Los Angeles Flyover, California Flyover, Gulf Coast Flyover, Gulf-Florida Flyover, East Coast Flyover, Southwestern U.S. Flyover, and Northwestern U.S. Flyover.

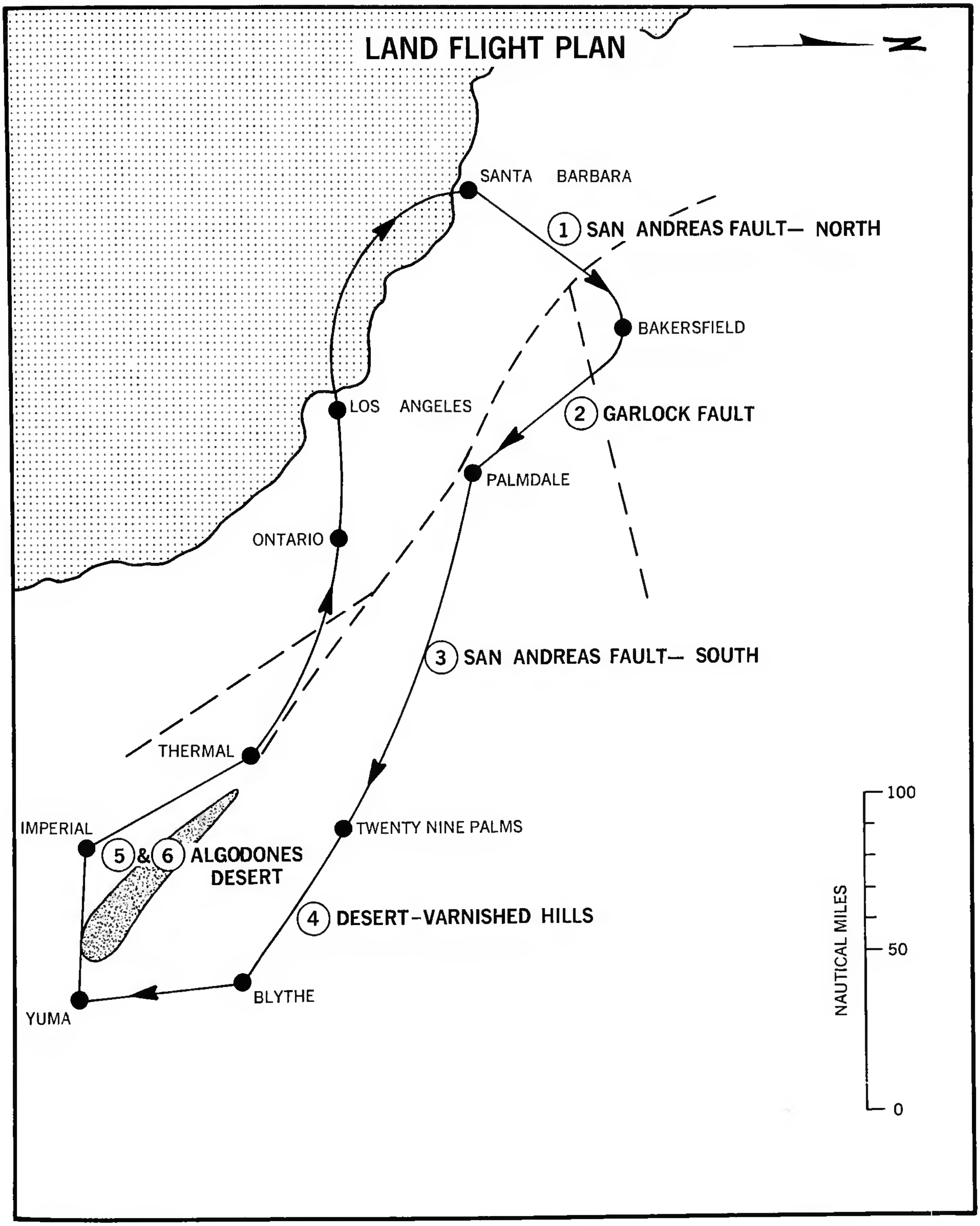

HOUSTON TO LOS ANGELES FLYOVER
N
CALIFORNIA
PACIFIC OCEAN
LOS ANGELES
SAN DIEGO
BLYTHE
PHOENIX
ARIZONA
NEW MEXICO
EL PASO
MEXICO
TEXAS
SAN ANTONIO
AUSTIN
HOUSTON
GULF OF MEXICO
0
0
200
500
400
600
1000
KM
MILES


BLYTHE TO LOS ANGELES:
SONORA AND MOJAVE DESERTS
SAN ANDREAS FAULT SYSTEM;
FLIGHT LINE INCLUDES:
1. MISSION CREEK FAULT
2. SAN ANDREAS FAULT
3. SAN JACINTO FAULT
4. ELSINORE FAULT
PENINSULAR RANGES; EXTENSION OF COAST RANGES
TECTONIC MAP OF THE SOUTHWEST U.S.
N
EL PASO TO BLYTHE:
BASIN AND RANGE TOPOGRAPHY; INCLUDING VOLCANIC AREAS
SAN ANDREAS FAULT SYSTEM
LOS ANGELES
GARLOCK FAULT
BLYTHE
CALDERA
VOLCANIC CONE
TRANSCURRENT FAULT
THRUST FAULT
AUSTIN TO EL PASO:
1. BALCONES ESCARPMENT; WEST OF AUSTIN RISES 300 FEET OVER TERRAIN TO EAST
2. LLANO UPLIFT; INCLUDING CENTRAL MINING DISTRICT; PRECAMBRIAN SCHISTS AND GRANITES
3. EDWARDS PLATEAU; DISSECTED WEST OF AUSTIN BUT FLAT BEYOND THAT; GRADING INTO PLAINS
4. CENTRAL BASIN PLATFORM; CONSISTING OF TWO LARGE BASINS, THE MIDLAND (OIL PRODUCING) AND THE DELAWARE
EL PASO
5
4
3
2
1
BALCONES ESCARPMENT
LLANO UPLIFT
AUSTIN
HOUSTON
5. DIABLO PLATFORM; EXTENSION OF ROCKIES; MADE UP OF FAULTED AND TILTED SEDIMENTS; SOME VOLCANICS
HOUSTON TO AUSTIN:
COASTAL PLAIN; FLAT-LYING TOPOGRAPHY
0
0
200
500
400
600
1000
KM
MILES

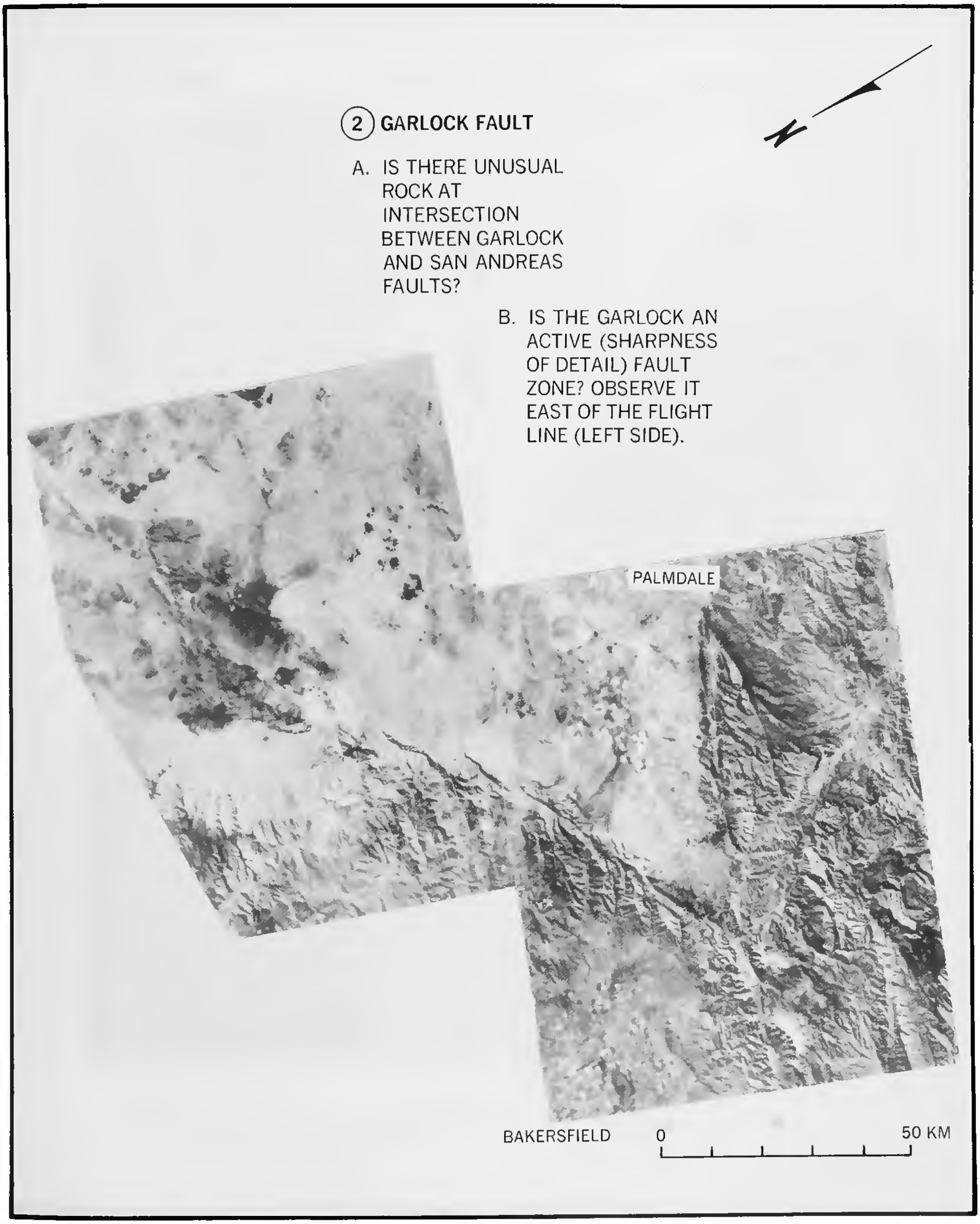

BLYTHE TO LOS ANGELES:
SONORA AND MOJAVE DESERTS
SAN ANDREAS FAULT SYSTEM;
FLIGHT LINE INCLUDES:
1. MISSION CREEK FAULT
2. SAN ANDREAS FAULT
3. SAN JACINTO FAULT
4. ELSINORE FAULT
PENINSULAR RANGES; EXTENSION OF COAST RANGES
PHYSIOGRAPHIC PROVINCES OF THE SOUTHWEST U.S.
N
COAST RANGE
CENTRAL VALLEY OF CALIFORNIA
CASCADE-KLAMATH-SIERRA NEVADA RANGES
LOS ANGELES
INTERMONTANE DIVISION
BLYTHE
BASIN AND RANGE AREA
AUSTIN TO EL PASO:
1. BALCONES ESCARPMENT; WEST OF AUSTIN RISES 300 FEET OVER TERRAIN TO EAST
2. LLANO UPLIFT; INCLUDING CENTRAL MINING DISTRICT; PRECAMBRIAN SCHISTS AND GRANITES
3. EDWARDS PLATEAU; DISSECTED WEST OF AUSTIN BUT FLAT BEYOND THAT; GRADING INTO PLAINS
4. CENTRAL BASIN PLATFORM; CONSISTING OF TWO LARGE BASINS, THE MIDLAND (OIL PRODUCING) AND THE DELAWARE
5. DIABLO PLATFORM; EXTENSION OF ROCKIES; MADE UP OF FAULTED AND TILTED SEDIMENTS; SOME VOLCANICS
COLORADO RIVER PLATEAU
EL PASO TO BLYTHE:
BASIN AND RANGE TOPOGRAPHY; INCLUDING COAST RANGES
UPPER GILA MOUNTAINS
EL PASO
ROCKY MOUNTAIN PIEDMONT
HIGH PLAINS
STOCKTON-BALCONES ESCARPMENT
MID-CONTINENT PLAINS AND ESCARPMENTS
AUSTIN
GULF-ATLANTIC ROLLING PLAIN
GULF-ATLANTIC COASTAL FLATS
HOUSTON
HOUSTON TO AUSTIN:
COASTAL PLAIN; FLAT-LYING TOPOGRAPHY
0
0
200
500
400
600
1000
KM
MILES


VOLCANIC AND INTRUSIVE ROCKS
OF THE SOUTHWEST U.S.
N
VOLCANIC ROCKS
QUATERNARY AND TERTIARY
INTRUSIVE ROCKS
LOWER TERTIARY, MESOZOIC,
AND PALEOZOIC
LOS ANGELES
BLYTHE
EL PASO
AUSTIN
HOUSTON
BLYTHE TO LOS ANGELES:
SONORA AND MOJAVE
DESERTS
SAN ANDREAS FAULT
SYSTEM;
FLIGHT LINE INCLUDES:
1. MISSION CREEK
FAULT
2. SAN ANDREAS
FAULT
3. SAN JACINTO FAULT
4. ELSINORE FAULT
PENINSULAR RANGES;
EXTENSION OF COAST
RANGES
EL PASO TO BLYTHE:
BASIN AND RANGE
TOPOGRAPHY; INCLUDING
VOLCANIC AREAS
AUSTIN TO EL PASO:
1. BALCONES
ESCARPMENT; WEST
OF AUSTIN RISES 300
FEET OVER TERRAIN
TO EAST
2. LLANO UPLIFT;
INCLUDING CENTRAL
MINING DISTRICT;
PRECAMBRIAN
SCHISTS AND
GRANITES
3. EDWARDS PLATEAU;
DISSECTED WEST OF
AUSTIN BUT FLAT
BEYOND THAT;
GRADING INTO BASINS
4. CENTRAL BASIN
PLATFORM;
CONSISTING OF TWO
LARGE BASINS, THE
MIDLAND (OIL
PRODUCING) AND THE
DELAWARE
5. DIABLO PLATFORM;
EXTENSION OF
ROCKIES; MADE UP OF
FAULTED AND TILTED
SEDIMENTS; SOME
VOLCANICS
HOUSTON TO AUSTIN:
COASTAL PLAIN; FLAT-
LYING TOPOGRAPHY
0
0
200
500
400
600
1000
KM MILES


CALIFORNIA FLYOVER
N
SANTA BARBARA
BAKERSFIELD
OCEAN FLIGHT PLAN
LOS ANGELES
PALMDALE
OCEANSIDE
ONTARIO
SAN DIEGO
LAND FLIGHT PLAN
100
THERMAL
IMPERIAL
TWENTY NINE PALMS
NAUTICAL MILES
50
YUMA
BLYTHE
0

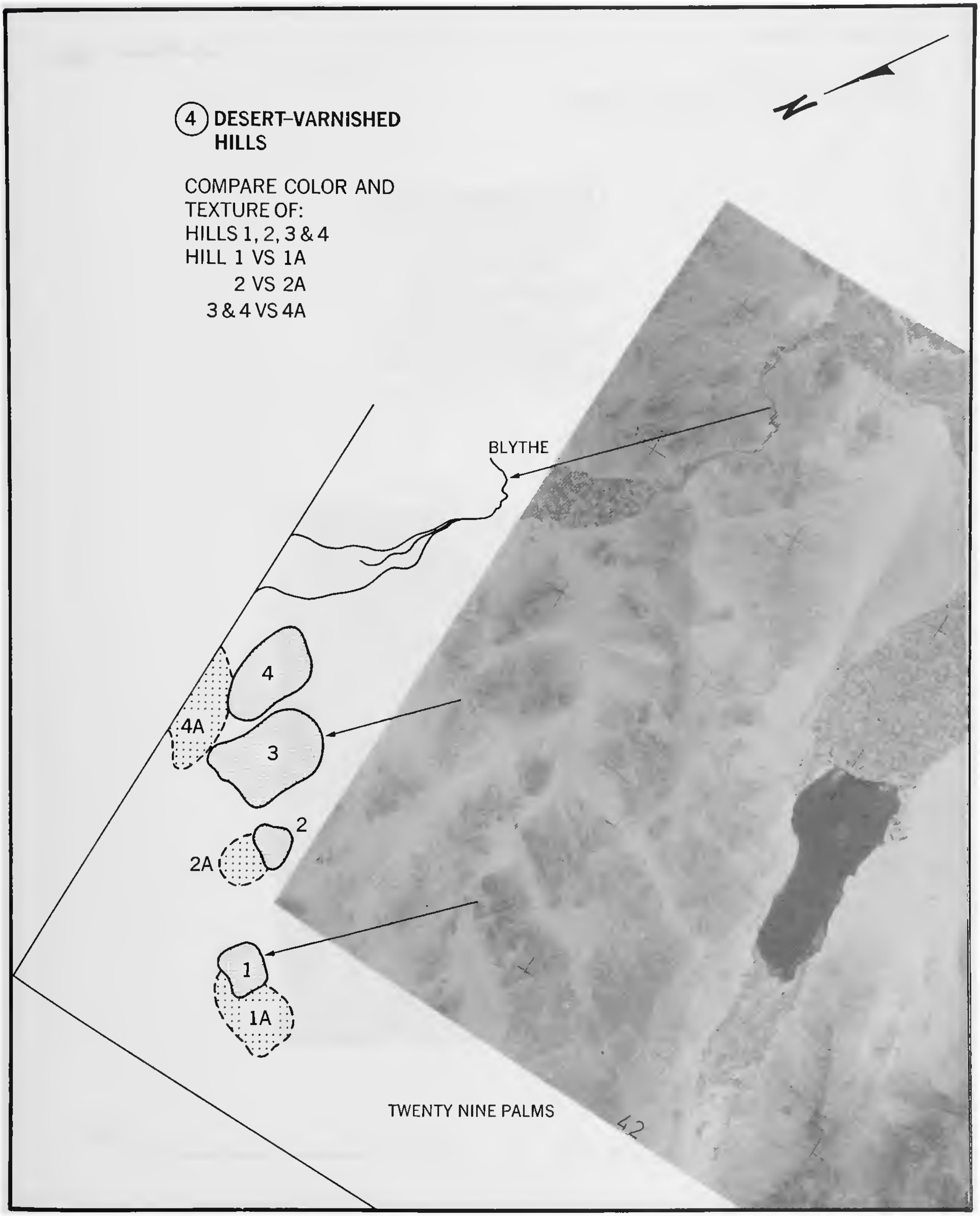

LAND FLIGHT PLAN
N
SANTA BARBARA
1 SAN ANDREAS FAULT— NORTH
BAKERSFIELD
LOS ANGELES
2 GARLOCK FAULT
PALMDALE
ONTARIO
3 SAN ANDREAS FAULT— SOUTH
THERMAL
IMPERIAL
TWENTY NINE PALMS
5 & 6 ALGODONES DESERT
4 DESERT-VARNISHED HILLS
BLYTHE
YUMA
NAUTICAL MILES
100
50
0


N
(1) SAN ANDREAS FAULT—NORTH
A. WHERE DO THE EASTWARD TRENDING VALLEYS TERMINATE?
B. HOW DO YOU DISTINGUISH THE SAN ANDREAS FAULT?
SCARP
COLOR DIFFERENCE
DRAINAGE
DISPLACEMENT
BAKERSFIELD
SANTA BARBARA
0
50 KM


2 GARLOCK FAULT
A. IS THERE UNUSUAL ROCK AT INTERSECTION BETWEEN GARLOCK AND SAN ANDREAS FAULTS?
B. IS THE GARLOCK AN ACTIVE (SHARPNESS OF DETAIL) FAULT ZONE? OBSERVE IT EAST OF THE FLIGHT LINE (LEFT SIDE).
N
PALMDALE
BAKERSFIELD
0
50 KM

**③ SAN ANDREAS FAULT—SOUTH**

A. OBSERVE TOPOGRAPHIC EXPRESSION (LINED RIDGES, STREAM OFFSET, ETC.) ALONG SCARP
B. HOW MANY STRANDS OF SAN ANDREAS SYSTEM CAN YOU SEE?
C. DESCRIBE INTERSECTION BETWEEN SAN ANDREAS AND SAN JACINTO
D. WHICH OF THE TWO FAULTS LOOKS MORE ACTIVE? (COMPARE SHARPNESS AND FRESHNESS)

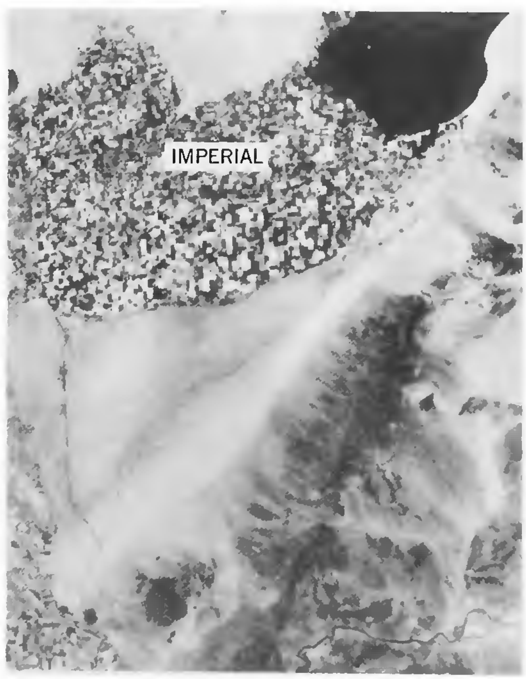

4 DESERT-VARNISHED HILLS
COMPARE COLOR AND
TEXTURE OF:
HILLS 1, 2, 3 & 4
HILL 1 VS 1A
2 VS 2A
3 & 4 VS 4A
N
BLYTHE
4
4A
3
2
2A
1
1A
TWENTY NINE PALMS
42

**BLYTHE TO YUMA**

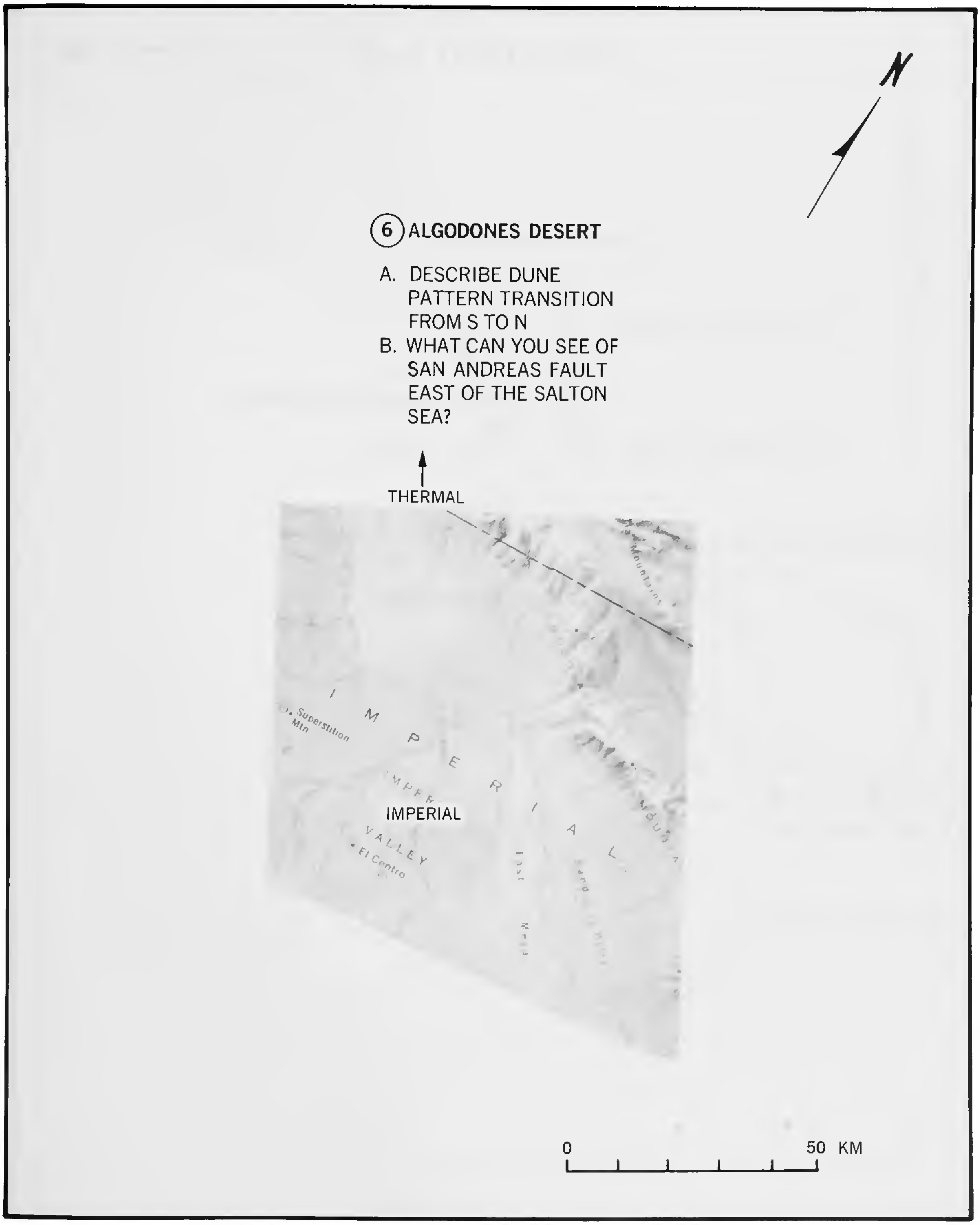
SWITCH TAPE OVER
CRUISE OVER THE COLORADO RIVER

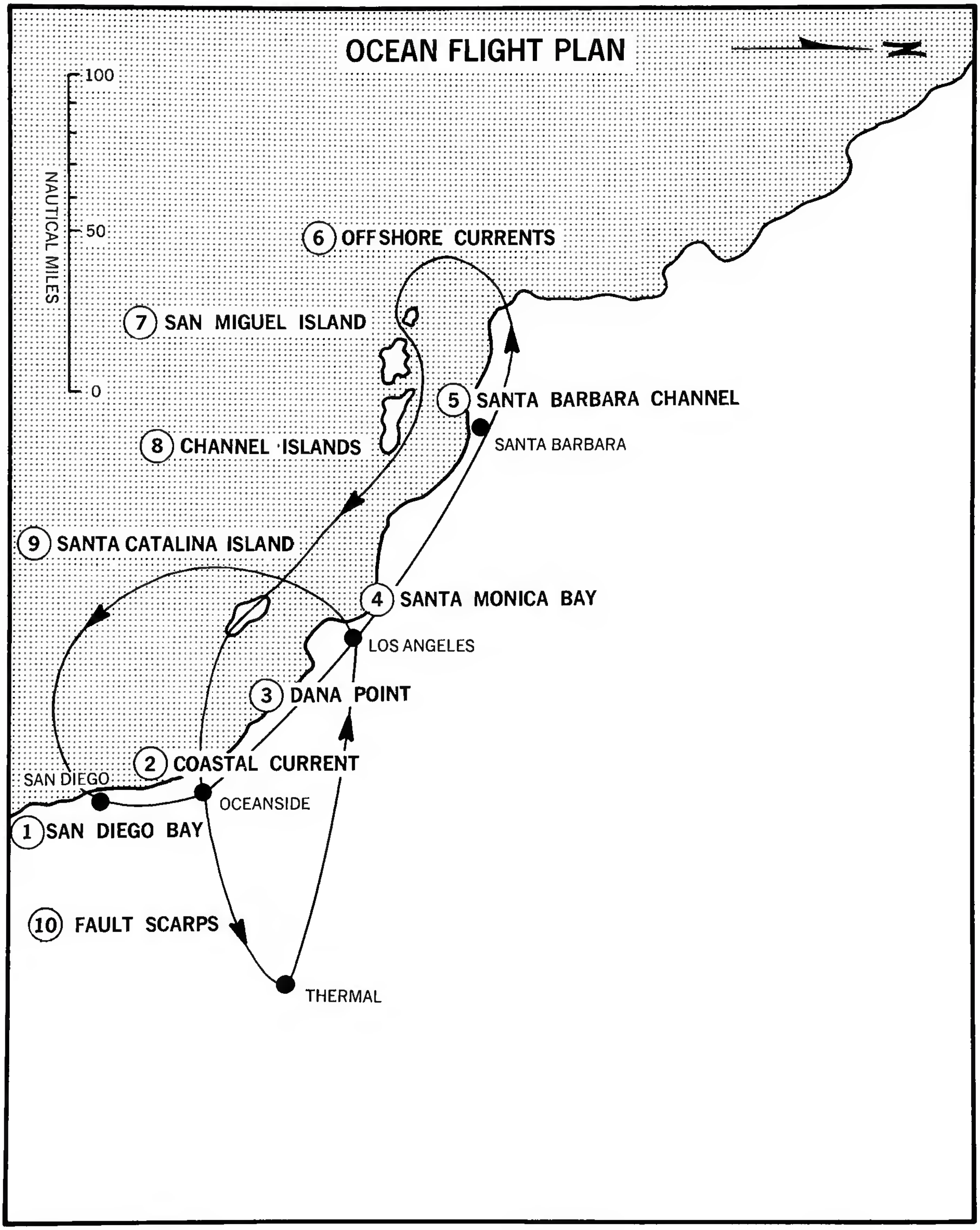
**(5) ALGODONES DESERT**

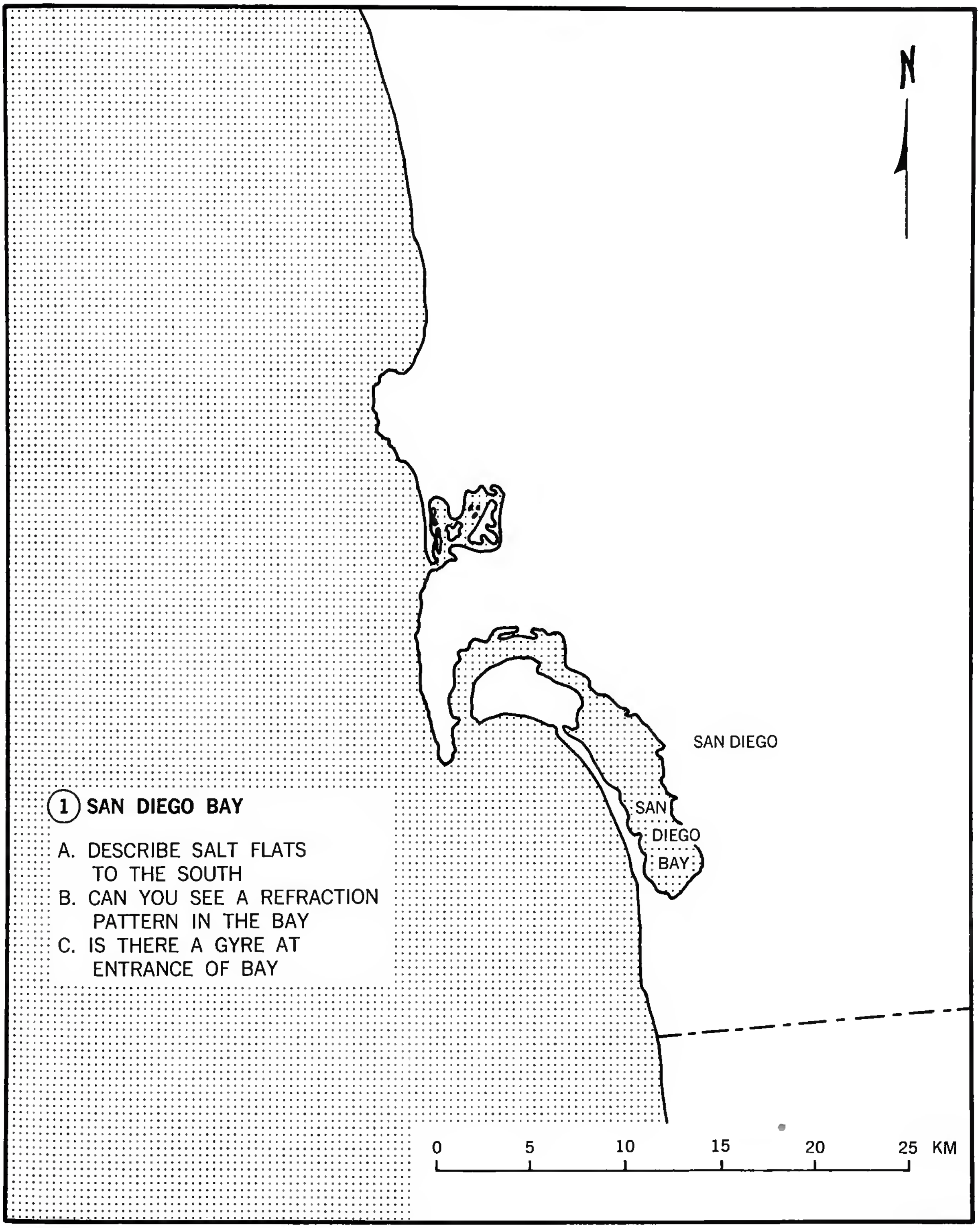
A. USE CHART TO IDENTIFY COLORS
B. DESCRIBE COLOR TRANSITION IF ANY.
C. DESCRIBE RIDGES ON SW EDGE OF DESERT.

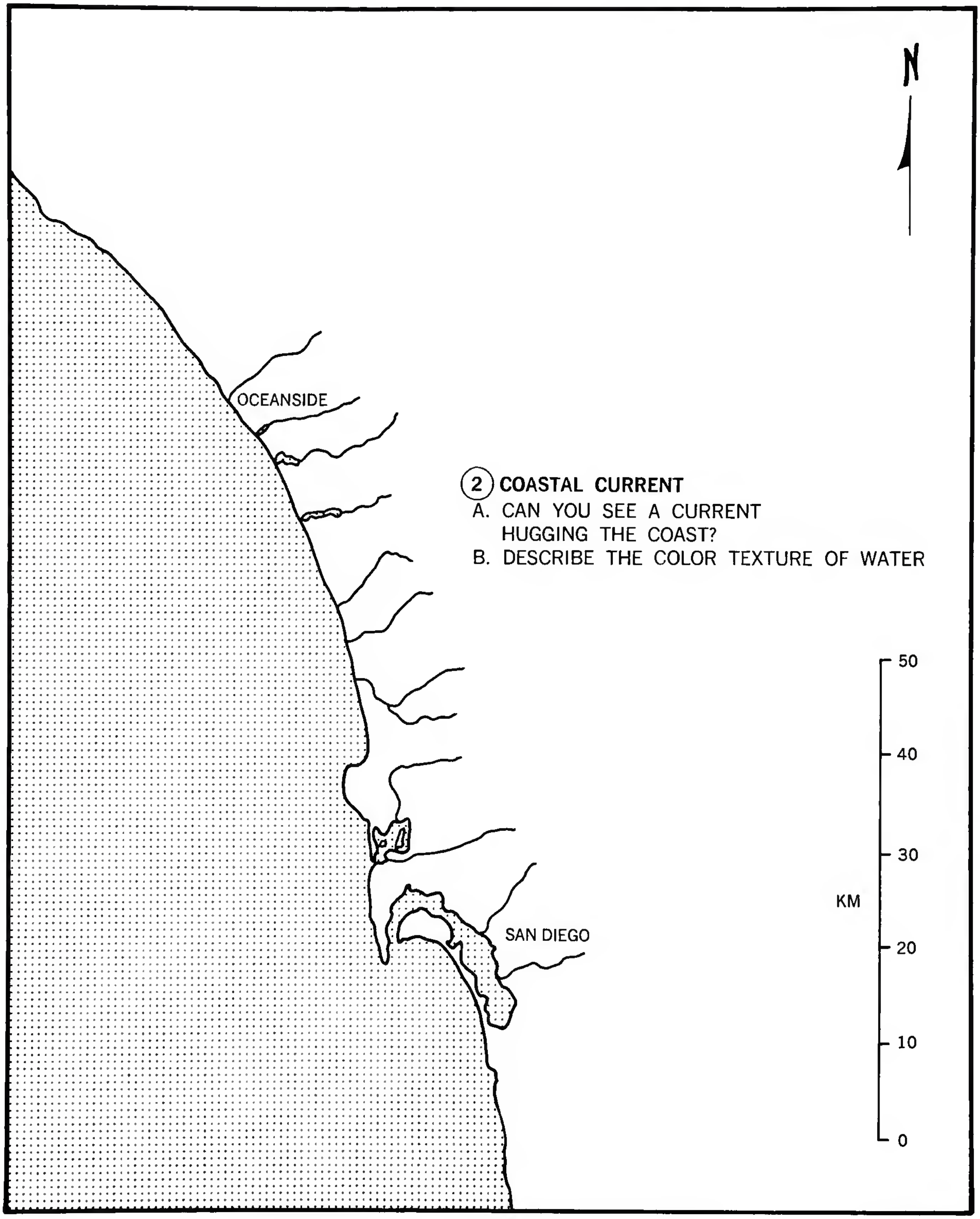


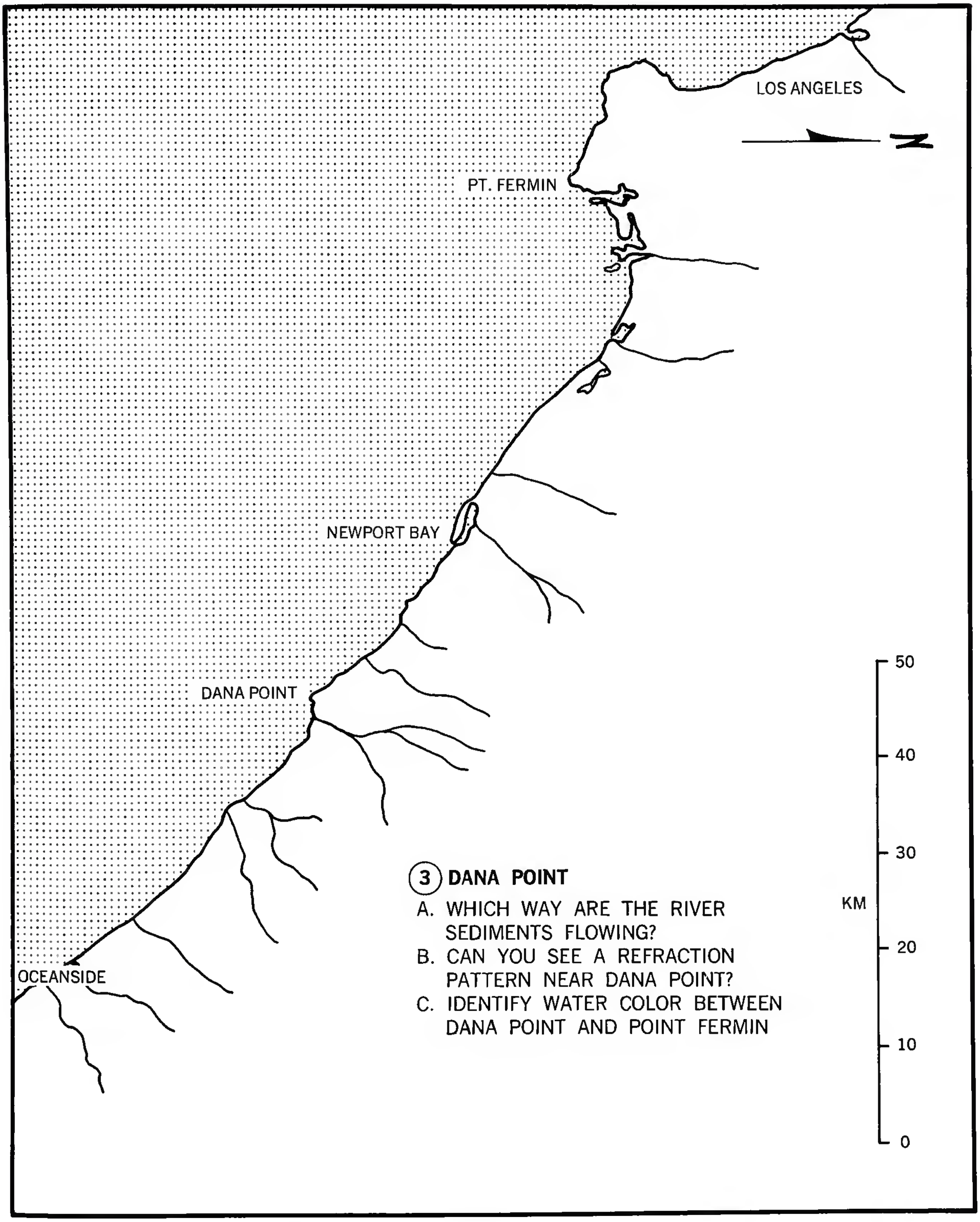

0 50 KM

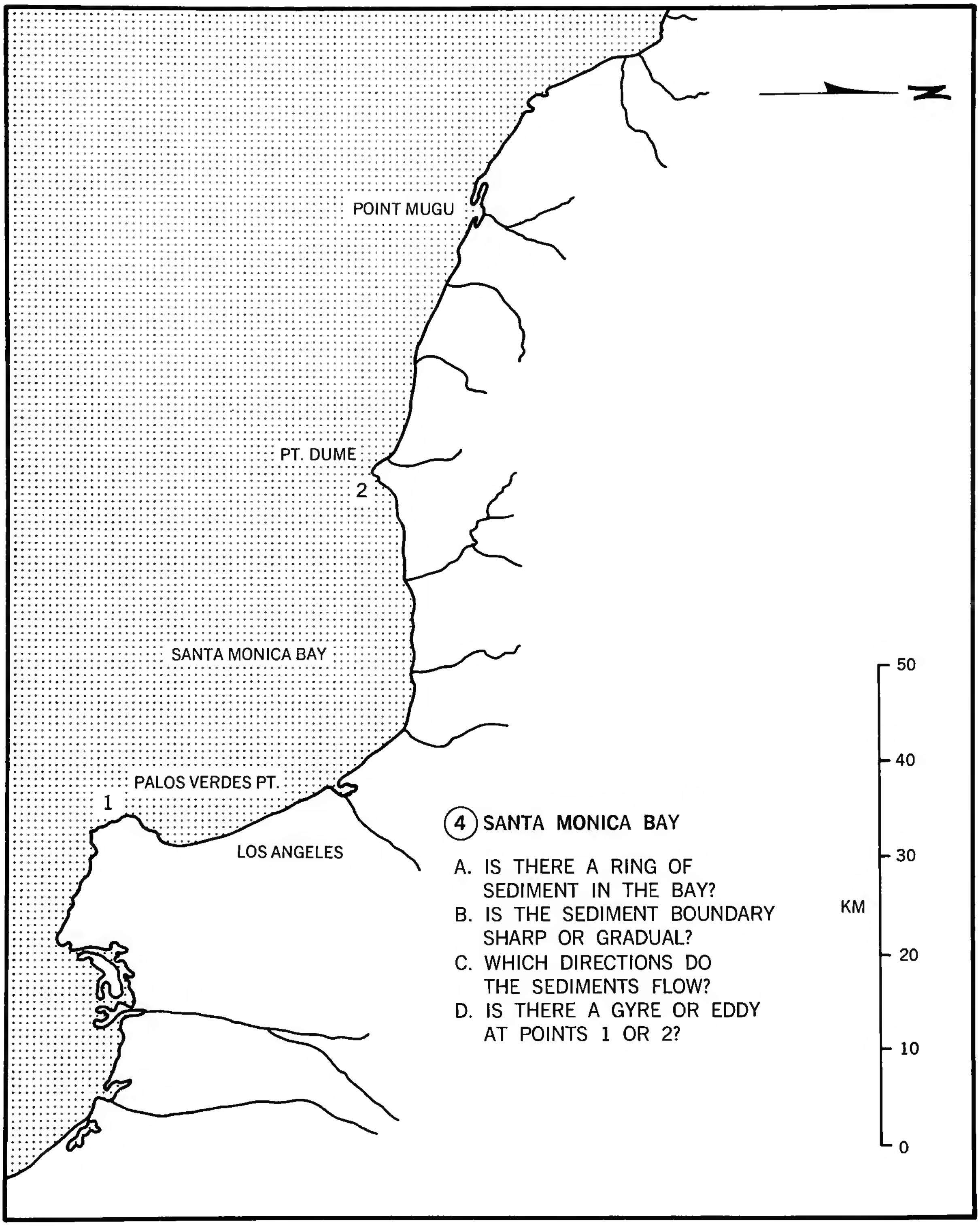

N
6 ALGODONES DESERT
A. DESCRIBE DUNE PATTERN TRANSITION FROM S TO N
B. WHAT CAN YOU SEE OF SAN ANDREAS FAULT EAST OF THE SALTON SEA?
THERMAL
I M P E R I A L
Superstition Mtn
IMPERIAL
IMPERIAL VALLEY
El Centro
Mountains
0
50 KM

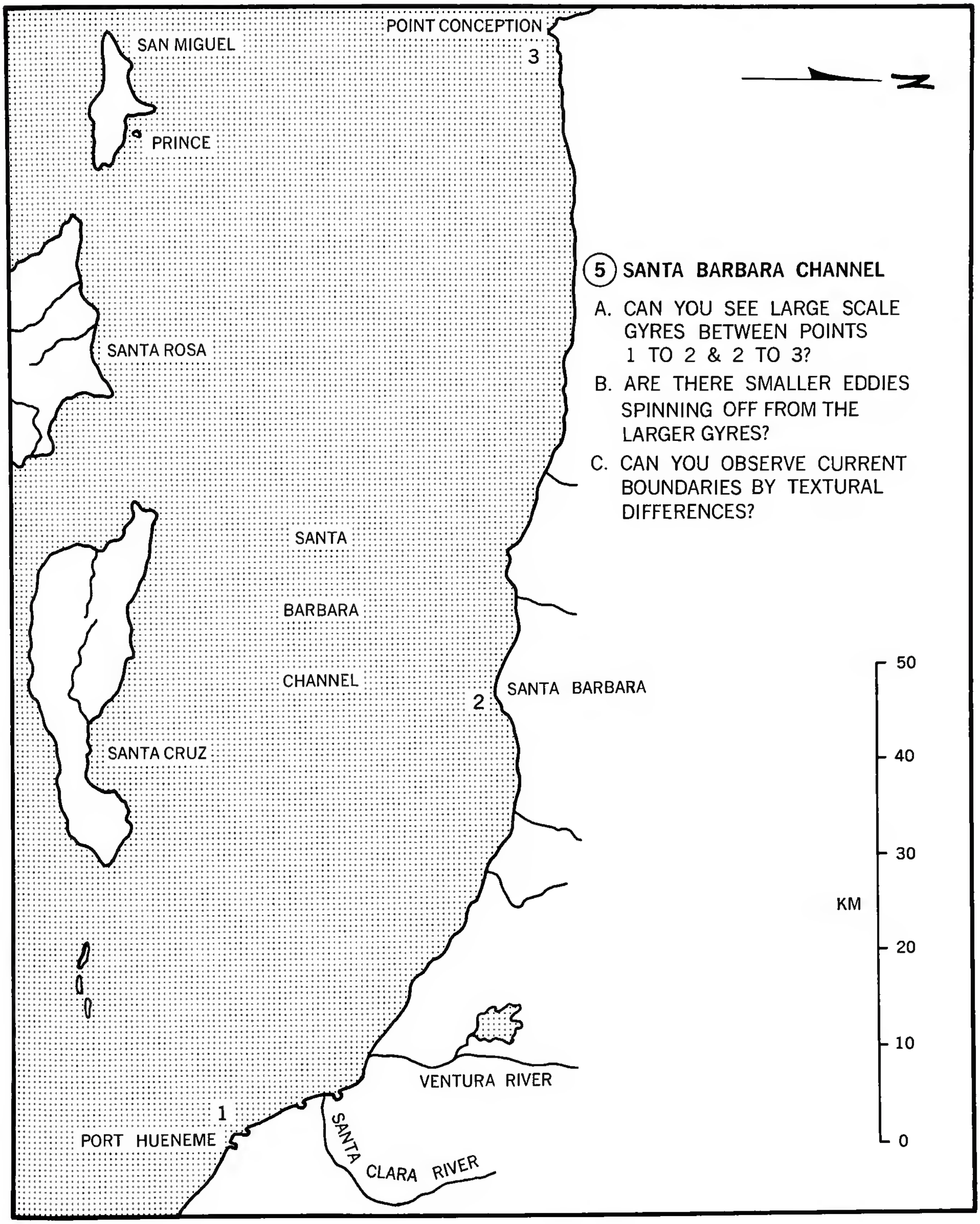

OCEAN FLIGHT PLAN
100
50
0
NAUTICAL MILES
6 OFFSHORE CURRENTS
7 SAN MIGUEL ISLAND
5 SANTA BARBARA CHANNEL
SANTA BARBARA
8 CHANNEL ISLANDS
9 SANTA CATALINA ISLAND
4 SANTA MONICA BAY
LOS ANGELES
3 DANA POINT
2 COASTAL CURRENT
SAN DIEGO
OCEANSIDE
1 SAN DIEGO BAY
10 FAULT SCARPS
THERMAL

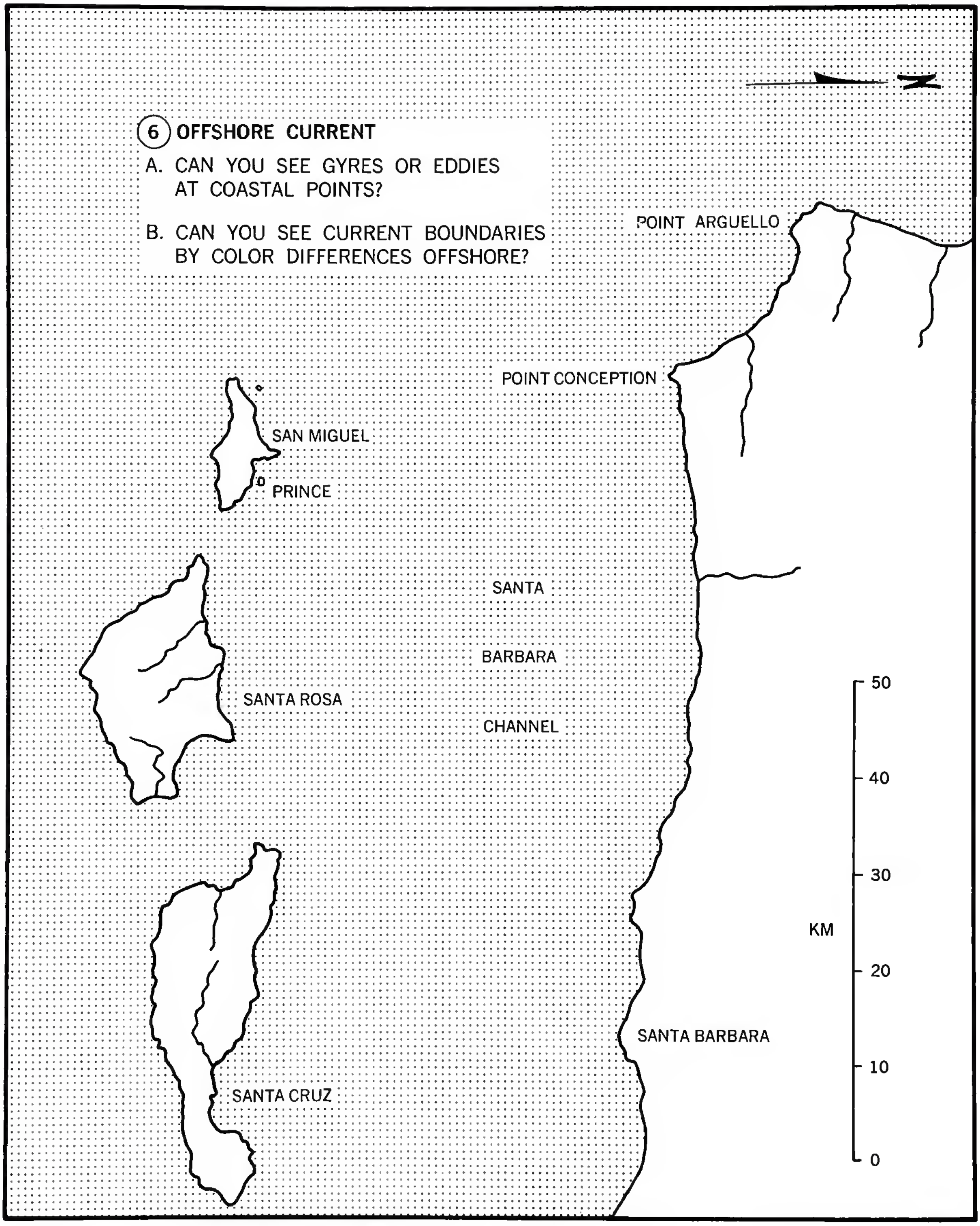

N
SAN DIEGO
SAN
DIEGO
BAY
1 SAN DIEGO BAY
A. DESCRIBE SALT FLATS
TO THE SOUTH
B. CAN YOU SEE A REFRACTION
PATTERN IN THE BAY
C. IS THERE A GYRE AT
ENTRANCE OF BAY
0 5 10 15 20 25 KM

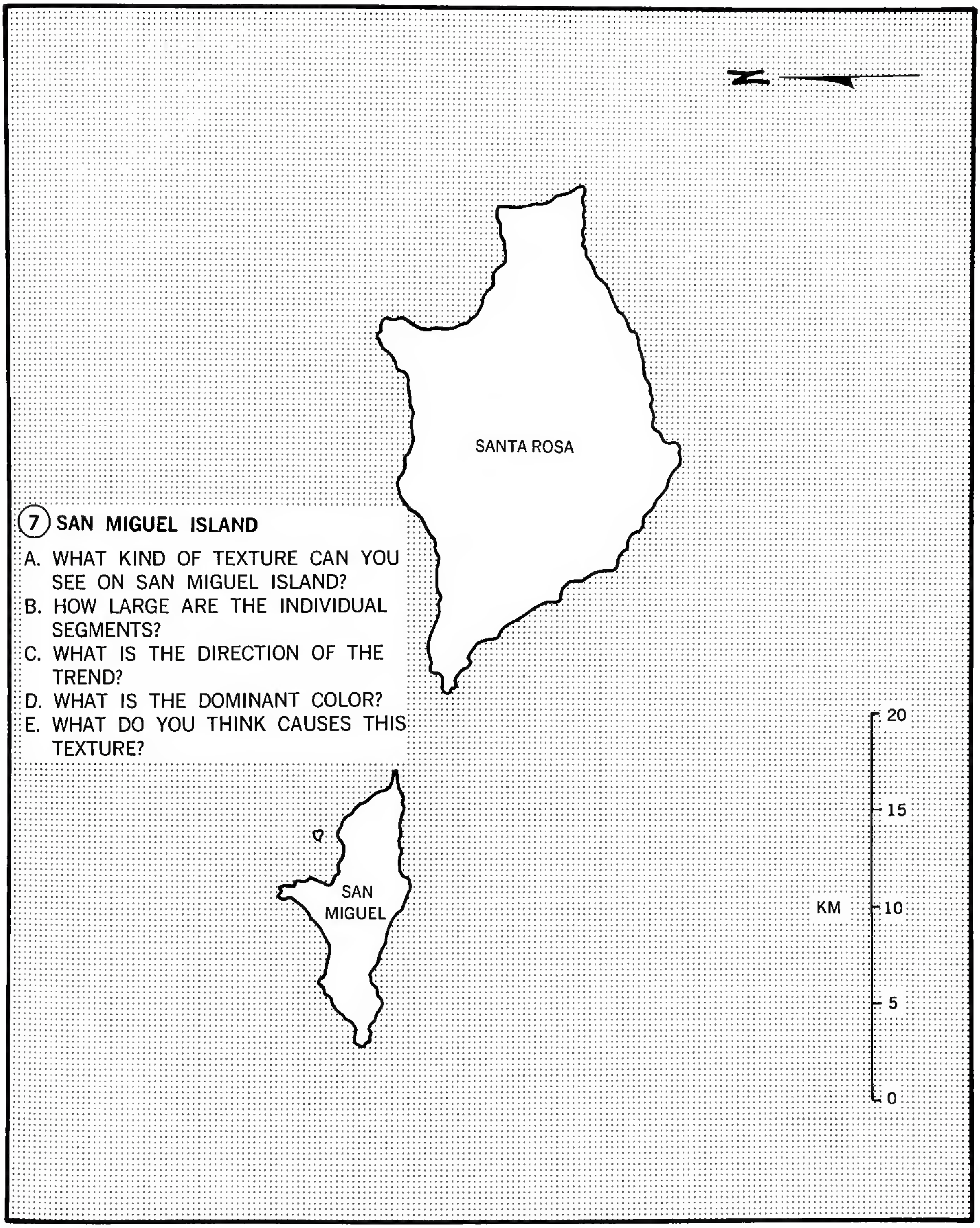

N
OCEANSIDE
SAN DIEGO
2 COASTAL CURRENT
A. CAN YOU SEE A CURRENT HUGGING THE COAST?
B. DESCRIBE THE COLOR TEXTURE OF WATER
KM
50
40
30
20
10
0


LOS ANGELES
N
PT. FERMIN
NEWPORT BAY
DANA POINT
OCEANSIDE
50
40
30
KM
20
10
0
3 DANA POINT
A. WHICH WAY ARE THE RIVER SEDIMENTS FLOWING?
B. CAN YOU SEE A REFRACTION PATTERN NEAR DANA POINT?
C. IDENTIFY WATER COLOR BETWEEN DANA POINT AND POINT FERMIN


N
POINT MUGU
PT. DUME
2
SANTA MONICA BAY
PALOS VERDES PT.
1
LOS ANGELES
(4) SANTA MONICA BAY
A. IS THERE A RING OF SEDIMENT IN THE BAY?
B. IS THE SEDIMENT BOUNDARY SHARP OR GRADUAL?
C. WHICH DIRECTIONS DO THE SEDIMENTS FLOW?
D. IS THERE A GYRE OR EDDY AT POINTS 1 OR 2?
50
40
30
KM
20
10
0

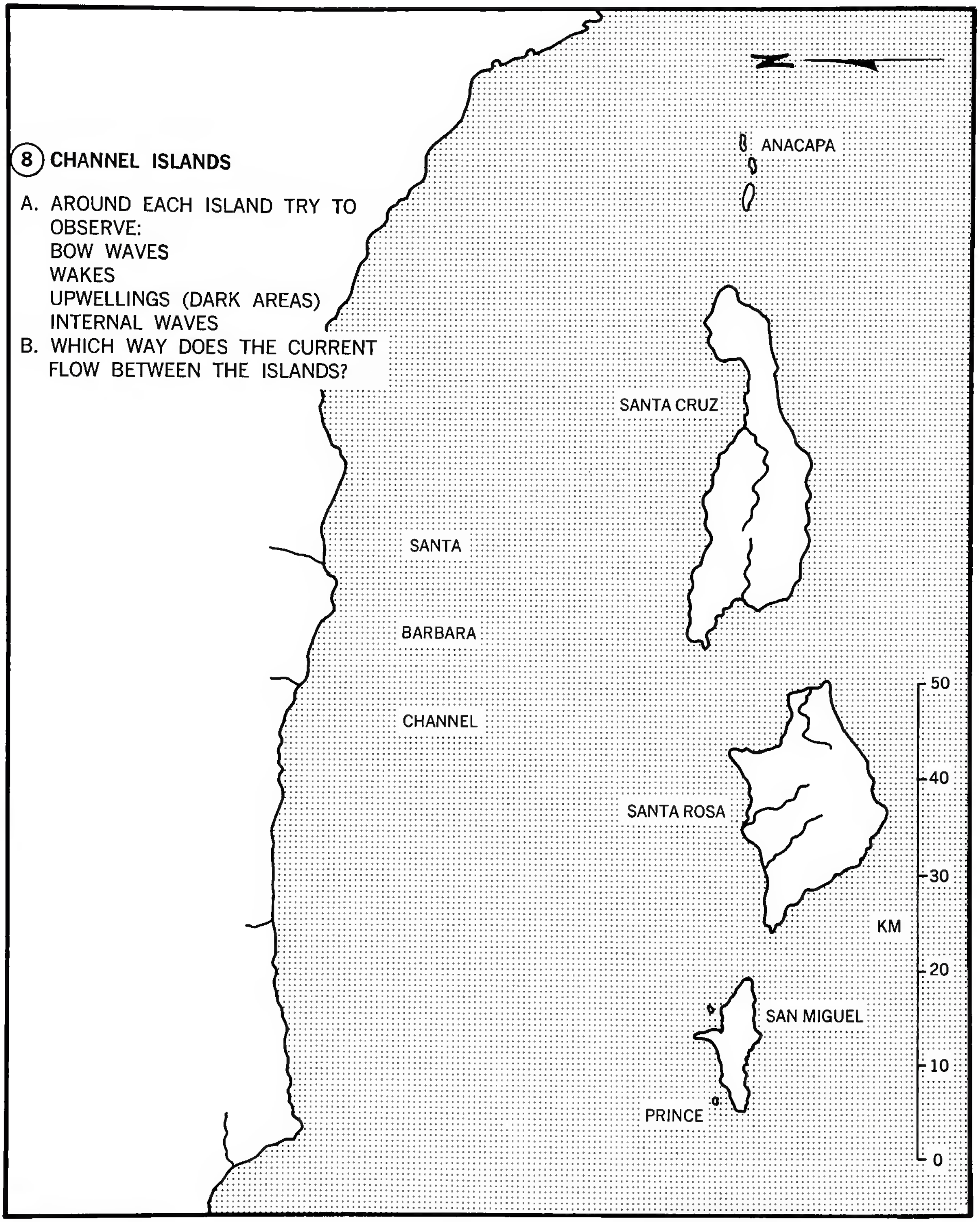

POINT CONCEPTION
3
SAN MIGUEL
PRINCE
SANTA ROSA
5 SANTA BARBARA CHANNEL
A. CAN YOU SEE LARGE SCALE GYRES BETWEEN POINTS 1 TO 2 & 2 TO 3?
B. ARE THERE SMALLER EDDIES SPINNING OFF FROM THE LARGER GYRES?
C. CAN YOU OBSERVE CURRENT BOUNDARIES BY TEXTURAL DIFFERENCES?
SANTA
BARBARA
CHANNEL
2
SANTA BARBARA
SANTA CRUZ
50
40
30
KM
20
10
0
VENTURA RIVER
1
PORT HUENEME
SANTA CLARA RIVER


6 OFFSHORE CURRENT
A. CAN YOU SEE GYRES OR EDDIES AT COASTAL POINTS?
B. CAN YOU SEE CURRENT BOUNDARIES BY COLOR DIFFERENCES OFFSHORE?
POINT ARGUELLO
POINT CONCEPTION
SAN MIGUEL
PRINCE
SANTA
BARBARA
CHANNEL
SANTA ROSA
SANTA CRUZ
SANTA BARBARA
KM
50
40
30
20
10
0

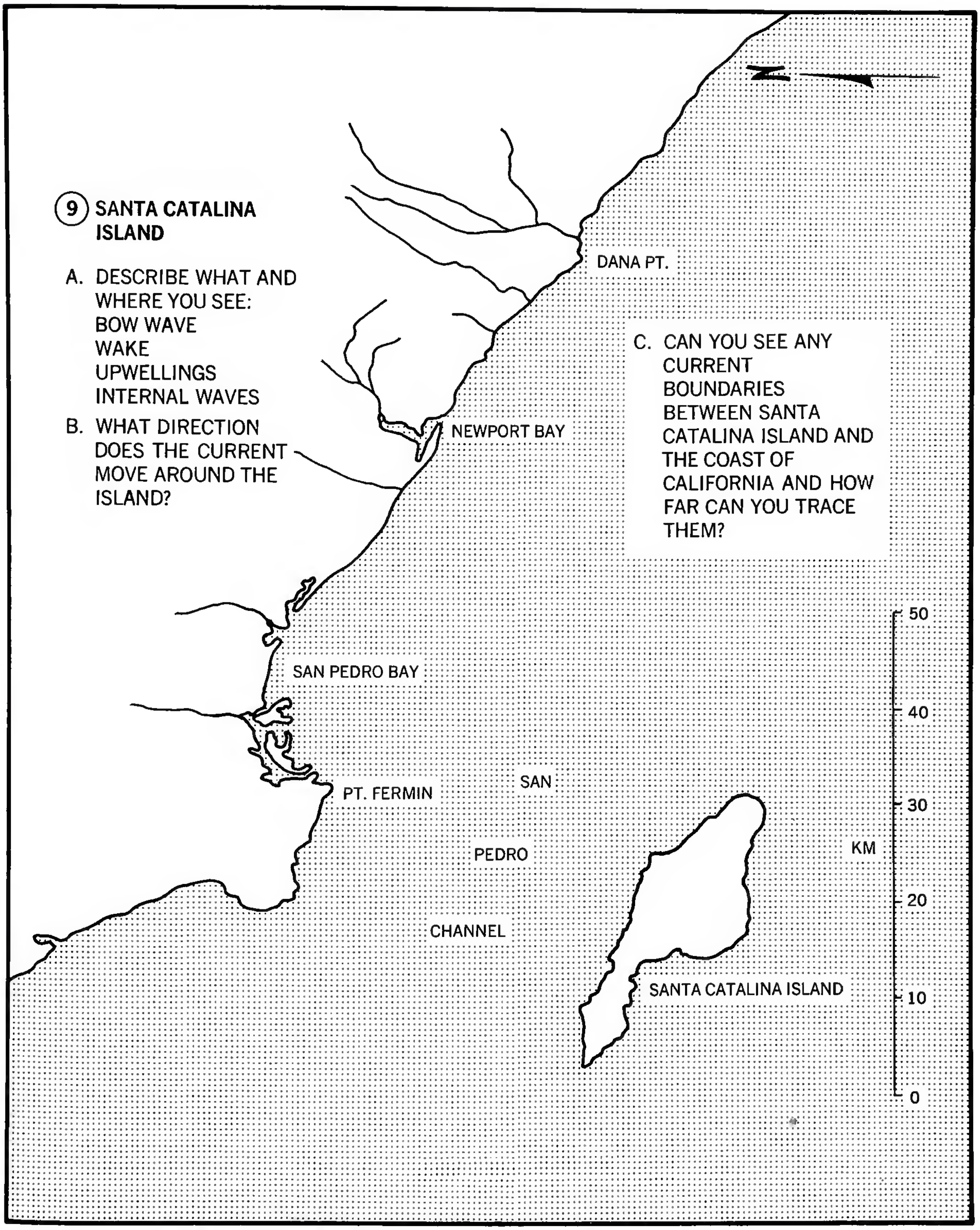



**7 SAN MIGUEL ISLAND**

A. WHAT KIND OF TEXTURE CAN YOU SEE ON SAN MIGUEL ISLAND?
B. HOW LARGE ARE THE INDIVIDUAL SEGMENTS?
C. WHAT IS THE DIRECTION OF THE TREND?
D. WHAT IS THE DOMINANT COLOR?
E. WHAT DO YOU THINK CAUSES THIS TEXTURE?



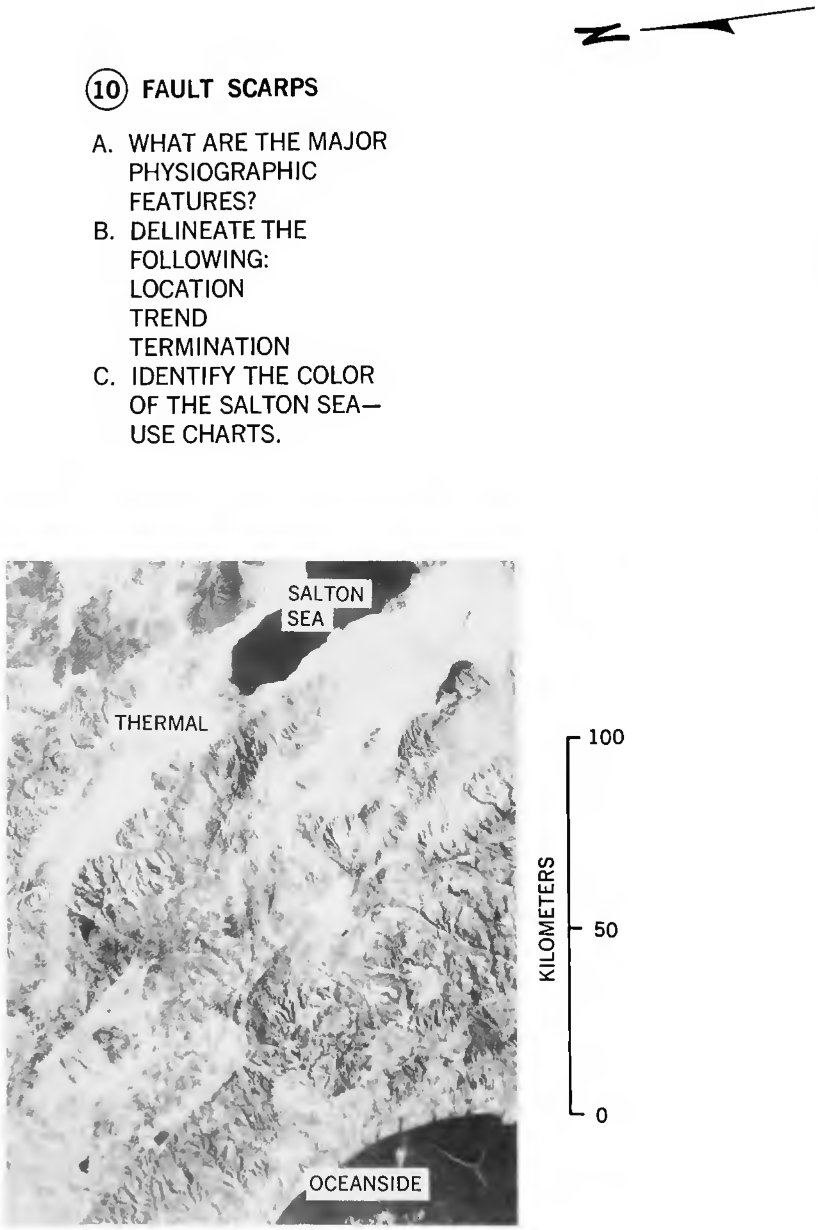
8 CHANNEL ISLANDS
A. AROUND EACH ISLAND TRY TO OBSERVE:
BOW WAVES
WAKES
UPWELLINGS (DARK AREAS)
INTERNAL WAVES
B. WHICH WAY DOES THE CURRENT FLOW BETWEEN THE ISLANDS?
N
ANACAPA
SANTA CRUZ
SANTA
BARBARA
CHANNEL
SANTA ROSA
SAN MIGUEL
PRINCE
KM
50
40
30
20
10
0

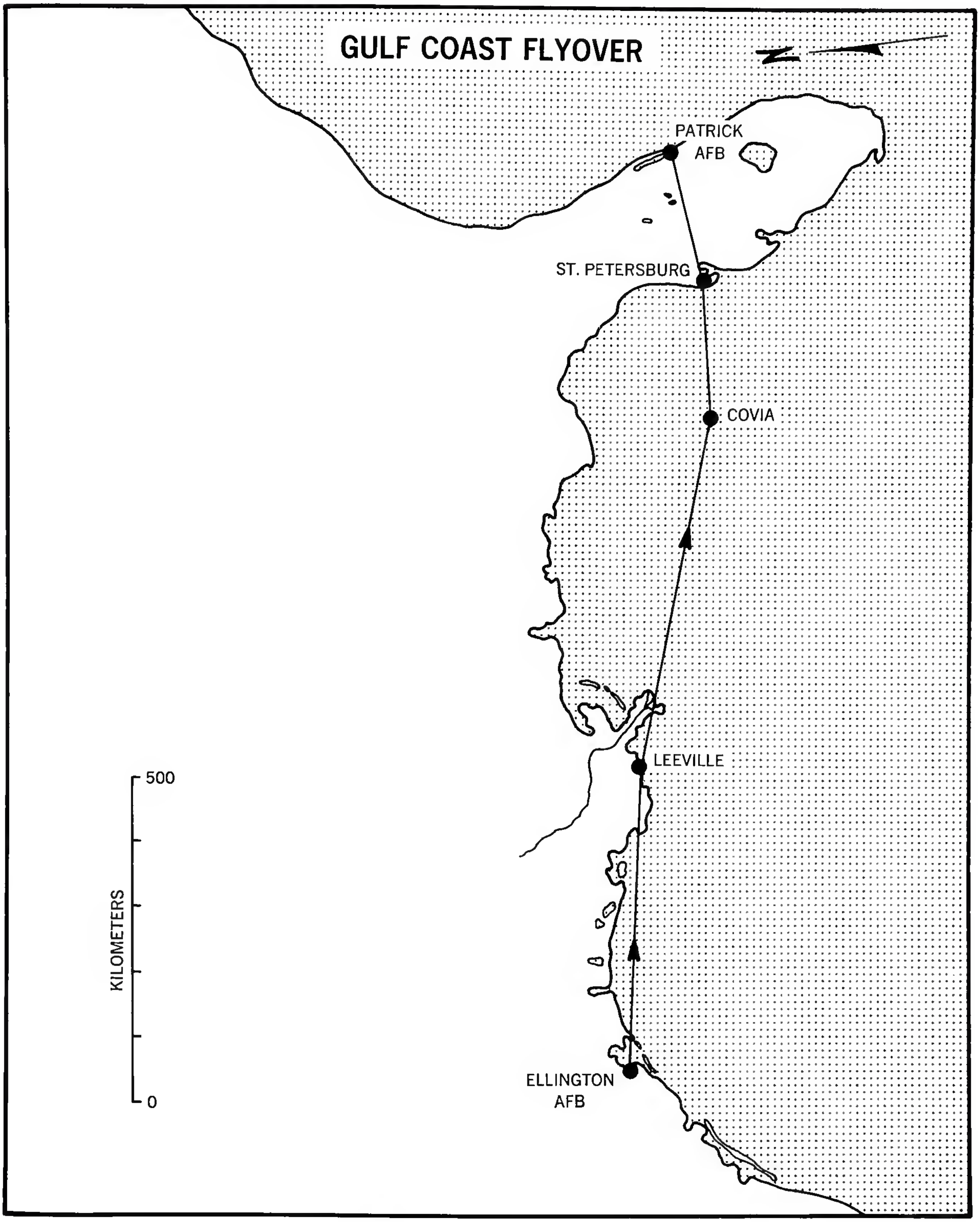


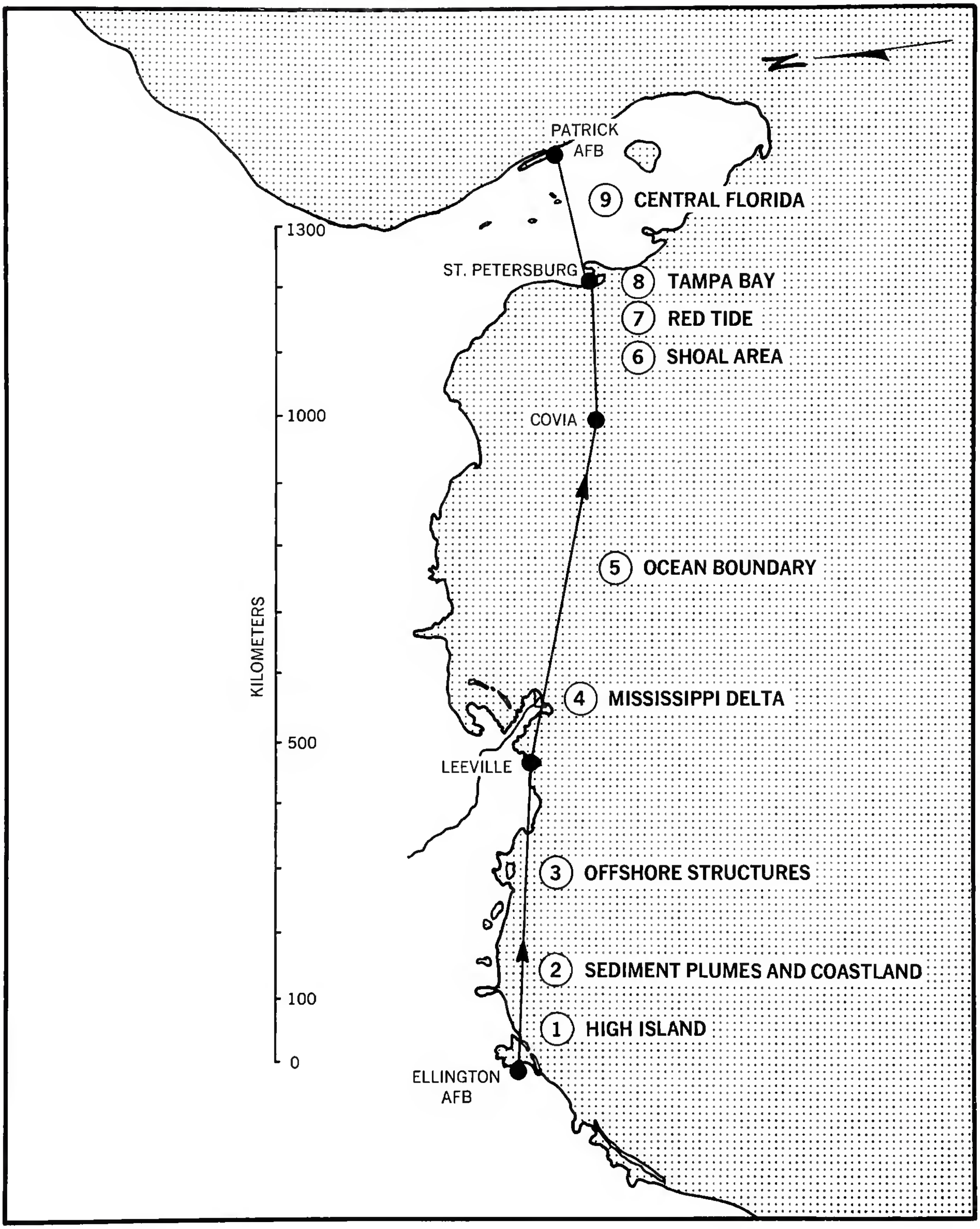
(9) SANTA CATALINA ISLAND
A. DESCRIBE WHAT AND WHERE YOU SEE:
BOW WAVE
WAKE
UPWELLINGS
INTERNAL WAVES
B. WHAT DIRECTION DOES THE CURRENT MOVE AROUND THE ISLAND?
C. CAN YOU SEE ANY CURRENT BOUNDARIES BETWEEN SANTA CATALINA ISLAND AND THE COAST OF CALIFORNIA AND HOW FAR CAN YOU TRACE THEM?
N
DANA PT.
NEWPORT BAY
SAN PEDRO BAY
PT. FERMIN
SAN
PEDRO
CHANNEL
SANTA CATALINA ISLAND
50
40
30
KM
20
10
0

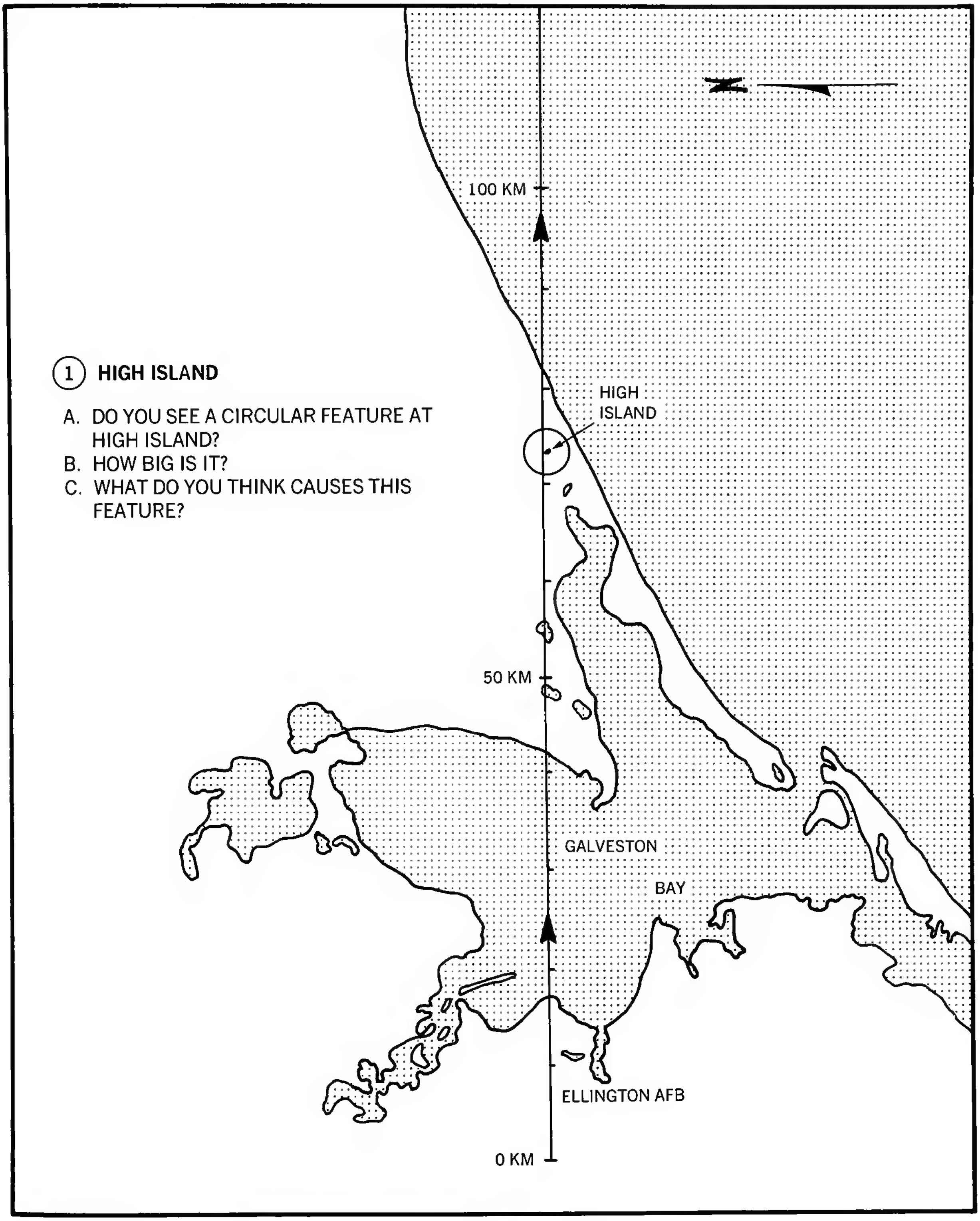
## (10) FAULT SCARPS

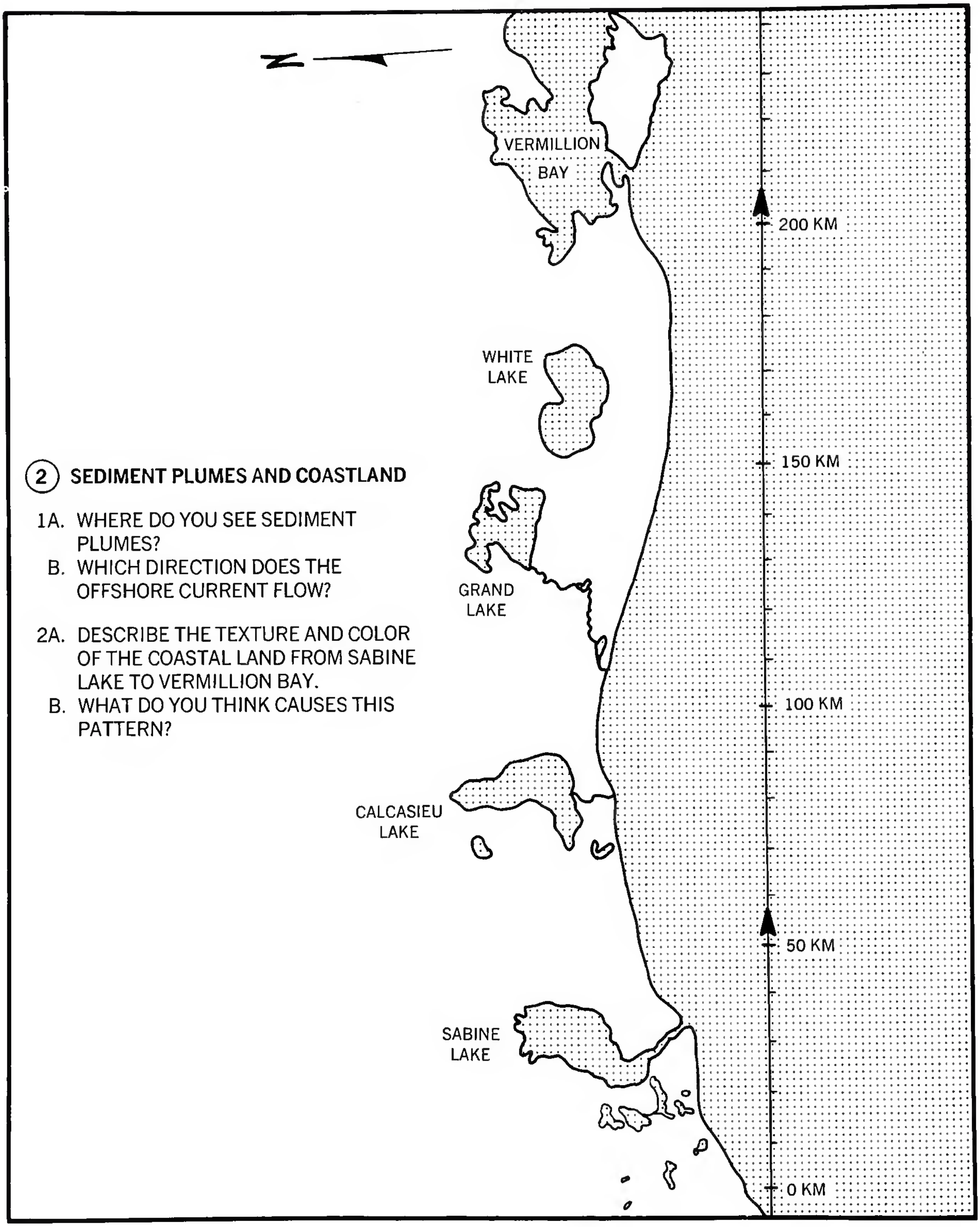
A. WHAT ARE THE MAJOR PHYSIOGRAPHIC FEATURES?
B. DELINEATE THE FOLLOWING:
LOCATION
TREND
TERMINATION
C. IDENTIFY THE COLOR OF THE SALTON SEA—USE CHARTS.




GULF COAST FLYOVER
N
PATRICK AFB
ST. PETERSBURG
COVIA
LEEVILLE
ELLINGTON AFB
KILOMETERS
500
0


PATRICK AFB
9 CENTRAL FLORIDA
ST. PETERSBURG
8 TAMPA BAY
7 RED TIDE
6 SHOAL AREA
COVIA
5 OCEAN BOUNDARY
4 MISSISSIPPI DELTA
LEEVILLE
3 OFFSHORE STRUCTURES
2 SEDIMENT PLUMES AND COASTLAND
1 HIGH ISLAND
ELLINGTON AFB
KILOMETERS
1300
1000
500
100
0

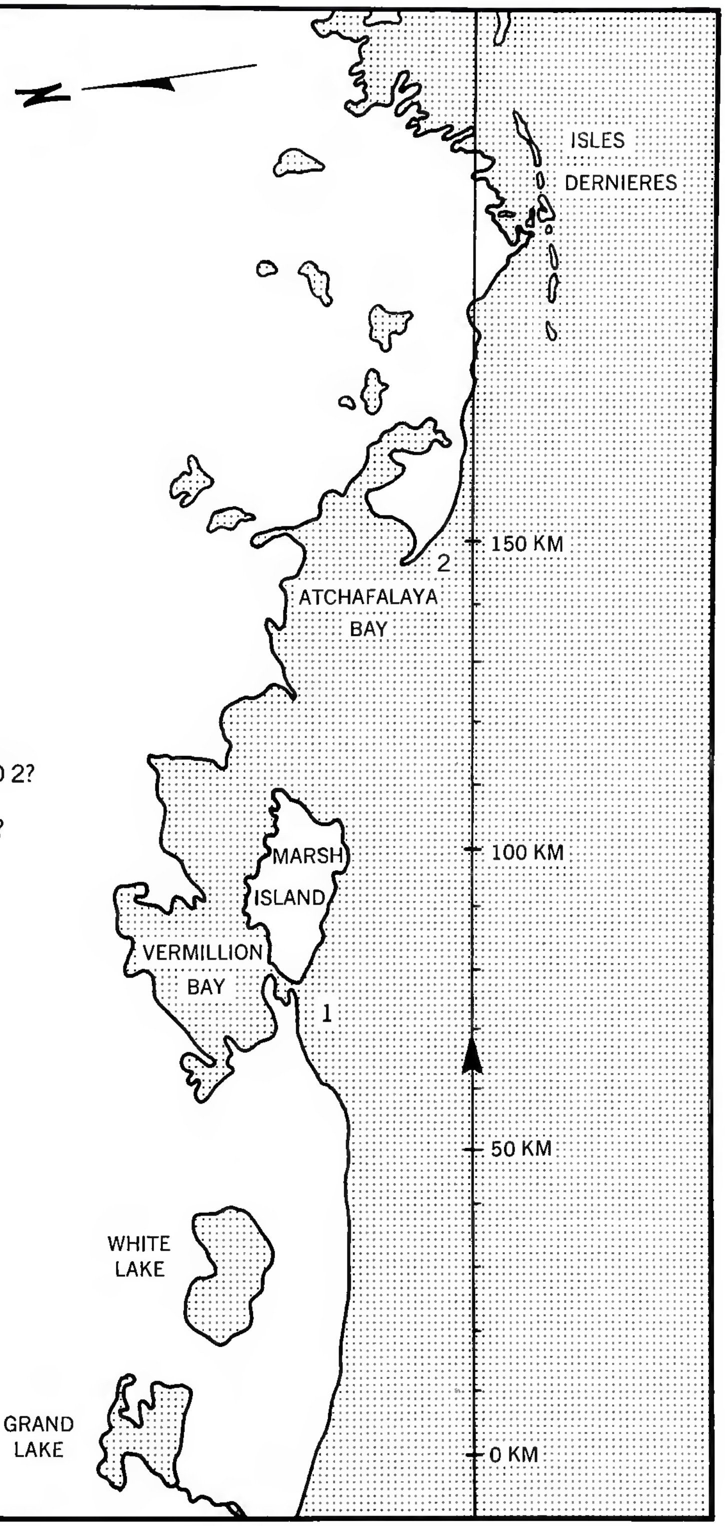

1 HIGH ISLAND
A. DO YOU SEE A CIRCULAR FEATURE AT HIGH ISLAND?
B. HOW BIG IS IT?
C. WHAT DO YOU THINK CAUSES THIS FEATURE?
100 KM
HIGH ISLAND
50 KM
GALVESTON
BAY
ELLINGTON AFB
0 KM




**(2) SEDIMENT PLUMES AND COASTLAND**

1A. WHERE DO YOU SEE SEDIMENT PLUMES?
B. WHICH DIRECTION DOES THE OFFSHORE CURRENT FLOW?

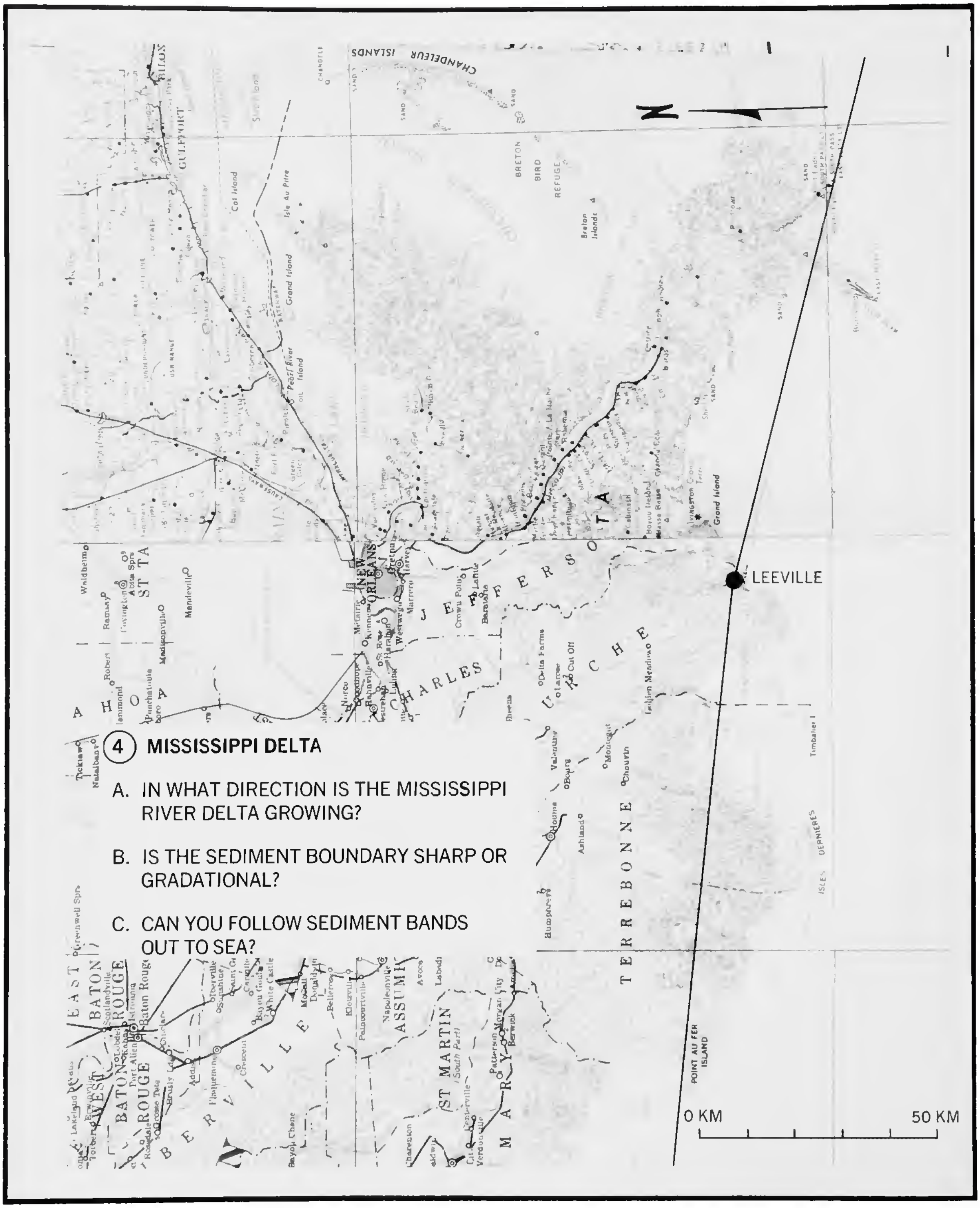
2A. DESCRIBE THE TEXTURE AND COLOR OF THE COASTAL LAND FROM SABINE LAKE TO VERMILLION BAY.
B. WHAT DO YOU THINK CAUSES THIS PATTERN?

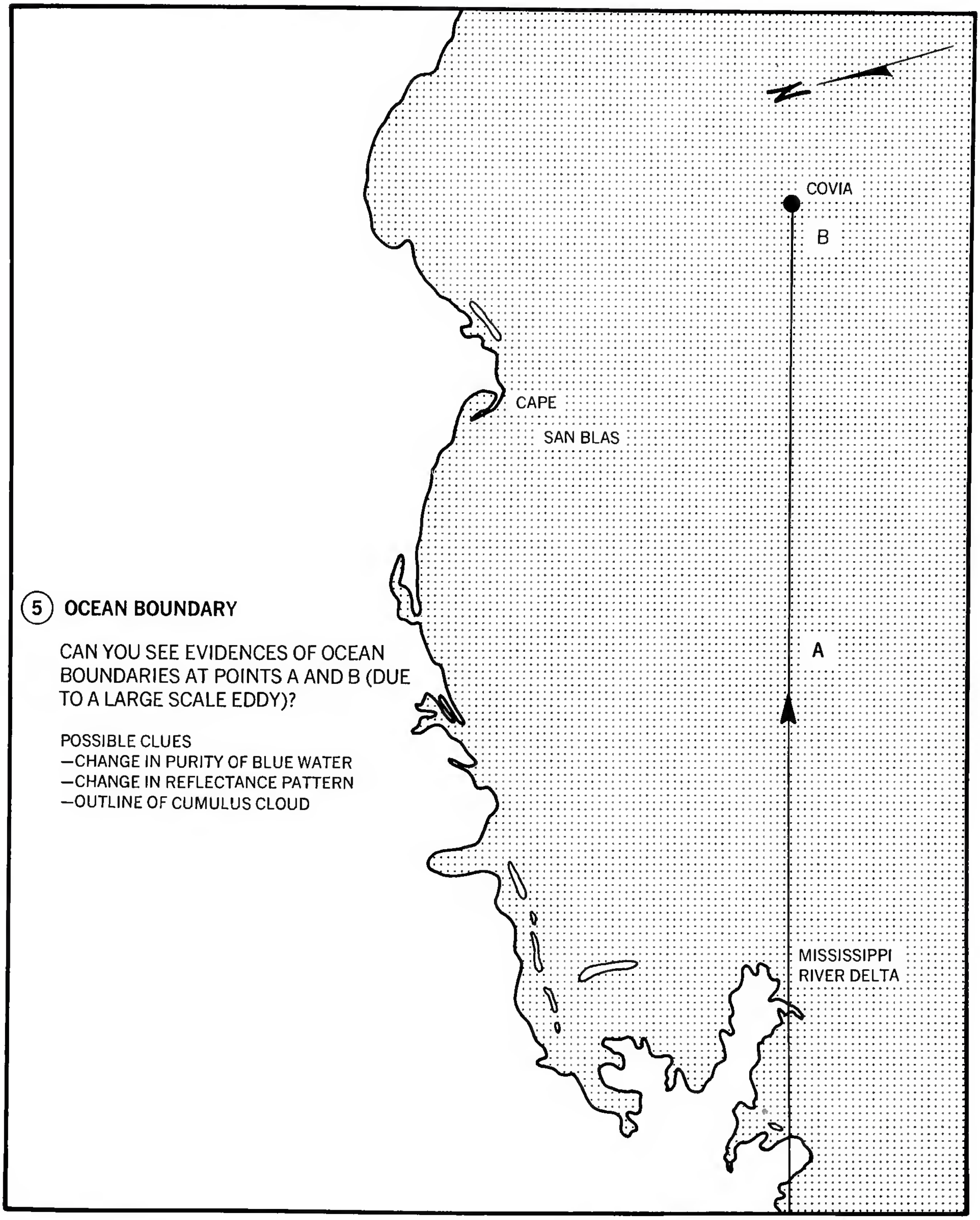



**(3) OFFSHORE STRUCTURES**

A. DO YOU SEE ANY STRUCTURES OFF THE COAST BETWEEN POINTS 1 AND 2?

B. WHICH DIRECTION DO THEY TREND?

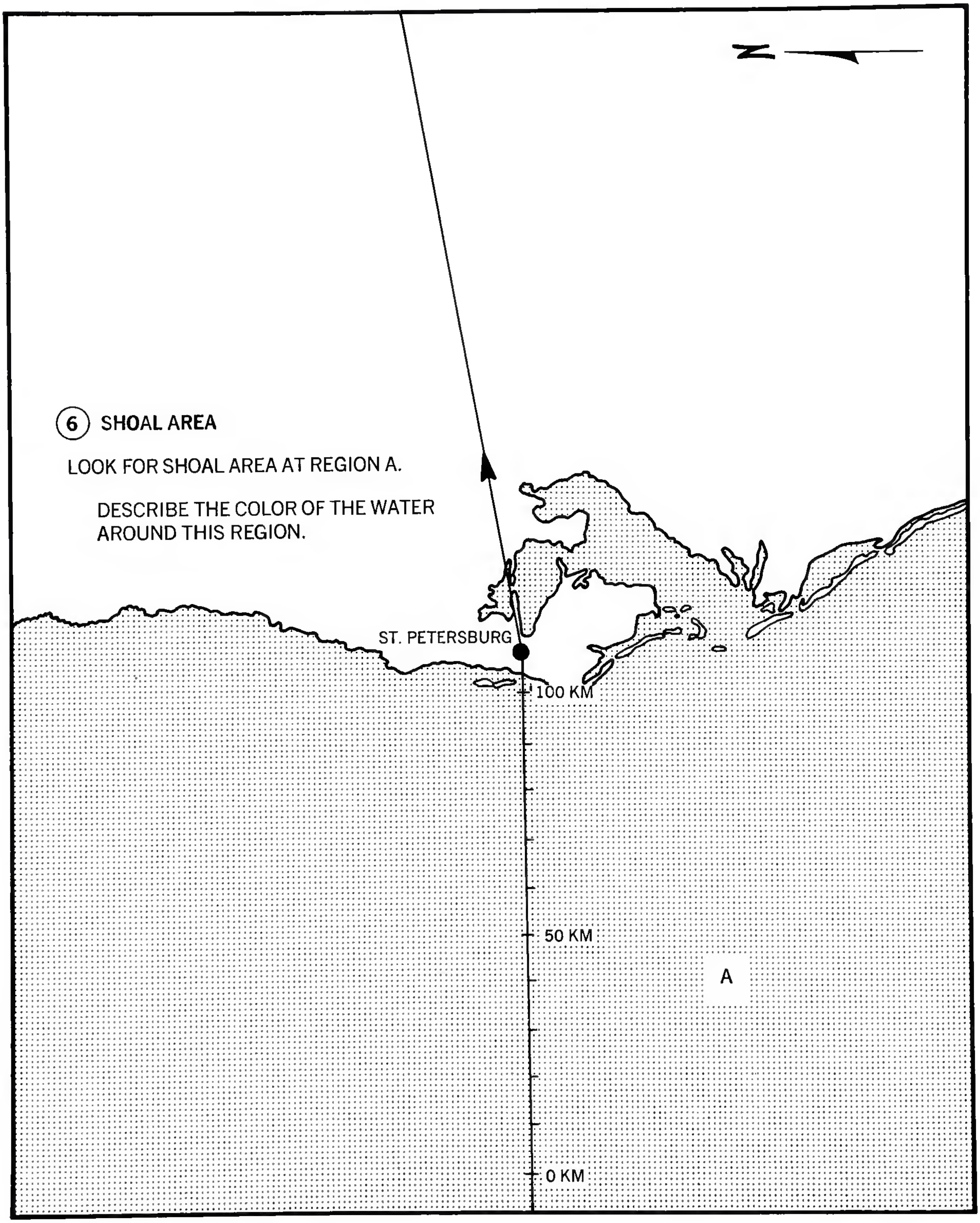

4 MISSISSIPPI DELTA
A. IN WHAT DIRECTION IS THE MISSISSIPPI RIVER DELTA GROWING?
B. IS THE SEDIMENT BOUNDARY SHARP OR GRADATIONAL?
C. CAN YOU FOLLOW SEDIMENT BANDS OUT TO SEA?
LEEVILLE
0 KM
50 KM
N

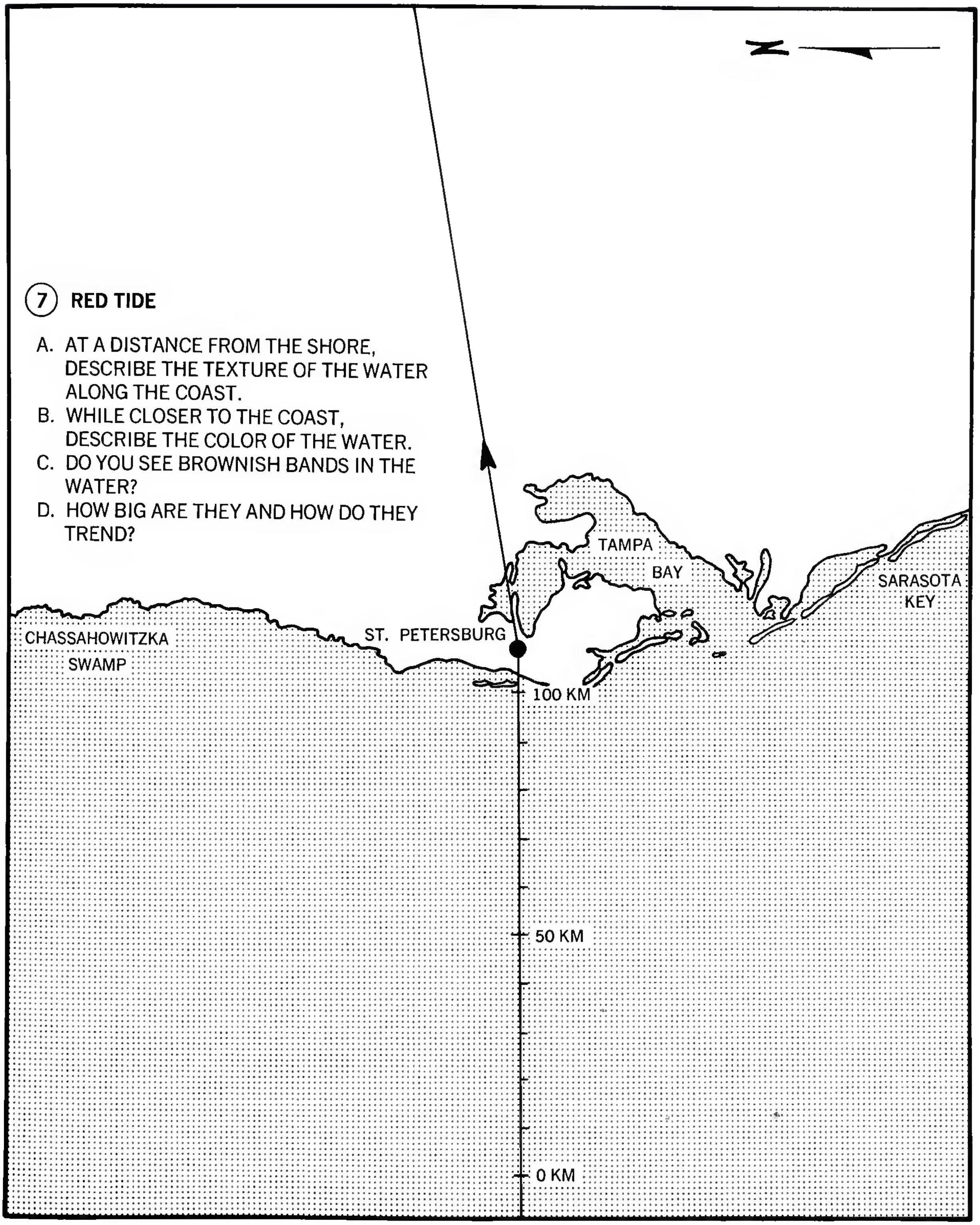


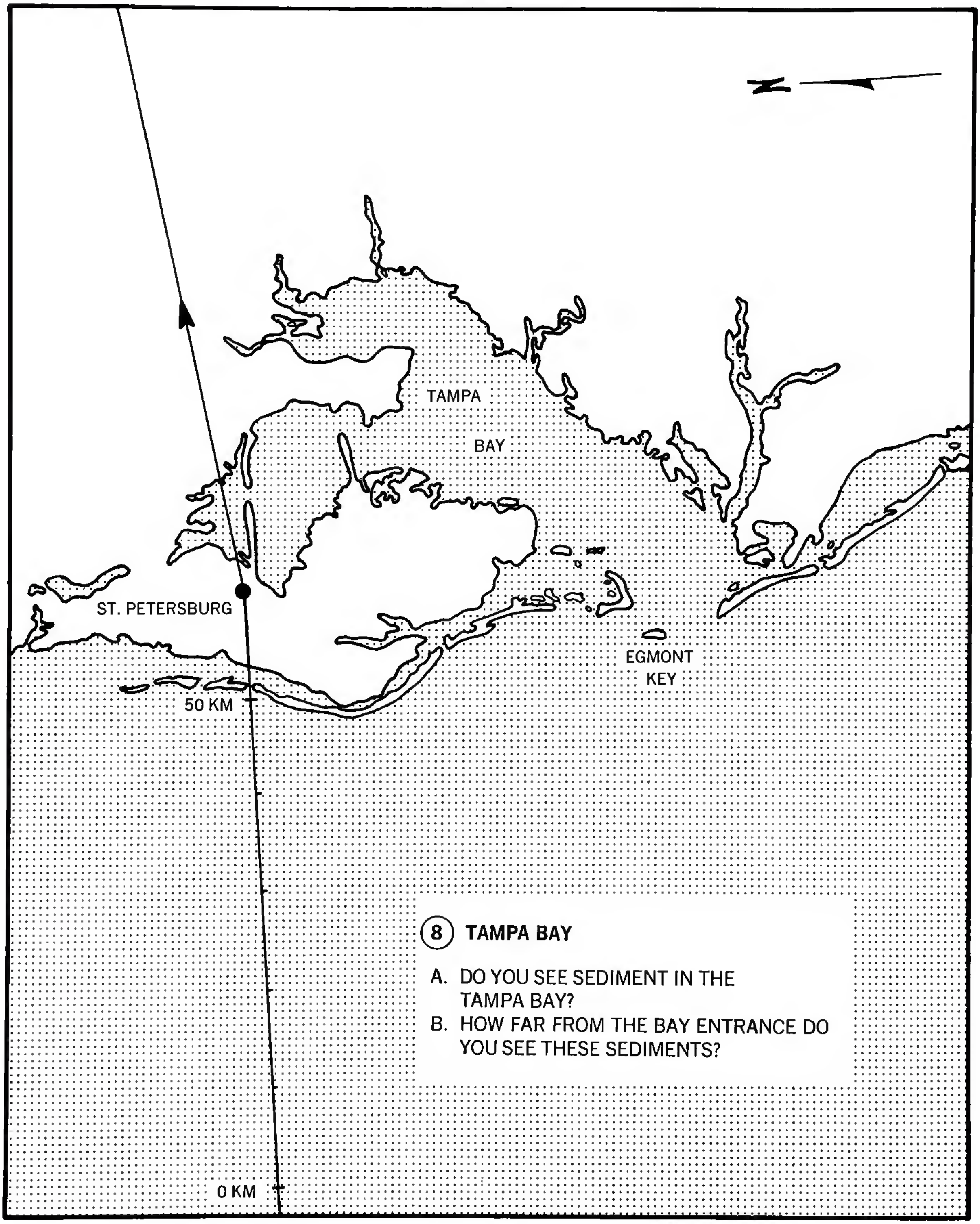

## (5) OCEAN BOUNDARY

CAN YOU SEE EVIDENCES OF OCEAN BOUNDARIES AT POINTS A AND B (DUE TO A LARGE SCALE EDDY)?

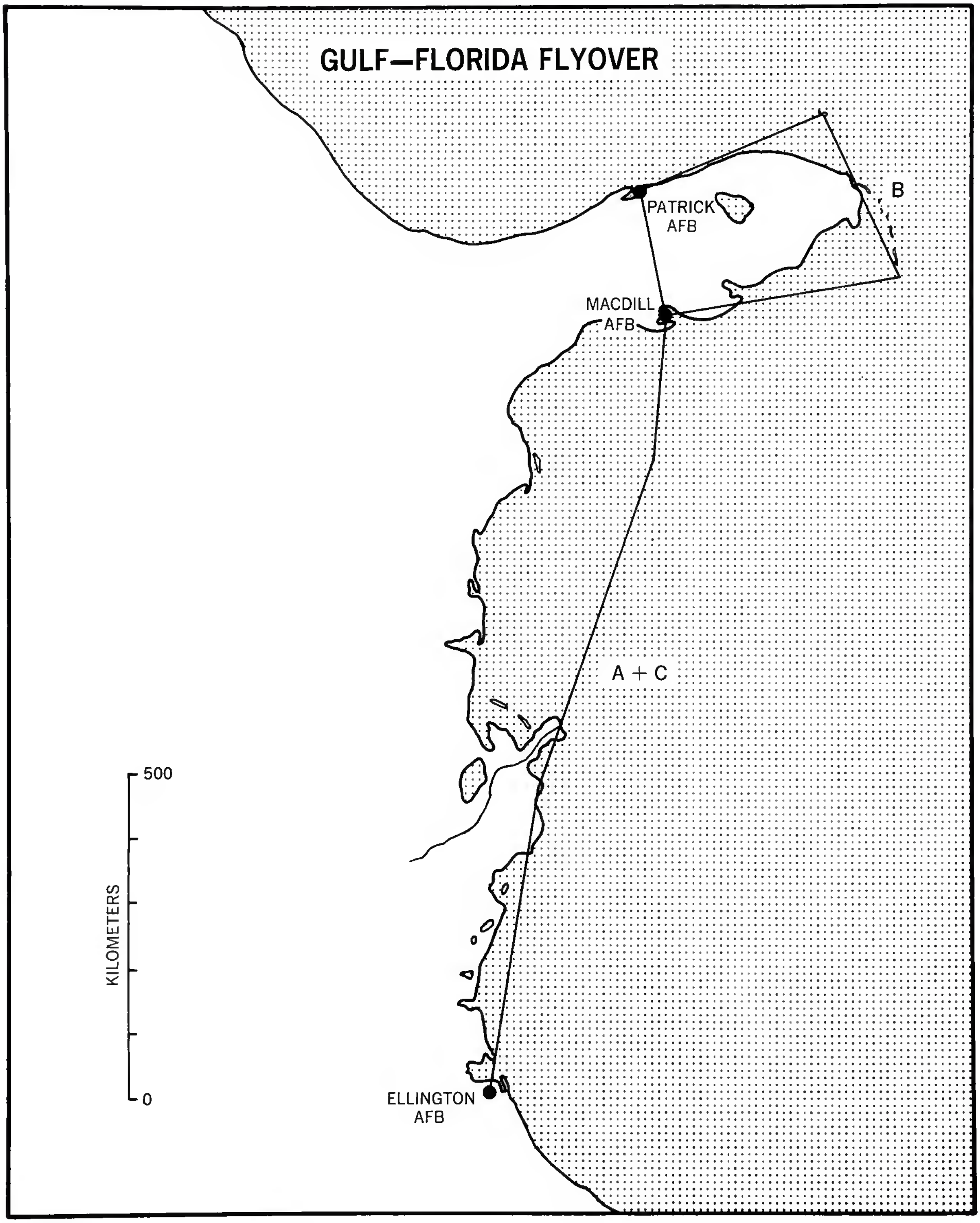
POSSIBLE CLUES
- —CHANGE IN PURITY OF BLUE WATER
- —CHANGE IN REFLECTANCE PATTERN
- —OUTLINE OF CUMULUS CLOUD


N
(6) SHOAL AREA
LOOK FOR SHOAL AREA AT REGION A.
DESCRIBE THE COLOR OF THE WATER AROUND THIS REGION.
ST. PETERSBURG
100 KM
50 KM
A
0 KM


N
7 RED TIDE
A. AT A DISTANCE FROM THE SHORE, DESCRIBE THE TEXTURE OF THE WATER ALONG THE COAST.
B. WHILE CLOSER TO THE COAST, DESCRIBE THE COLOR OF THE WATER.
C. DO YOU SEE BROWNISH BANDS IN THE WATER?
D. HOW BIG ARE THEY AND HOW DO THEY TREND?
TAMPA
BAY
SARASOTA
KEY
CHASSAHOWITZKA
SWAMP
ST. PETERSBURG
100 KM
50 KM
0 KM


N
TAMPA
BAY
ST. PETERSBURG
EGMONT
KEY
50 KM
0 KM
8 TAMPA BAY
A. DO YOU SEE SEDIMENT IN THE TAMPA BAY?
B. HOW FAR FROM THE BAY ENTRANCE DO YOU SEE THESE SEDIMENTS?


PATRICK AFB
200 KM
150 KM
100 KM
50 KM
0 KM
ST. PETERSBURG
TAMPA
BAY
9 CENTRAL FLORIDA
A. DESCRIBE THE TEXTURE OF CENTRAL FLORIDA.
B. HOW FAR CAN YOU FOLLOW THE TREND?
C. WHAT DO YOU THINK CAUSES THIS PATTERN?


GULF—FLORIDA FLYOVER
PATRICK AFB
B
MACDILL AFB
A + C
ELLINGTON AFB
500
KILOMETERS
0

## GULF-FLORIDA FLYOVER

### CAMERA SETTINGS

A. ELLINGTON AFB TO PATRICK AFB —— **820nm**

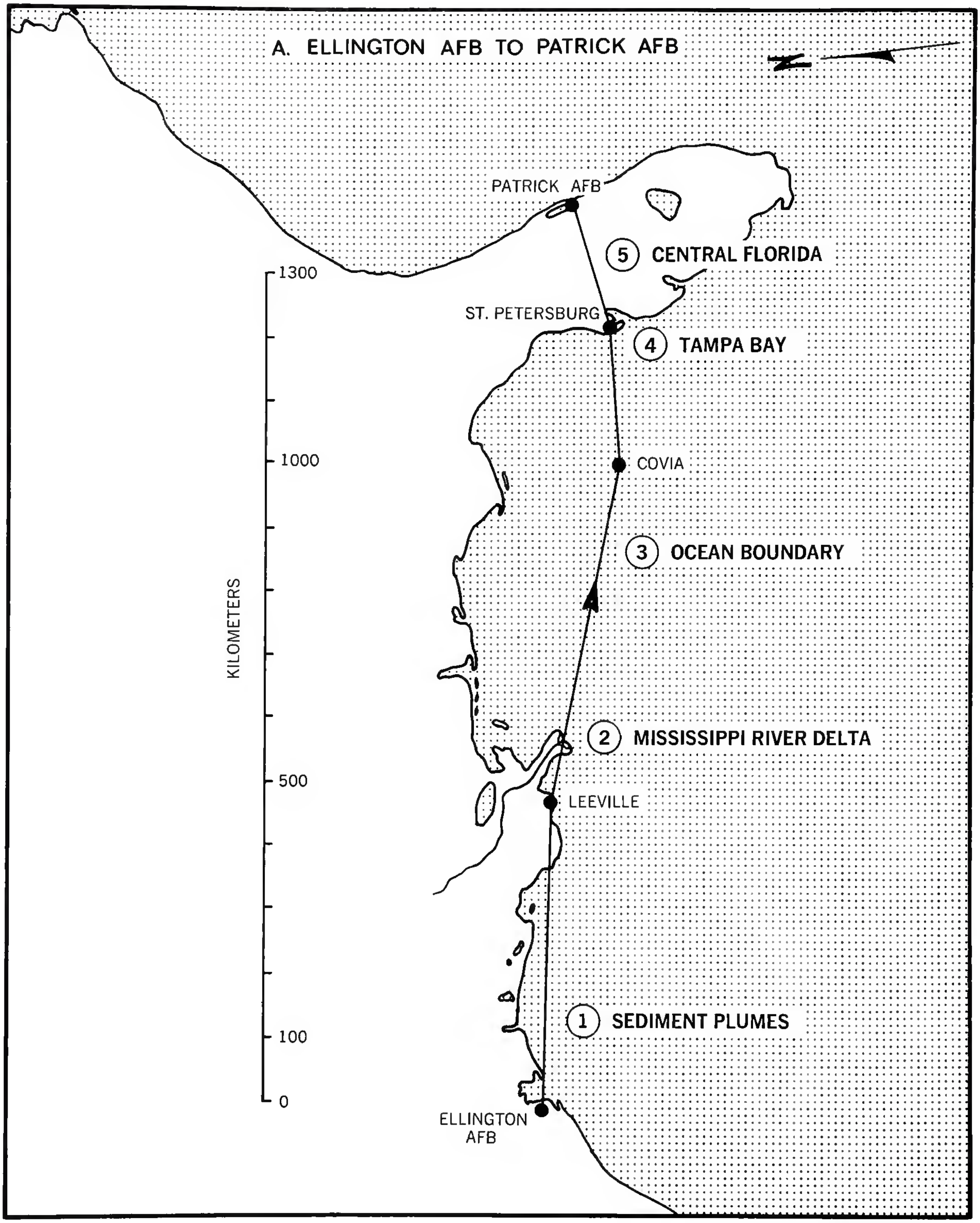
| Lens | Shutter | Aperture |
|---|---|---|
| 250mm | 1/125 | f 5.6 |

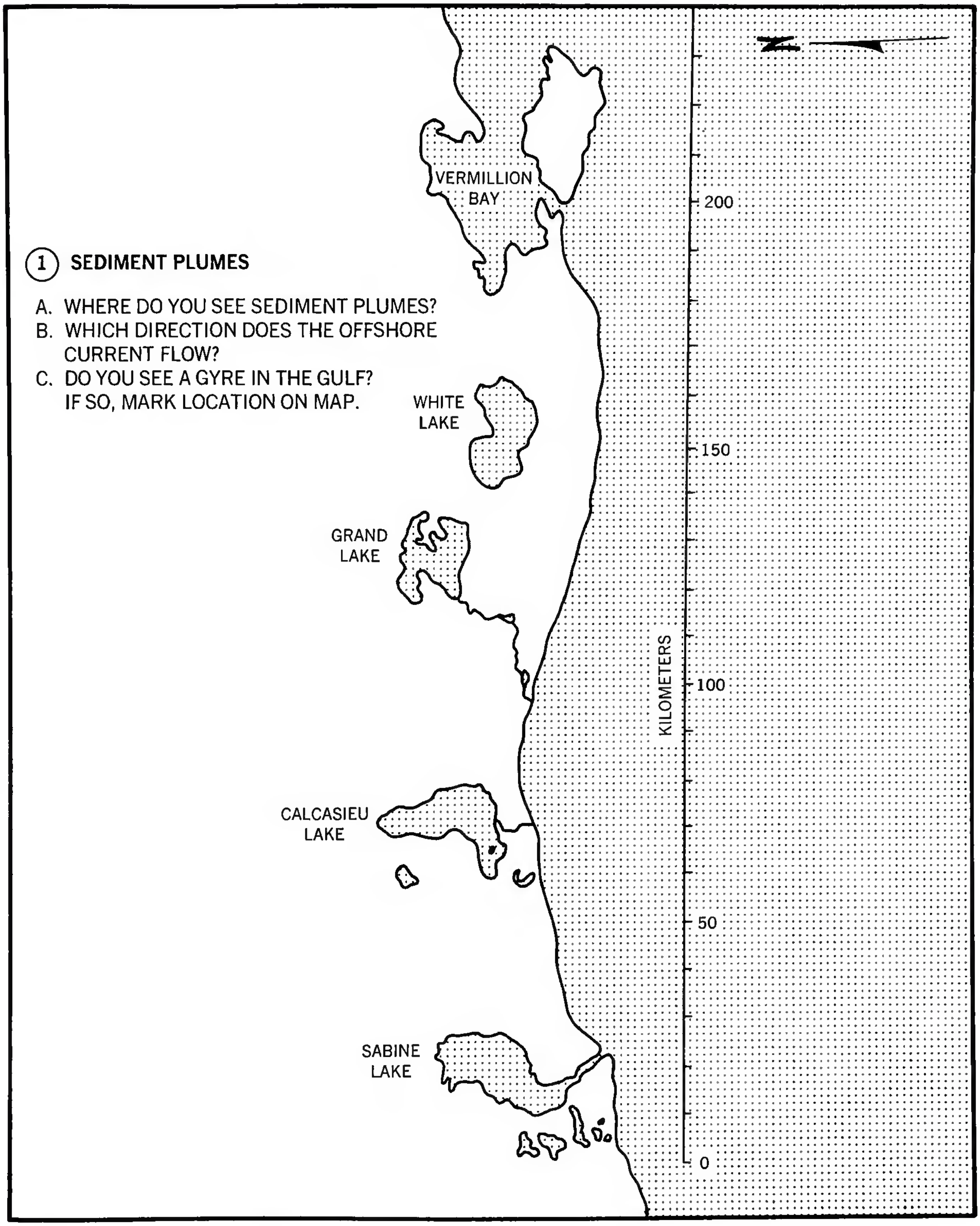
B. PATRICK AFB TO MACDILL AFB —— **570nm**

| Lens | Shutter | Aperture |
|---|---|---|
| 50mm | 1/125 | f 4.0 |

C. MACDILL AFB TO ELLINGTON AFB —— **720nm**

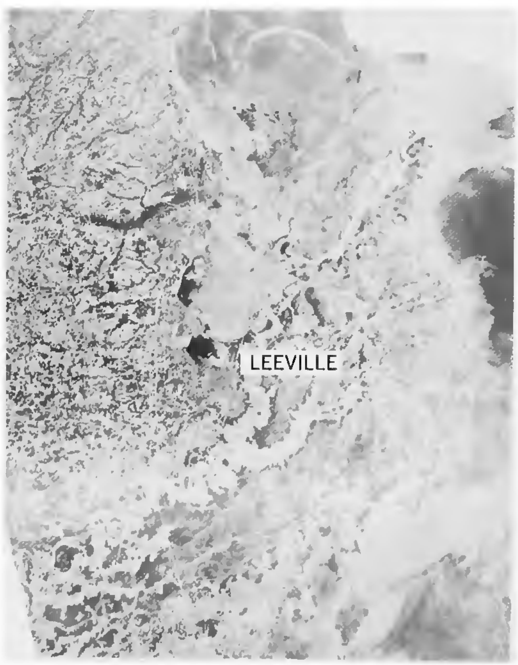
| Lens | Shutter | Aperture |
|---|---|---|
| 250mm | 1/125 | f 5.6 |

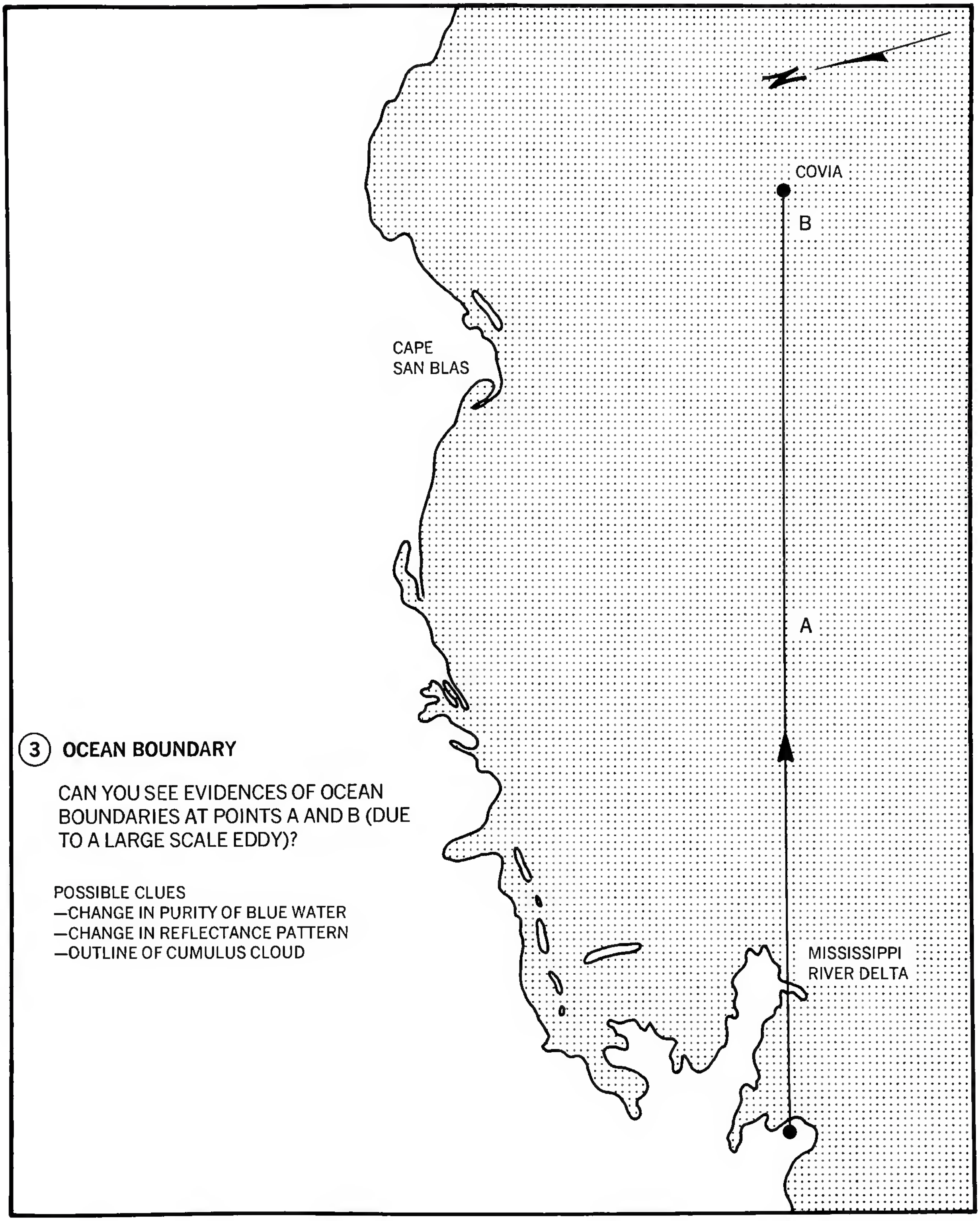

A. ELLINGTON AFB TO PATRICK AFB
PATRICK AFB
5 CENTRAL FLORIDA
ST. PETERSBURG
4 TAMPA BAY
COVIA
3 OCEAN BOUNDARY
2 MISSISSIPPI RIVER DELTA
LEEVILLE
1 SEDIMENT PLUMES
ELLINGTON AFB
KILOMETERS
1300
1000
500
100
0

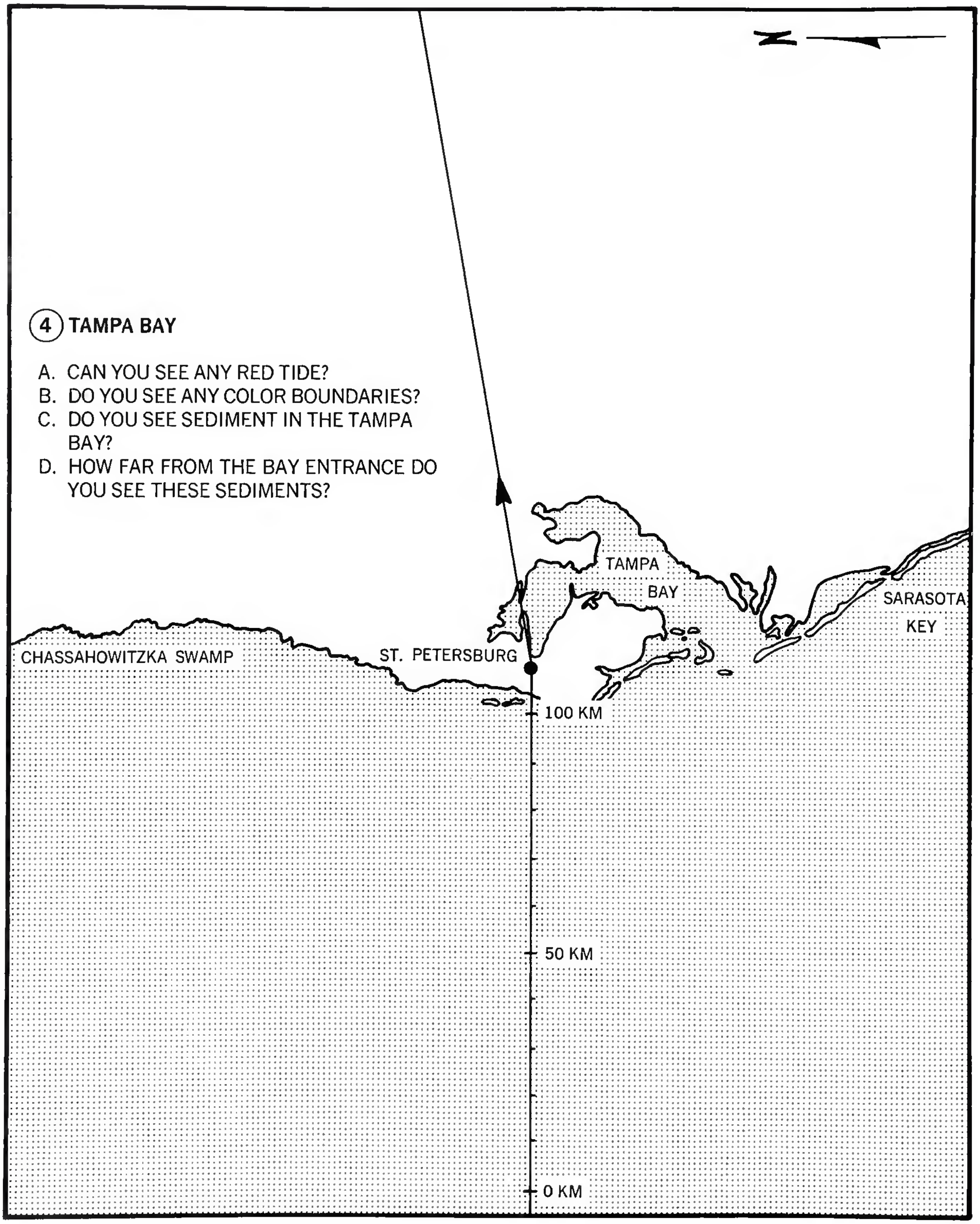

1 SEDIMENT PLUMES
A. WHERE DO YOU SEE SEDIMENT PLUMES?
B. WHICH DIRECTION DOES THE OFFSHORE CURRENT FLOW?
C. DO YOU SEE A GYRE IN THE GULF? IF SO, MARK LOCATION ON MAP.
N
VERMILLION BAY
WHITE LAKE
GRAND LAKE
CALCASIEU LAKE
SABINE LAKE
KILOMETERS
200
150
100
50
0

(2) **MISSISSIPPI RIVER DELTA**

A. IN WHAT DIRECTION IS THE MISSISSIPPI DELTA GROWING?
B. IS THE SEDIMENT BOUNDARY SHARP OR GRADATIONAL?
C. CAN YOU FOLLOW SEDIMENT BANDS OUT TO SEA?

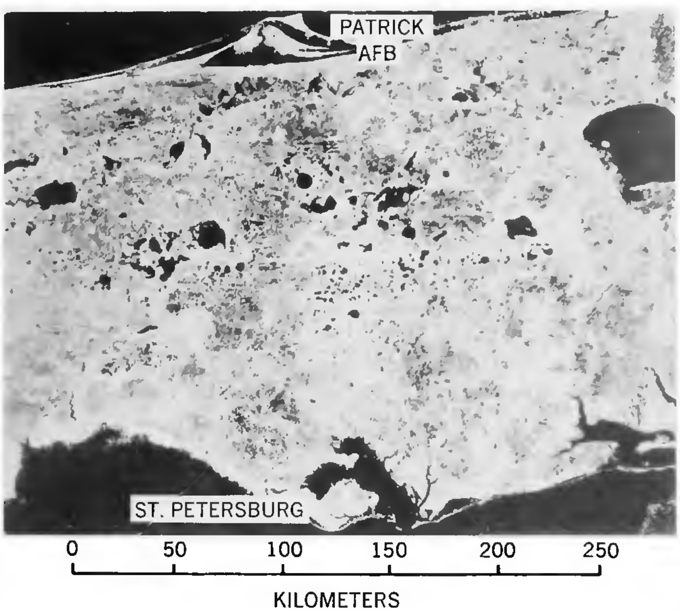


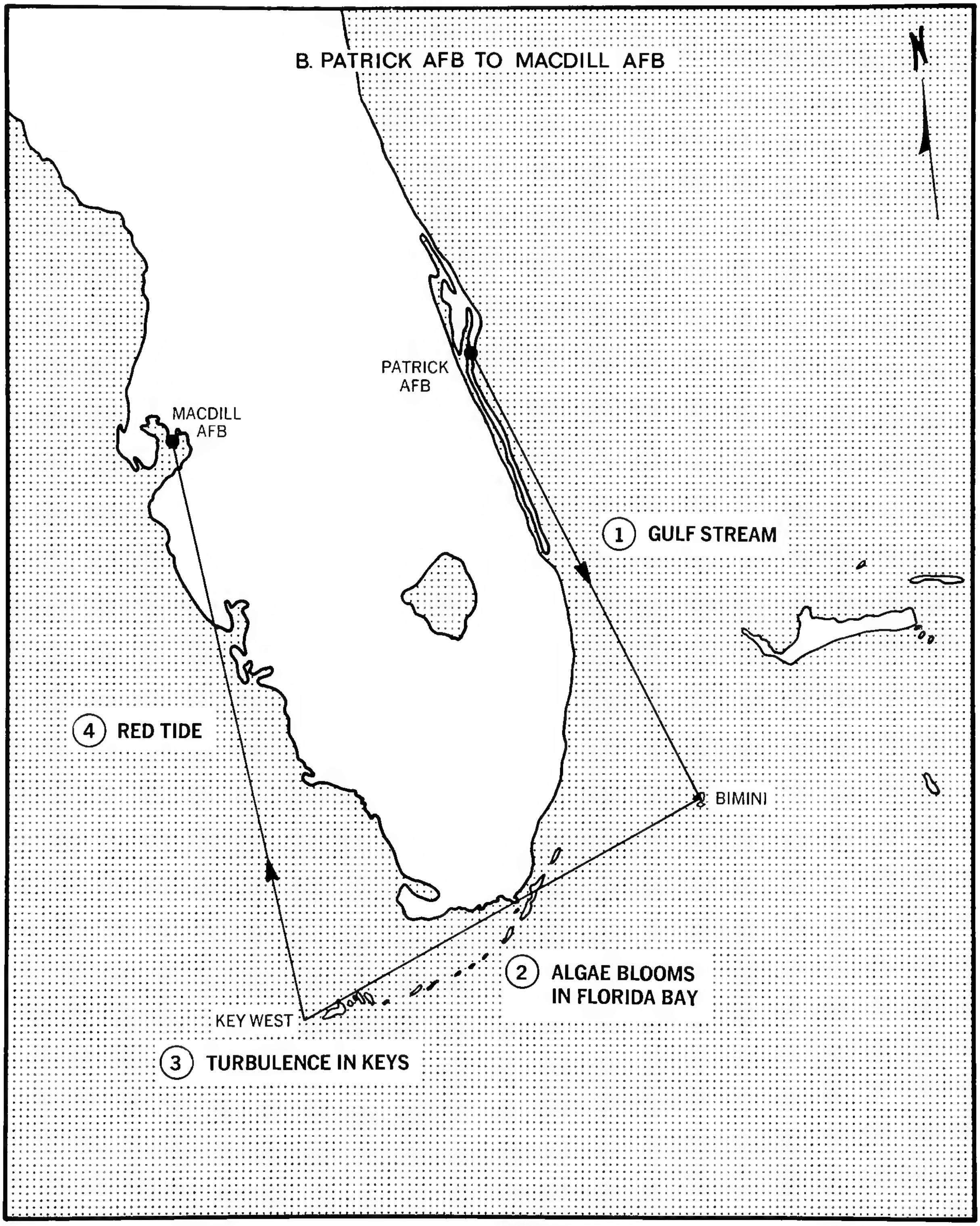

COVIA
B
CAPE
SAN BLAS
A
③ OCEAN BOUNDARY
CAN YOU SEE EVIDENCES OF OCEAN BOUNDARIES AT POINTS A AND B (DUE TO A LARGE SCALE EDDY)?
POSSIBLE CLUES
—CHANGE IN PURITY OF BLUE WATER
—CHANGE IN REFLECTANCE PATTERN
—OUTLINE OF CUMULUS CLOUD
MISSISSIPPI
RIVER DELTA

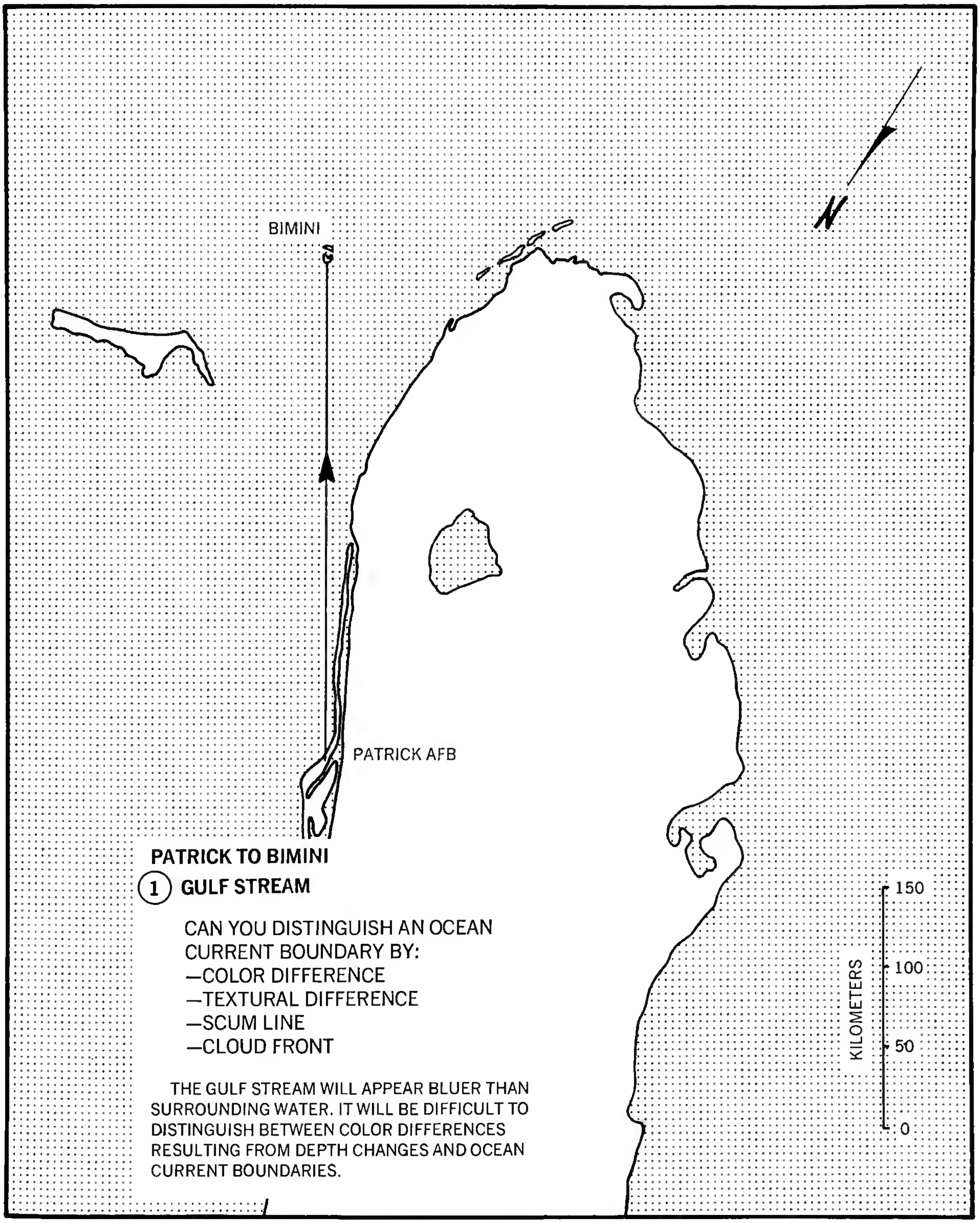

N
4 TAMPA BAY
A. CAN YOU SEE ANY RED TIDE?
B. DO YOU SEE ANY COLOR BOUNDARIES?
C. DO YOU SEE SEDIMENT IN THE TAMPA BAY?
D. HOW FAR FROM THE BAY ENTRANCE DO YOU SEE THESE SEDIMENTS?
TAMPA BAY
SARASOTA KEY
CHASSAHOWITZKA SWAMP
ST. PETERSBURG
100 KM
50 KM
0 KM

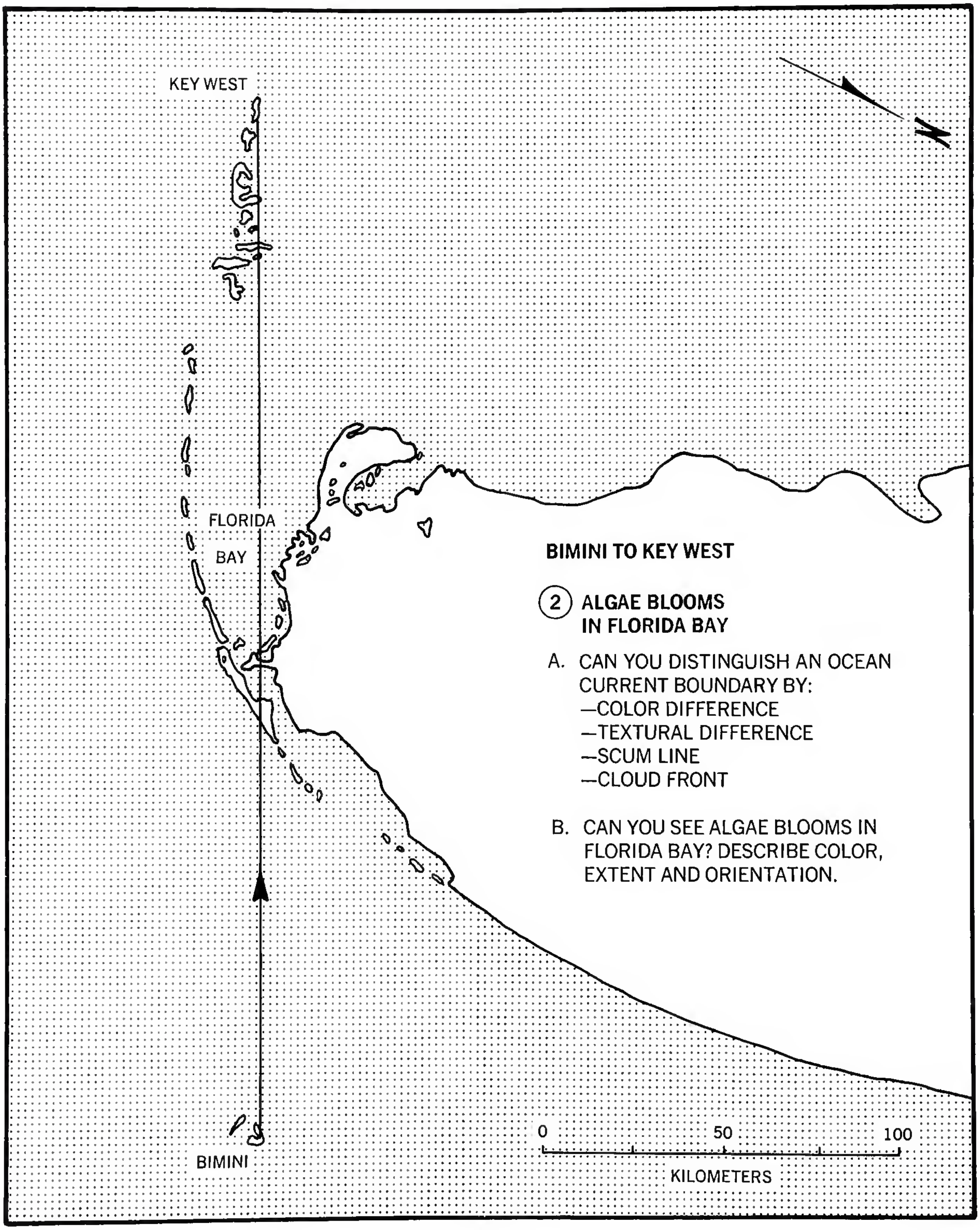
## (5) CENTRAL FLORIDA

A. DESCRIBE THE TEXTURE OF CENTRAL FLORIDA.
B. HOW FAR CAN YOU FOLLOW THE TREND?
C. WHAT DO YOU THINK CAUSES THIS PATTERN?




B. PATRICK AFB TO MACDILL AFB
N
PATRICK
AFB
MACDILL
AFB
1 GULF STREAM
4 RED TIDE
BIMINI
2 ALGAE BLOOMS
IN FLORIDA BAY
KEY WEST
3 TURBULENCE IN KEYS


BIMINI
PATRICK AFB
N
PATRICK TO BIMINI
1 GULF STREAM
CAN YOU DISTINGUISH AN OCEAN CURRENT BOUNDARY BY:
—COLOR DIFFERENCE
—TEXTURAL DIFFERENCE
—SCUM LINE
—CLOUD FRONT
THE GULF STREAM WILL APPEAR BLUER THAN SURROUNDING WATER. IT WILL BE DIFFICULT TO DISTINGUISH BETWEEN COLOR DIFFERENCES RESULTING FROM DEPTH CHANGES AND OCEAN CURRENT BOUNDARIES.
KILOMETERS
150
100
50
0


KEY WEST
FLORIDA
BAY
BIMINI TO KEY WEST
2 ALGAE BLOOMS
IN FLORIDA BAY
A. CAN YOU DISTINGUISH AN OCEAN
CURRENT BOUNDARY BY:
—COLOR DIFFERENCE
—TEXTURAL DIFFERENCE
—SCUM LINE
—CLOUD FRONT
B. CAN YOU SEE ALGAE BLOOMS IN
FLORIDA BAY? DESCRIBE COLOR,
EXTENT AND ORIENTATION.
N
0
50
100
KILOMETERS
BIMINI

N

MACDILL AFB

KEY WEST

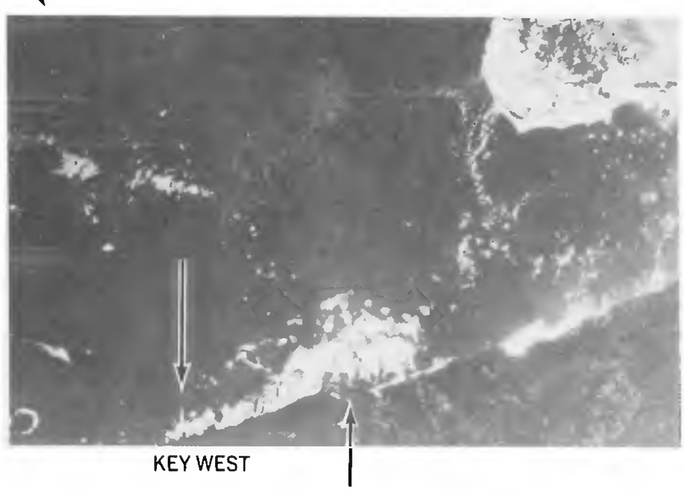
**KEY WEST TO MACDILL**

**(3) TURBULENCE IN KEYS**

DESCRIBE THE TURBULENCE PATTERN THROUGH THE NORTH-SOUTH ELONGATED KEYS (ARROWS).

**(4) RED TIDE**

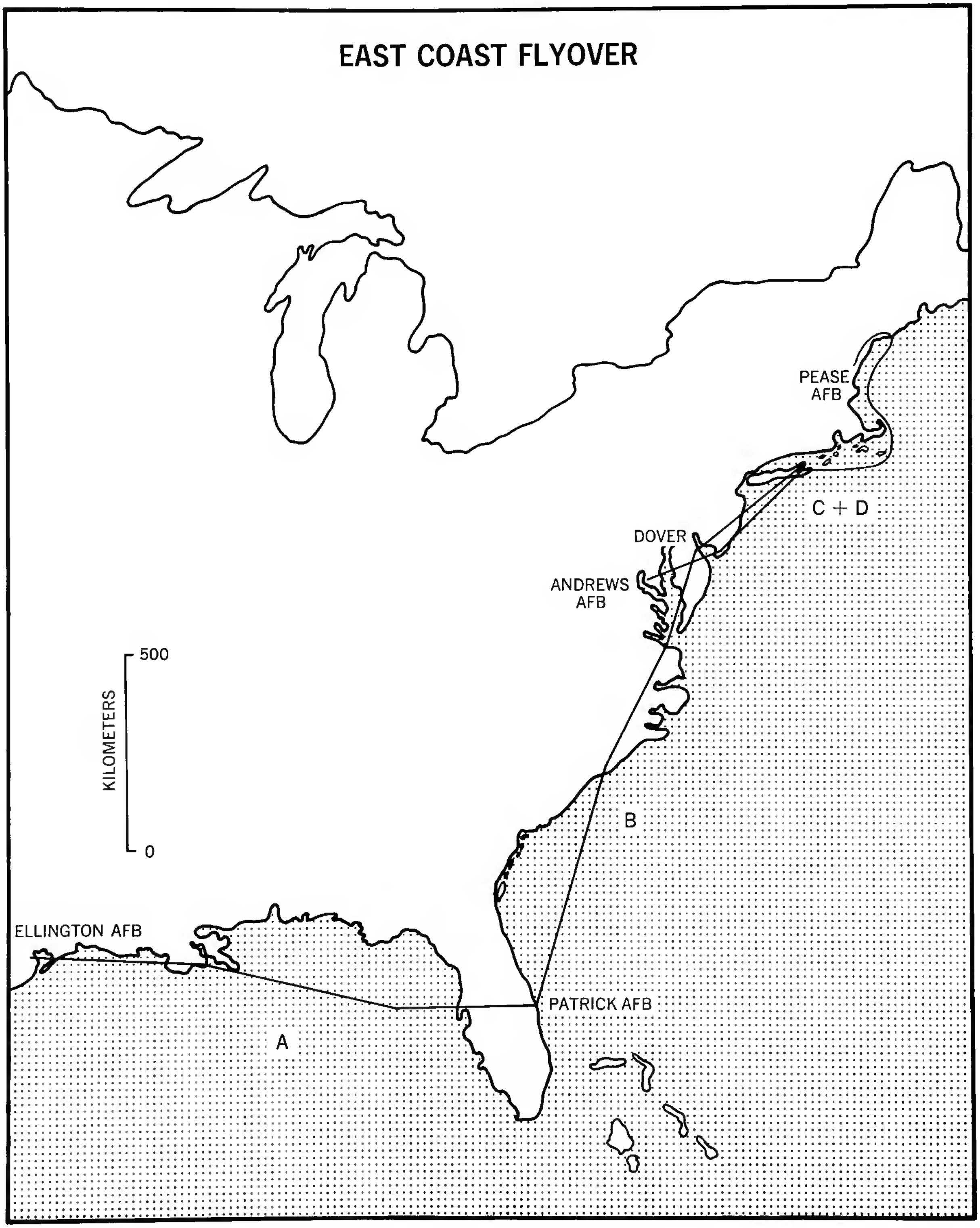
A. DESCRIBE THE WATER COLOR OFF THE COAST.
B. DO YOU SEE BROWNISH BANDS?
C. HOW BIG, AND HOW DO THEY TREND?



KEY WEST

0 50 100

KILOMETERS


EAST COAST FLYOVER
PEASE AFB
C + D
DOVER
ANDREWS AFB
500
KILOMETERS
0
B
ELLINGTON AFB
PATRICK AFB
A

## EAST COAST FLYOVER

| | |
|---|---|
| A. ELLINGTON AFB TO PATRICK AFB<br>SAME AS IN GULF-FLORIDA FLYOVER | 820nm |
| B. PATRICK AFB TO DOVER | 750nm |
| C. DOVER TO PEASE AFB | 620nm |
| D. PEASE AFB TO ANDREWS AFB<br>(RETURN VIA CAPE MAY) | 700nm |

## CAMERA SETTINGS

FILM SO-242

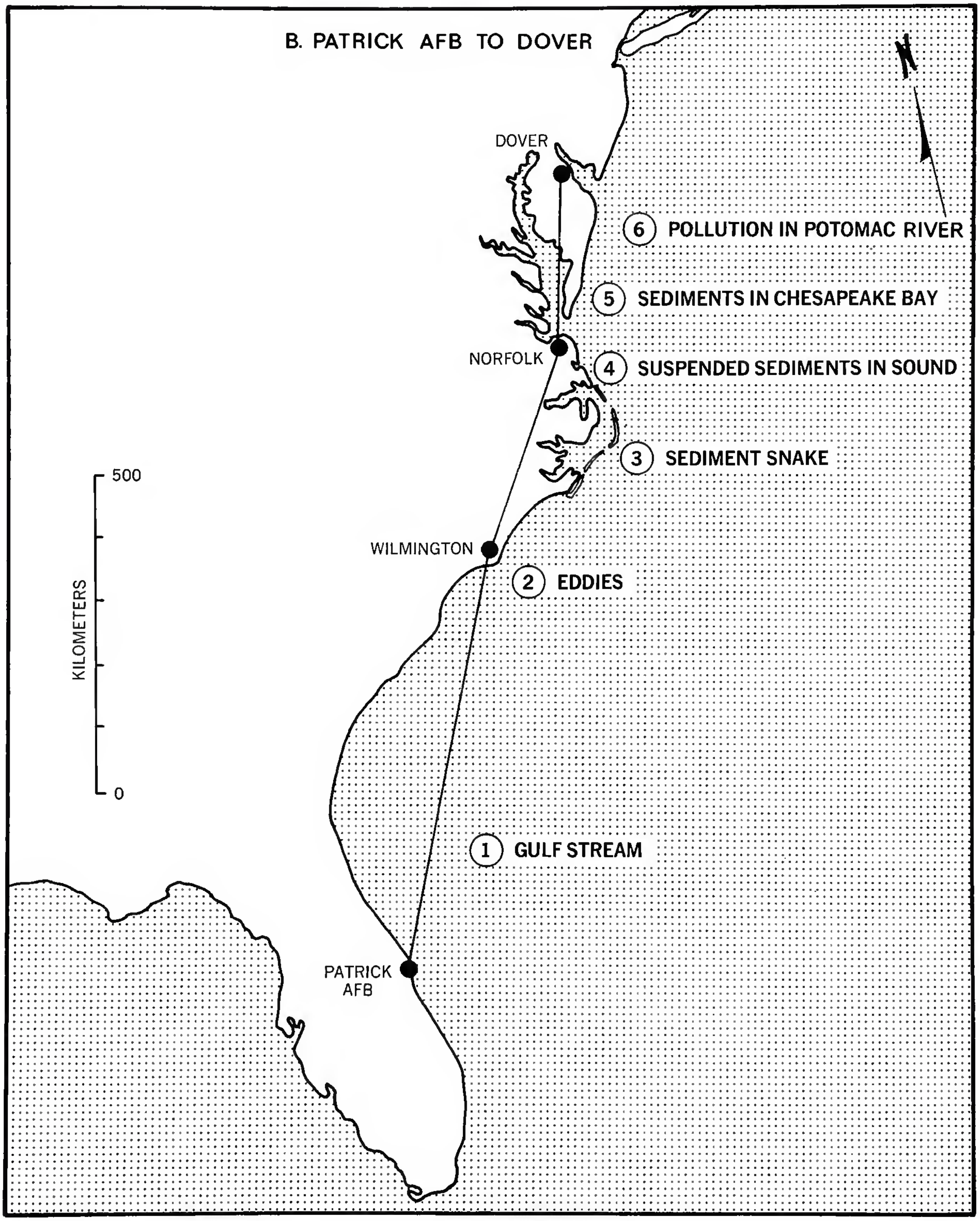
SHUTTER SPEED AT 1/250

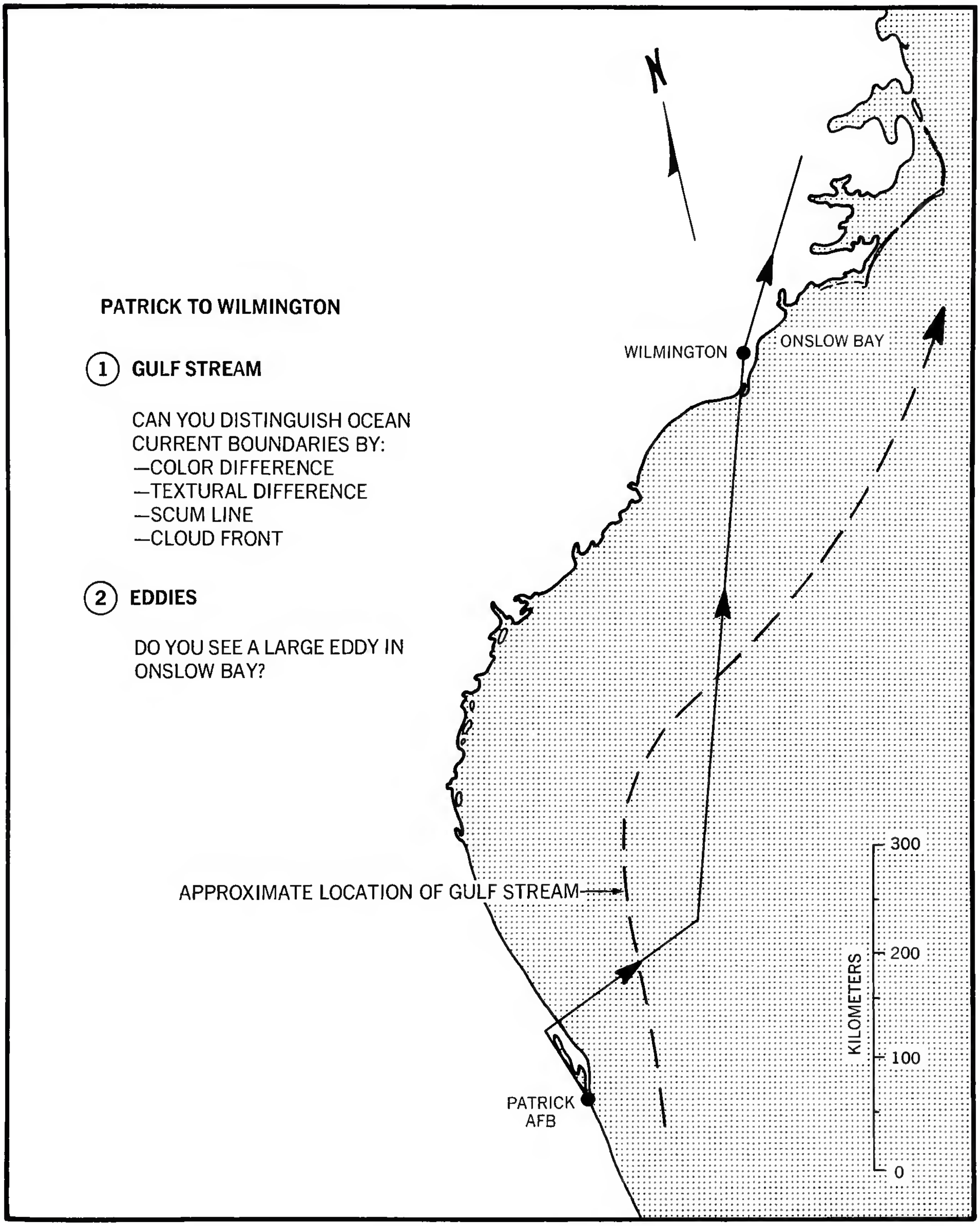
| Time | APERTURE<br>50mm LENS | 250mm LENS |
|---|---|---|
| 900–1030 | 4.7 | 5.6 |
| 1030–1430 | 5.6 | 5.6 |
| 1430–1530 | 4.7 | 5.6 |
| 1530–1700 | 4.7 | 4.7 |

FILM SO-368

SHUTTER SPEED AT 1/500

| Time | APERTURE<br>50/250mm LENS |
|---|---|
| 900–1030 | 6.7 |
| 1030–1430 | 8.0 |
| 1430–1700 | 6.7 |


B. PATRICK AFB TO DOVER
DOVER
NORFOLK
WILMINGTON
PATRICK AFB
6 POLLUTION IN POTOMAC RIVER
5 SEDIMENTS IN CHESAPEAKE BAY
4 SUSPENDED SEDIMENTS IN SOUND
3 SEDIMENT SNAKE
2 EDDIES
1 GULF STREAM
500
KILOMETERS
0
N


N
PATRICK TO WILMINGTON
1 GULF STREAM
CAN YOU DISTINGUISH OCEAN CURRENT BOUNDARIES BY:
—COLOR DIFFERENCE
—TEXTURAL DIFFERENCE
—SCUM LINE
—CLOUD FRONT
2 EDDIES
DO YOU SEE A LARGE EDDY IN ONSLOW BAY?
WILMINGTON
ONSLOW BAY
APPROXIMATE LOCATION OF GULF STREAM
PATRICK AFB
KILOMETERS
300
200
100
0

**WILMINGTON TO NORFOLK**

(FLY EAST OF FLIGHT LINE, IF POSSIBLE)

**(3) SEDIMENT SNAKE**

CAN YOU SEE A SEDIMENT SNAKE AT OREGON INLET OUT TO SEA?

**(4) SUSPENDED SEDIMENTS IN SOUND**

CAN YOU SEE SUSPENDED SEDIMENTS IN THE INLAND BAYS AND SOUND?

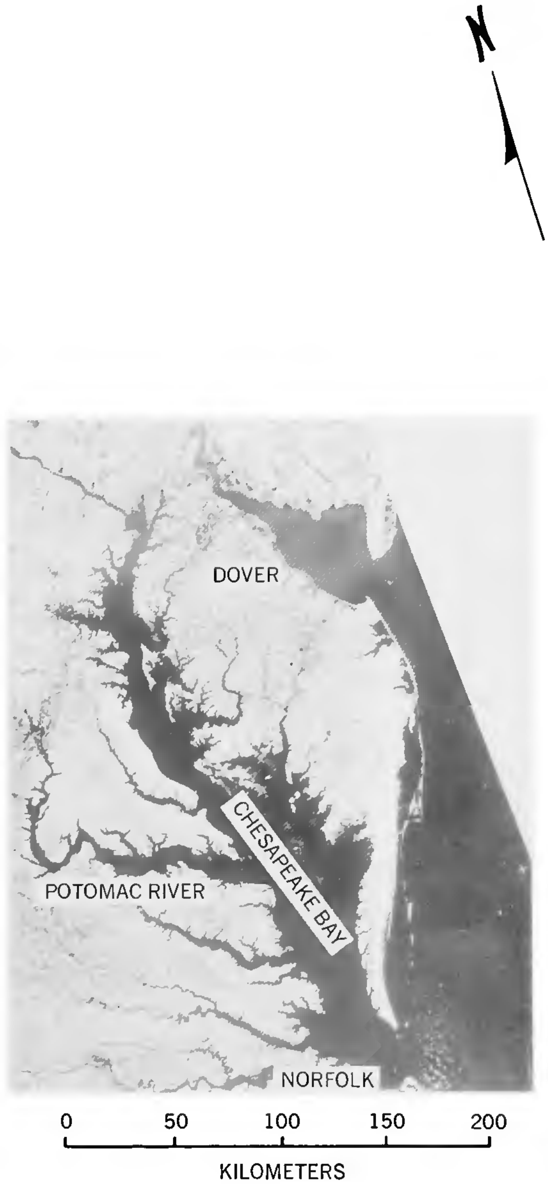
**NORFOLK TO DOVER**

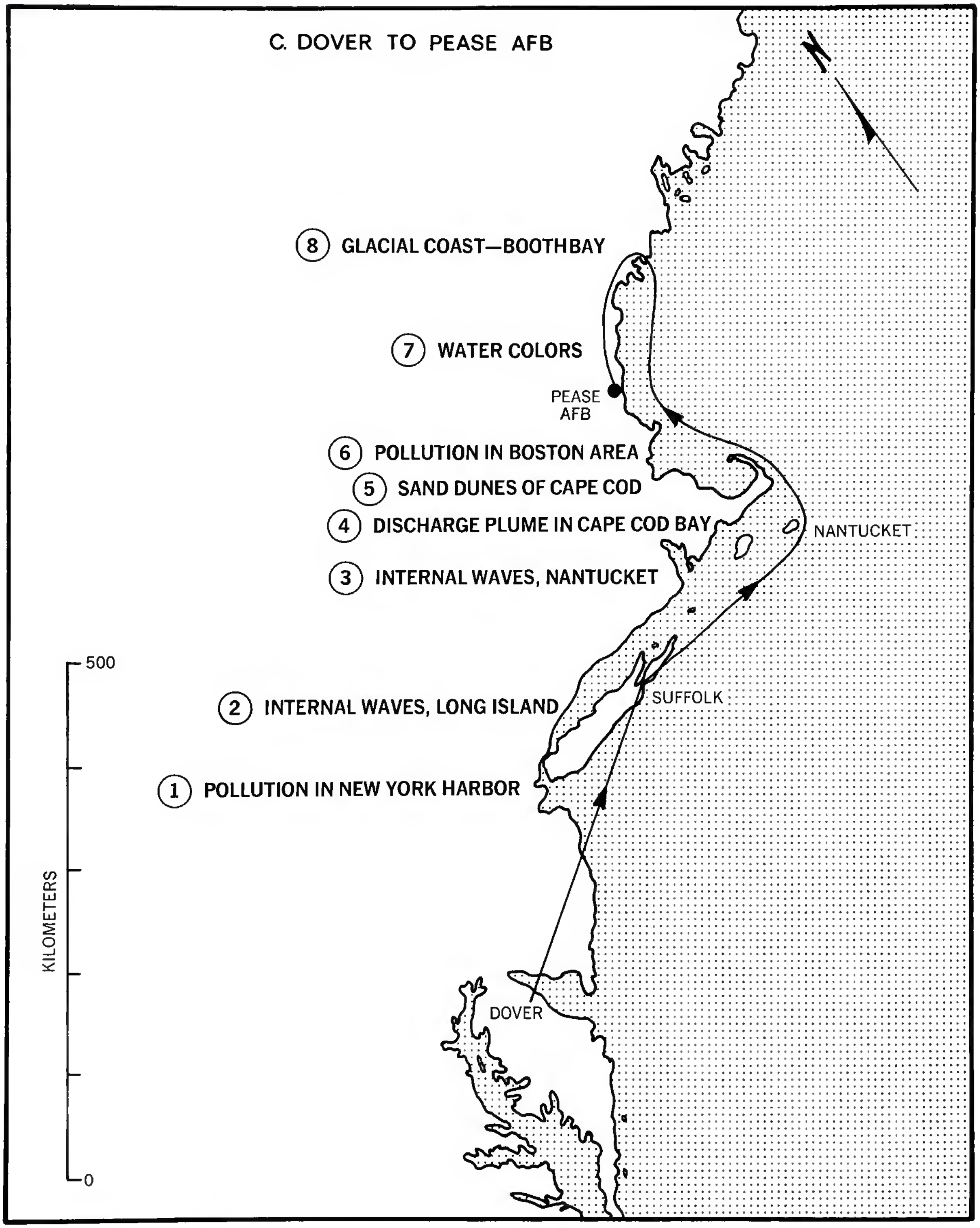
**(5) SEDIMENTS IN CHESAPEAKE BAY**

CAN YOU SEE ANY SUSPENDED SEDIMENTS IN THE CHESAPEAKE BAY?

**(6) POLLUTION IN POTOMAC RIVER**

ARE THERE ANY POLLUTION PLUMES IN THE POTOMAC RIVER?




C. DOVER TO PEASE AFB
8 GLACIAL COAST—BOOTHBAY
7 WATER COLORS
PEASE
AFB
6 POLLUTION IN BOSTON AREA
5 SAND DUNES OF CAPE COD
4 DISCHARGE PLUME IN CAPE COD BAY
NANTUCKET
3 INTERNAL WAVES, NANTUCKET
500
2 INTERNAL WAVES, LONG ISLAND
SUFFOLK
1 POLLUTION IN NEW YORK HARBOR
KILOMETERS
DOVER
0

DOVER TO SUFFOLK

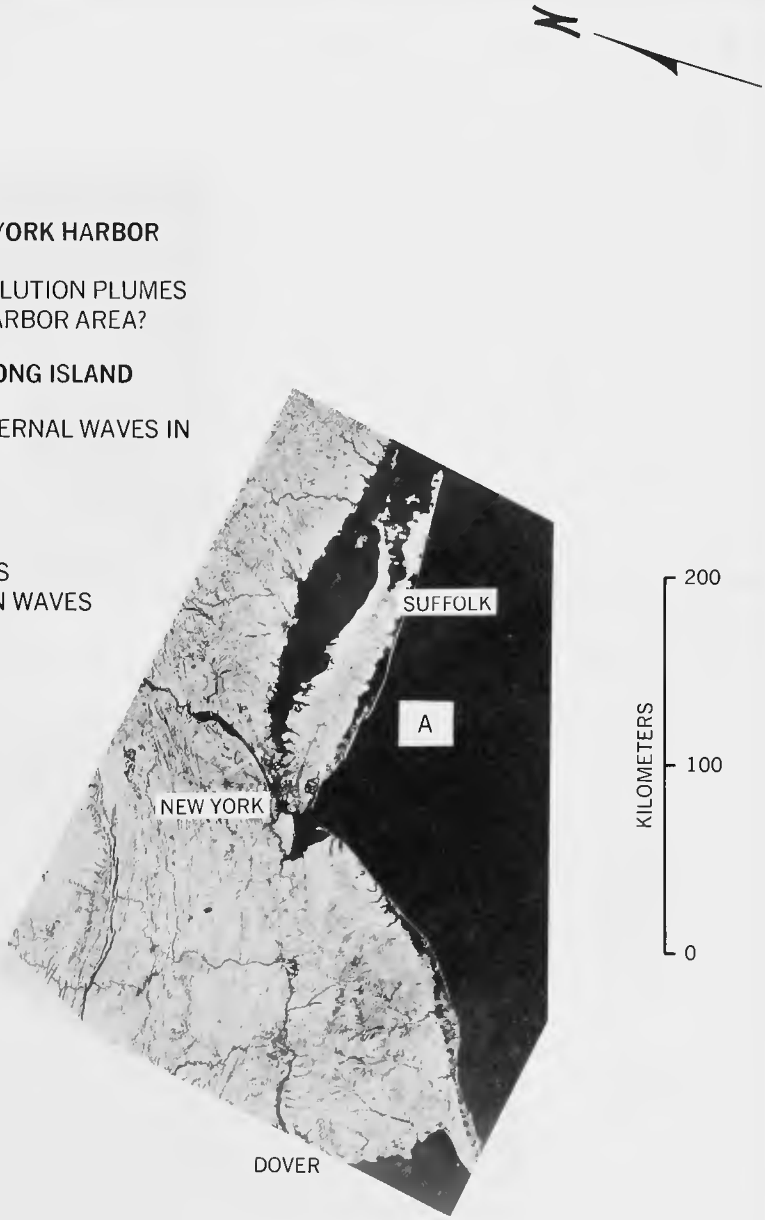
(1) **POLLUTION IN NEW YORK HARBOR**

DO YOU SEE ANY POLLUTION PLUMES IN THE NEW YORK HARBOR AREA?

(2) **INTERNAL WAVES, LONG ISLAND**

DO YOU SEE ANY INTERNAL WAVES IN AREA A? DESCRIBE:

—LOCATION
—ORIENTATION
—NUMBER OF WAVES
—SPACING BETWEEN WAVES



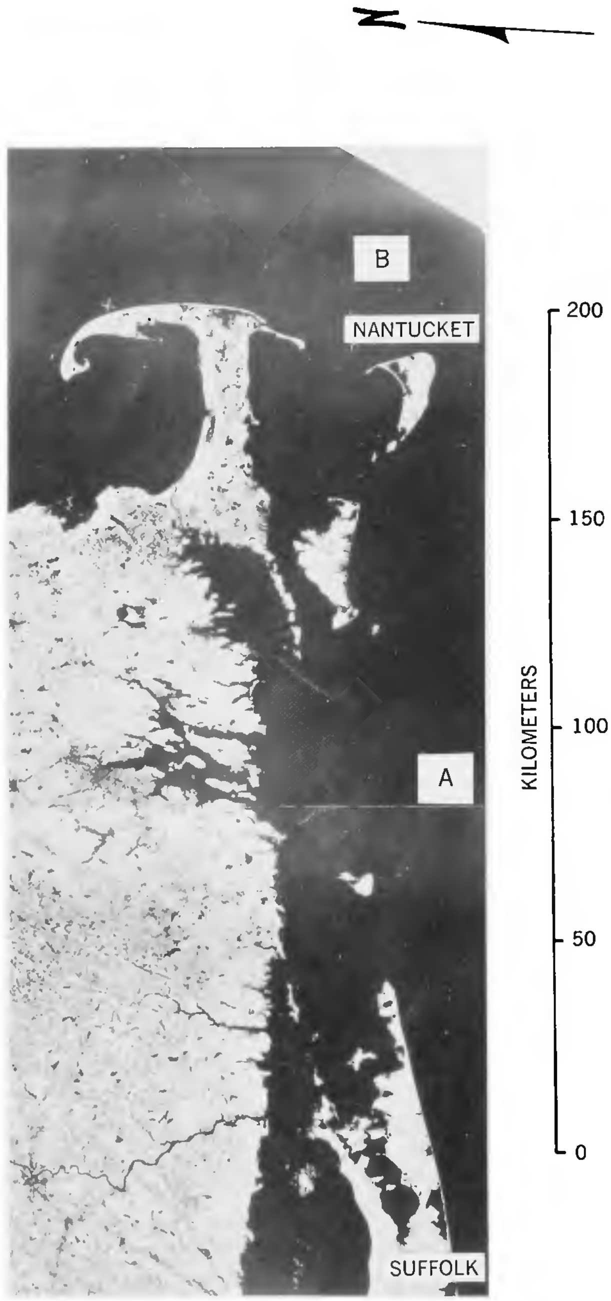
**SUFFOLK TO NANTUCKET**

**(3) INTERNAL WAVES, NANTUCKET**

DO YOU SEE ANY INTERNAL WAVES IN AREA A OR B?

DESCRIBE:

—LOCATION
—ORIENTATION
—NUMBER OF WAVES
—SPACING BETWEEN WAVES



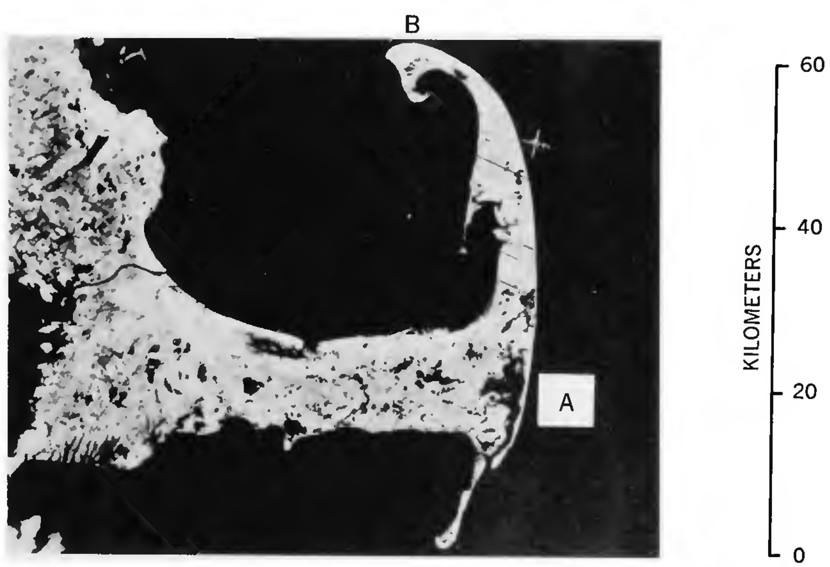

**CAPE COD**

**(4) DISCHARGE PLUME IN CAPE COD BAY**

CAN YOU SEE A DISCHARGE PLUME IN BAY A?

**(5) SAND DUNES OF CAPE COD**

DESCRIBE TYPE AND SIZE OF SAND DUNES AT POINT B.

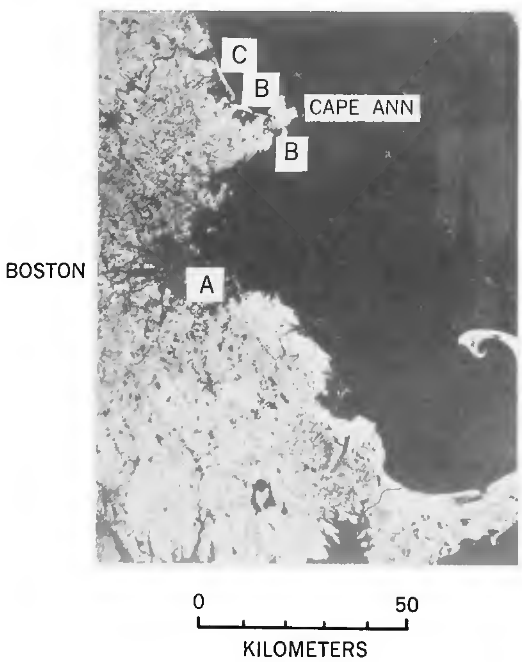


**BOSTON AREA**

**(6) POLLUTION IN BOSTON AREA**

CAN YOU SEE DISCHARGE PLUMES AT:

A. SOUTHERN PART OF BOSTON HARBOR
B. NORTH AND SOUTH OF CAPE ANN
C. PLUM ISLAND SOUND



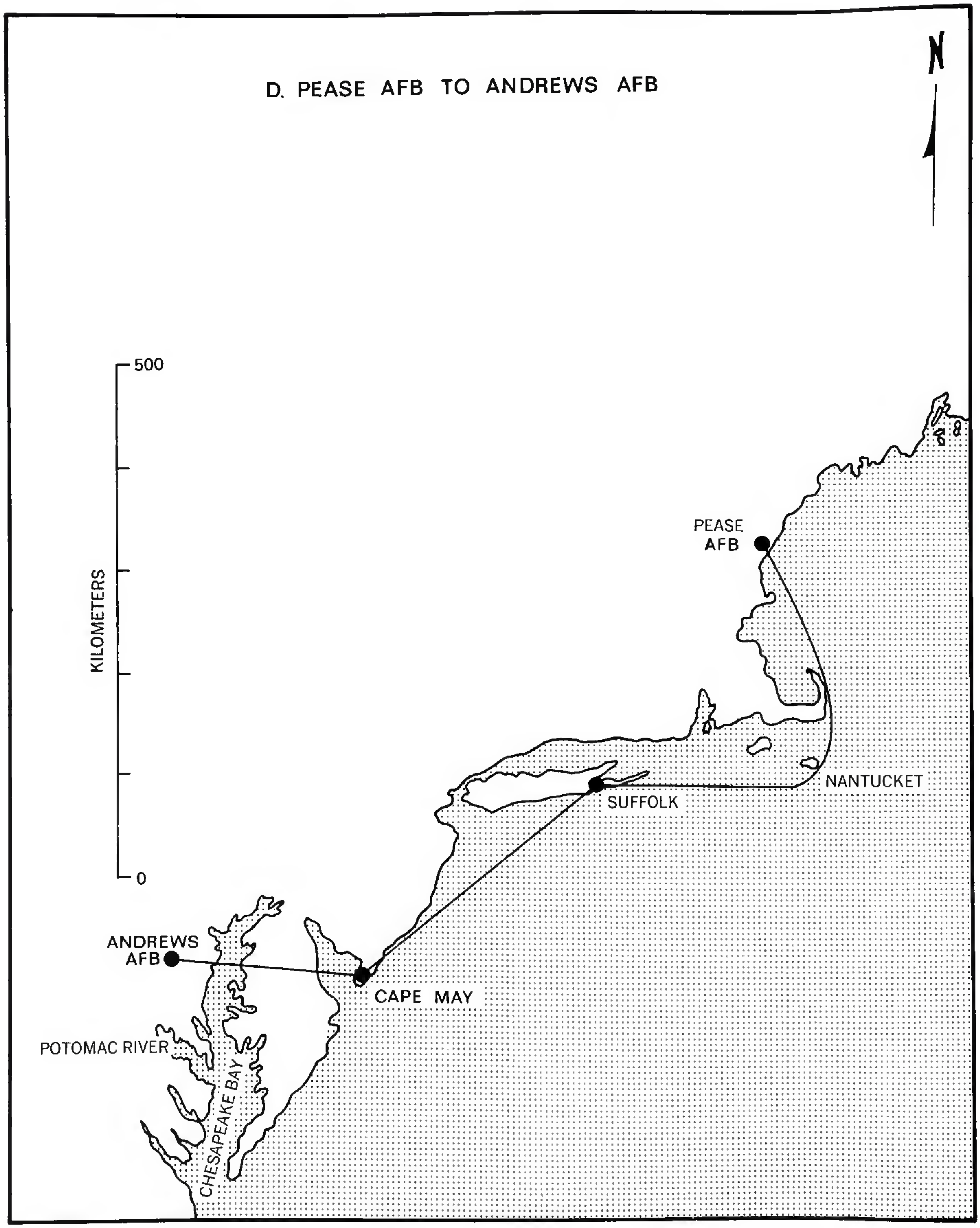
**MAINE**

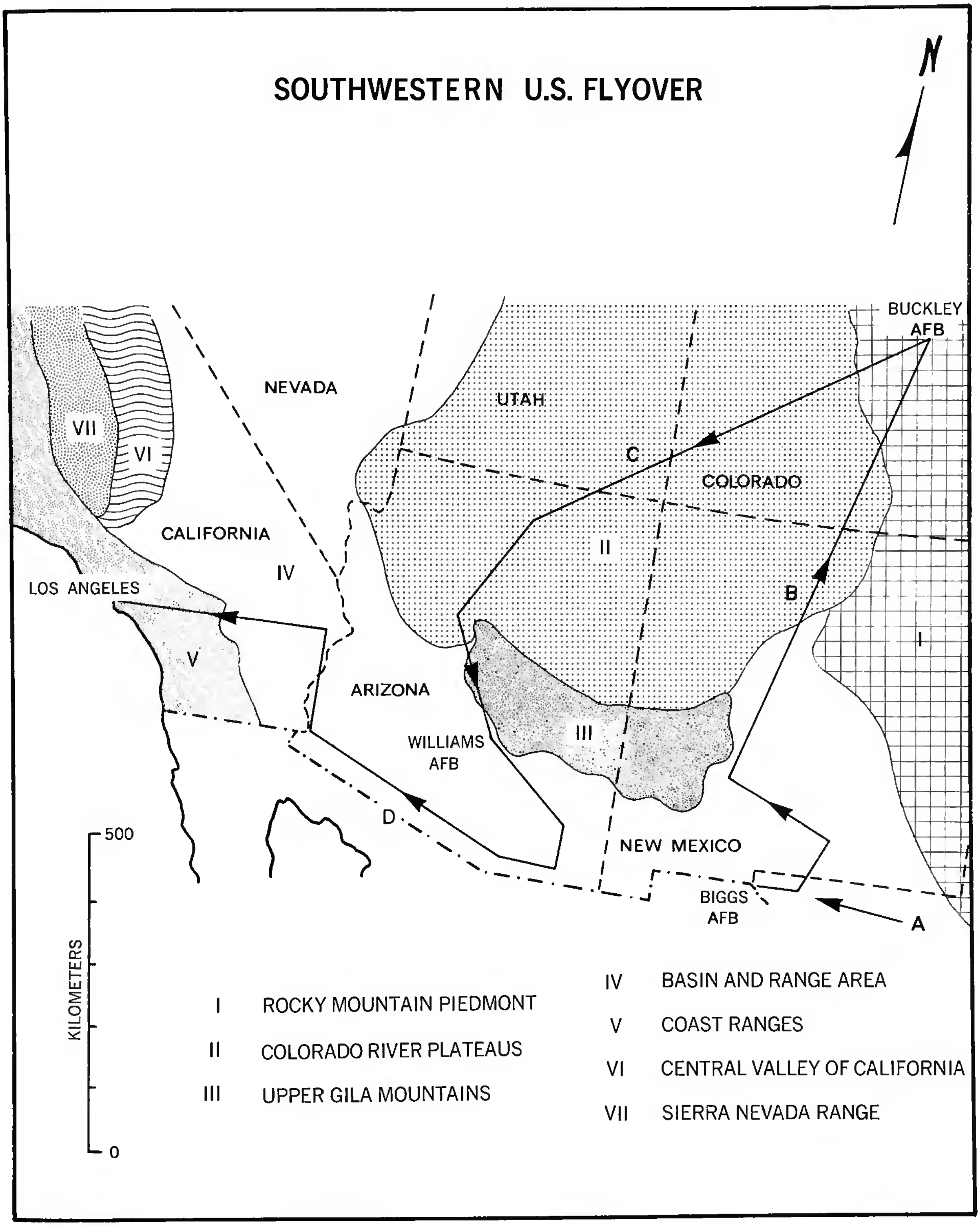
**(7) WATER COLORS**

USE COLOR CHART TO GET A READING OF THE WATER COLOR.

**(8) GLACIAL COAST—BOOTHBAY**

PHOTOGRAPH GLACIAL COAST LINE IN THE BOOTH BAY AREA.


D. PEASE AFB TO ANDREWS AFB
N
500
KILOMETERS
0
PEASE
AFB
NANTUCKET
SUFFOLK
ANDREWS
AFB
CAPE MAY
POTOMAC RIVER
CHESAPEAKE BAY


SOUTHWESTERN U.S. FLYOVER
N
BUCKLEY AFB
NEVADA
UTAH
COLORADO
CALIFORNIA
LOS ANGELES
ARIZONA
NEW MEXICO
WILLIAMS AFB
BIGGS AFB
VII
VI
V
IV
III
II
I
A
B
C
D
500
0
KILOMETERS
I ROCKY MOUNTAIN PIEDMONT
II COLORADO RIVER PLATEAUS
III UPPER GILA MOUNTAINS
IV BASIN AND RANGE AREA
V COAST RANGES
VI CENTRAL VALLEY OF CALIFORNIA
VII SIERRA NEVADA RANGE

## SOUTHWESTERN U.S. FLYOVER

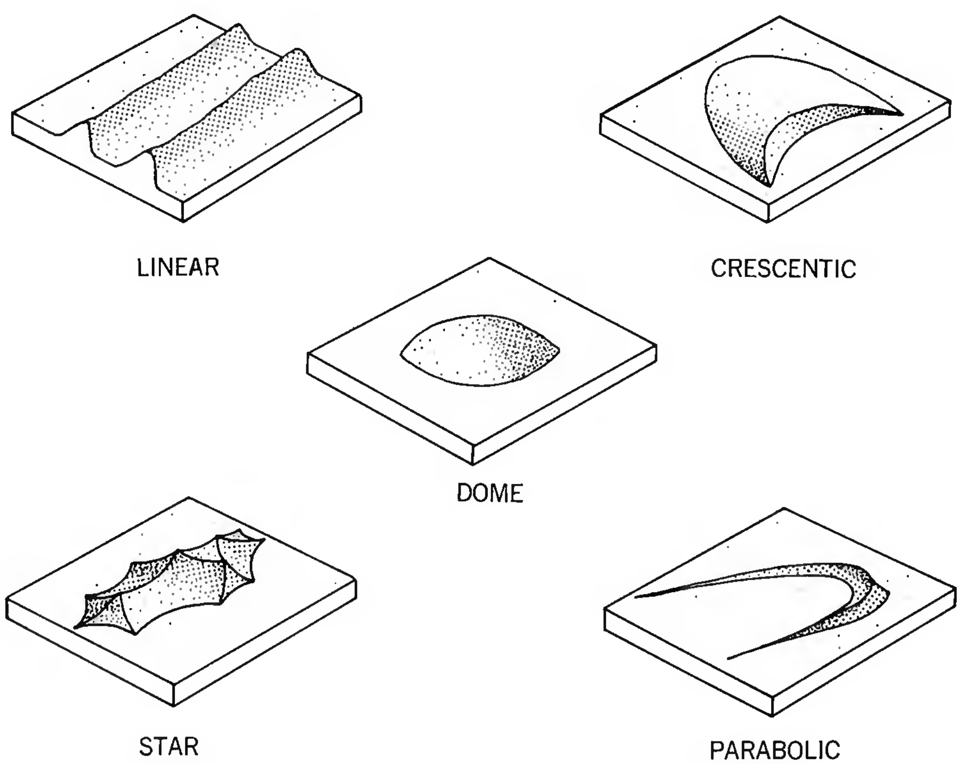
A. ELLINGTON AFB TO BIGGS AFB —— 600nm
TRANSPORTATION ROUTE ONLY

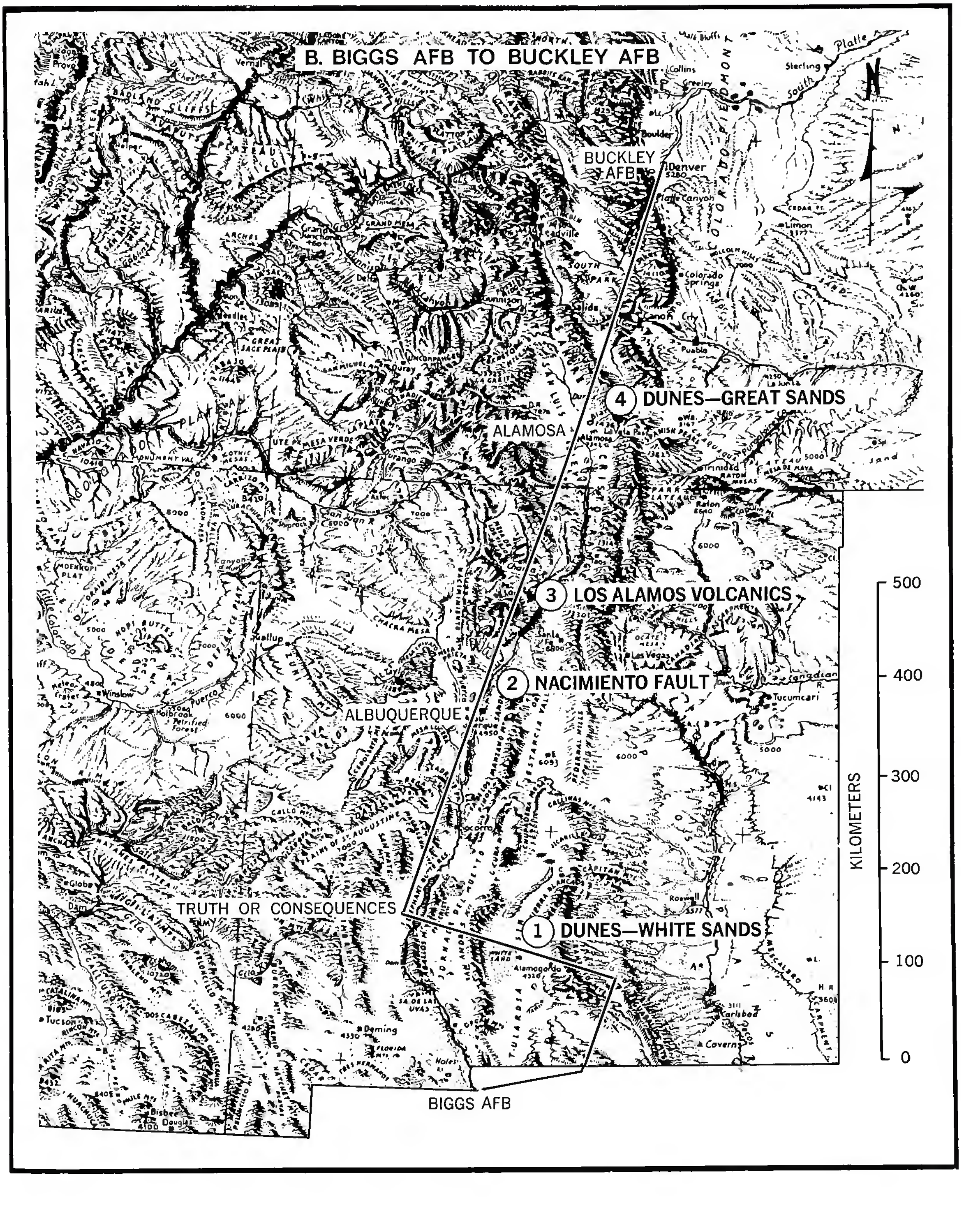
B. BIGGS AFB TO BUCKLEY AFB —— 610nm

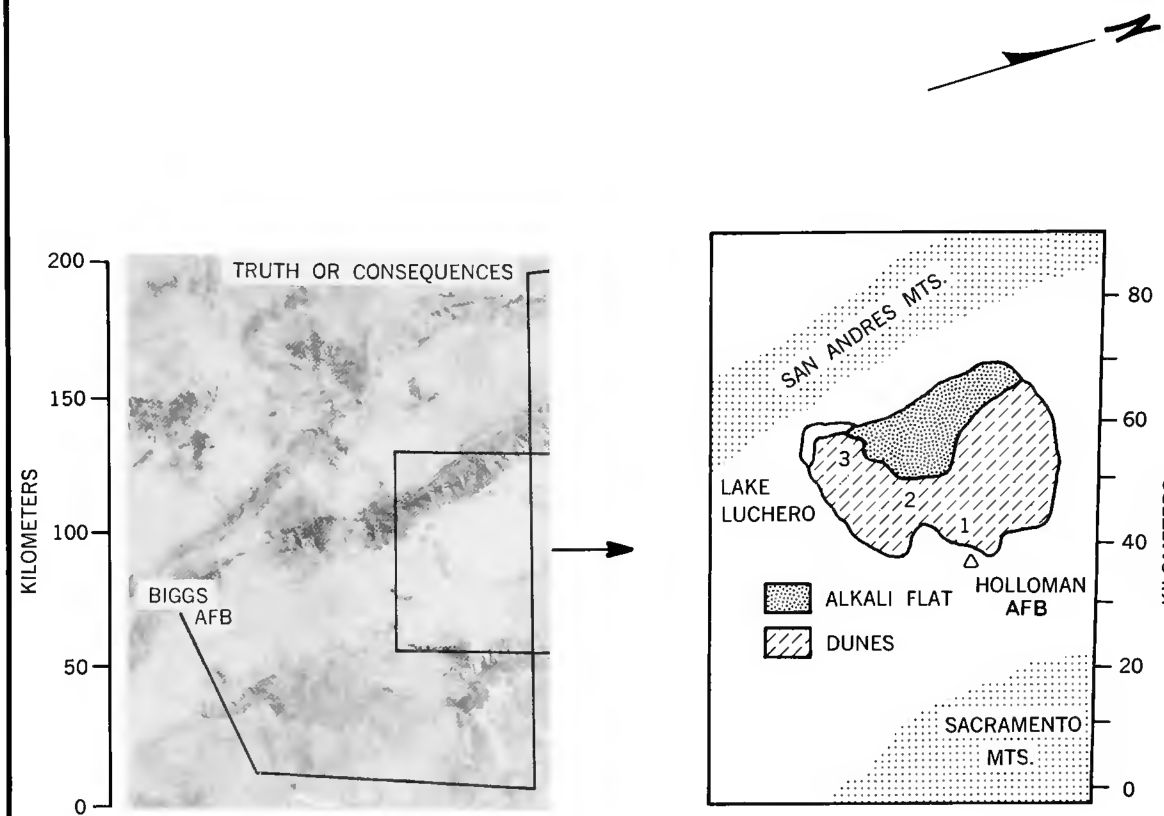
C. BUCKLEY AFB TO WILLIAMS AFB —— 575nm

D. WILLIAMS AFB TO LOS ANGELES —— 700nm

### SAND DUNE TYPES




B. BIGGS AFB TO BUCKLEY AFB
BUCKLEY AFB
4 DUNES—GREAT SANDS
ALAMOSA
3 LOS ALAMOS VOLCANICS
2 NACIMIENTO FAULT
ALBUQUERQUE
TRUTH OR CONSEQUENCES
1 DUNES—WHITE SANDS
BIGGS AFB
KILOMETERS
500
400
300
200
100
0




**BIGGS TO TRUTH OR CONSEQUENCES**

**(1) DUNES—WHITE SANDS**

A. WHAT TYPE OF DUNES ARE AT 1, 2, AND 3?

B. IS THE TRANSITION BETWEEN DUNE TYPES OF 1 AND 2 SHARP OR GRADATIONAL?

C. USE CHART TO DESCRIBE COLOR OF DUNES.

**TRUTH OR CONSEQUENCES—**
**ALBUQUERQUE—ALAMOSA**

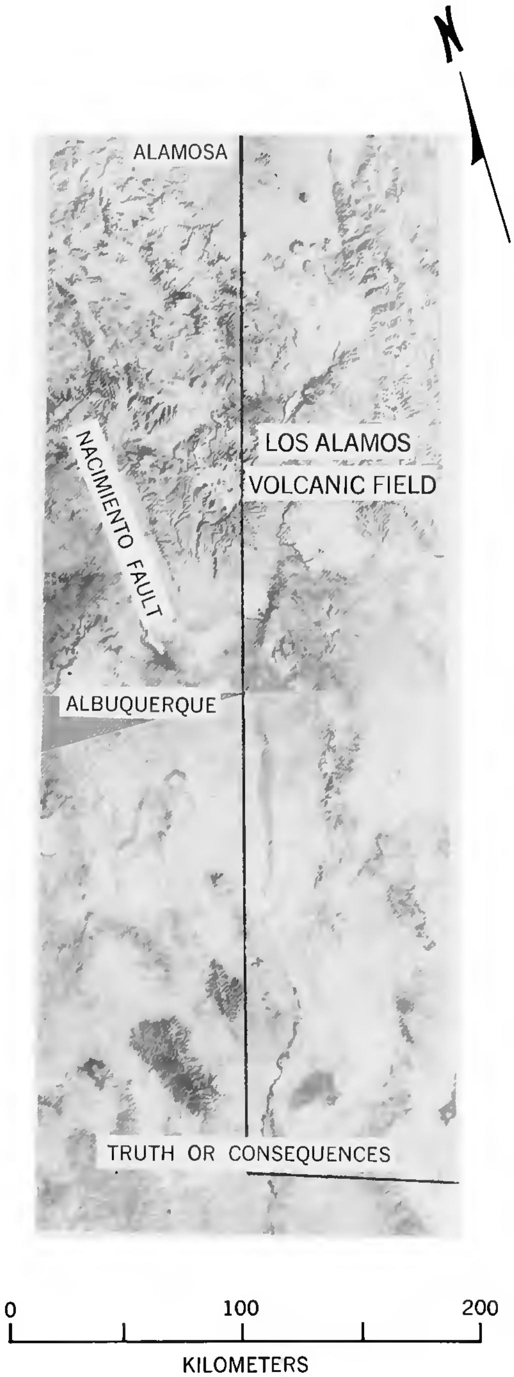
**(2) NACIMIENTO FAULT**

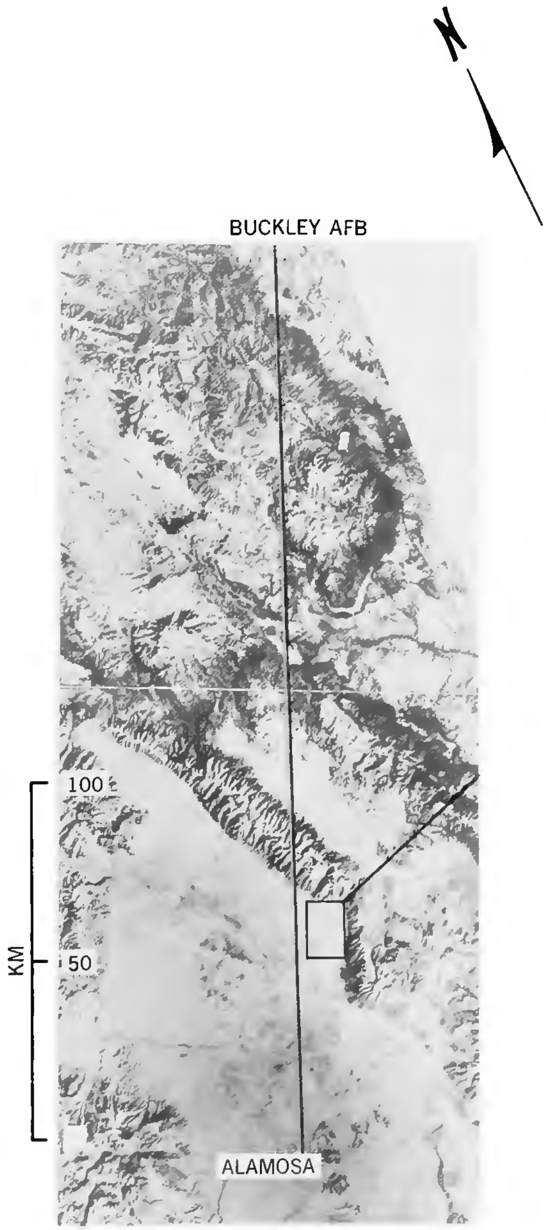
CAN YOU DISTINGUISH THE NACIMIENTO FAULT BY:
—SCARP
—COLOR DIFFERENCE
—DRAINAGE DISPLACEMENT

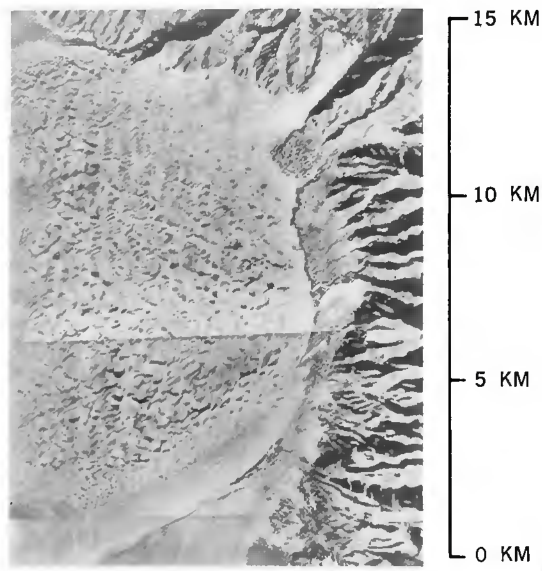
**(3) LOS ALAMOS VOLCANICS**

IN THE LOS ALAMOS VOLCANIC FIELD, CAN YOU DISTINGUISH:

—CONCENTRIC FEATURES
—RADIATING FEATURES
—INDIVIDUAL FLOWS





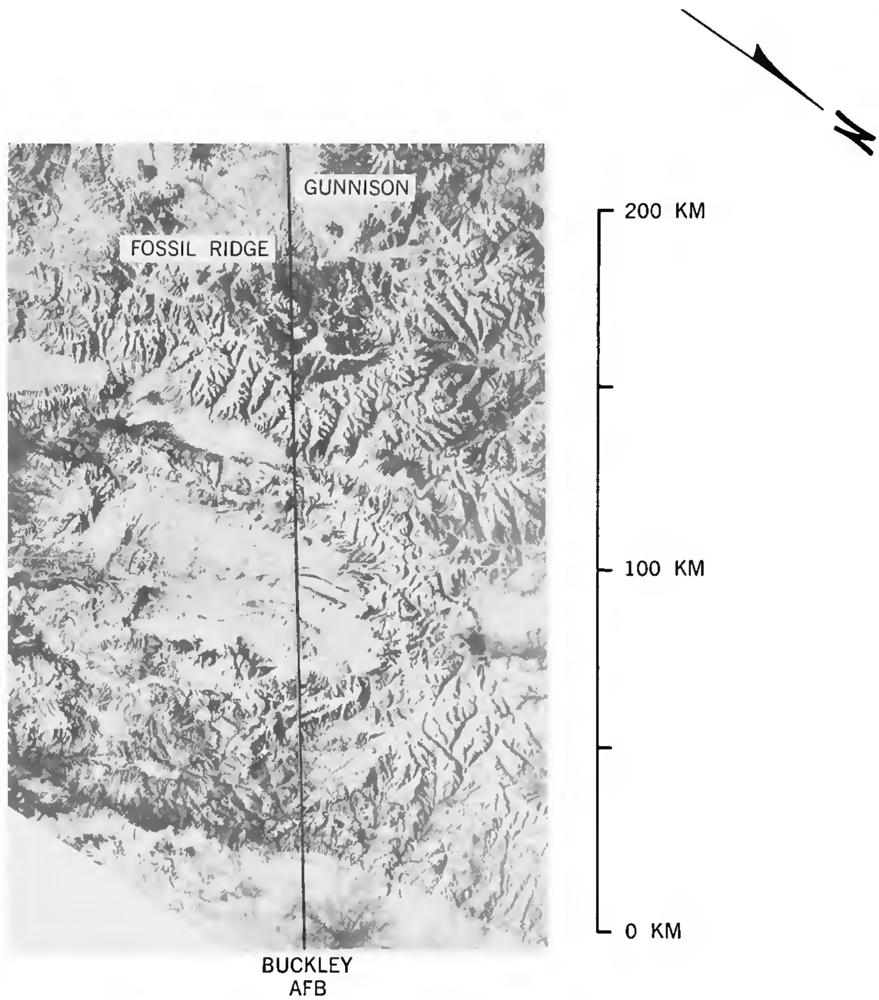




**ALAMOSA TO BUCKLEY**

**(4) DUNES—GREAT SANDS**

A. DESCRIBE THE RELATIONSHIP OF THE SAND PATCH TO THE MOUNTAINS AND THE VALLEY.
B. DESCRIBE THE DUNE PATTERN OR PATTERNS WITHIN THE SAND PATCH.
C. USE CHART TO DESCRIBE COLOR OF DUNES.


C. BUCKLEY AFB TO WILLIAMS AFB
WILLIAMS AFB
7 COPPER MINING—BIG BUG MTS.
PRESCOTT
6 LINEAR FEATURES—COCONINO PLATEAU
5 DUNES—MOENKOPI PLATEAU
TUBA CITY
4 DUNES—KAIBITO PLATEAU
3 DUNES—COMB RIDGE
2 SAN JUAN MTS.
GUNNISON
1 FOSSIL RIDGE
BUCKLEY AFB
N
0
500
KILOMETERS

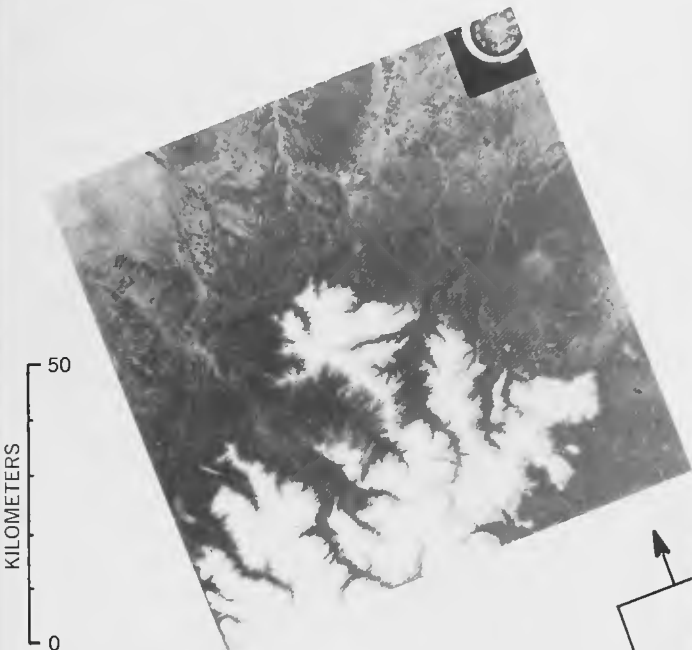


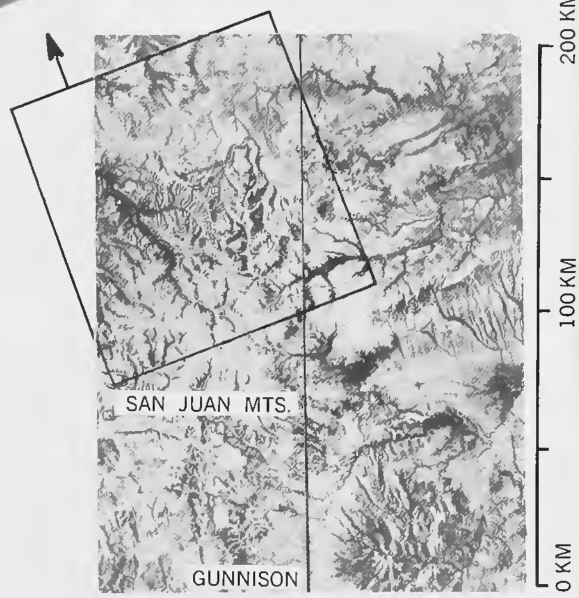

**BUCKLEY TO GUNNISON**

**(1) FOSSIL RIDGE**

A. DESCRIBE THE NUMBER, LENGTH, AND ORIENTATION OF SEGMENTS AT FOSSIL RIDGE.

B. WHAT DO YOU THINK MADE THESE RIDGES?

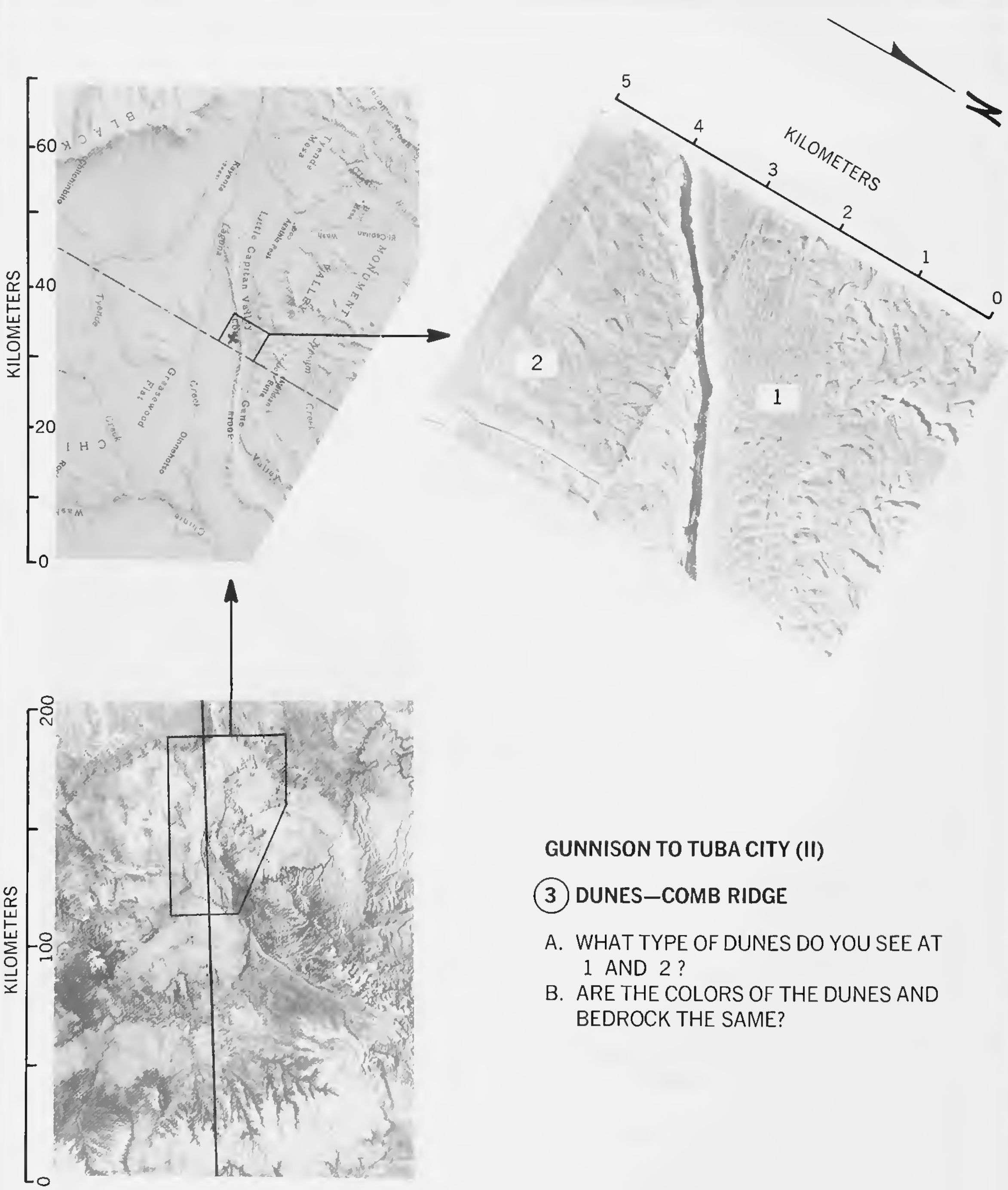



**GUNNISON TO TUBA CITY (I)**

**(2) SAN JUAN MTS.**

A. DESCRIBE ANY CIRCULAR STRUCTURES THAT YOU SEE.
B. IF THESE FEATURES ARE NOT SNOW-COVERED, DESCRIBE THE COLORS ASSOCIATED WITH THEM.




**GUNNISON TO TUBA CITY (II)**

**(3) DUNES—COMB RIDGE**

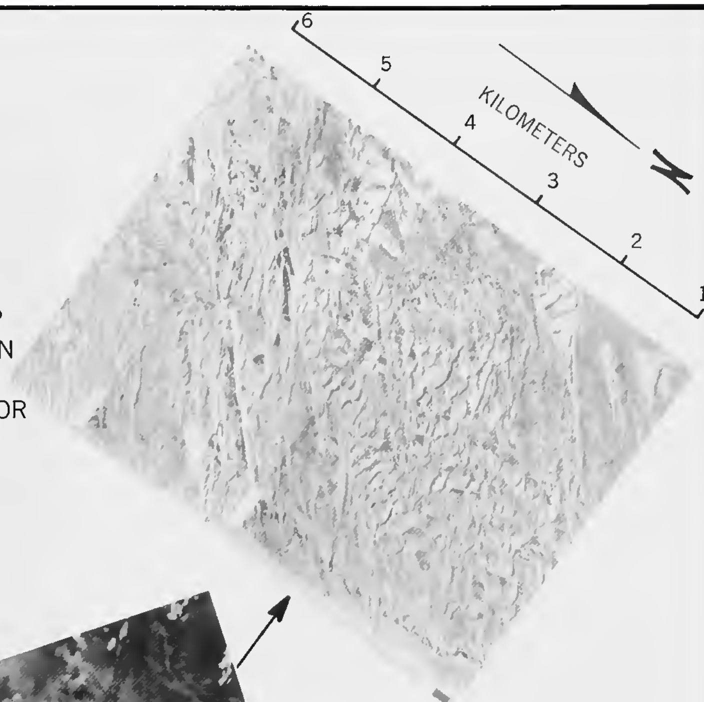
A. WHAT TYPE OF DUNES DO YOU SEE AT 1 AND 2?

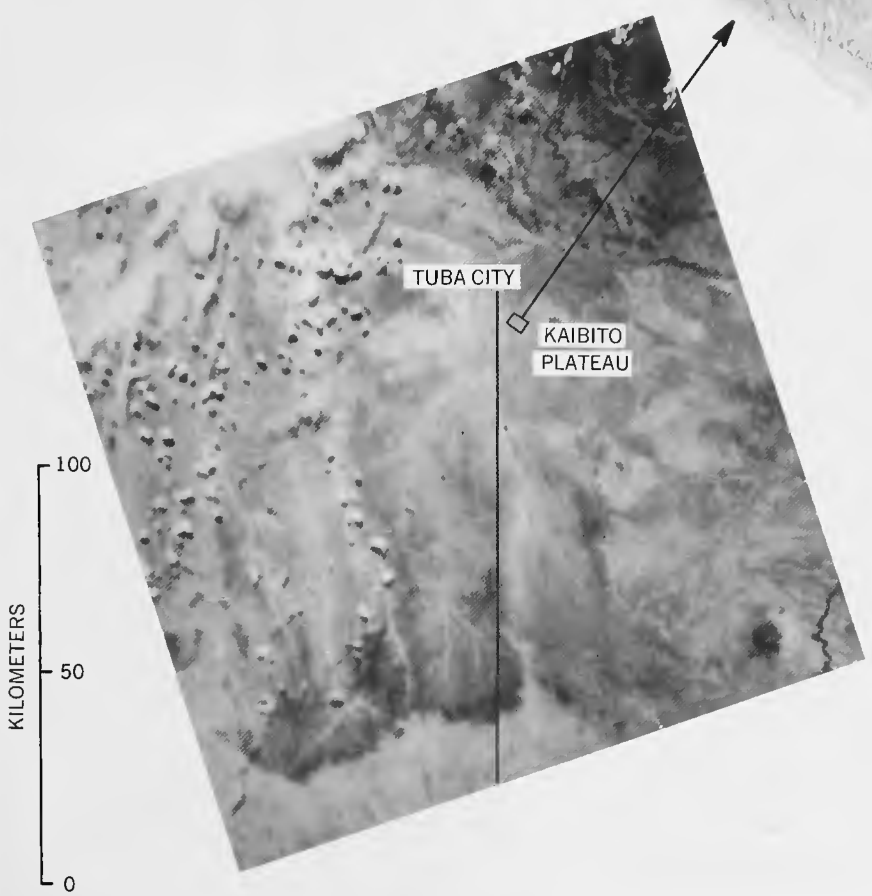
B. ARE THE COLORS OF THE DUNES AND BEDROCK THE SAME?

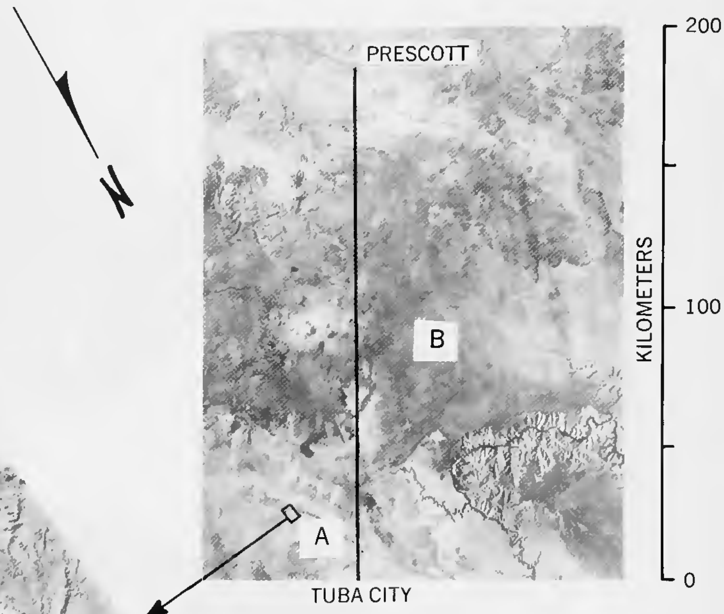
GUNNISON TO TUBA CITY (III)

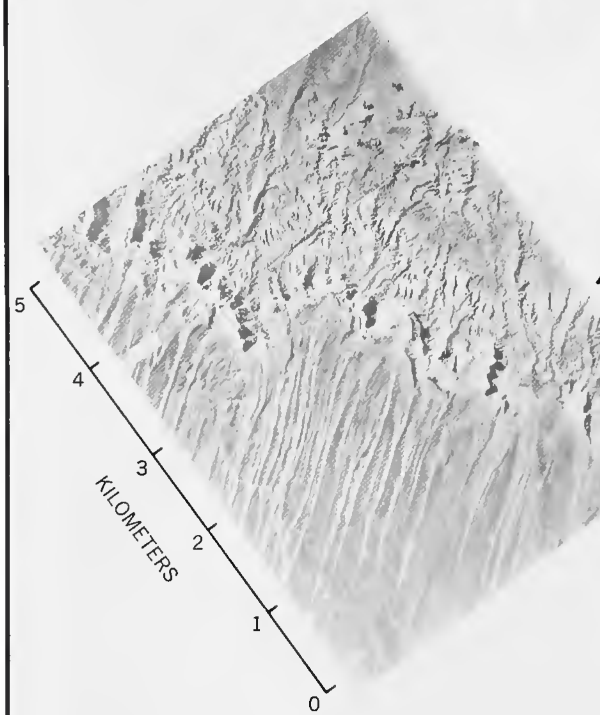
(4) DUNES—KAIBITO PLATEAU

A. WHAT TYPES OF DUNES CAN YOU SEE?
B. DESCRIBE THE BOUNDARIES BETWEEN SAND AND CULTIVATED AREAS.
C. USE COLOR CHART TO DESCRIBE COLOR OF DUNES.
D. ARE THE COLORS OF THE DUNES AND BEDROCK THE SAME?





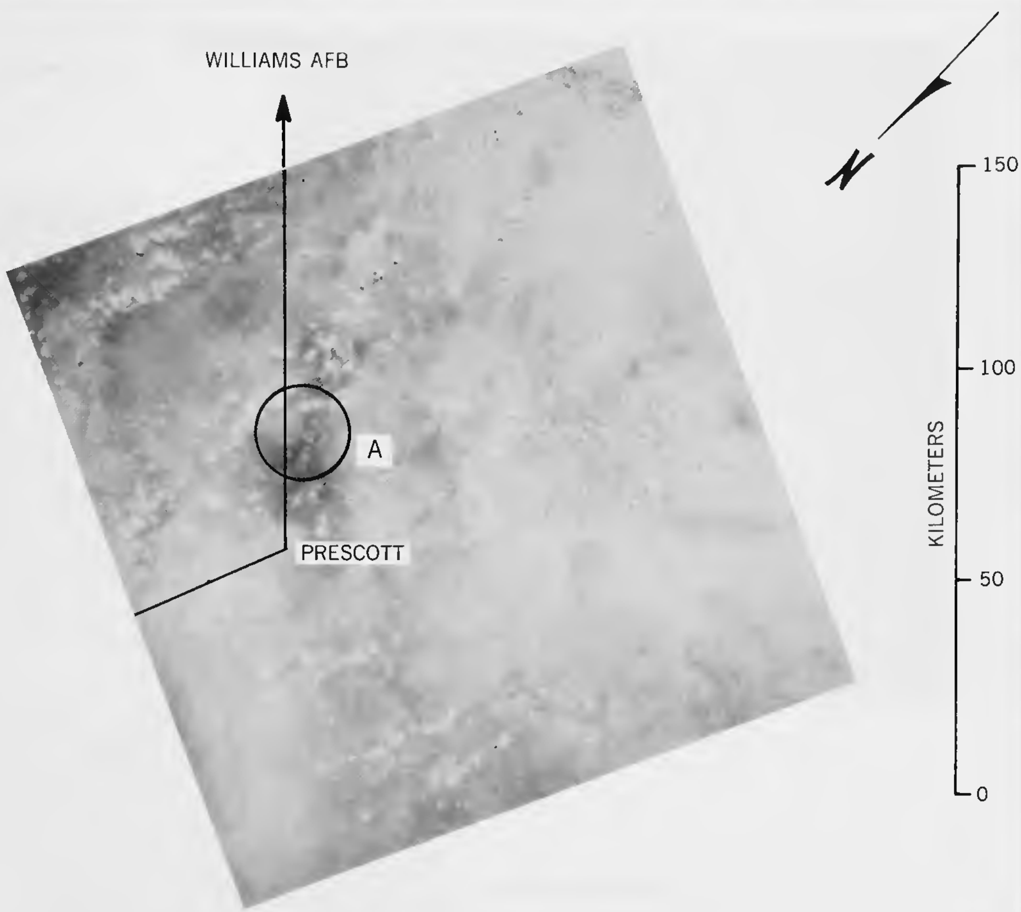

**TUBA CITY TO PRESCOTT**

**(5) DUNES—MOENKOPI PLATEAU**

A. DESCRIBE TYPE, ORIENTATION AND SIZE OR LENGTH OF DUNES AT AREA A .
B. WHAT IS THE RELATIONSHIP OF THE DUNES TO TOPOGRAPHY?

**(6) LINEAR FEATURES—COCONINO PLATEAU**

DESCRIBE NUMBER AND LENGTH OF NORTH-SOUTH TRENDING LINEAR FEATURES ON THE COCONINO PLATEAU ( B ).

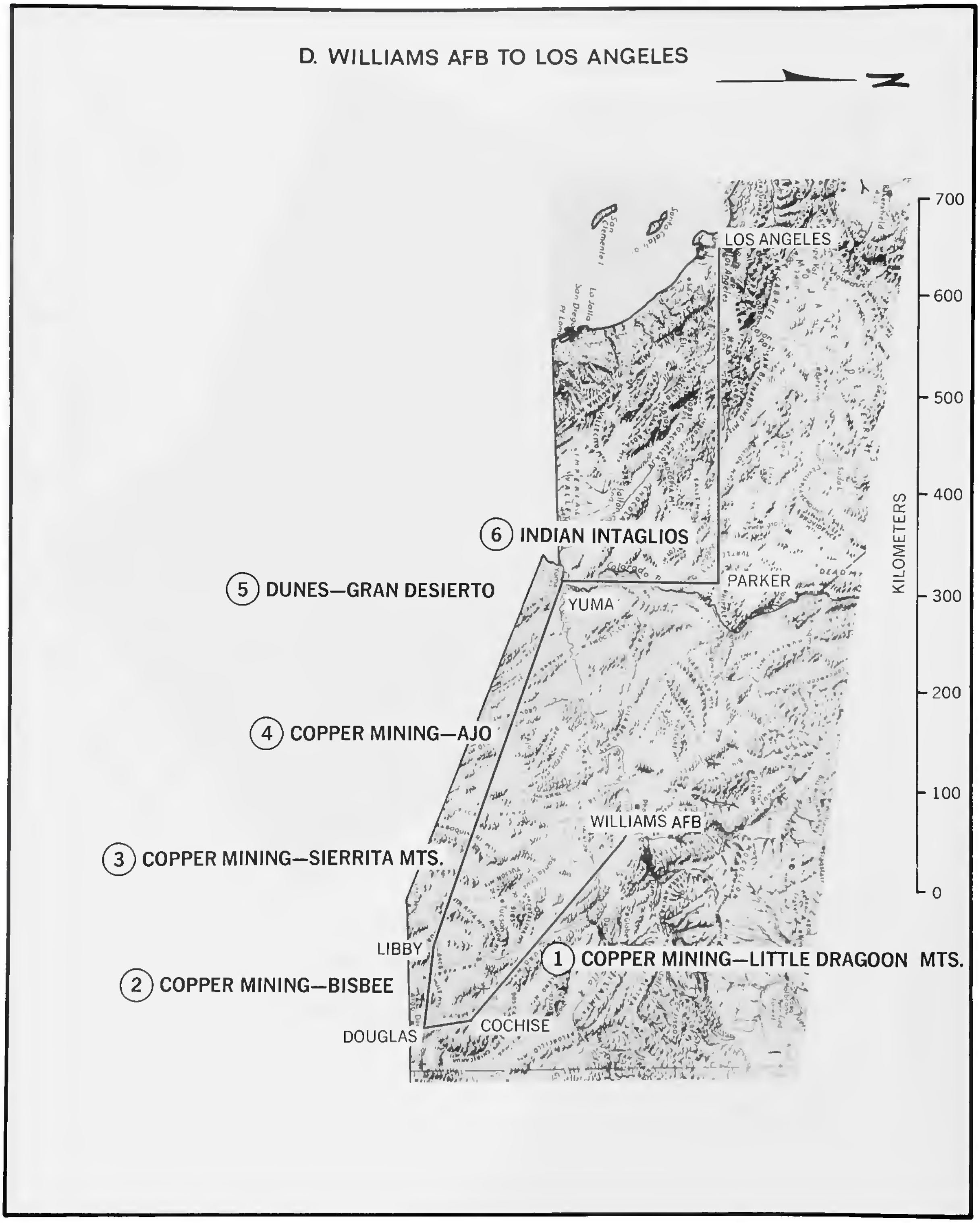


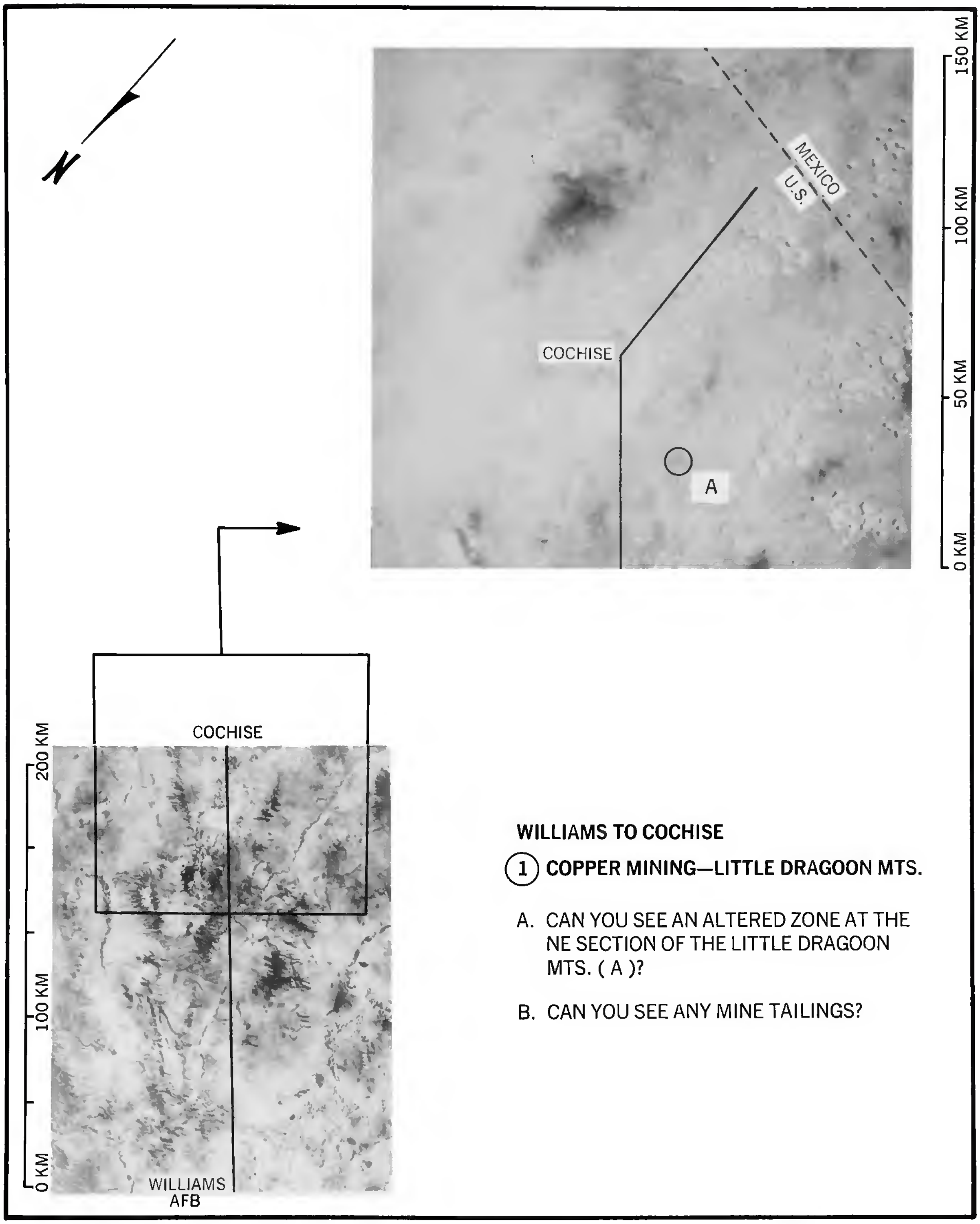

**PRESCOTT TO WILLIAMS**

**(7) COPPER MINING—BIG BUG MTS.**

A. DESCRIBE COLORS OF ALTERED ZONE AT A .

B. DESCRIBE ANY FAULTS OR STRUCTURAL FEATURES ASSOCIATED WITH THE ALTERED ZONE.


D. WILLIAMS AFB TO LOS ANGELES
N
LOS ANGELES
6 INDIAN INTAGLIOS
5 DUNES—GRAN DESIERTO
YUMA
PARKER
4 COPPER MINING—AJO
WILLIAMS AFB
3 COPPER MINING—SIERRITA MTS.
LIBBY
1 COPPER MINING—LITTLE DRAGOON MTS.
2 COPPER MINING—BISBEE
DOUGLAS
COCHISE
KILOMETERS
700
600
500
400
300
200
100
0

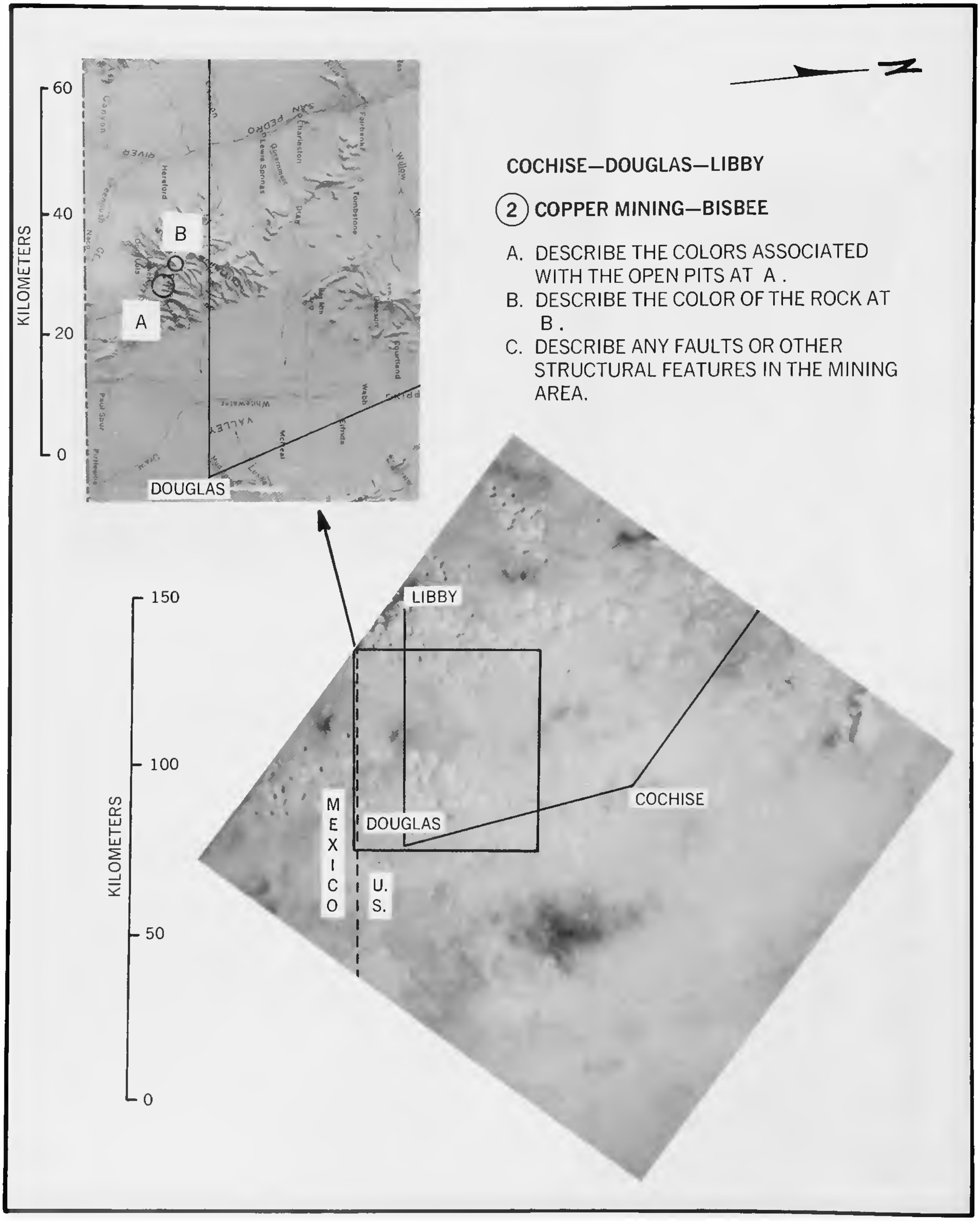


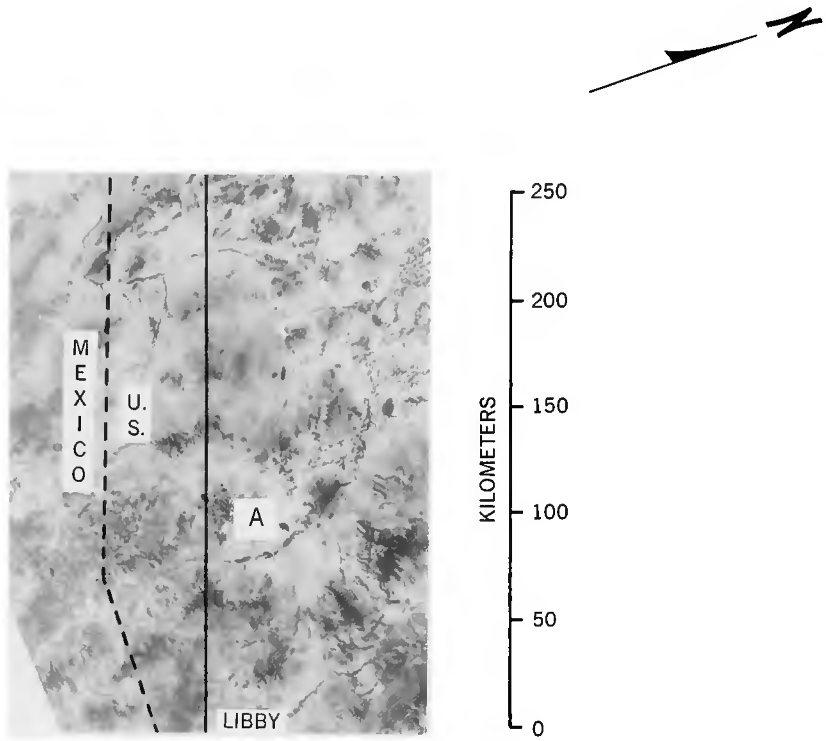

**WILLIAMS TO COCHISE**

**(1) COPPER MINING—LITTLE DRAGOON MTS.**

A. CAN YOU SEE AN ALTERED ZONE AT THE NE SECTION OF THE LITTLE DRAGOON MTS. ( A )?

B. CAN YOU SEE ANY MINE TAILINGS?

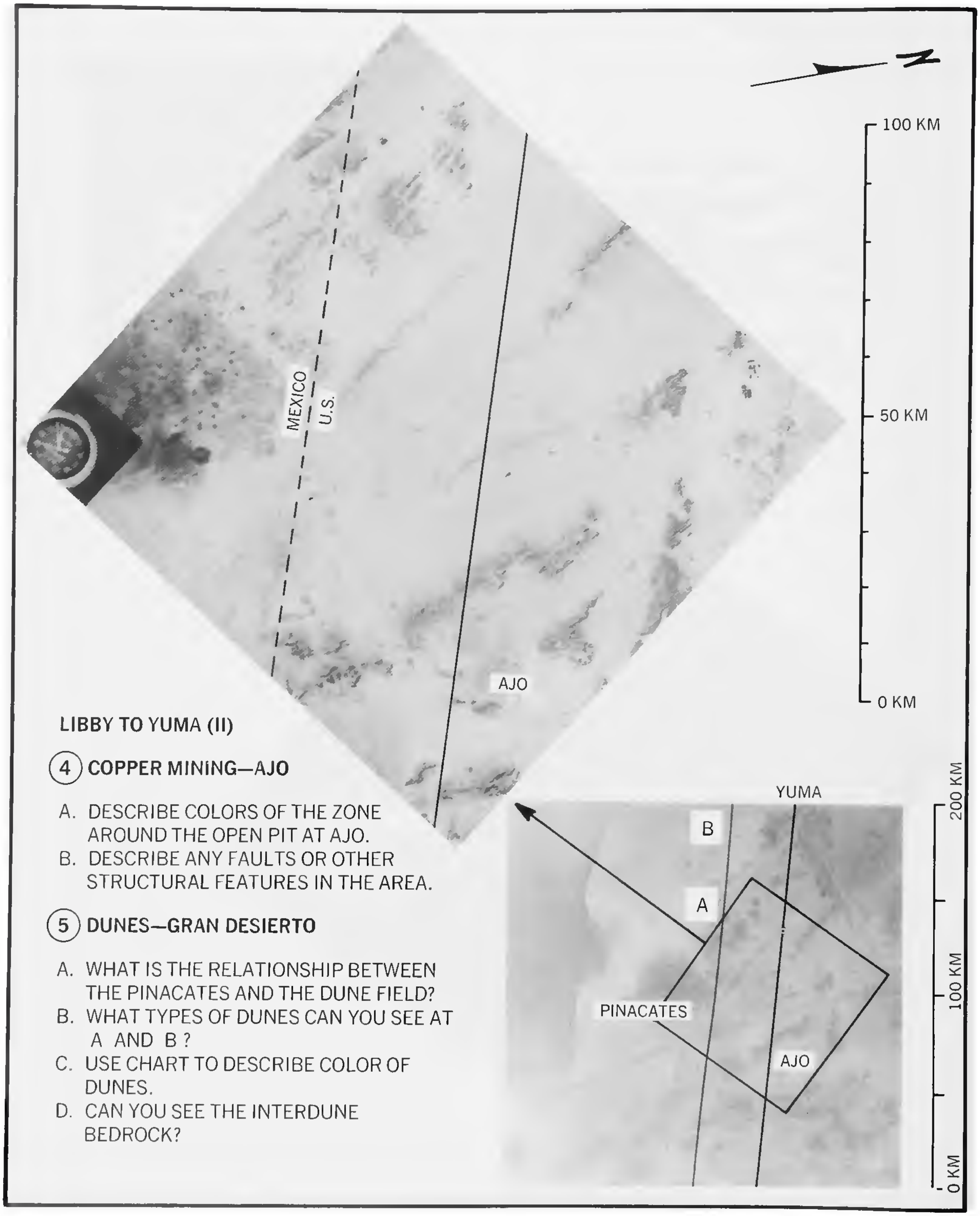

N
COCHISE—DOUGLAS—LIBBY
(2) COPPER MINING—BISBEE
A. DESCRIBE THE COLORS ASSOCIATED WITH THE OPEN PITS AT A .
B. DESCRIBE THE COLOR OF THE ROCK AT B .
C. DESCRIBE ANY FAULTS OR OTHER STRUCTURAL FEATURES IN THE MINING AREA.
KILOMETERS
60
40
20
0
A
B
DOUGLAS
KILOMETERS
150
100
50
0
LIBBY
DOUGLAS
COCHISE
MEXICO
U.S.

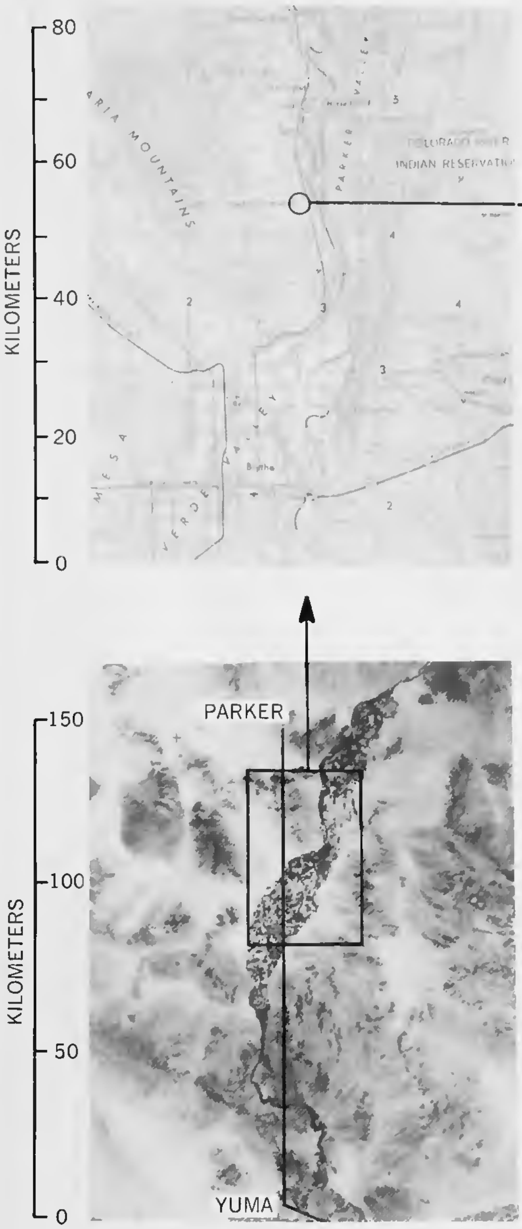


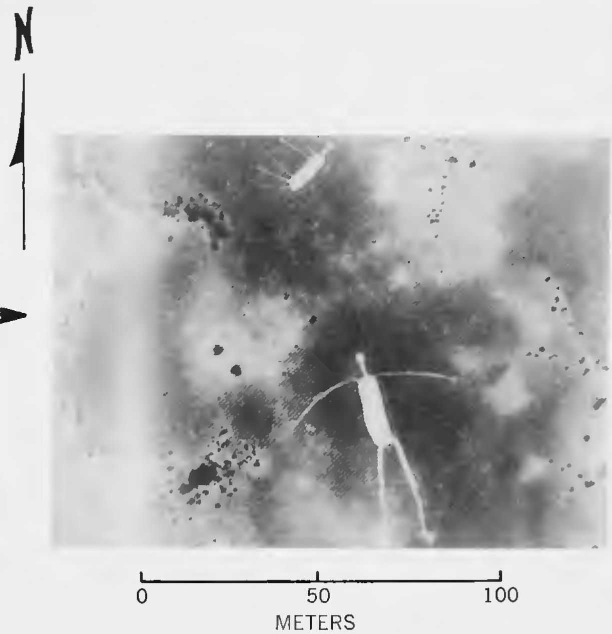

**LIBBY TO YUMA (I)**

**(3) COPPER MINING—SIERRITA MTS.**

A. DESCRIBE THE COLOR AND LOCATIONS (WITH RESPECT TO MOUNTAINS, ETC.) OF MINE TAILINGS IN AREA A .
B. CAN YOU SEE ANY ALTERED ROCK ZONES?


100 KM
50 KM
0 KM
MEXICO
U.S.
AJO
LIBBY TO YUMA (II)
4 COPPER MINING—AJO
A. DESCRIBE COLORS OF THE ZONE AROUND THE OPEN PIT AT AJO.
B. DESCRIBE ANY FAULTS OR OTHER STRUCTURAL FEATURES IN THE AREA.
5 DUNES—GRAN DESIERTO
A. WHAT IS THE RELATIONSHIP BETWEEN THE PINACATES AND THE DUNE FIELD?
B. WHAT TYPES OF DUNES CAN YOU SEE AT A AND B ?
C. USE CHART TO DESCRIBE COLOR OF DUNES.
D. CAN YOU SEE THE INTERDUNE BEDROCK?
YUMA
B
A
PINACATES
AJO
200 KM
100 KM
0 KM

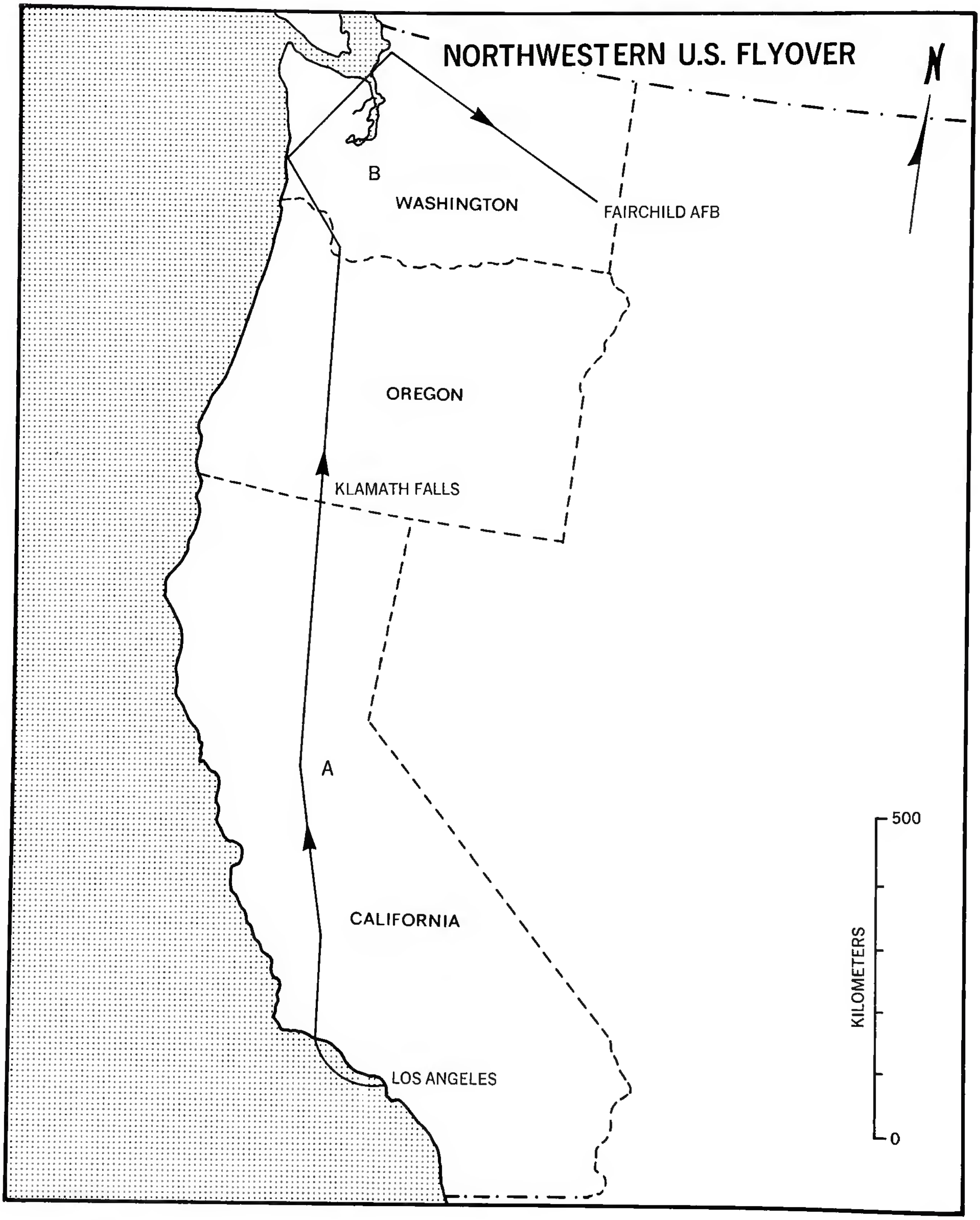


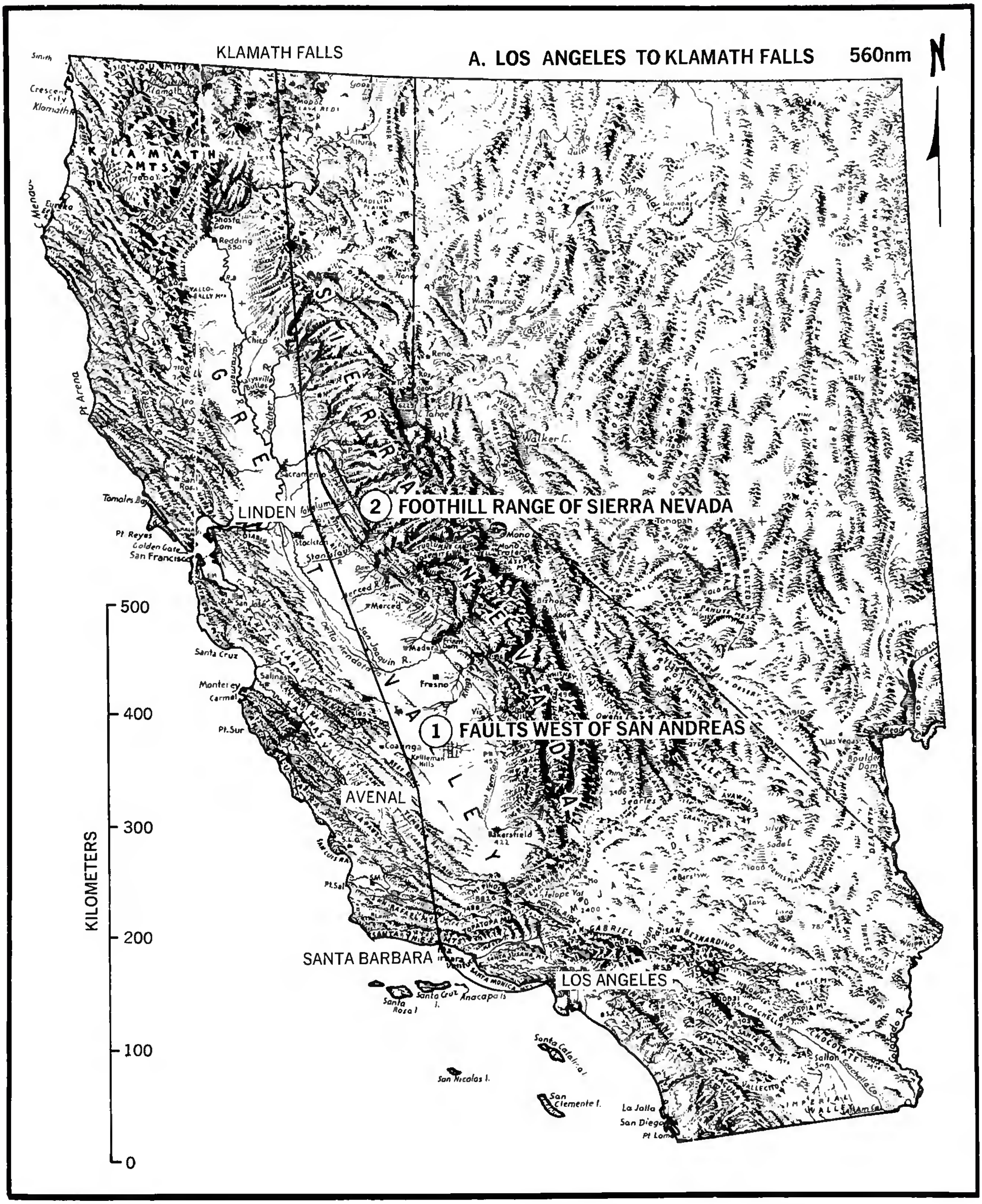



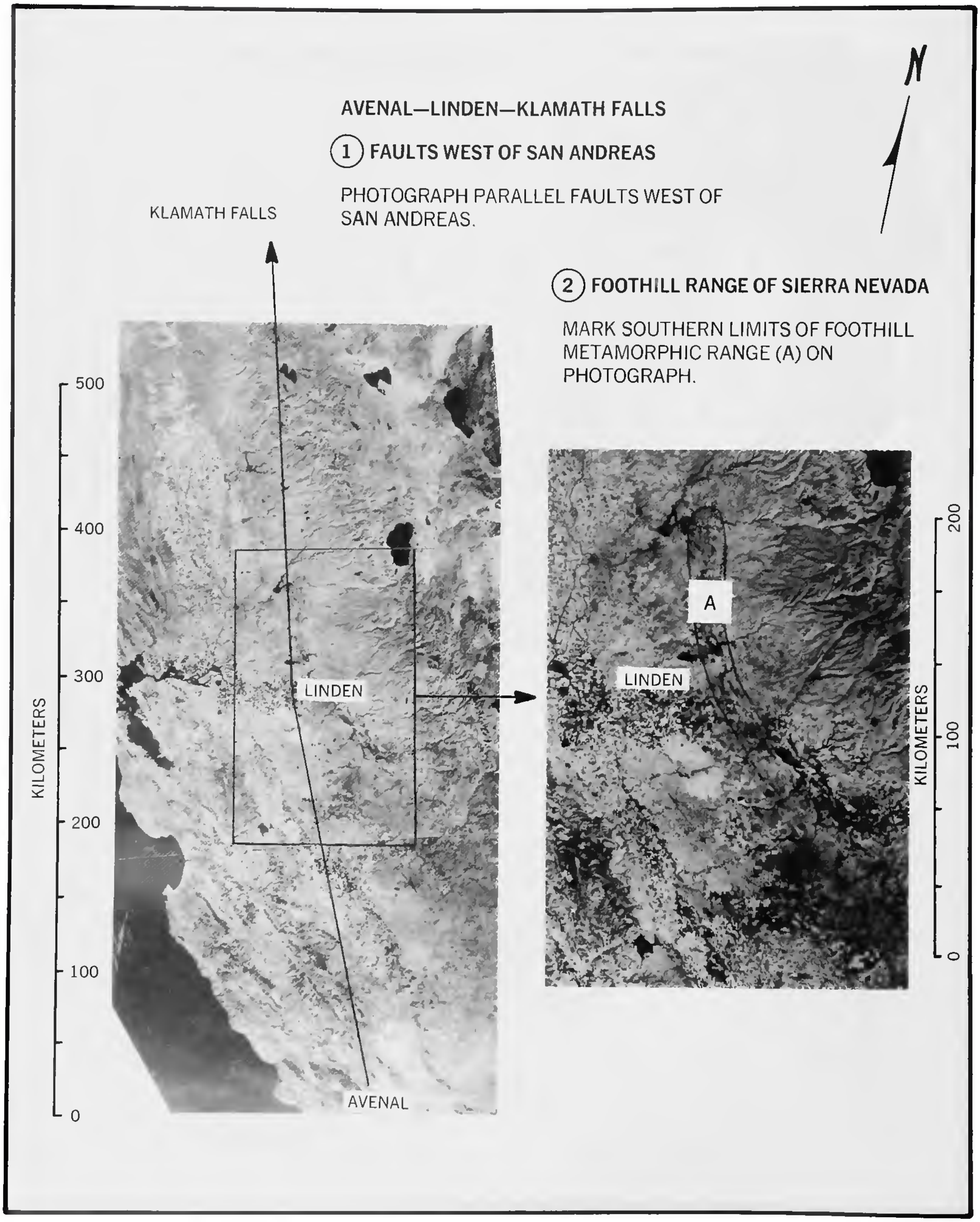

**YUMA TO PARKER**

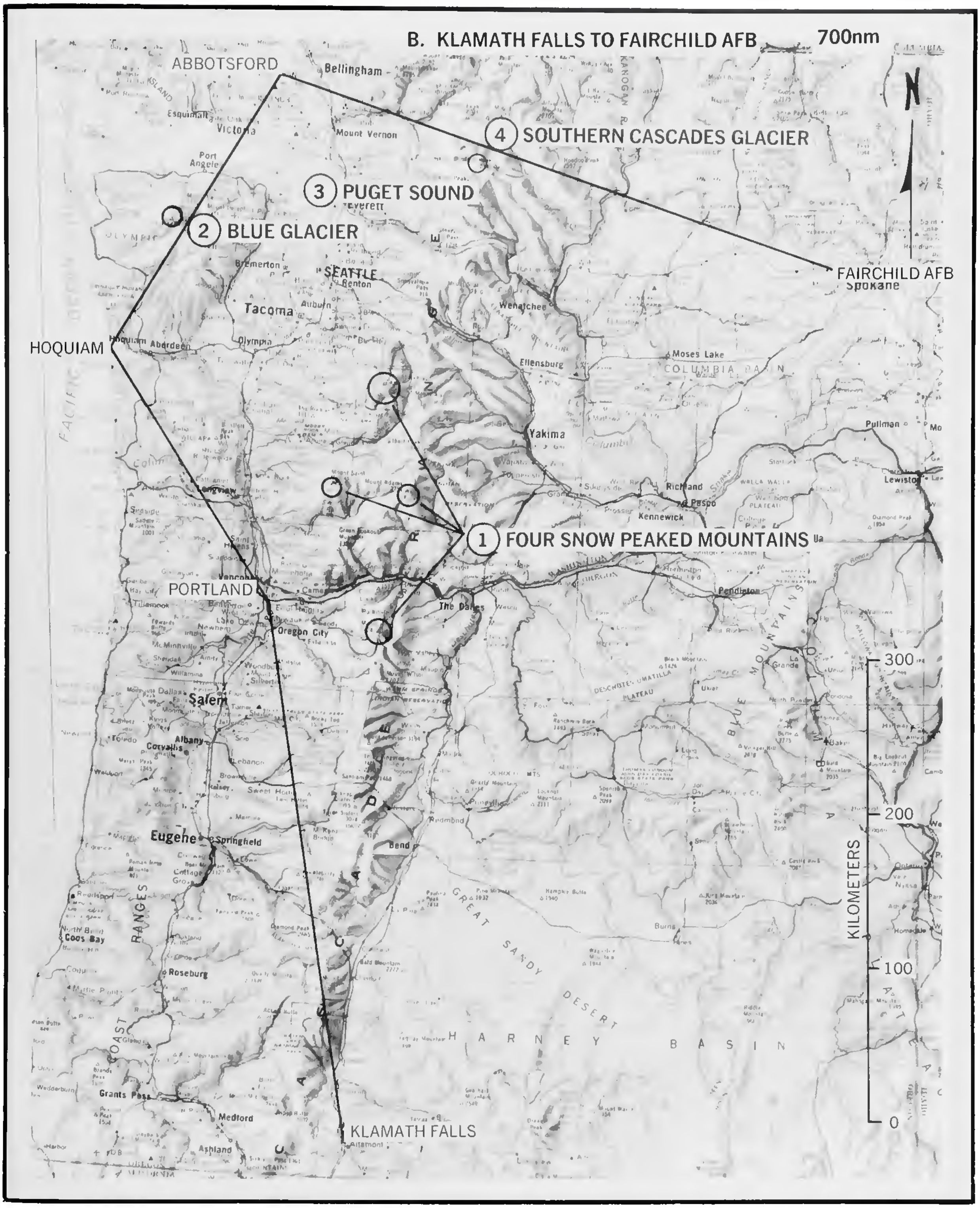
**(6) INDIAN INTAGLIOS**

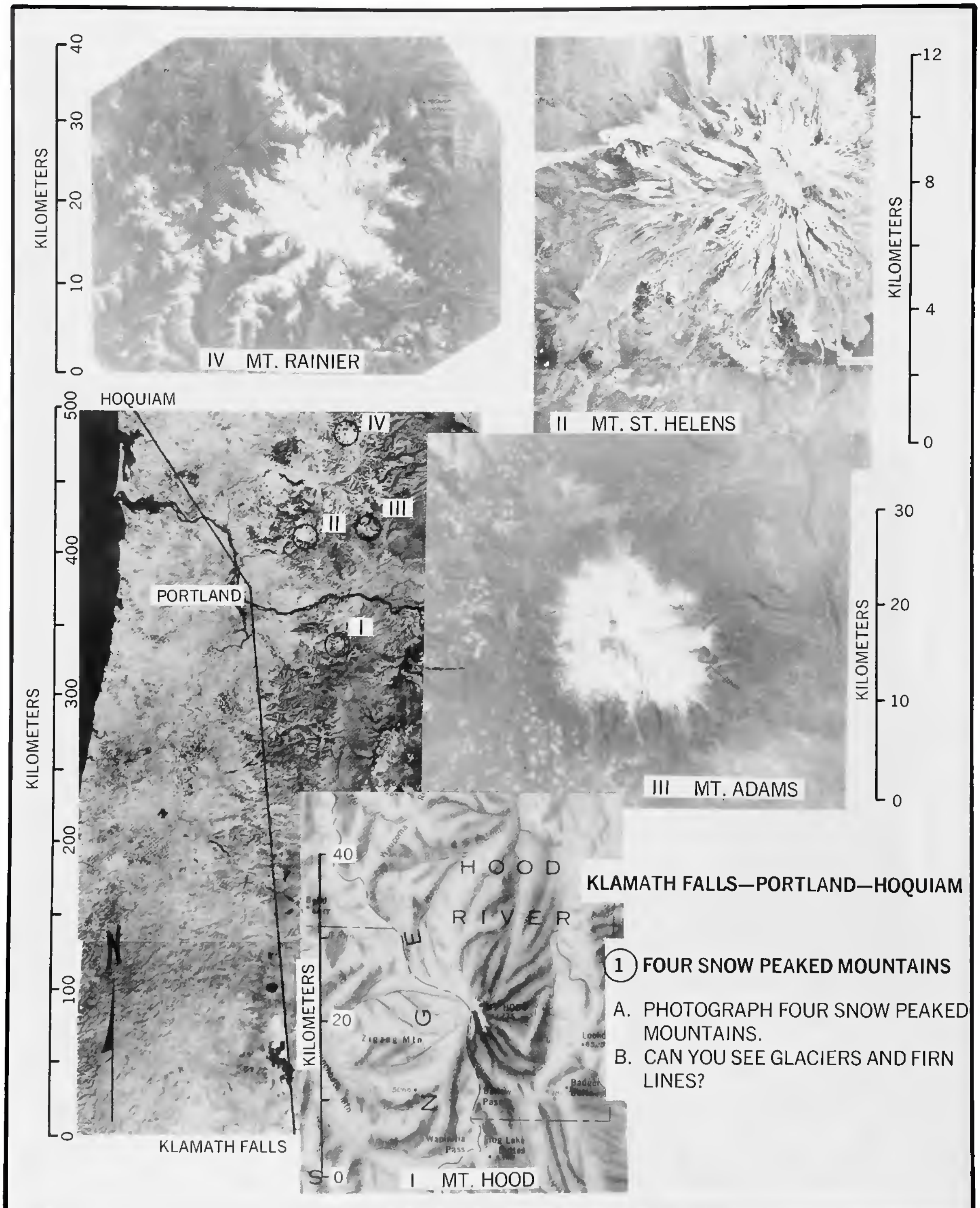
CAN YOU RESOLVE THE INDIAN INTAGLIOS? IF SO, PHOTOGRAPH.


NORTHWESTERN U.S. FLYOVER
N
B
WASHINGTON
FAIRCHILD AFB
OREGON
KLAMATH FALLS
A
CALIFORNIA
LOS ANGELES
500
KILOMETERS
0


A. LOS ANGELES TO KLAMATH FALLS
560nm
N
KLAMATH FALLS
LINDEN
2 FOOTHILL RANGE OF SIERRA NEVADA
1 FAULTS WEST OF SAN ANDREAS
AVENAL
SANTA BARBARA
LOS ANGELES
KILOMETERS
500
400
300
200
100
0


N
AVENAL—LINDEN—KLAMATH FALLS
1 FAULTS WEST OF SAN ANDREAS
PHOTOGRAPH PARALLEL FAULTS WEST OF SAN ANDREAS.
2 FOOTHILL RANGE OF SIERRA NEVADA
MARK SOUTHERN LIMITS OF FOOTHILL METAMORPHIC RANGE (A) ON PHOTOGRAPH.
KLAMATH FALLS
LINDEN
AVENAL
KILOMETERS
500
400
300
200
100
0
A
LINDEN
KILOMETERS
200
100
0


B. KLAMATH FALLS TO FAIRCHILD AFB 700nm
ABBOTSFORD
4 SOUTHERN CASCADES GLACIER
3 PUGET SOUND
2 BLUE GLACIER
FAIRCHILD AFB
HOQUIAM
1 FOUR SNOW PEAKED MOUNTAINS
PORTLAND
KLAMATH FALLS
KILOMETERS
300
200
100
0


IV MT. RAINIER
KILOMETERS
0 10 20 30 40
II MT. ST. HELENS
KILOMETERS
0 4 8 12
HOQUIAM
IV
II
III
PORTLAND
I
KLAMATH FALLS
KILOMETERS
0 100 200 300 400 500
III MT. ADAMS
KILOMETERS
0 10 20 30
HOOD
RIVER
KILOMETERS
0 20 40
I MT. HOOD
KLAMATH FALLS—PORTLAND—HOQUIAM
1 FOUR SNOW PEAKED MOUNTAINS
A. PHOTOGRAPH FOUR SNOW PEAKED MOUNTAINS.
B. CAN YOU SEE GLACIERS AND FIRN LINES?

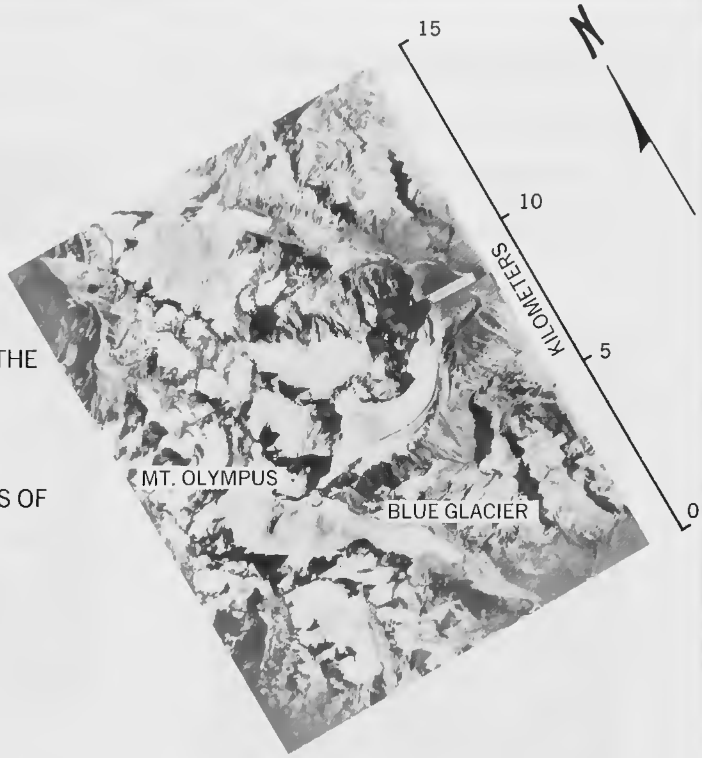
## HOQUIAM TO ABBOTSFORD

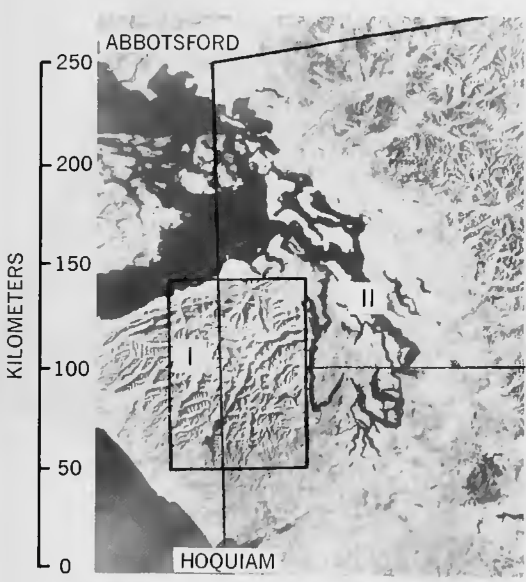
### (2) BLUE GLACIER

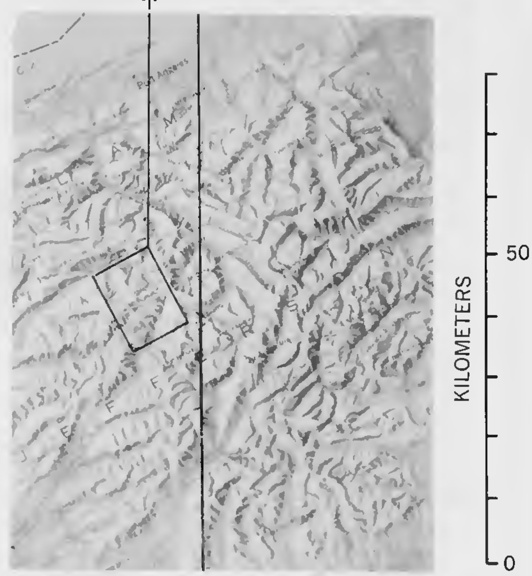
A. PHOTOGRAPH MT. OLYMPUS (I).
B. CAN YOU SEE BLUE GLACIER AND THE FIRN LINES?

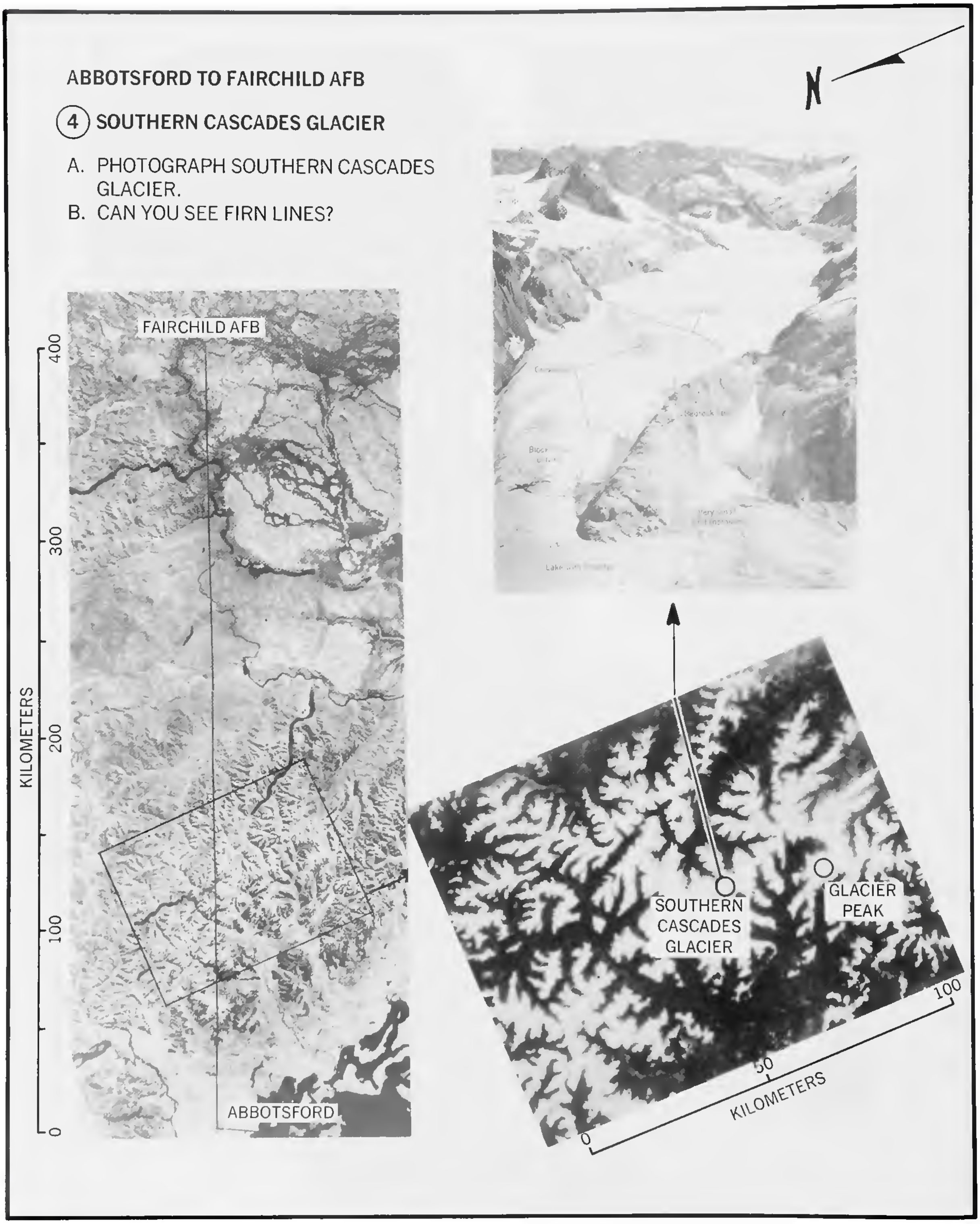
### (3) PUGET SOUND

A. DESCRIBE SUSPENDED SEDIMENTS OF PUGET SOUND (II).
B. CAN YOU SEE ANY GYRES THERE?




ABBOTSFORD TO FAIRCHILD AFB
4 SOUTHERN CASCADES GLACIER
A. PHOTOGRAPH SOUTHERN CASCADES GLACIER.
B. CAN YOU SEE FIRN LINES?
N
FAIRCHILD AFB
ABBOTSFORD
KILOMETERS
0
100
200
300
400
SOUTHERN CASCADES GLACIER
GLACIER PEAK
0
50
100
KILOMETERS

# Appendix 3

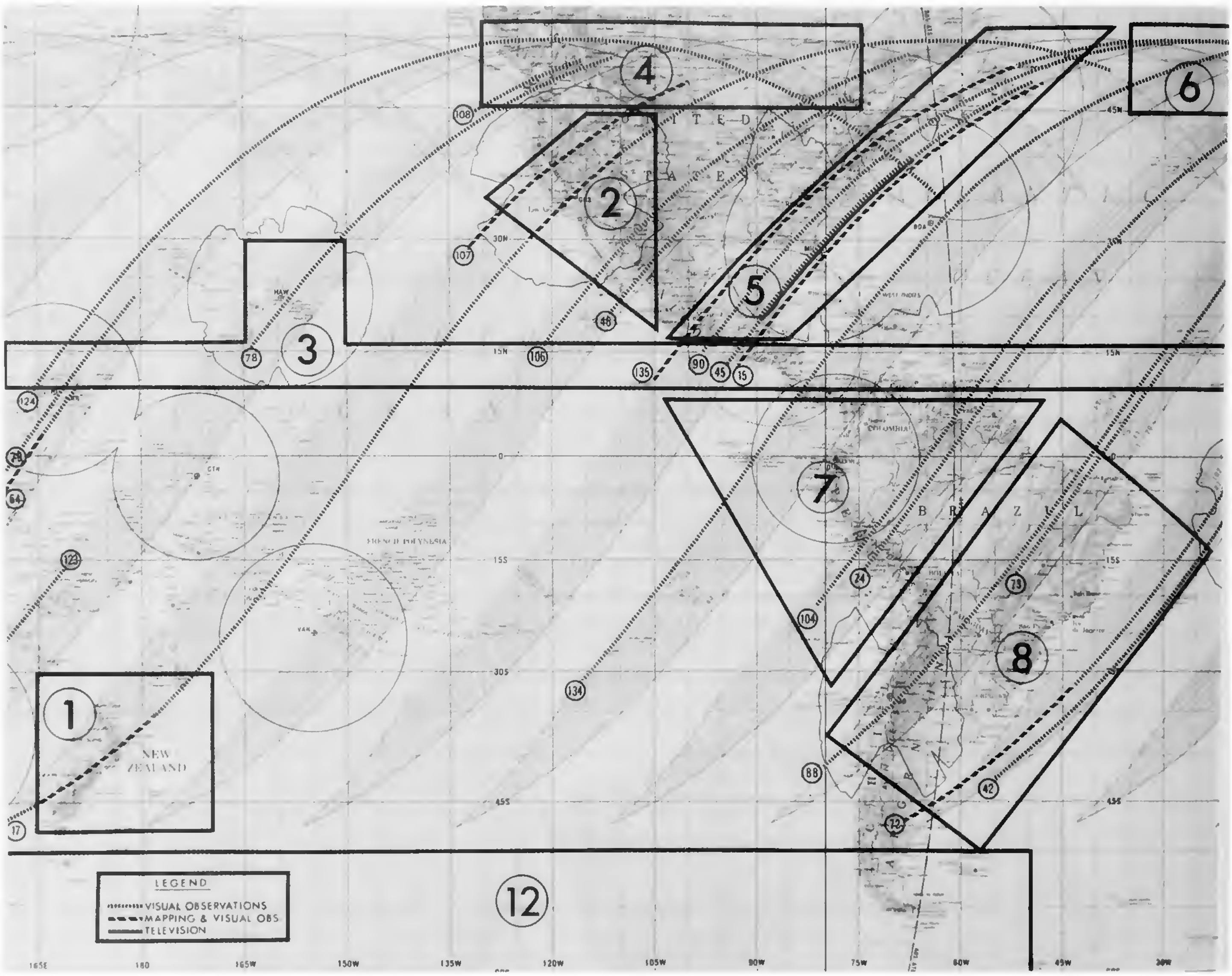
## "Earth Observations Book"

This appendix includes the basic document that the Apollo-Soyuz astronauts carried onboard the spacecraft in support of the Earth Observations and Photography Experiment. It contains all the necessary information on observation sites and camera configurations.

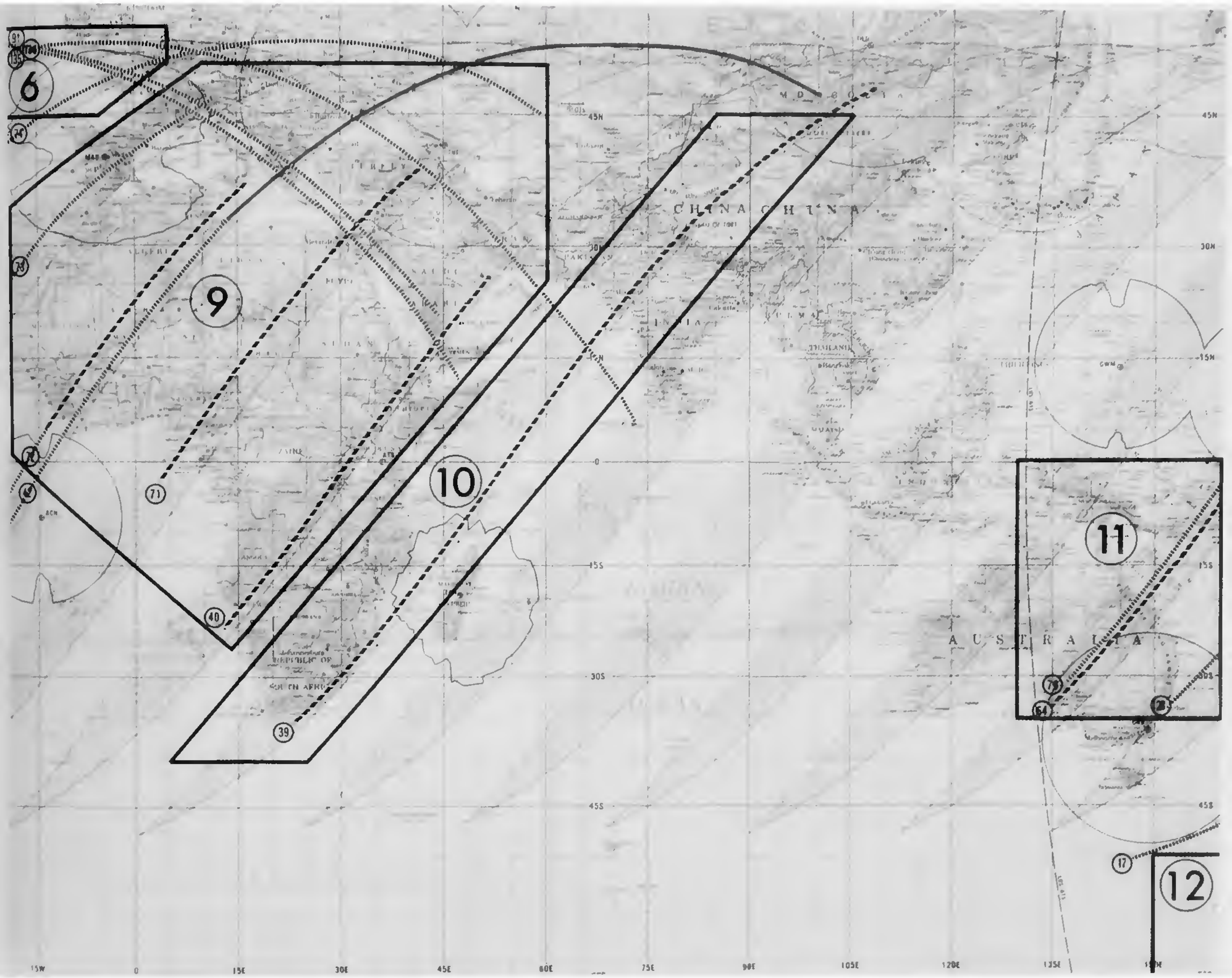
The first section of the "book" (pp. 310–322) includes a summary timeline, a stowage list, and a manifest of operational procedures. The sound and main section (pp. 323–394) includes summary pages for each of the 12 sites and detailed instructions on the 60 observation targets. As the mission progressed, many notations had to be added to the original art of this book, particularly of those features that were not familiar to the crew. Therefore, the illustrations represent an evolutionary progression of notations superimposed on the original visual aids. The last section of the book (pp. 395–400) is a concise reference and atlas of major Earth features and phenomena.

In the main section of the book, the sites and targets are arranged in numerical order. For a list of the observation targets refer to Table 5, and for remarks on the results of the observations, to Table 11 in the text. For an explanation of the camera data refer to the chapter on "flight planning." The list of abbreviations and acronyms and the glossary may also be helpful.

The illustration labeled "Ocean Floor" (p. 395) is a reduction of the "Floor of the Oceans," a map based on bathymetric studies by Bruce C. Heezen and Marie Tharp supported by the Office of Naval Research, published by the American Geographical Society of New York. The illustration labeled "Ocean Currents" (p. 397) is based on a map from a Britannica Atlas, published by Encyclopaedia Britannica, Inc. This appendix was published on 26 March 1975, by NASA and limited to internal distribution within the Lyndon B. Johnson Space Center, Houston, Texas, as the *ASTP Final Earth Observations Book.*




# WESTERN HEMISPHERE




EASTERN HEMISPHERE

# TIMELINE AND MAPPING PAD

## 1st and 2nd LAUNCH OPPORTUNITY

AC–★ ☆ ☆THIS PASS WILL BE SCHEDULED IN 1st OPP ONLY.☆ ☆
DP–□

### Rev. 15/16 M1

★ MAPPING CAMERA CONFIGURATION:
CM5/BLACK/60/CX13-BRKT,IVL 16 (f6.7,1/500),78 FR

GET 31:00

□ USE VOICE RECORDER & R/T COMM FOR VOICE COMMENTS

★ CONFIGURE DSE (HBR/RCO/FWD/CMD RESET) FOR IVL PULSE
★ M1 START (31:02:00)

05 — □ 5A ☐☐:☐☐:☐☐

□ 5B ☐☐:☐☐:☐☐

:10 — ★ MAPPING EXP CHG A: (f6.7,1/250) AT 31:10:00

□ 5C ☐☐:☐☐:☐☐

:15 — ★ M1 STOP (31:15:00)

★ LEAVE BLACK HDC IN WINDOW

DP–★ ☆ ☆THIS PASS WILL BE SCHEDULED IN 1st OPP ONLY.☆ ☆
CP–□

### Rev. 17/18 M2,M3

★MAPPING CAMERA CONFIGURATION:
CM5/BLACK/60/CX13-BRKT,IVL 10 (f6.7,1/250), 24FR

GET 33:35

★(HAVE 100mm LENS & CT02 MAG READY FOR CHANGE BEFORE M3)
□USE VOICE RECORDER & R/T COMM FOR VOICE COMMENTS

□ 12A

★CONFIGURE DSE (HBR/RCO/FWD/CMD RESET) FOR IVL PULSE
★M2 START (33:39:00)

:40 — □ 1 ☐☐:☐☐:☐☐

★M2 STOP (33:43:00) ☐☐:☐☐:☐☐
★CONFIGURE DSE
(LBR/RCO/FWD/CMD RESET)

:45

★RECONFIGURE MAPPING CAMERA:
CM5/BLACK/100/CT02-BRKT, IVL 6 (f4.7,1/250), 23FR

:50

□ 3A

:55

34:00

★M3 START (34:04:00) ☐☐:☐☐:☐☐

:05 — □ 2A

★M3 STOP (34:06:20) ☐☐:☐☐:☐☐

★LEAVE BLACK HDC IN WINDOW
★STOW BLACK CX13 IN U1 FOR LATER USE

DP

### Rev. 39 M4

STOW SILVER CX10 IN F1
STOW BLACK CT02 IN F2
MAPPING CAMERA CONFIGURATION:
CM5/BLACK/60/CT03-BRKT, IVL 10 (f5.6,1/125), 170FR

USE VOICE RECORDER FOR VOICE COMMENTS

67:40

M4 START (67:41:00)

10A ☐☐:☐☐:☐☐

:45

10B

:50

10C

:55 ☐☐:☐☐:☐☐

MAPPING EXP CHG A: (f5.6,1/250) AT 67:58:00

68:00

10D

M4 STOP (68:03:30)
~~MAPPING EXP CHG B: (f6.7,1/125) AT 68:04:00~~

:05

10E ☐☐:☐☐:☐☐

:10

~~M4 STOP (END OF MAGAZINE)~~
LEAVE BLACK HDC IN WINDOW

DP

### Rev. 40 M5

STOW BLACK CT03 IN F1
MAPPING CAMERA CONFIGURATION:
CM5/BLACK/60/CT02-BRKT, IVL 10 (f5.6,1/125), 96FR

USE VOICE RECORDER FOR VOICE COMMENTS

M5 START (69:14:00)

69:15 ☐☐:☐☐:☐☐

:20

:25 ☐☐:☐☐:☐☐

9A

MAPPING EXP CHG A: (f5.6,1/250) AT 69:26:00
CHANGE TO WINDOW CM5

9B

:30

M5 STOP (69:30:00) ☐☐:☐☐:☐☐
STOW BLACK HDC & BRACKET

# TIMELINE AND MAPPING PAD

## 1st and 2nd LAUNCH OPPORTUNITY

DP

## Rev. 42

(HAVE SILVER MAG IF01 AND ORANGE FILTER READY FOR CHANGE BEFORE 9H)
USE VOICE RECORDER FOR VOICE COMMENTS

72:05
— 8A
:10
— 3A
:15

RECONFIGURE SILVER CAMERA (CHG MAG TO IF01)
(INSTALL ORANGE FILTER)

:20
— 9H
:25
— 9I
— 9J
:30

STOW SILVER IF01 IN F1
INSTALL CX11 ON SILVER HRC

DP

## Rev. 45/46

USE VOICE RECORDER FOR VOICE COMMENTS

78:20
— 5D
— 5A
— 5E

TV TOUR OF FLORIDA & U.S. EAST COAST

:25
— 5F
:30
— 5C

CP

## Rev. 46

USE VOICE RECORDER FOR VOICE COMMENTS

79:50
— 2E
:55
— 4D
80:00

AC-★
CP-□

## Rev. 64 M6

★ STOW BLACK CT02 IN F2
□ STOW SILVER CX11 IN F1
★ MAPPING CAMERA CONFIGURATION:
CM5/BLACK/60/CT04-BRKT, IVL 10 (f5.6,1/125), 72FR

□ USE VOICE RECORDER FOR VOICE COMMENTS
★ CONFIGURE OSE (H8R/RCD/FWD/CMD RESET) FOR IVL PULSE
★ M6 START (107:40:00)

107:40
— □ 11C [ ][ ][ ] : [ ][ ] : [ ][ ]
:45
— □ 11B
:50
— □ 3A [ ][ ][ ] : [ ][ ] : [ ][ ]
★ M6 STOP (107:52:00)

★ CONFIGURE OSE (STOP/CMD RESET)
★ LEAVE BLACK HDC IN WINDOW
:55

DP-★
CP-□

## Rev. 71 M7

★ MAPPING CAMERA CONFIGURATION:
CM5/BLACK/60/CT04-BRKT, IVL 10 (f5.6,1/125), 84FR

118:10
□ USE VOICE RECORDER FOR VOICE COMMENTS

★ M7 START (118:12:00) [ ][ ][ ] : [ ][ ] : [ ][ ]
— □ 9C
:15
★ MAPPING EXP CHG A: (f5.6,1/250) AT 118:16:00
— □ 9D [ ][ ][ ] : [ ][ ] : [ ][ ]
:20
— □ 9E [ ][ ][ ] : [ ][ ] : [ ][ ]
— □ 9F
★ MAPPING EXP CHG B: (f5.6,1/125) AT 118:24:00
:25
— □ 9G
★ M7 STOP (118:26:00)
★ LEAVE BLACK HDC IN WINDOW

# TIMELINE AND MAPPING PAD

## 1st and 2nd LAUNCH OPPORTUNITY

AC–★
DP–□

## Rev. 72 M8,M9

★ STOW BLACK CT04 IN F1
★ MAPPING CAMERA CONFIGURATION:
CM5/BLACK/6D/CX13-BRKT, IVL 10 (f8,1/125), 36FR

□ DAC CAMERA CONFIGURATION:
CM3/DAC/25/CT01/6 fps (f8,1/125), 11 minutes

★ (HAVE 100mm LENS & CT05 MAG READY FOR CHANGE BEFORE M9)
□ USE VOICE RECORDER FOR VOICE COMMENTS
★ CONFIGURE DSE (HBR/RCD/FWD/CMD RESET) FOR IVL PULSE

119:25 — □★ 12A, M8 START (119:25:00)

□ 8A

:30 — ★ M8 STOP (119:31:00)

★ RECONFIGURE MAPPING CAMERA:
CM5/BLACK/100/CT05-BRKT, IVL 6 (f5.6,1/250), 110 FR

:35

:40

★□ M9 & DAC START (119:43:00)

:45

□ DAC: 9H,9I,9J

:50

★ MAPPING EXP CHG A: (f4,1/250) AT 119:52:00

★□ M9 & DAC STOP (119:54:00)
★ STOW BLACK HOC AND BRACKET

:55

□ STOW CT01 IN F2 FOR USE LATER
★ STOW BLACK CX13 IN F1

AC

## Rev. 73

STOW SILVER CX12 IN F1
USE VOICE RECORDER & R/T COMM FOR VOICE COMMENTS

121:05

:10 — 3A

:15

:20 — 9K

:25 — 9L

AC

## Rev. 74

USE VOICE RECORDER & R/T COMM FOR VOICE COMMENTS

122:35 — 7B

:40 — 7C

:45

:50 — 6A ← ☆ THIS PASS WILL STOP HERE ☆ ☆ DURING NO ATS CASE ONLY. ☆

:55 — 6B

123:00

:05

AC

## Rev. 74/75

☆ THIS PASS WILL BE SCHEDULED ☆ IN NO ATS CASE ONLY. ☆

USE VOICE RECORDER FOR VOICE COMMENTS

124:00 — 3A

:05 — 7F

:10 — 3B, 5D

:15 — 7G

:20

DP

## Rev. 78

USE VOICE RECORDER FOR VOICE COMMENTS

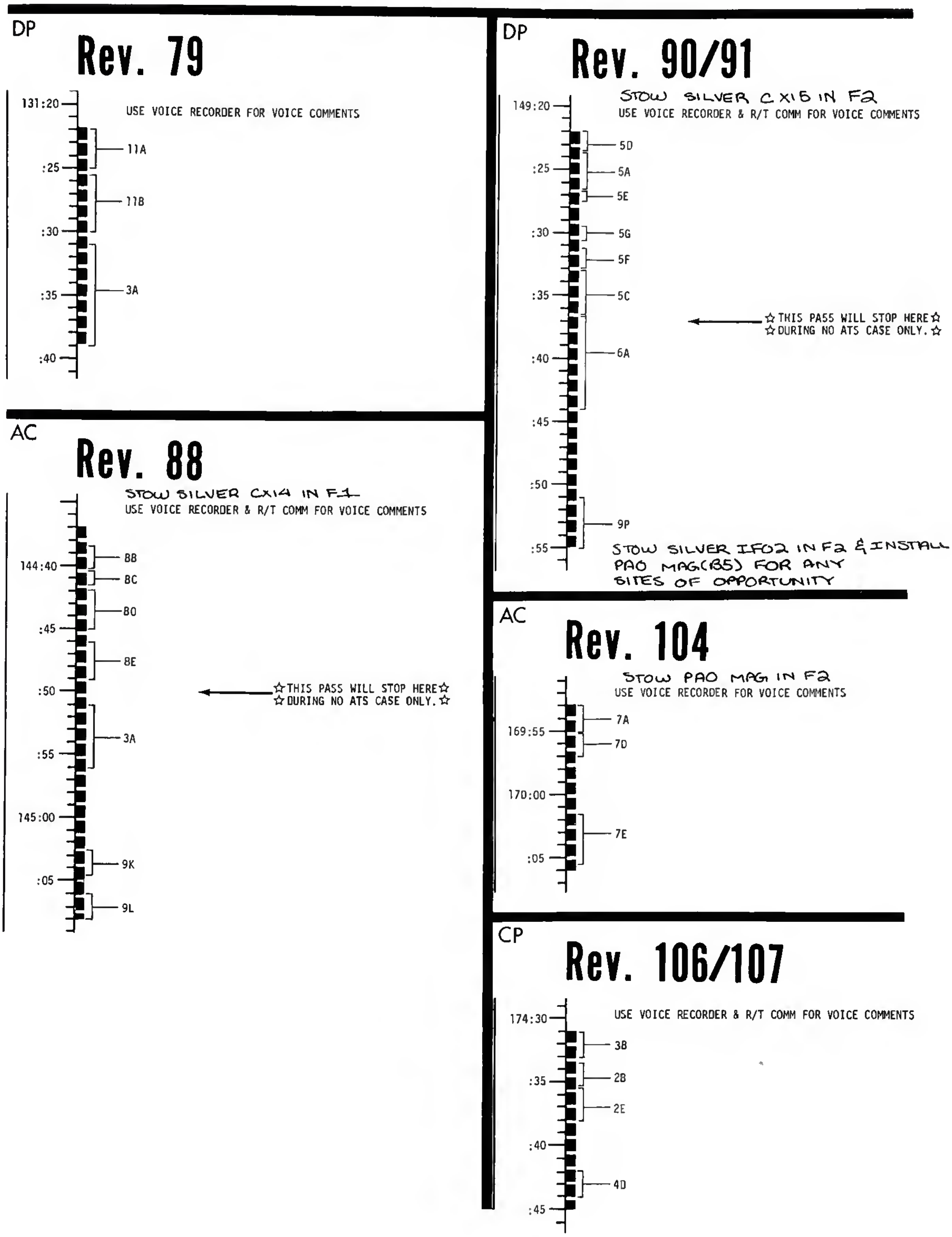
130:10 — 3C

:15

:20 — 4A

# TIMELINE AND MAPPING PAD

## 1st and 2nd LAUNCH OPPORTUNITY

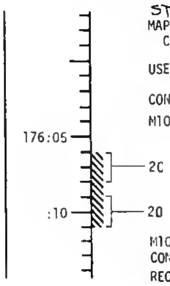


# TIMELINE AND MAPPING PAD

## 1st LAUNCH OPPORTUNITY

CP

## Rev. 107 M10




STOW SILVER CX15 IN F1
MAPPING CAMERA CONFIGURATION:
CMS/SILVER/SO/CX16-BRKT,IVL 10 (f4,1/250), 30FR

USE VOICE RECORDER FOR VOICE COMMENTS

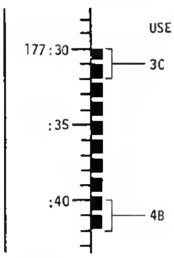
CONFIGURE DSE (HBR/RCD/FWD/CMD RESET) FOR IVL PULSE

M10 START (176:06:00)

M10 STOP (176:11:00)
CONFIGURE DSE (LBR/CMD RESET)
RECORD LAST FR NO: PAGE 5

CP

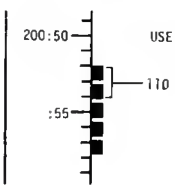
## Rev. 108




USE VOICE RECORDER FOR VOICE COMMENTS

DP

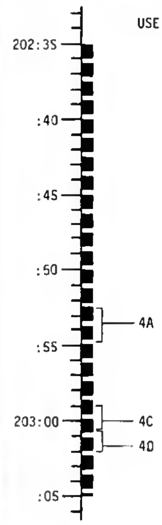
## Rev. 123




USE VOICE RECORDER FOR VOICE COMMENTS

CP

## Rev. 124




USE VOICE RECORDER FOR VOICE COMMENTS

# TIMELINE AND MAPPING PAD

## 1st LAUNCH OPPORTUNITY

AC

## Rev. 134/135

STOW SILVER CX16 IN F1

USE VOICE RECORDER FOR VOICE COMMENTS

PET
94:20 (218:38 GET)
:25
:30 — 7F
:35 — 7G
:40
:45 — 6A
:50 — 6B
:55 — 9M
CHANGE TO WINDOW CM5
95:00 — 9N
CHANGE TO WINDOW CM3
:05 — 9P
:10

DP-★
CP-□

## Rev. 135/136 M11

★ STOW BLACK CT05 IN F1

★ MAPPING CAMERA CONFIGURATION: CM5/BLACK/60/CT06-BRKT, IVL 10 (f5.6,1/125), 90FR

□ USE VOICE RECORDER FOR VOICE COMMENTS

□ (HAVE SILVER MAG IF02 AND ORANGE FILTER READY FOR CHANGE BEFORE 9L)

★ CONFIGURE OSE (HBR/RCO/FWD/CMO RESET) FOR IVL PULSE

★ M11 START (96:02:00 PET)

PET
96:00 (220:18 GET)
□ 3B [ ][ ]:[ ][ ]:[ ][ ]
:05 □ 5A
:10 □ 5G
□ 5F
:15
★ M11 STOP (96:17:00 PET) [ ][ ]:[ ][ ]:[ ][ ]
:20 □ 6A
□ RECONFIGURE SILVER CAMERA: (CHANGE MAG TO IF02) (INSTALL ORANGE FILTER)
:25 □ 9L
□ 9O
:30
:35 □ 9P
:40
★ STOW BLACK HDC & BRACKET

# VISUAL OBS FILM BUDGET (SILVER HRC)

| | HASSELBLAD MAGAZINES—70 FR/MAG | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CX10 (U1) | | | IF01 (A6) | | | CX11 (A6) | | | CX12 (A6) | | | CX14 (A6) | | |
| | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG |
| REV 15/16 | 15 | 15 | ____ | | | | | | | | | | | | |
| REV 17/18 | 49 | 64 | ____ | | | | | | | | | | | | |
| REV 39 | | | | 32 | 32 | ____ | | | | | | | | | |
| REV 40 | | | | 12 | 44 | ____ | | | | | | | | | |
| REV 42 | | | | 18 | 62 | ____ | 9 | 9 | ____ | | | | | | |
| REV 45/46 | | | | | | | 30 | 39 | ____ | | | | | | |
| REV 46 | | | | | | | 9 | 48 | ____ | | | | | | |
| REV 64 | | | | | | | | | | 12 | 12 | ____ | | | |
| REV 71 | | | | | | | | | | 24 | 36 | ____ | | | |
| REV 72 | | | | | | | | | | 12 | 48 | ____ | | | |
| REV 73 | | | | | | | | | | | | | 15 | 15 | ____ |
| REV 74 | | | | | | | | | | | | | 15 | 30 | ____ |
| REV 78 | | | | | | | | | | | | | 9 | 39 | ____ |
| REV 79 | | | | | | | | | | | | | 15 | 54 | ____ |

# VISUAL OBS FILM BUDGET (SILVER HRC)

| | HASSELBLAD MAGAZINES—70 FR/MAG | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CX15 (A6) | | | IF02 (A6) | | | CX16 (A6) | | | CX17 (A6) | | |
| | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG | FRAMES/PASS | MAG COUNTER SCHED. | MAG COUNTER LOG |
| REV 88 | 36 | 36 | ____ | | | | | | | | | |
| REV 90/91 | | | | 53 | 53 | ____ | | | | | | |
| REV 104 | 12 | 48 | ____ | | | | | | | | | |
| REV 106/107 | 21 | 69 | ____ | | | | | | | | | |
| REV 107 | | | | | | | 30 | 30 | ____ | | | |
| REV 108 | | | | | | | 6 | 36 | ____ | | | |
| REV 123 | | | | | | | 6 | 42 | ____ | | | |
| REV 124 | | | | | | | 15 | 57 | ____ | | | |
| REV 134/135 | | | | | | | | | | 38 | 38 | ____ |
| REV 135/136 | | | | 9 | 62 | ____ | | | | 30 | 68 | ____ |

| | HASSELBLAD PAO MAGAZINES—70 FR/MAG | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CX06 (B5) | | CX07 (B5) | | CX08 (B5) | | CX09 (B5) | |
| REV ____ | | ____ | | ____ | | ____ | | ____ |
| REV ____ | | ____ | | ____ | | ____ | | ____ |
| REV ____ | | ____ | | ____ | | ____ | | ____ |
| REV ____ | | ____ | | ____ | | ____ | | ____ |
| REV ____ | | ____ | | ____ | | ____ | | ____ |
| REV ____ | | ____ | | ____ | | ____ | | ____ |

# OPERATIONAL STOWAGE

LAUNCH STOWAGE FOR EQUIPMENT USED IN EARTH OBSERVATIONS

**BLACK SYSTEM**

Hasselblad data camera system:
- HDC..................B3
  - 60 MM lens..........B5
  - 100 MM lens.........B5
  - Film magazines:
    - CT02.............B3 (on HDC)
    - CT03,4,5.........A6
    - CT06.............U1
    - CX13.............U1
  - Camera mount........A6
  - TM cable............A6
  - Ringsight...........B3

Intervalometer.........A6

Spotmeter.............B3

Voice recorder-Sony....A4
- Cassettes............A4
- Batteries............A4

Spotting Scope.........A1

Nikon camera system:
- 35 MM Nikon..........B2
- 35 MM lens...........B2
- 300 MM lens...........A5
- 300 MM bracket........A5
- Film cassettes........B2, B5
- Cable release.........B2

**SILVER SYSTEM**

Hasselblad reflex camera system:
- HRC....................B5
  - 50 MM lens............B5
  - 250 MM lens...........B5
  - Film magazines:
    - CX06...............B5 (on HRC)
    - CX07,8,9...........B5
    - CX10...............U1
    - CX11,12,14.........A6
    - CX15,16,17.........A6
    - IF01,02............A6
  - Orange Filter.........B5

16 MM data aquisition camera system:
- DAC.....................B3
  - 10 MM lens.............B5
  - 25 MM lens.............B3
  - 75 MM lens.............B3
  - Film mag CT01 .........D3
  - Camera mount...........U2
  - Mirror.................B3
  - Power cable............B3
  - Timing cable...........A6

Flight data file:
- Earth Observation book.R3
- World Map Pack.........A2
- Color Wheel............R3
- Orbital slider map.....R3

NOTE: CAMERA EQUIPMENT NEEDED FOR EACH DAY WILL BE STOWED IN F2 DURING POST-SLEEP CHECKOUT ACTIVITY.

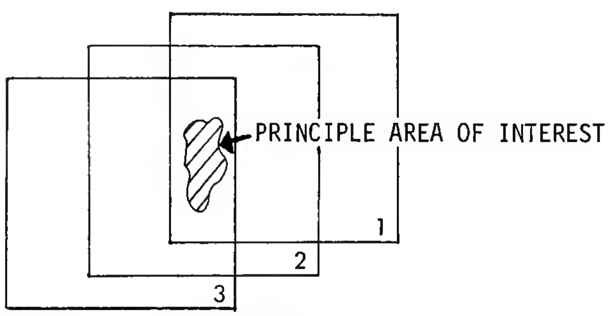
## INFORMATION TO BE RECORDED ON VOICE RECORDER

(Transmit this information concurrently on real-time voice or on DSE if these communication modes are available.)

1. MAGAZINE NUMBER IN HRC - at beginning of each pass.
   (Record magazine number in HDC if different from scheduled.)
2. SITE NUMBER OF EACH VISUAL OBS SITE
3. GET OF EACH VISUAL OBSERVATION
4. CAMERA SETTINGS - if different from scheduled.
5. COMMENTS:
   a. Answer as many questions as possible for each site in same order as listed in book.
   b. Give color wheel number when making a color comparison.
   c. Make any additional observations which is felt may add to scientific knowledge in the site area.
6. FRAME COUNT OF HRC - at end of each pass.

---

## PROCEDURE FOR TAKING A SET OF 3 STEREO PHOTOS




A. HOLD CAMERA AT APPROXIMATELY THE SAME ANGLE.
B. TAKE FIRST FRAME WHEN AREA OF INTEREST IS ON ONE SIDE OF CAMERA FIELD OF VIEW
C. TAKE SECOND FRAME WHEN AREA IS IN CENTER OF CAMERA FIELD OF VIEW
D. TAKE THIRD FRAME WHEN AREA IS ON OTHER SIDE OF CAMERA FIELD OF VIEW

[FRAME INTERVAL: 5 SECONDS]

# CAMERA SETUP PROCEDURES

SETUP FOR MAPPING CAMERA:

1. Install HDC Earth Obs camera mount (A6) in window CM5. (Remove R12)
2. Install specified lens (B5) on HDC (B3).
3. Install specified film magazine(U1,A6).(CT02 on camera at launch)
4. Mount camera/lens to mount.
5. SCI INST PWR-OFF (PNL 227).
6. Attach TM cable (A6) to PNL 227.
7. Connect intervalometer (A6) to TM cable.
8. Connect TM cable to HDC.
9. SCI INST PWR-PWR (PNL 227).
10. Set exposure for first picture sequence.

SETUP FOR REFLEX CAMERA:

1. Install specified lens (B5) on HRC (B5)
2. Install specified film magazine (U1, B5,A6).
3. Set exposure for first visual observation site.

---

# VOICE RECORDER
## OPERATION PROCEDURES

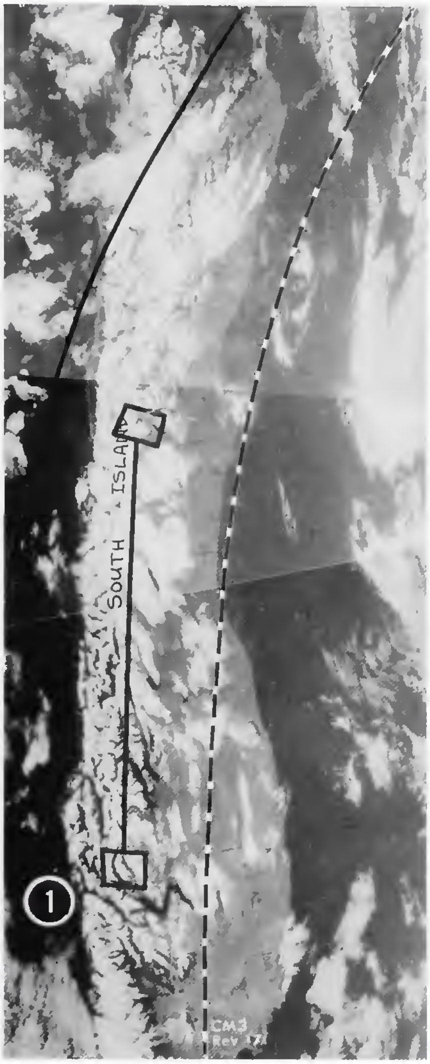
1. Remove tape cassette from tape cassette kit. (Use cassettes in following order: MA136-1,2,3,4,5,6,7,8,9)
2. Remove spool lock from tape cassette.
3. Install cassette in recorder with side 1 up.
4. Set counter to 000.
5. Set REC MUSIC/SPEECH to SPEECH.
6. Set START/STOP FRONT SWITCH to STOP.
7. Perform battery check.
8. To start recorder, simultaneously depress REC and FWD buttons.
9. Set FRONT SWITCH to START. Wait 4 seconds before making voice comments on a new side of tape. (This switch can be temporarily placed to STOP during periods of silence during a pass to save tape.)
10. At completion of Earth Obs comments depress STOP button on top of recorder. (Recorder will automatically stop at end of tape.)

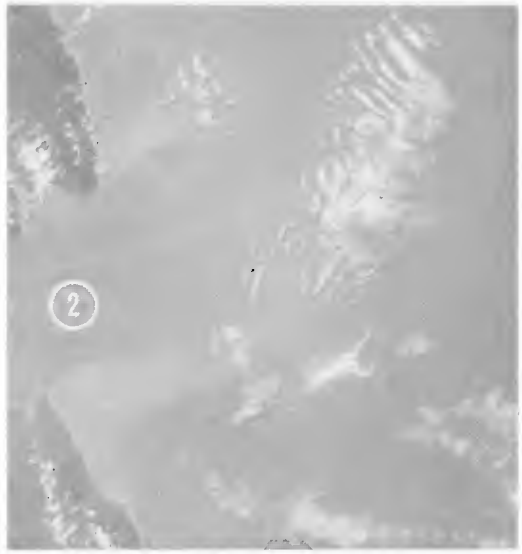
    NOTE: Use START/STOP FRONT SWITCH only for momentary pause.

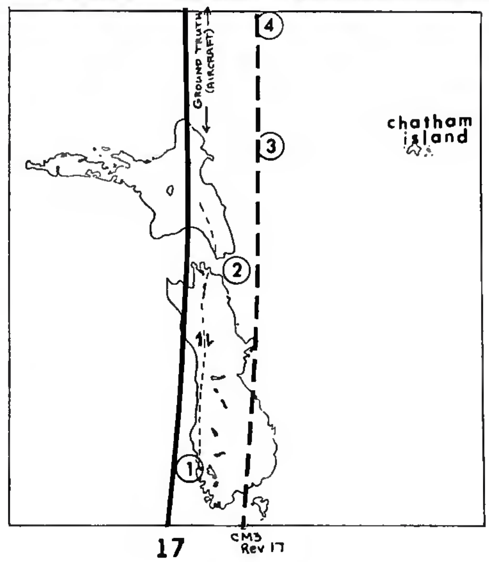
11. When a cassette side is completely recorded, mark cassette to avoid recording over that side.

# SITE 1: NEW ZEALAND

17






17

1. OBTAIN 19 PHOTOGRAPHS OF THE ALPINE FAULT ALONG SOLID BLACK LINE. (Photo strip) (FRAME INTERVAL: 2 SECS)

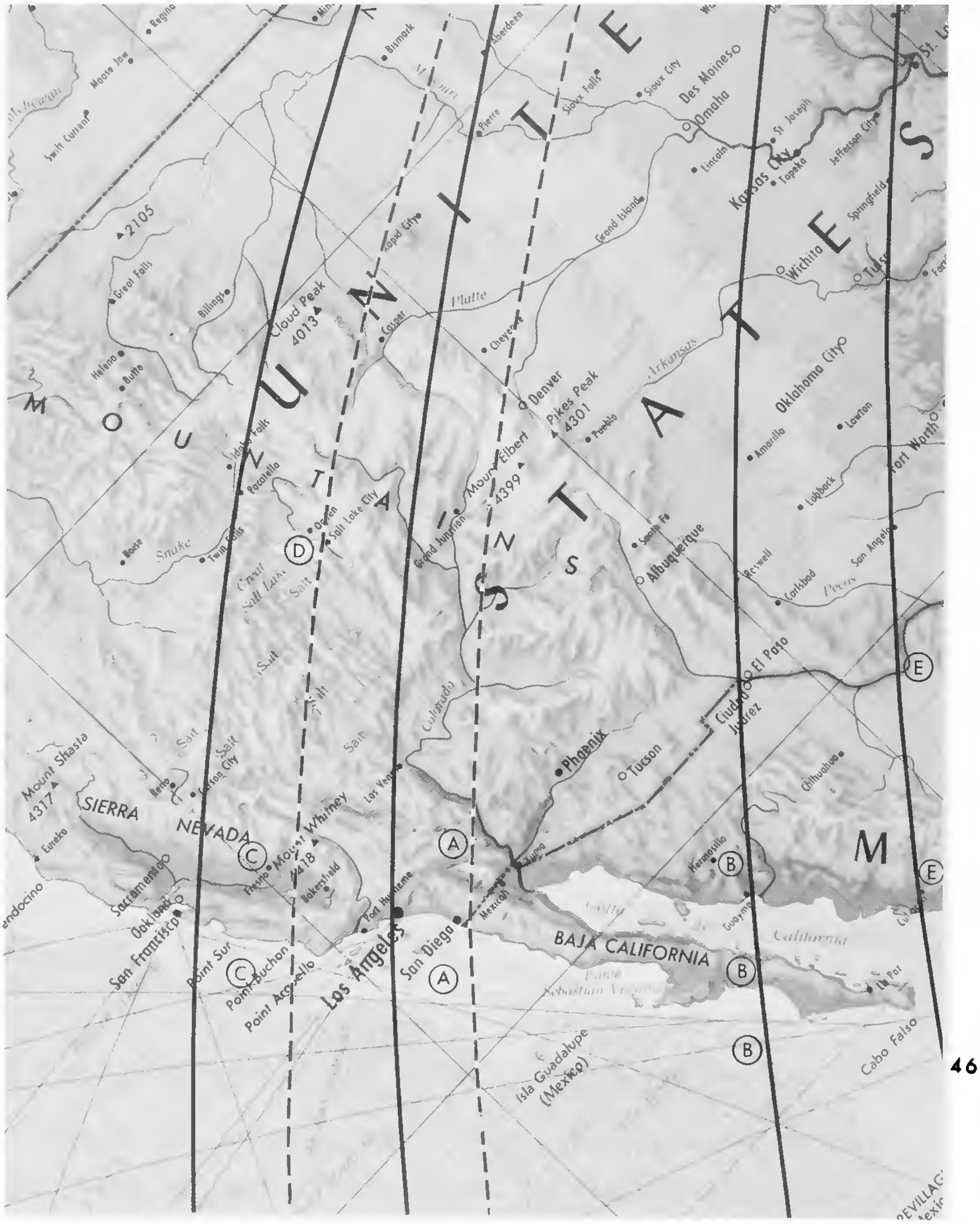
2. CAN YOU SEE INTERNAL WAVES BETWEEN THE TWO ISLANDS? NOTE ORIENTATION AND SIZE.

3. IF YOU CAN SEE PLANKTON BLOOMS E-NE OF THE ISLANDS, MARK LOCATION ON SKETCH.

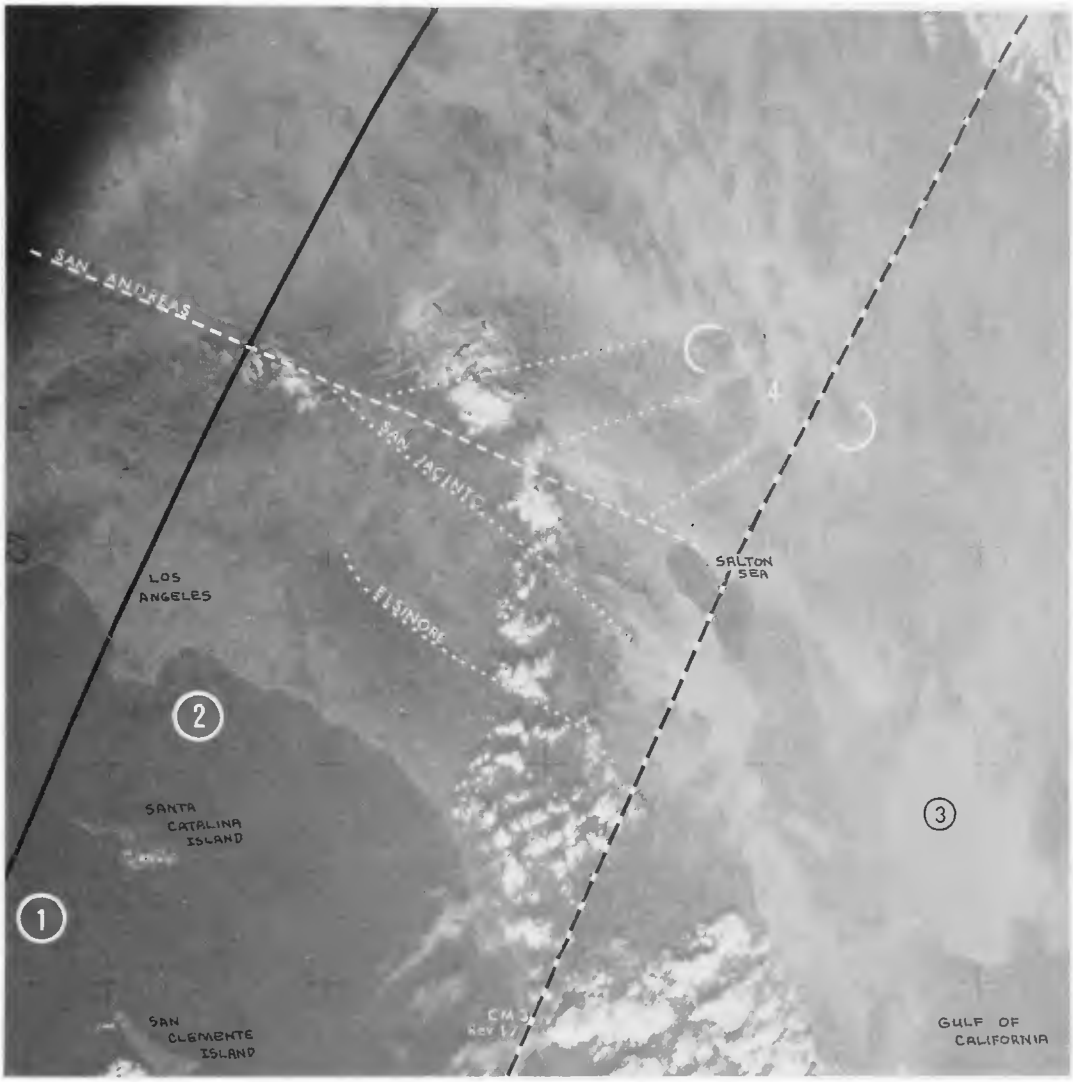
4. USE COLOR CHART TO DEFINE WATER COLOR OF THE SOUTH PACIFIC; MARK G.E.T.

REV 17: CM3/SILVER/250/CX10(f6.7,1/250) 22FR,[NEXT SITE: 3A]

# SITE 2: SOUTHWESTERN UNITED STATES



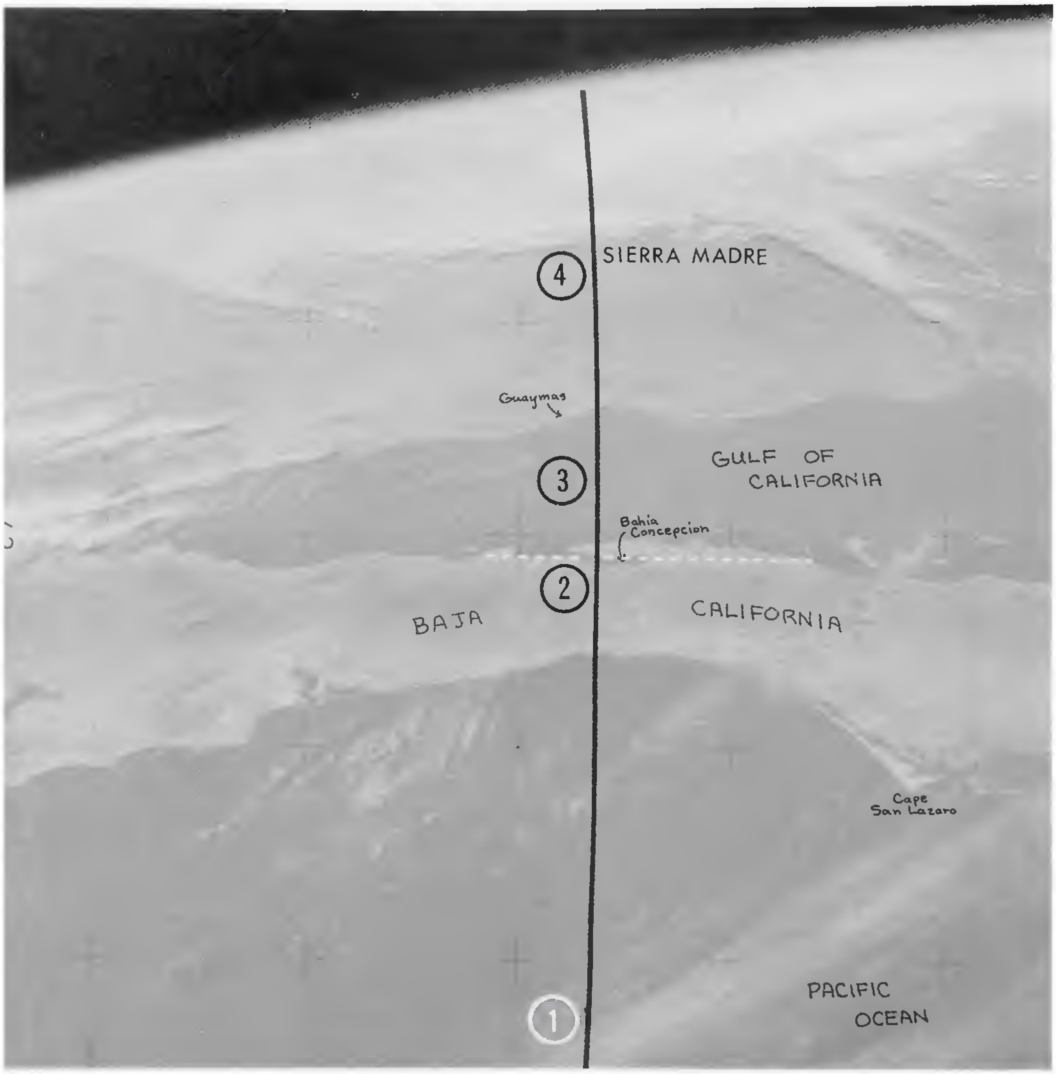
# 2A: SOUTHERN CALIFORNIA




1. CAN YOU SEE AN OCEAN CURRENT BOUNDARY? MARK LOCATION IF POSSIBLE.
2. IS ANY RED TIDE VISIBLE OFF THE COAST? MARK LOCATION OF BLOOM.
3. USE COLOR CHART TO DEFINE COLOR OF GRAN DESIERTO.
4. ARE THERE OTHER DESERT VARNISHED HILLS THAN THE FOUR MARKED?

REV 17: CM3/SILVER/250/CX10(f9.5,1/500) 9FR, [RECORD LAST FR NO: PAGE 4]

# 2B: BAJA CALIFORNIA




**106**

1. USE COLOR CHART TO DEFINE PACIFIC WATER COLOR.

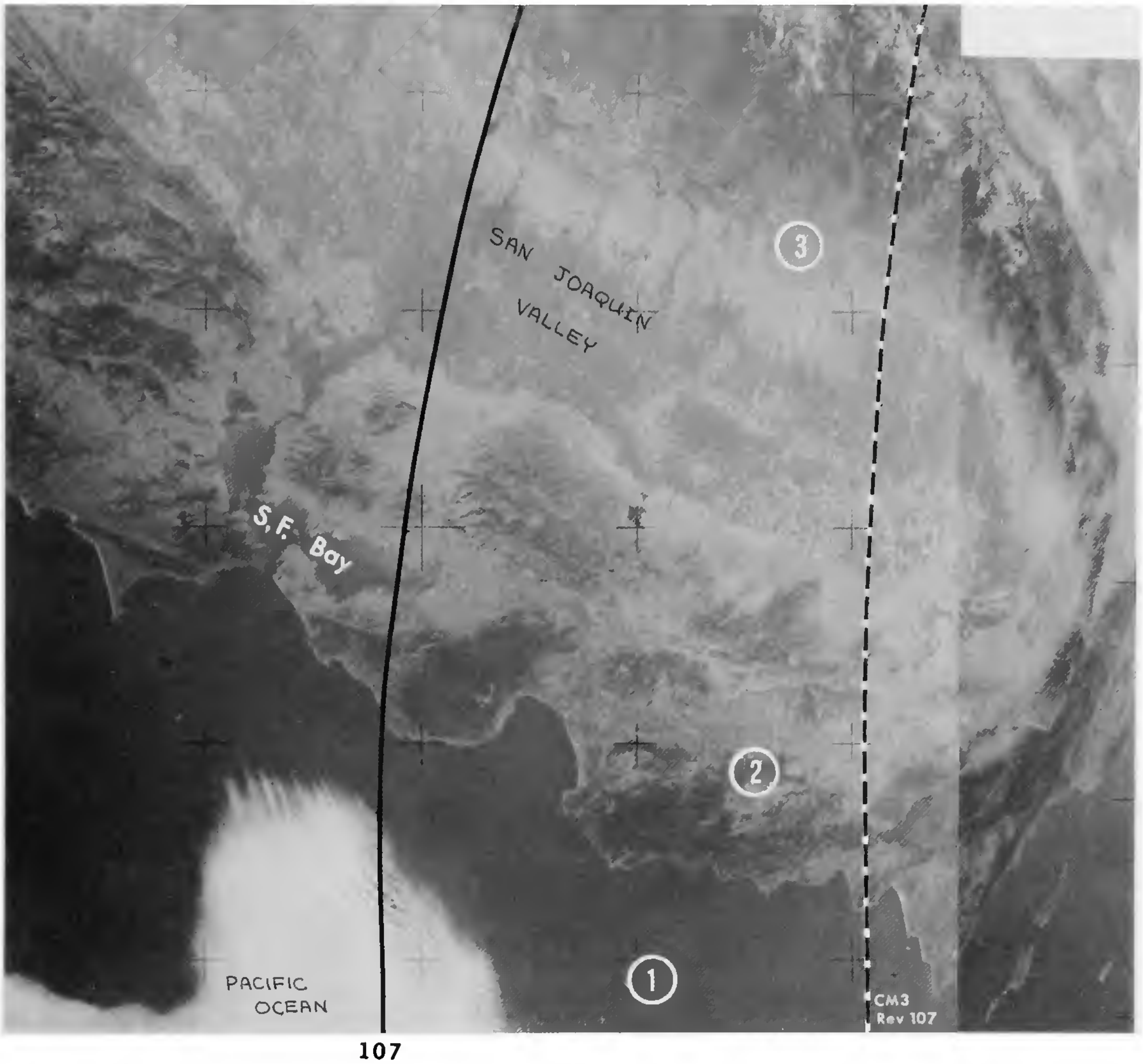
2. PHOTOGRAPH BAHIA CONCEPCION FAULT AND PARALLEL STRUCTURES. (3 STEREO FRAMES PER TARGET)

3. ARE THERE ANY INTERNAL WAVES IN THE GULF OF CALIFORNIA?

4. PHOTOGRAPH SLATY-GREY ROCK EXPOSURES AND STRUCTURES IN THE SIERRA MADRE. (3 STEREO FRAMES PER TARGET)

REV 106: CM3/SILVER/250/CX15(f8,1/500) 9FR,[NEXT SITE: 2E]

# 2C: CALIFORNIA CURRENT




1. USE COLOR CHART TO DEFINE PACIFIC WATER COLOR; MARK ANY COLOR BOUNDARIES.

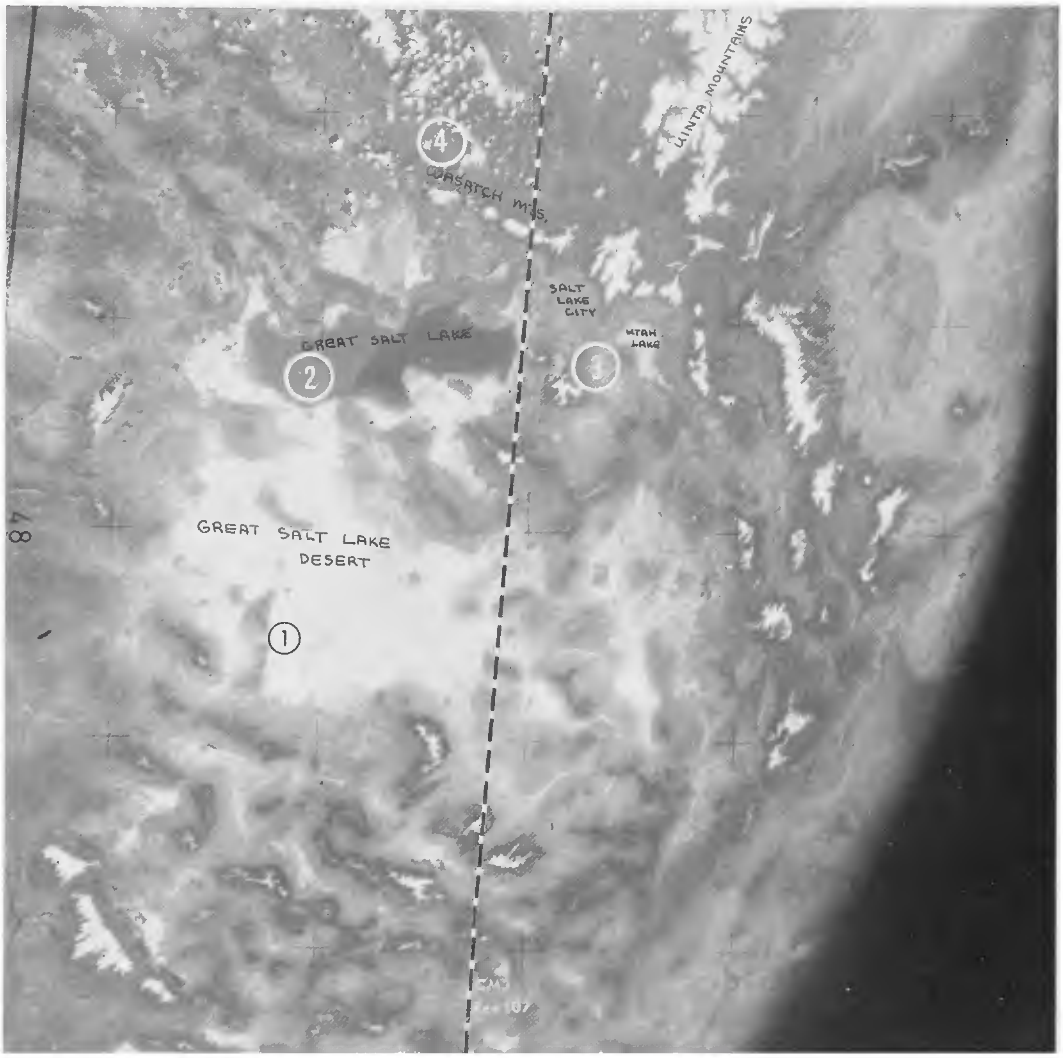
2. DESCRIBE PARALLEL FAULTS WEST OF SAN ANDREAS.

3. MARK SOUTHERN LIMITS OF FOOTHILL METAMORPHIC RANGE ON PHOTOGRAPH.

REV 107: CM3/VIS OBS COMMENTS ONLY [NEXT SITE: 2D]

# 2D: GREAT SALT LAKE

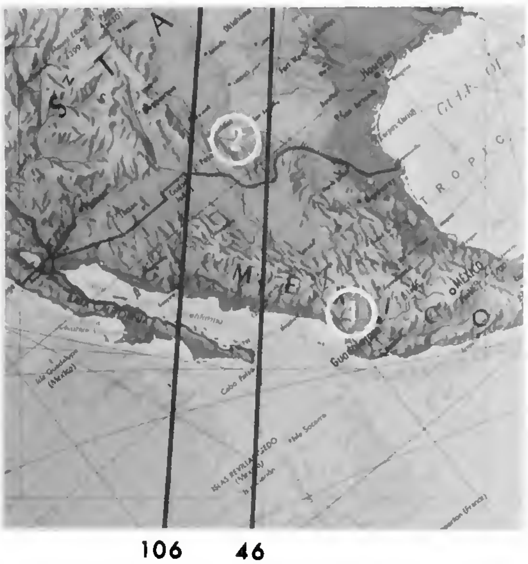
107




1. WITHOUT SCOPE CAN YOU SEE THE BONNEVILLE TRACK?
2. ARE THERE ANY COLOR BOUNDARIES OR SEDIMENT PLUMES WITHIN THE TWO HALVES OF THE LAKE?
3. DESCRIBE OXIDATION COLORS IN AREA OF BINGHAM COPPER MINE.
4. DESCRIBE ANY SNOW COVER OVER THE WASATCH MOUNTAINS.

<u>REV 107</u>: CM3/VIS OBS COMMENTS ONLY

# 2E: GUADALAJARA





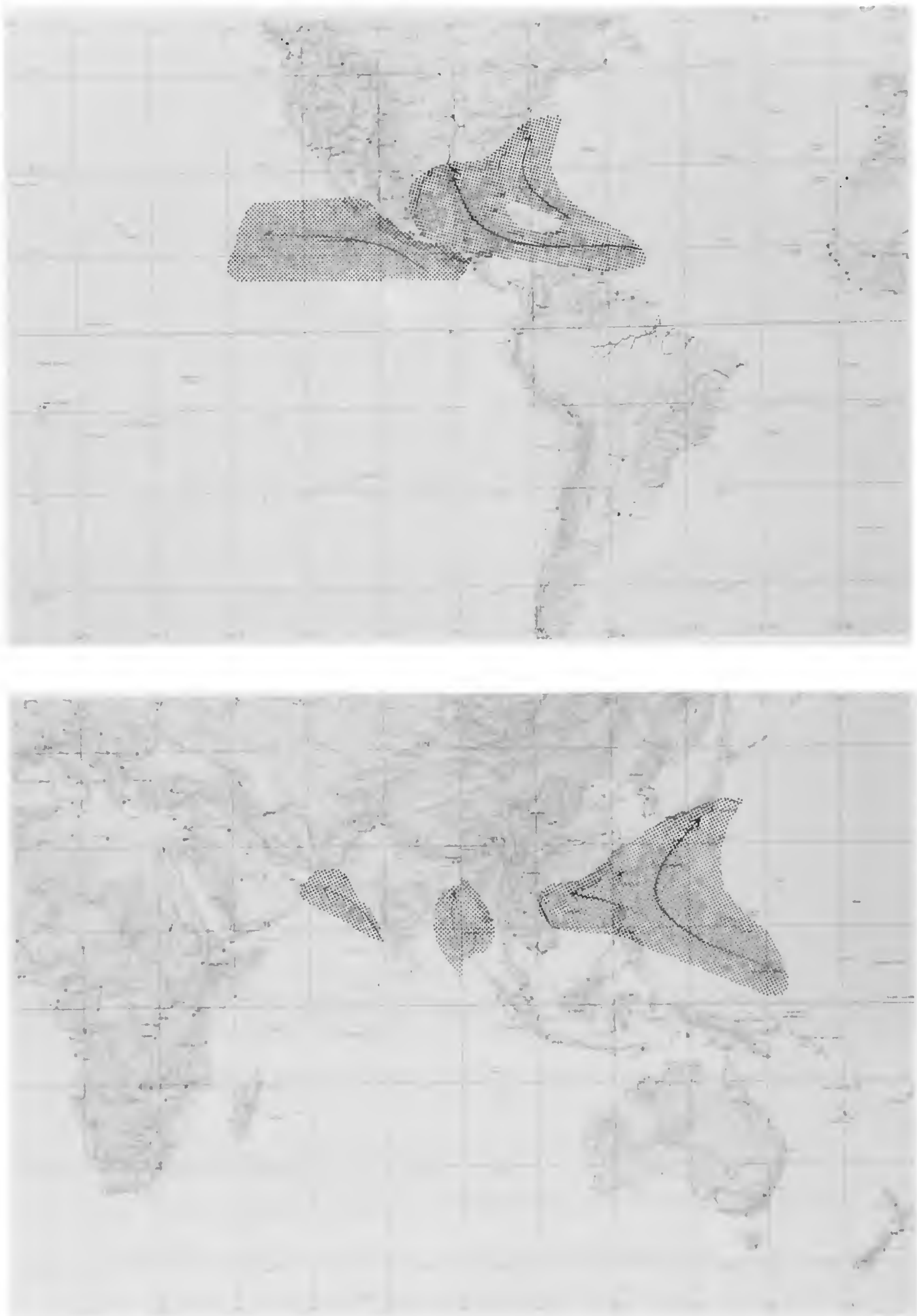
1. OBSERVE TERRAIN ON SOUTH SIDE OF GROUNDTRACK. PHOTOGRAPH MAJOR FAULT LINES IN AREA OF GUADALAJARA. KEEP IN MIND POSSIBLE INTERSECTION OF THREE MAJOR SETS.

2. PHOTOGRAPH STRUCTURES IN BIG BEND NATIONAL PARK AREA. (3 STEREO FRAMES PER TARGET)

REV 46: CM1/SILVER/50/CX11(f9.5,1/500) 6FR,[NEXT SITE: 4D]

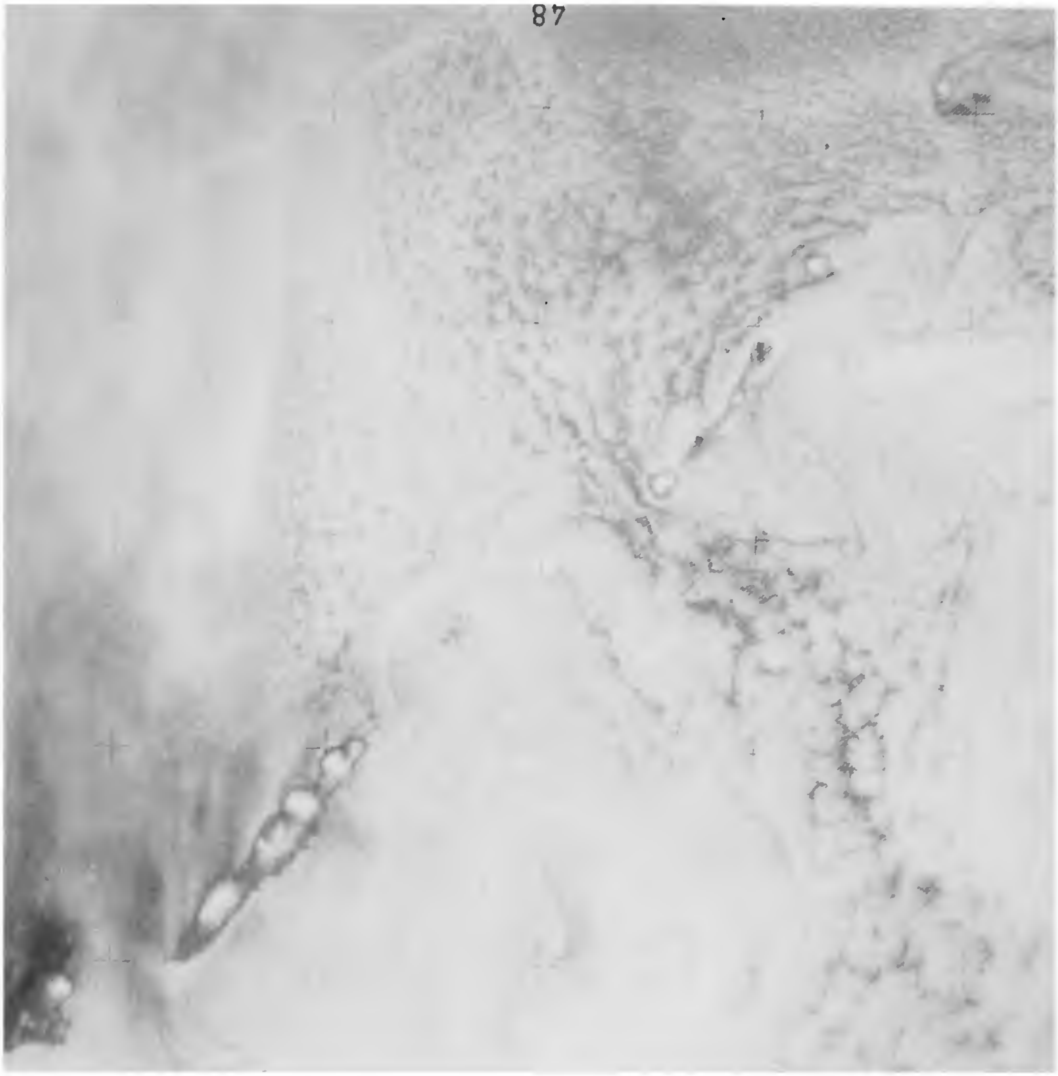
REV 106: CM3/SILVER/250/CX15(f8,1/500) 6FR,[NEXT SITE: 4D]

# SITE 3: WEATHER BELT



AREAS OF MAJOR TROPICAL STORM ACTIVITY

# 3A: CLOUD FEATURES




1. PHOTOGRAPH CONVECTIVE CLOUD FEATURES: 3 STEREO FRAMES PER TARGET

REV 17: CM3/SILVER/250/CX10(f16,1/500) 3FR,[NEXT SITE: 2A]

REV 42: CM3/SILVER/50/CX11(f16,1/500) 3FR,[NEXT SITE: 9H, CHANGE TO IF01]

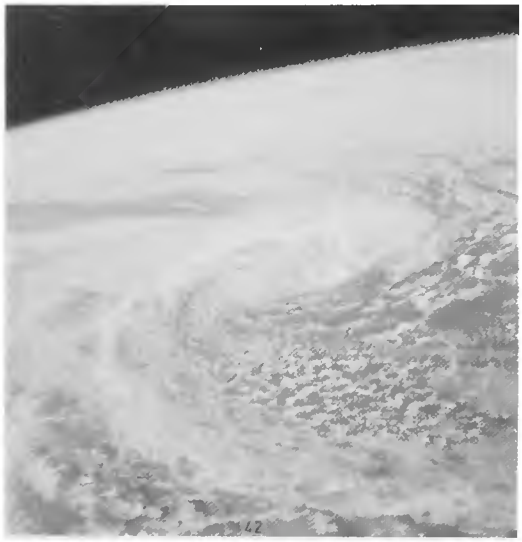
REV 64: CM3/SILVER/250/CX12(f16,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

REV 73: CM3/SILVER/50/CX14(f16,1/500) 3FR,[NEXT SITE: 9K]

REV 79: CM3/SILVER/50/CX14(f16,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

REV 88: CM3/SILVER/250/CX15(f16,1/500) 3FR,[NEXT SITE: 9K]

# 3B: TROPICAL STORMS



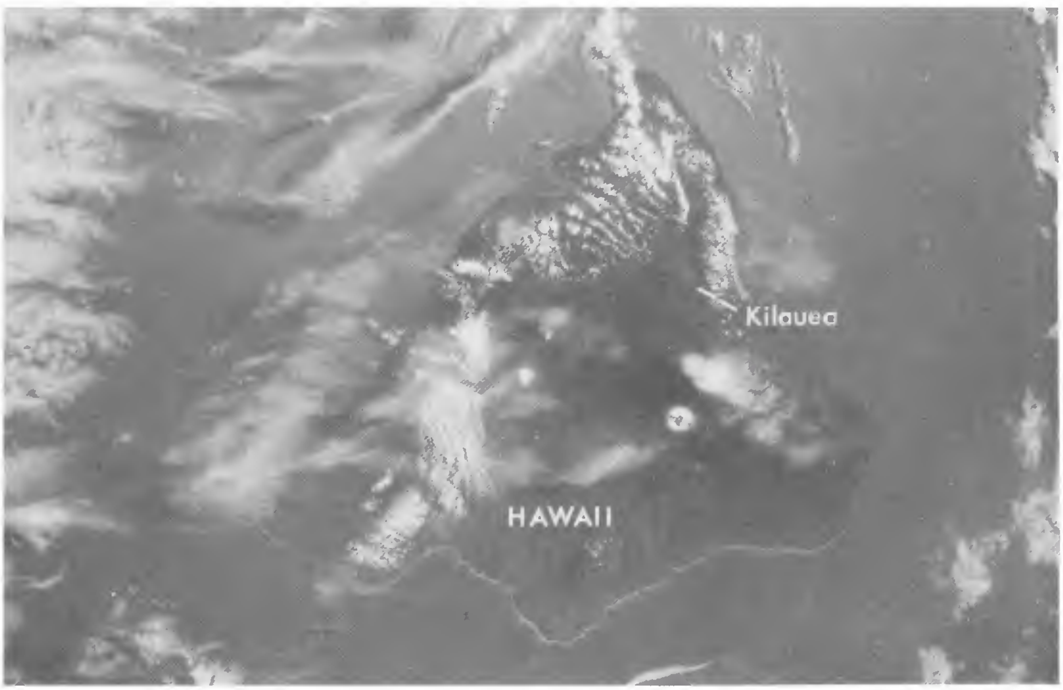
1. PHOTOGRAPH DEVELOPING OR MATURE STORM CENTERS; 3 STEREO FRAMES PER TARGET.

2. DESCRIBE TEXTURE AND STRUCTURE OF STORMS; USE SCOPE IF DESIRED.

REV 106: CM3/SILVER/250/CX15(f16,1/500) 3FR,[NEXT SITE: 2B]

REV 135: CM3/SILVER/250/CX17(f16,1/500) 3FR,[NEXT SITE: 5A]

# 3C: HAWAII

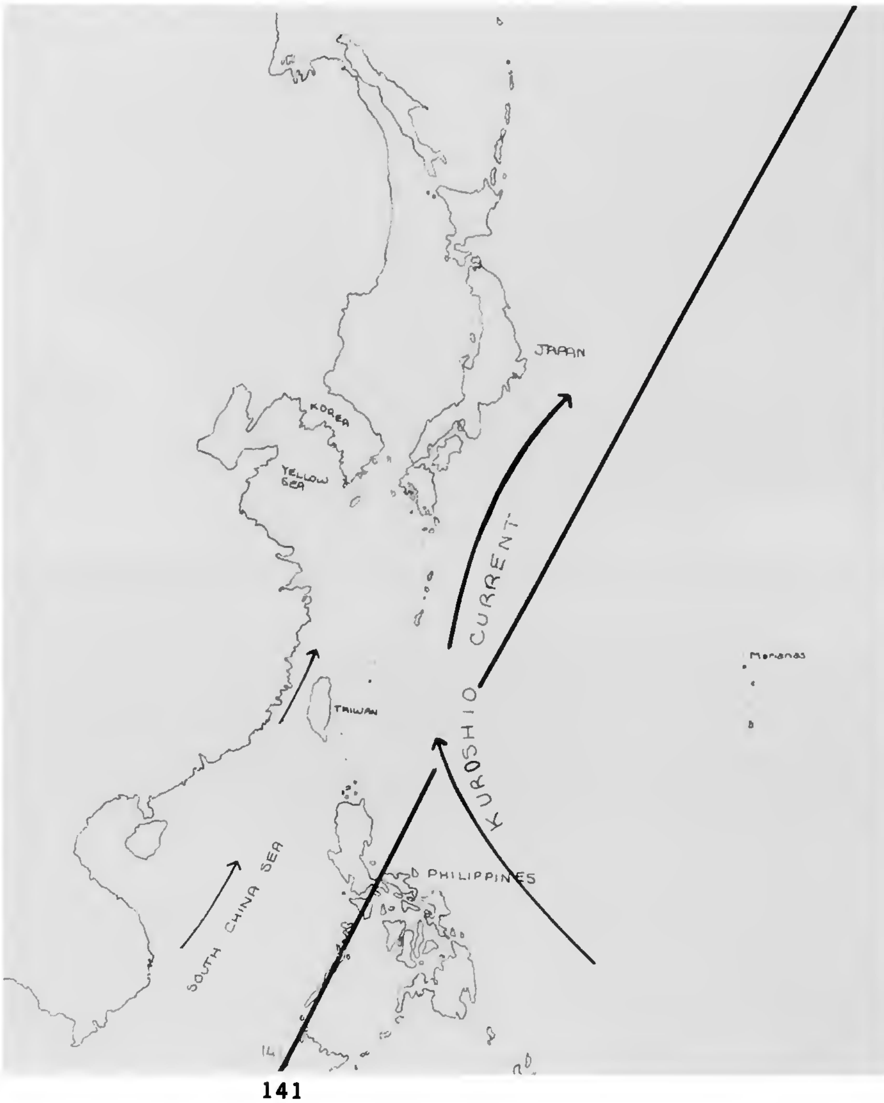




1. DO YOU OBSERVE UPWELLINGS, BOW WAVES, OR ISLAND WAKES?
   OBTAIN 3 STEREO FRAMES PER TARGET.
   (KILAUEA IS AN ACTIVE VOLCANO)

REV 78: CM3/SILVER/250/CX14(f6.7,1/500) 3FR,[NEXT SITE: 4A]

REV 108: CM3/SILVER/250/CX16(f6.7,1/500) 3FR,[NEXT SITE: 4B]

# 3D: KUROSHIO CURRENT



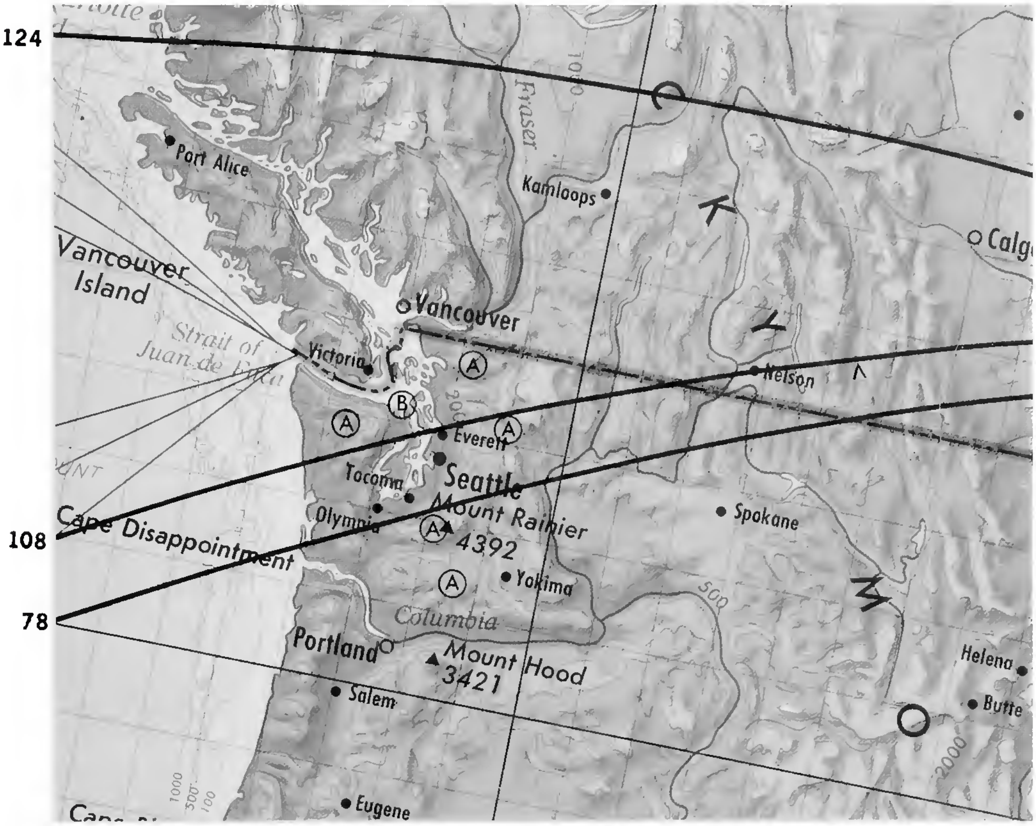

FOR ALTERNATE PLAN 9B ONLY.

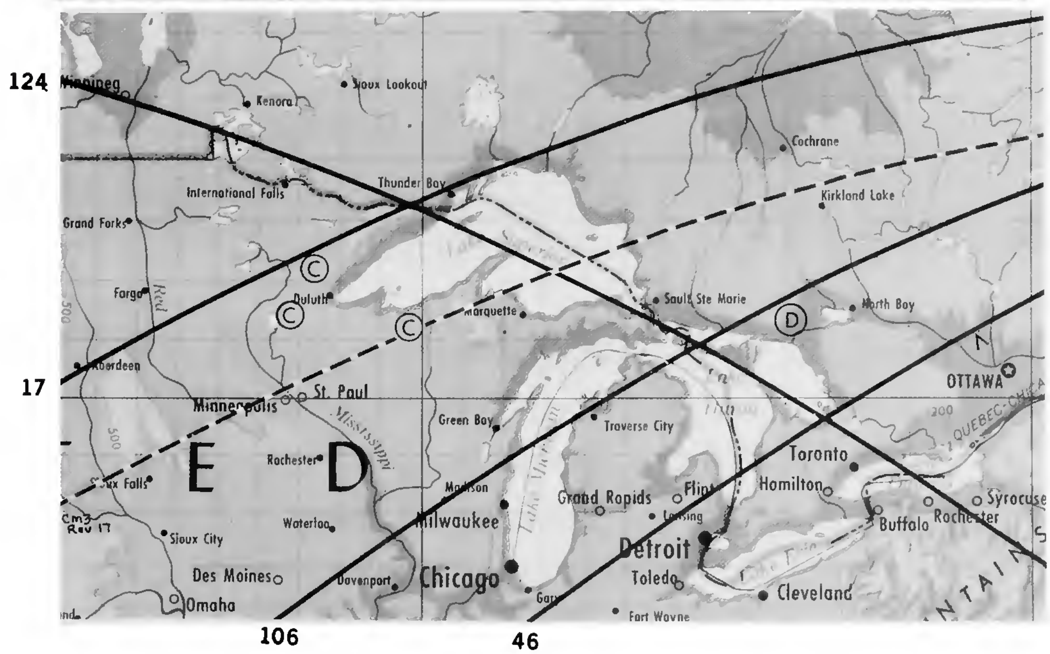
1. CAN YOU OBSERVE ANY MANIFESTATION OF THE KUROSHIO CURRENT? (LOOK FOR COLOR CHANGES, SCUM LINES, DETACHED MEANDERS, GYRES, ETC.)

2. OBTAIN 3 STEREO PHOTOGRAPHS OF ANY PLANKTON BLOOMS.

<u>REV 141</u>: CM3/SILVER/50/CX17(f6.7,1/500) 3FR

# SITE 4: NORTHERN NORTH AMERICA



# 4A: SNOW PEAKS

124


78

1. PHOTOGRAPH SNOW PEAKED MOUNTAINS; 3 STEREO FRAMES PER TARGET.
2. CAN YOU SEE GLACIERS AND FIRN LINES? (SCOPE MAY HELP)

REV 78: CM3/SILVER/250/CX14(f8,1/500) 6FR,[RECORD LAST FR NO: PAGE 4]

REV 124: CM3/SILVER/50/CX16(f8,1/500) 6FR,[NEXT SITE: 4C]

# 4B: PUGET SOUND

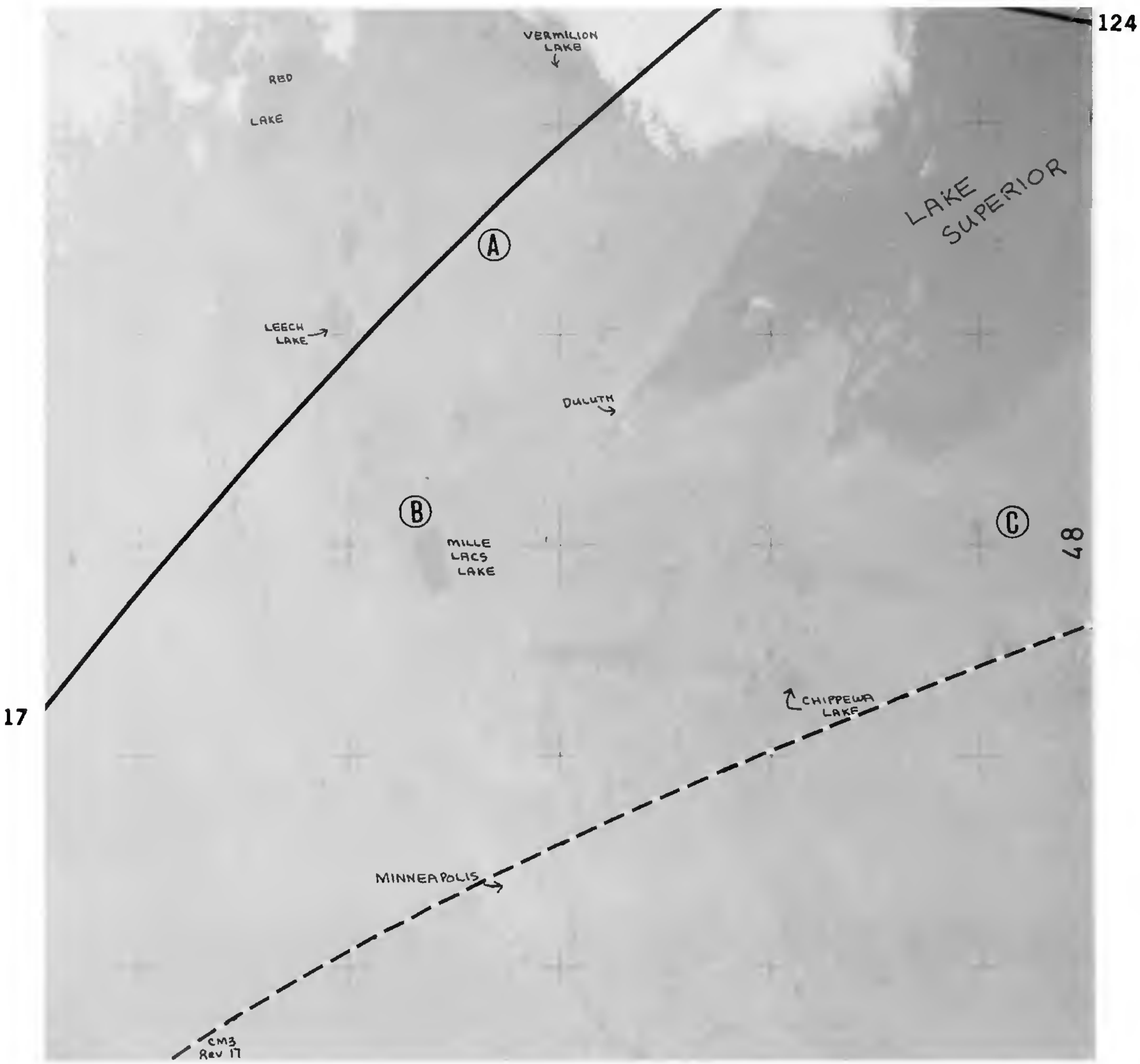

108

1. DESCRIBE SUSPENDED SEDIMENTS IN THE WATERS OF PUGET SOUND.
2. CAN YOU SEE ANY GYRES THERE? USE SCOPE IF DESIRED.
3. CAN YOU SEE MOUNTAIN GLACIERS AND FIRN LINES? (SCOPE MAY HELP)

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 108: CM3/SILVER/250/CX16(f8,1/250) 3FR,[RECORD LAST FR NO: PAGE 5]

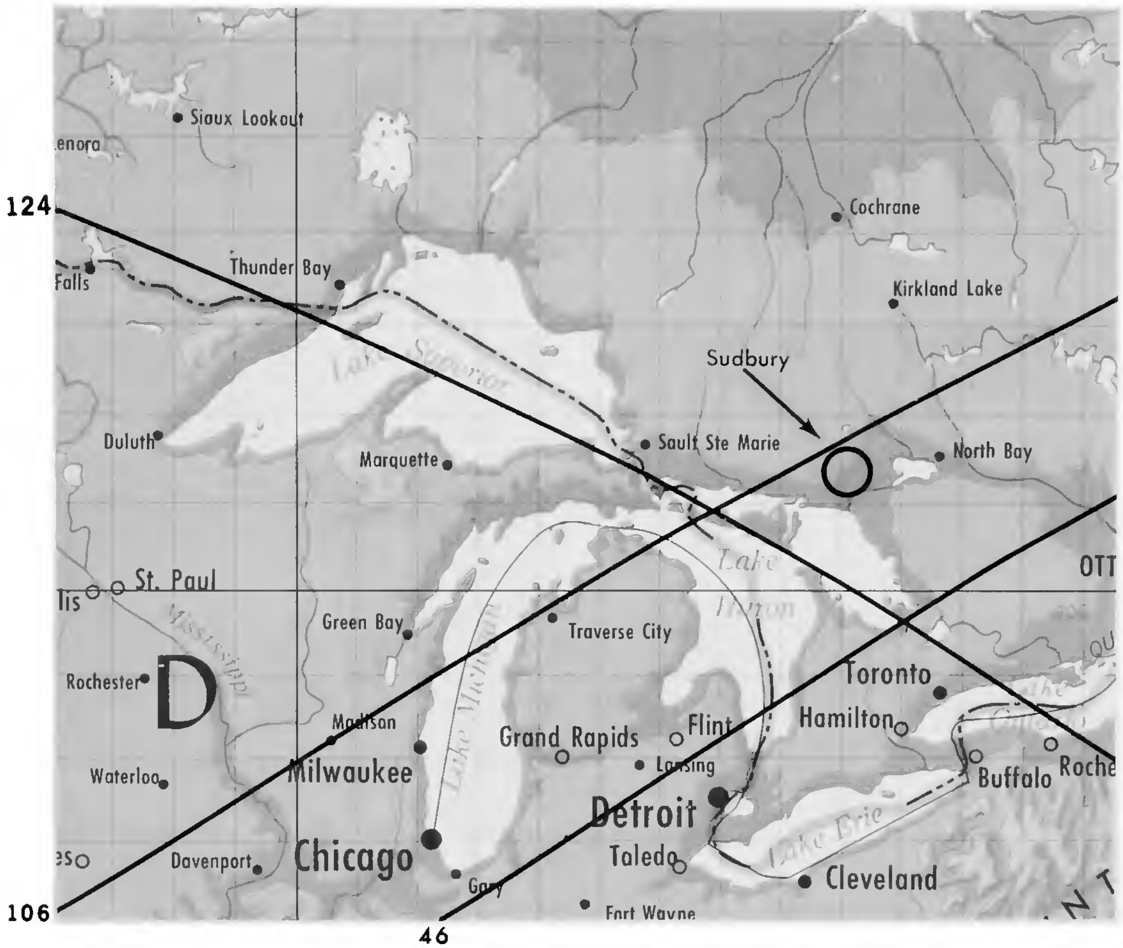
# 4C: SUPERIOR IRON




1. DESCRIBE COLOR OXIDATION ZONES OF IRON MINES IN THE LAKE SUPERIOR REGION. (USE COLOR WHEEL IF POSSIBLE)
2. IS THERE A DIFFERENCE IN COLOR BETWEEN AREAS A, B, AND C?
3. PHOTOGRAPH AREAS OF INTEREST; 3 STEREO FRAMES PER TARGET.

<u>REV 124</u>: CM3/SILVER/50/CX16(<u>f6.7</u>,1/500) 6FR,[NEXT SITE: 4D]

# 4D: SUDBURY NICKEL



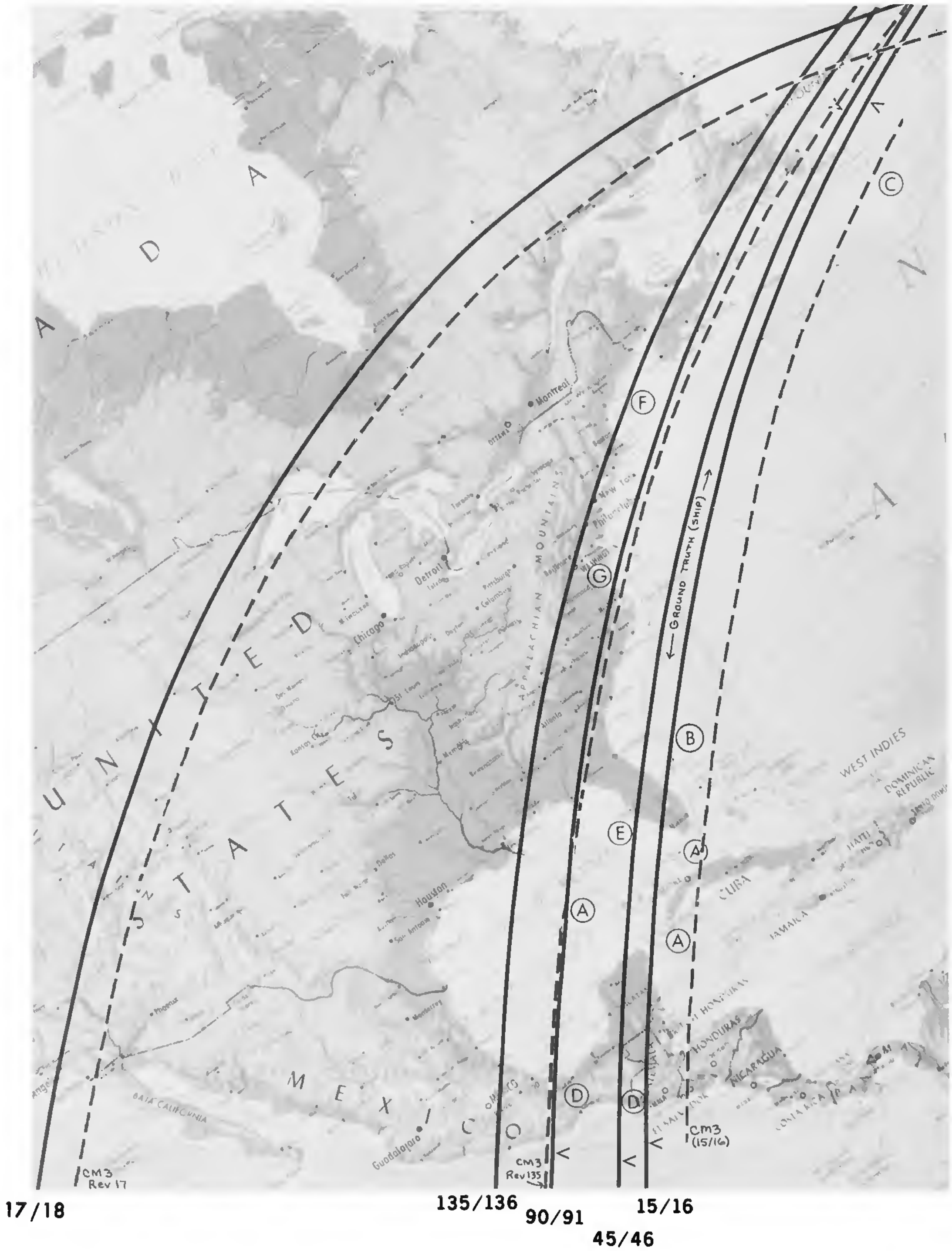

1. DESCRIBE COLOR OXIDATION ZONES OF SUDBURY AREA; ARROW. ( USE COLOR WHEEL IF POSSIBLE)
2. COMPARE WITH COLOR OF LAKE SUPERIOR REGION (SITE 4C).

REV 46: CM1/SILVER/50/CX11(f9.5,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

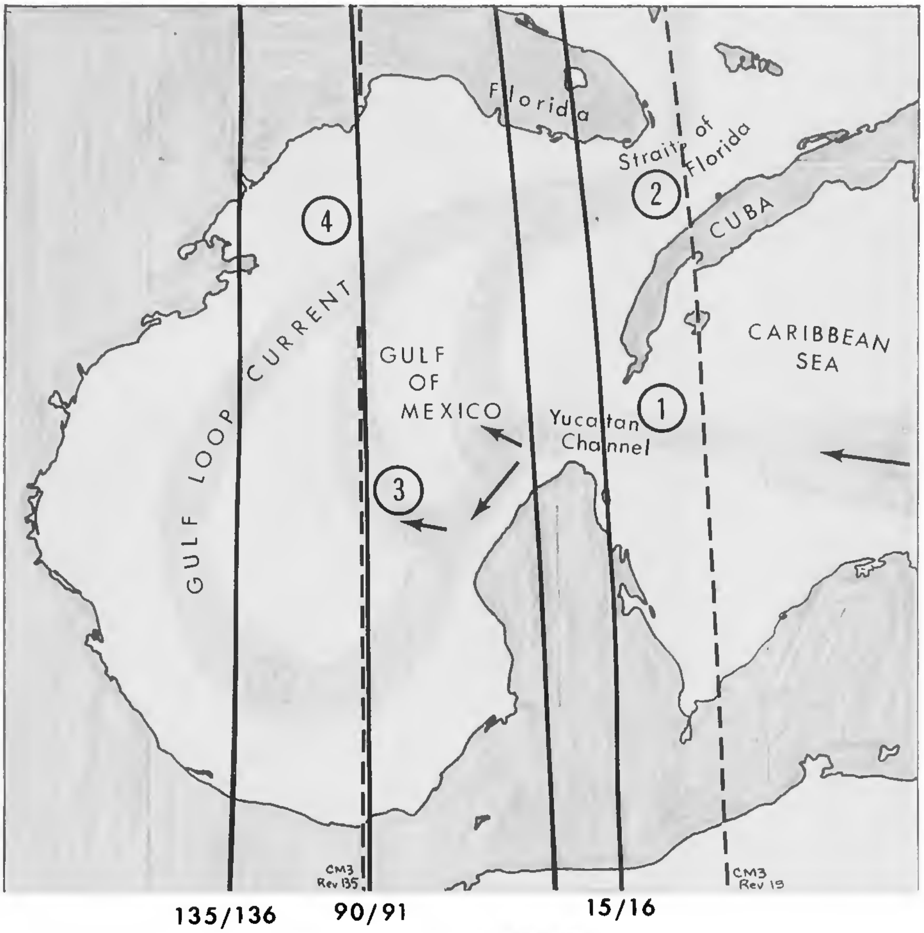
REV 106: CM3/SILVER/250/CX15(f8,1/500) 3FR,[RECORD LAST FR NO: PAGE 5]

REV 124: CM3/SILVER/50/CX16(f6.7,1/500) 3FR,[RECORD LAST FR NO: PAGE 5]

# SITE 5: EASTERN NORTH AMERICA



# 5A: GULF OF MEXICO




REVS 15 AND 45:

1. CAN YOU SEE EDDIES AT THE YUCATAN CHANNEL?
2. IS THE FLORIDA CURRENT VISIBLE IN THE STRAITS OF FLORIDA?

REVS 90 AND 135:

3. CAN YOU OBSERVE ANY PART OF THE GULF LOOP CURRENT?
4. DO YOU SEE INTERNAL WAVES IN THE GULF WATERS?

PHOTOGRAPHS; 3 STEREO FRAMES PER TARGET.

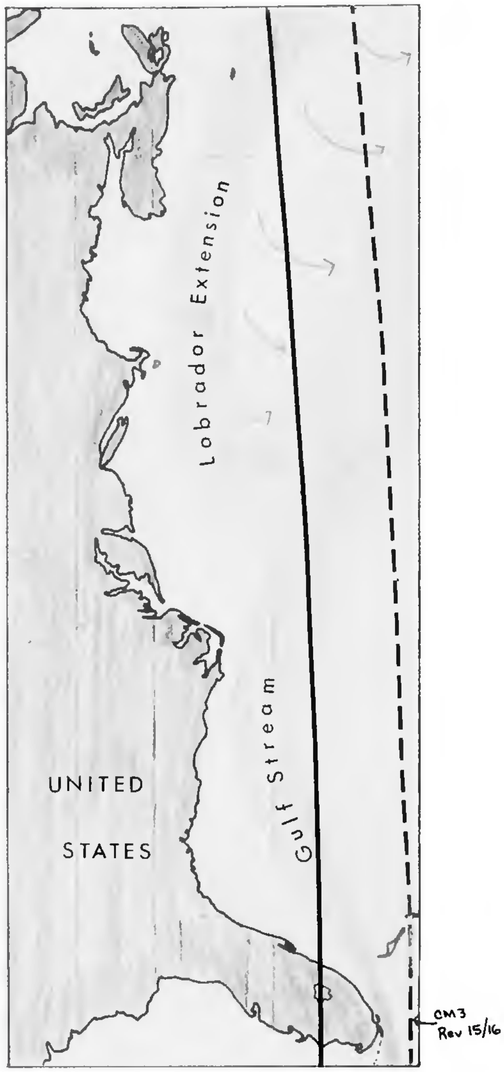
REV 15: CM3/SILVER/50/CX10(f8,1/500) 6FR,[NEXT SITE: 5B]

REV 45: CM1/SILVER/50/CX11(f9.5,1/500) 6FR,[NEXT SITE: 5E]

REV 90: CM3/SILVER/50/IF02/ORANGE FILTER(f6.7,1/500) 6FR,[NEXT SITE: 5E]

REV 135: CM3/SILVER/250/CX17(f8,1/500) 6FR,[NEXT SITE: 5G]

# 5B: GULF STREAM



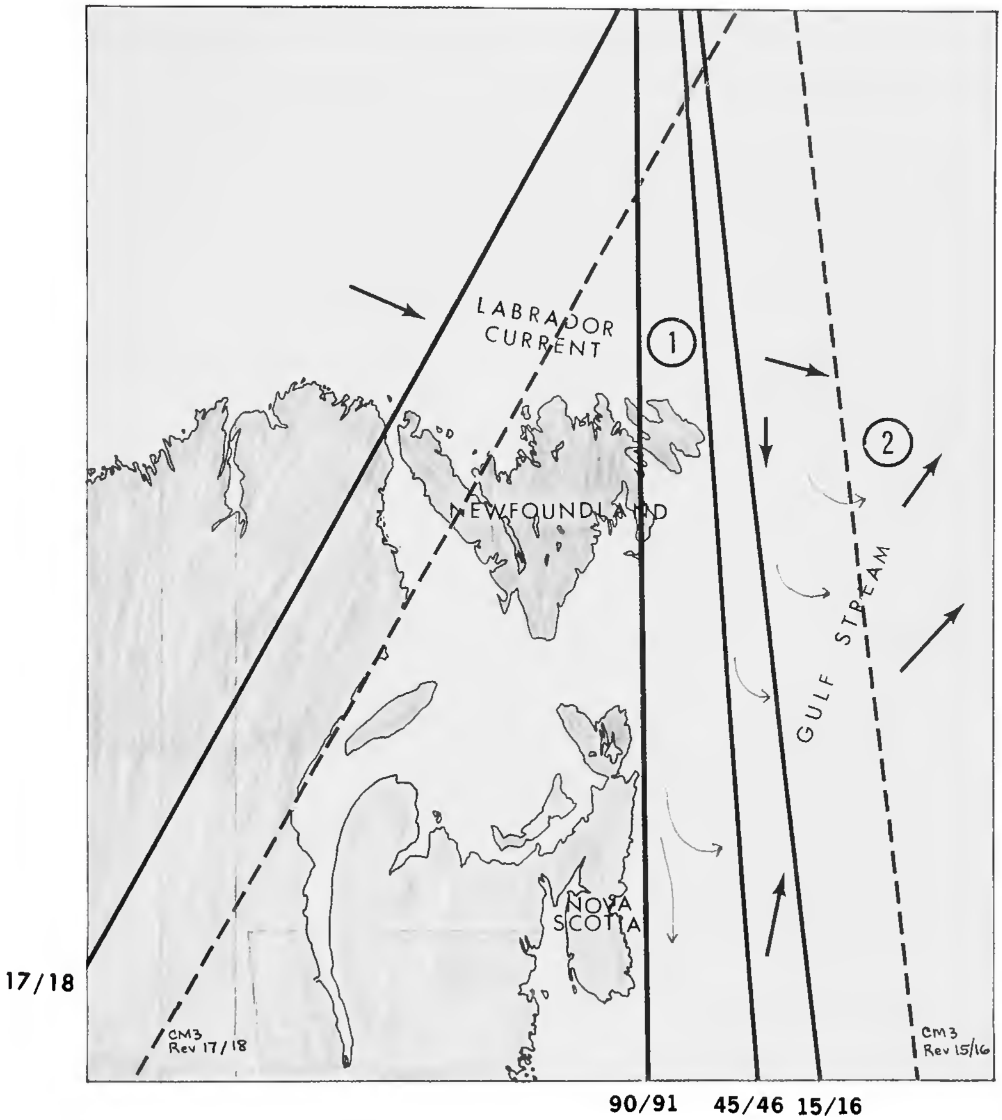

**15/16**

1. CAN YOU OBSERVE THE GULF STREAM BOUNDARY?
   (LOOK FOR COLOR CHANGES, SCUM LINES, DETACHED MEANDERS, GYRES, ETC.)
2. DO YOU SEE ANY INTERNAL WAVES? USE SCOPE IF DESIRED.
3. CAN YOU LOCATE THE CONFLUENCE OF THE GULF STREAM AND LABRADOR EXTENSION?

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 16: CM3/SILVER/50/CX10(f6.7,1/500) 6FR,[NEXT SITE: 5C]

# 5C: LABRADOR CURRENT




1. IS THE LABRADOR CURRENT VISIBLE?

2. CAN YOU LOCATE THE CONFLUENCE OF THE GULF STREAM AND THE LABRADOR CURRENTS?

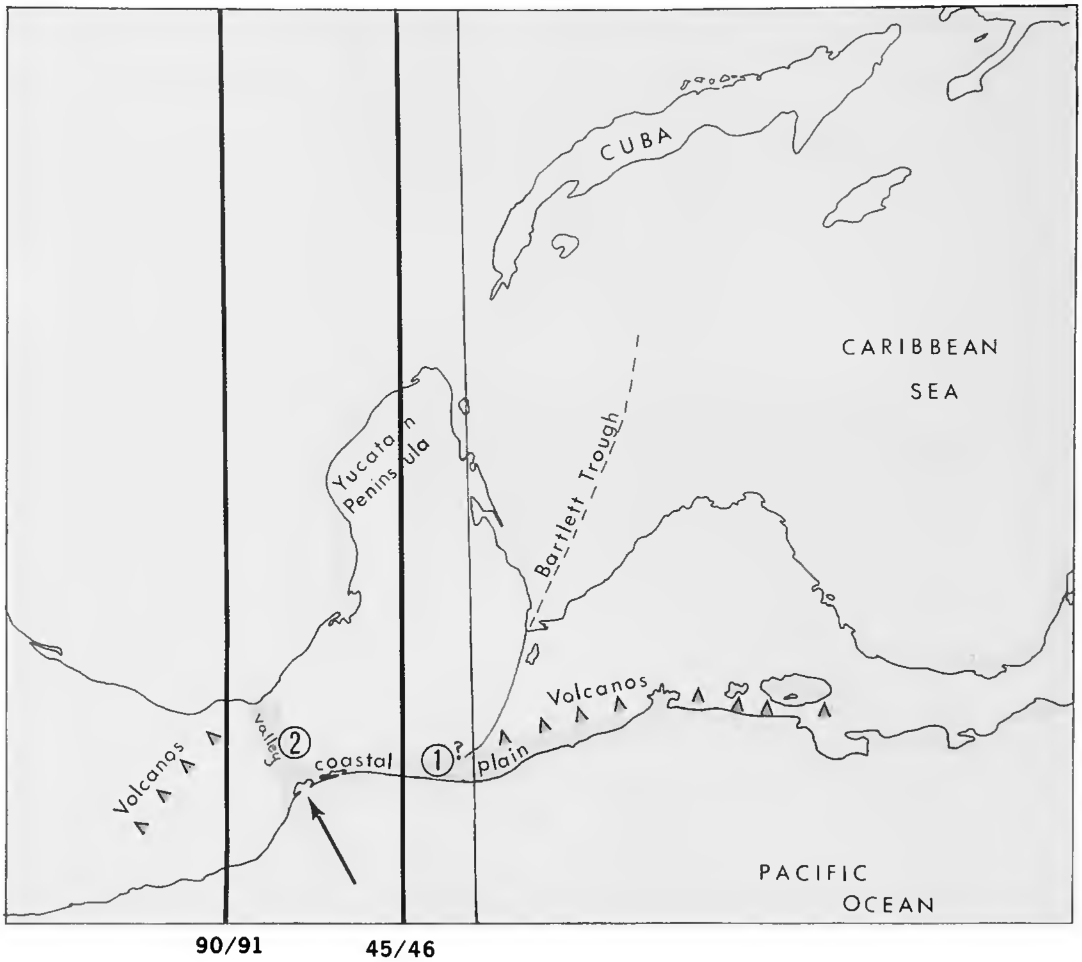
PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 16: CM3/SILVER/50/CX10(f6.7,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

REV 46: CM1/SILVER/50/CX11(f6.7,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

REV 91: CM3/SILVER/50/IF02/ORANGE FILTER(f6.7,1/250) 3FR,[NEXT SITE: 6A]

# 5D: CENTRAL AMERICAN STRUCTURES




USE SCOPE

1. CAN YOU SEE THE EXTENSION OF THE BARTLETT FAULT INTO THE PACIFIC COASTAL PLAIN?

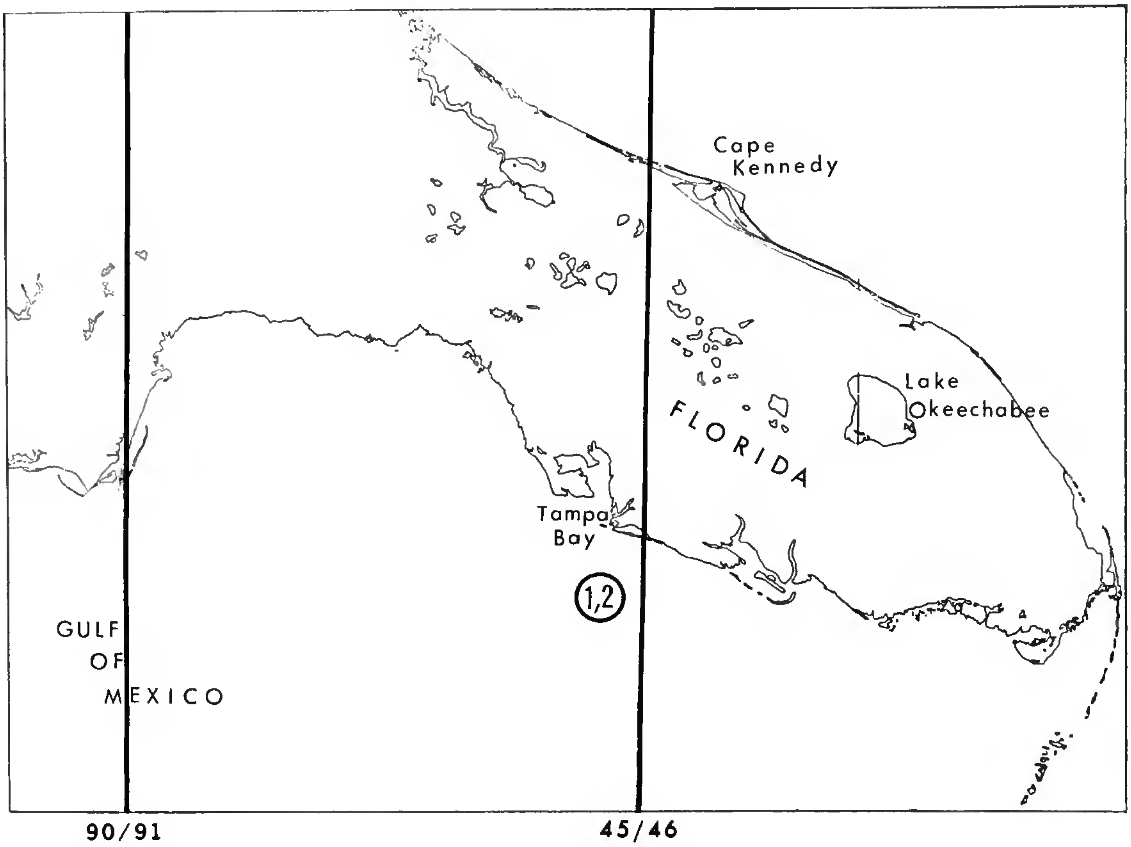
2. OBTAIN 3 STEREO FRAMES OF THE VALLEY INDICATED BY ARROW.

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 45: CM1/SILVER/50/CX11(f9.5,1/500) 6FR,[NEXT SITE: 5A]

REV 90: CM3/SILVER/50/IF02/ORANGE FILTER(f6.7,1/500) 6FR,[NEXT SITE: 5A]

# 5E: FLORIDA RED TIDE




1. IS THERE ANY RED TIDE VISIBLE WEST OF FLORIDA?

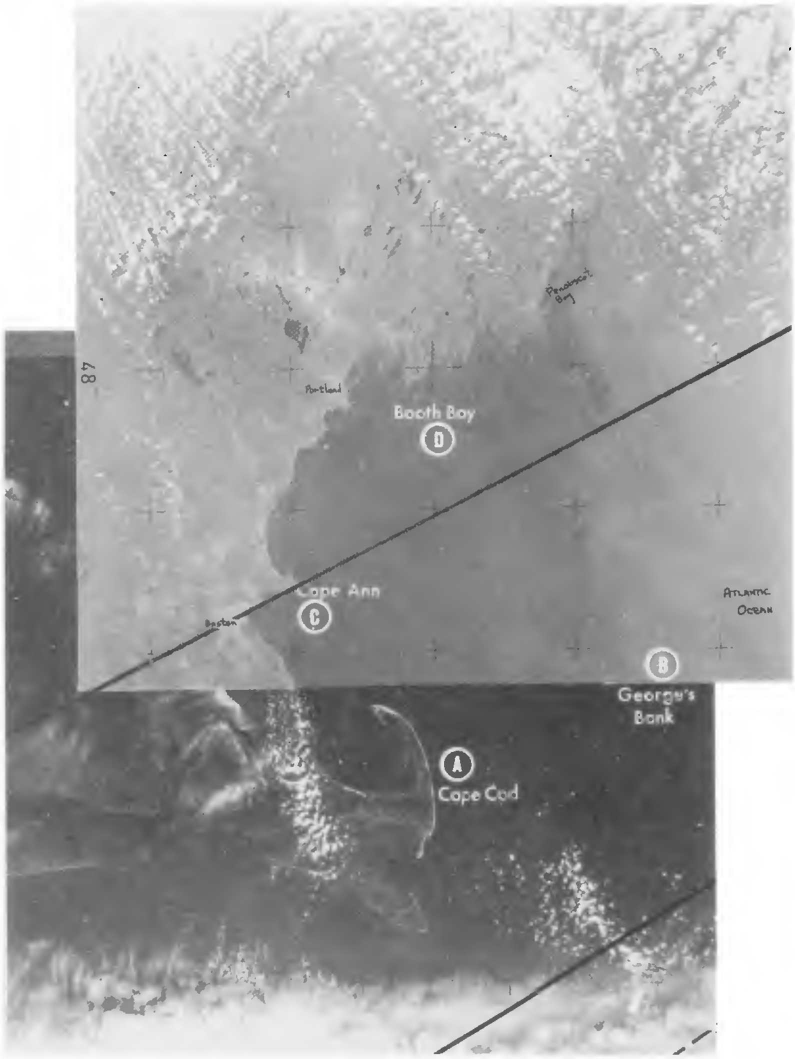
2. SKETCH LOCATION AND SHAPE OF BLOOM, ESPECIALLY WEST OF TAMPA BAY.

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 45: CM1/SILVER/50/CX11(f9.5,1/500) 3FR,[NEXT SITE: 5F]

REV 90: CM3/SILVER/50/IF02/ORANGE FILTER(f6.7,1/500) 3FR,[NEXT SITE: 5G]

# 5F: NEW ENGLAND RED TIDE




135/136

90/91

CM3 REV 135/136

1. IS THERE ANY RED TIDE VISIBLE OFF THE NEW ENGLAND COAST?

2. SKETCH LOCATION AND SHAPE OF BLOOM.

3. OBTAIN 3 STEREO FRAMES OF AREAS A, B, C AND D; AND EDGE OF CLOUDS OR FOG.

REV 46: CM1/SILVER/50/CX11(f6.7,1/500) 12FR,[NEXT SITE: 5C]

REV 91: CM3/SILVER/50/IF02/ORANGE FILTER(f6.7,1/250) 12FR,[NEXT SITE: 5C]

REV 136: CM3/SILVER/250/CX17(f8,1/500) 12FR,[NEXT SITE: 6A]

# 5G: CHESAPEAKE BAY


1. DESCRIBE SUSPENDED SEDIMENT PLUMES OR GYRES IN THE BAY.

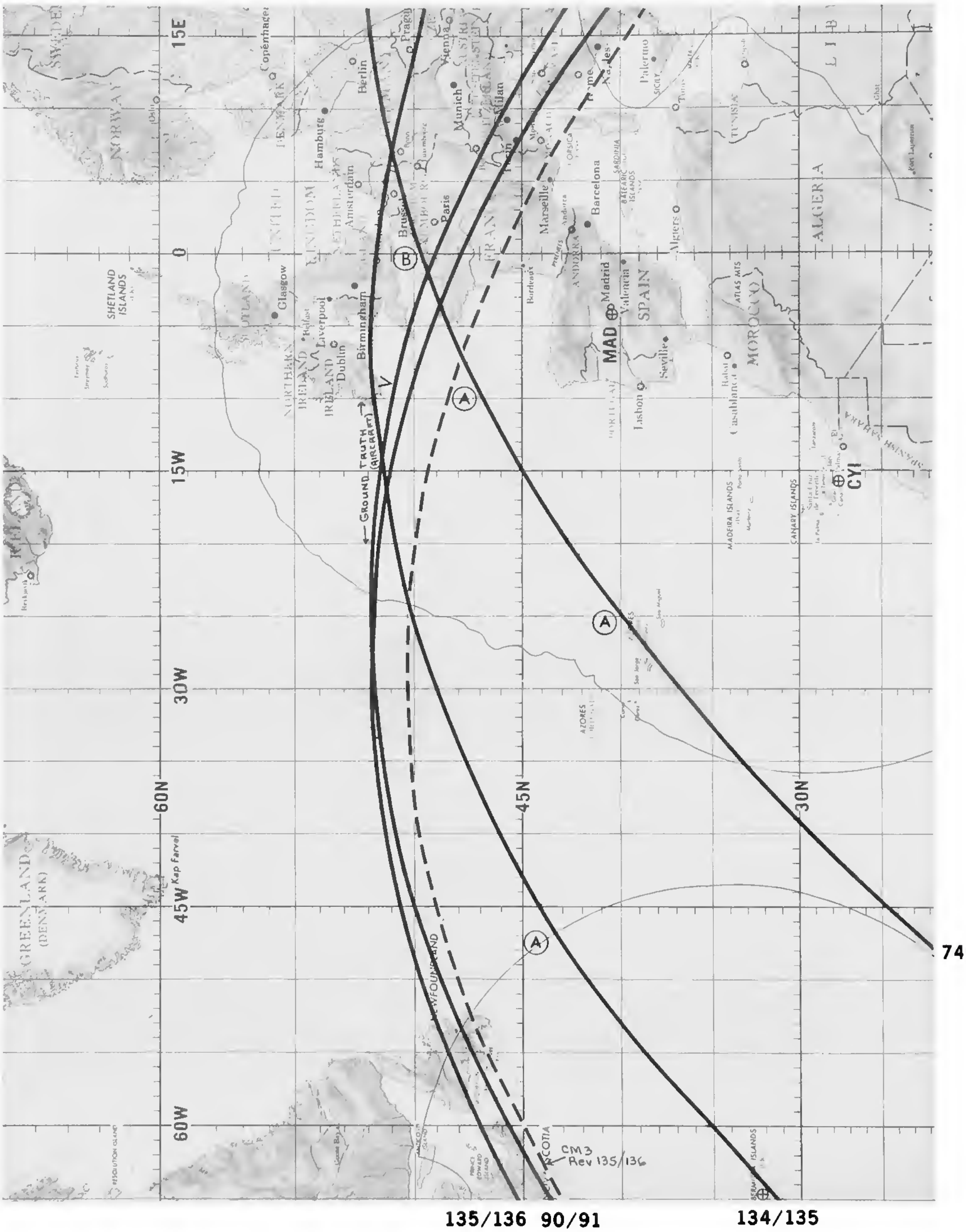
2. ARE THERE ANY POLLUTION PLUMES IN THE POTOMAC RIVER?

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

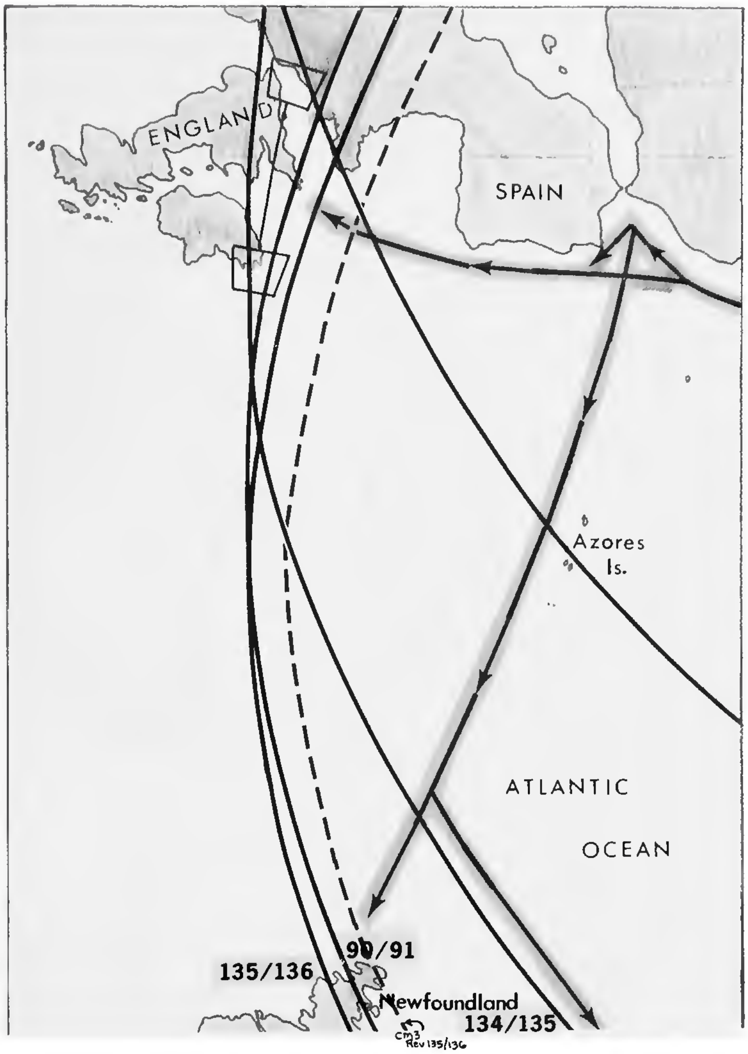
REV 91: CM3/SILVER/50/IF02/ORANGE FILTER(f6.7,1/500) 6FR,[NEXT SITE: 5F]

REV 136: CM3/SILVER/250/CX17(f8,1/500) 6FR,[NEXT SITE: 5F]

# SITE 6: NORTHERN ATLANTIC



# 6A: OIL SLICKS




OIL SLICKS ARE BEST OBSERVED JUST OFF SUNGLINT.

1. MARK G.E.T. ON OBSERVATION OF OIL SLICKS IN SHIP ROUTES.

2. DESCRIBE COLOR AND EXTENT OF SLICKS AND OBTAIN 3 FRAMES PER TARGET.

3. OBTAIN A STRIP OF PHOTOGRAPHS ALONG LINE INDICATED ON BOTH REVS 91 AND 134/135. (FRAME INTERVAL: 10 SECS FOR 50mm LENS)

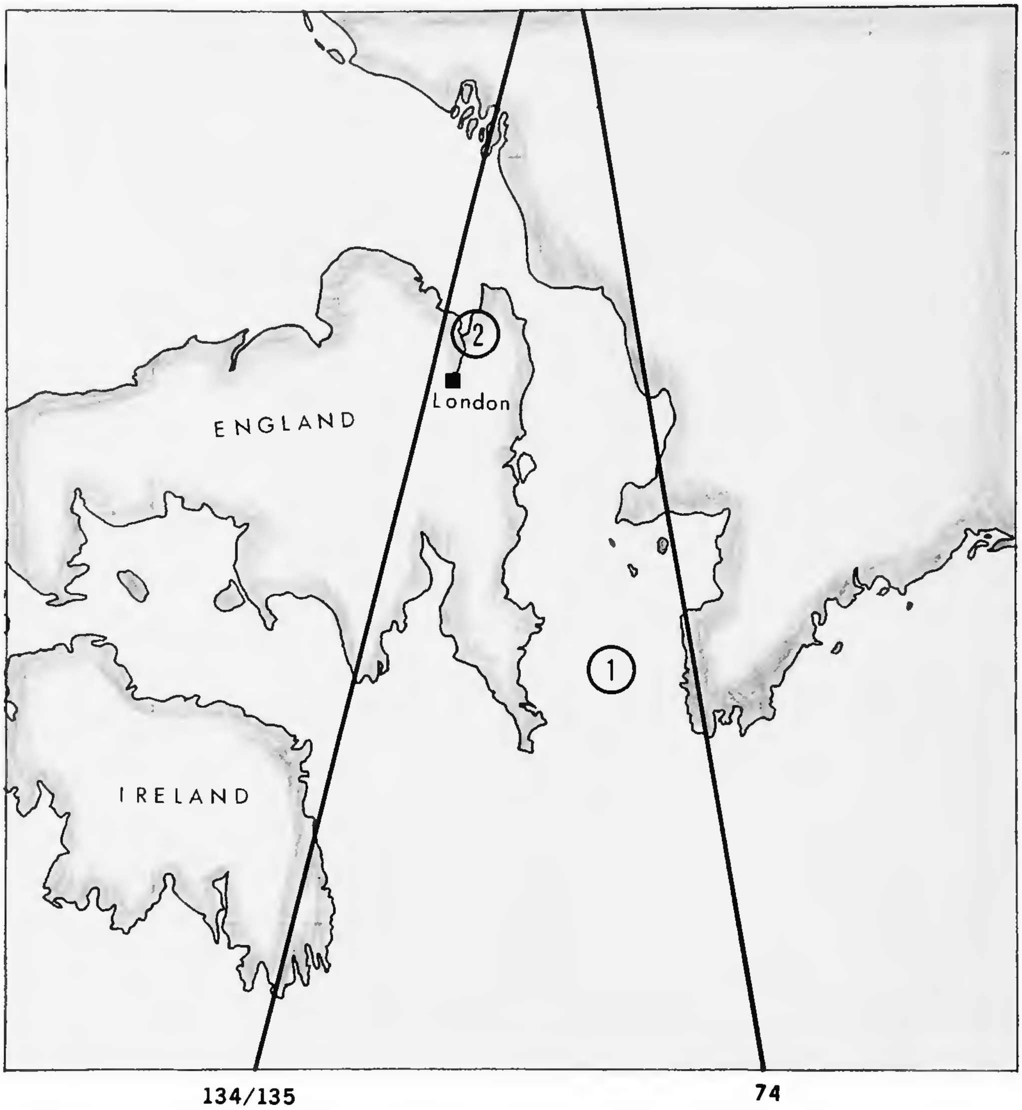
REV 74: CM3/SILVER/250/CX14(f8,1/250) 3FR,[NEXT SITE: 6B]

REV 91: CM3/SILVER/50/IF02/ORANGE FILTER(f6.7,1/250) 17FR,[NEXT SITE: 9P]

REV 134/135: CM3/SILVER/50/CX17(f6.7,1/500) 17FR,[NEXT SITE: 6B]

REV 135/136: CM3/SILVER/250/CX17(f5.6,1/500) 3FR,[NEXT SITE: 9L, CHANGE TO IF02]

# 6B: LONDON



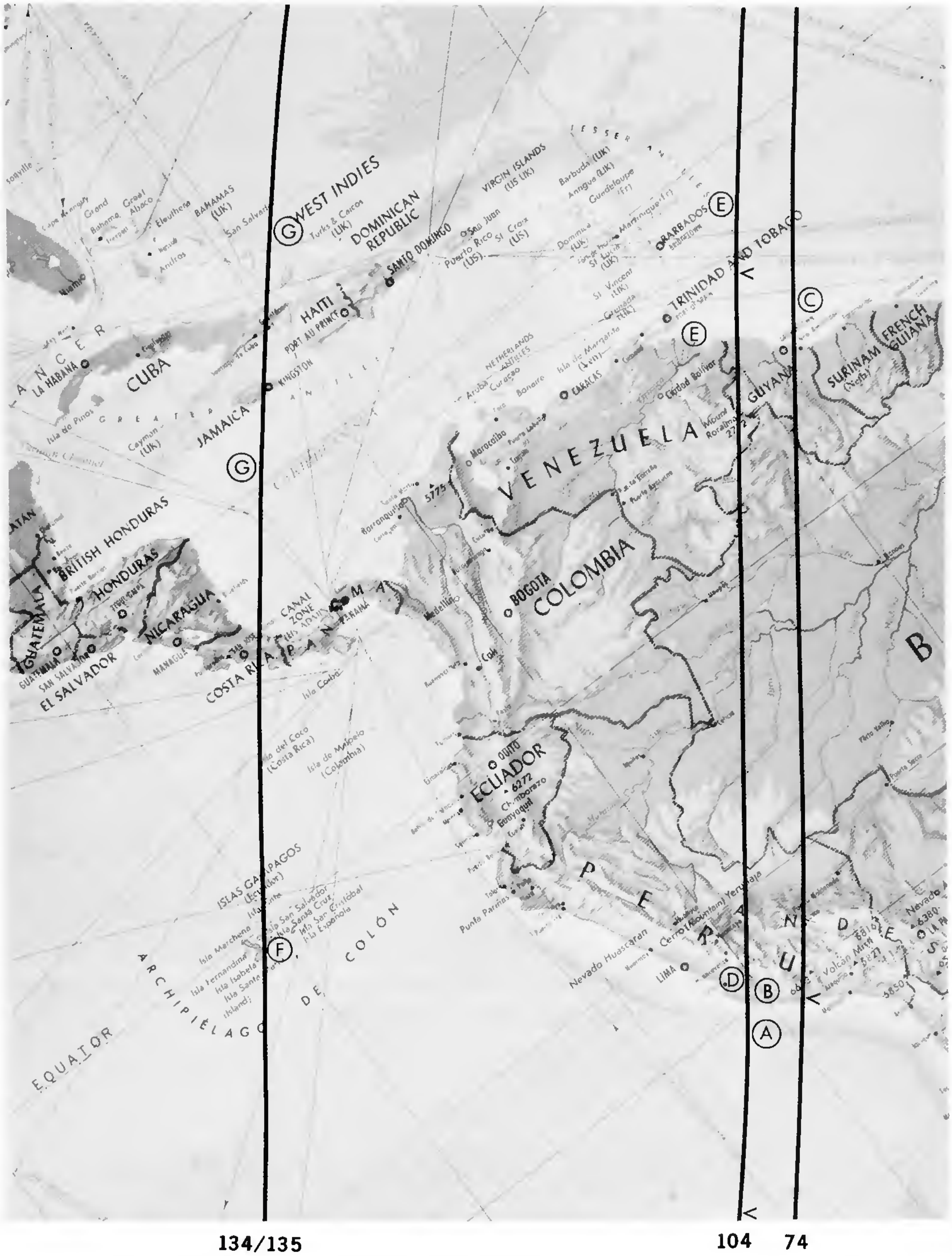

1. ARE SUSPENDED SEDIMENTS, EDDIES OR CURRENT BOUNDARIES VISIBLE IN THE ENGLISH CHANNEL? (USE SCOPE IF DESIRED)

2. OBTAIN 3 STEREO FRAMES OF LONDON HARBOR AREA.

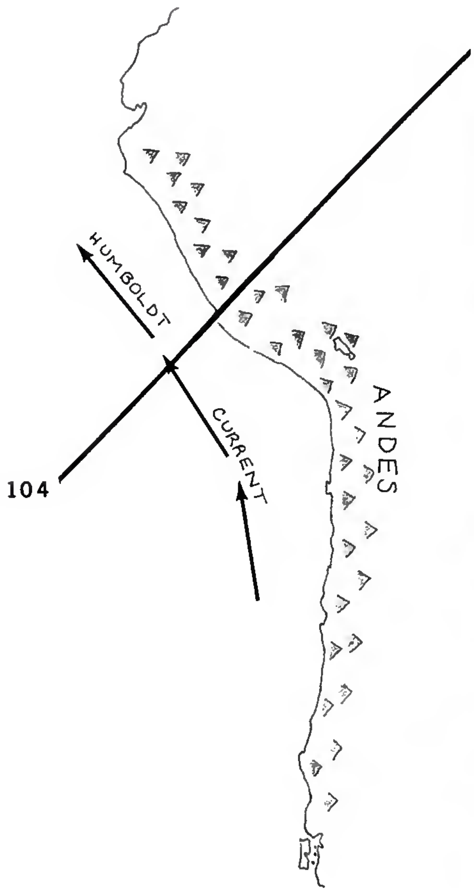
REV 74: CM3/SILVER/250/CX14(f8,1/250) 6FR,[RECORD LAST FR NO: PAGE 4]

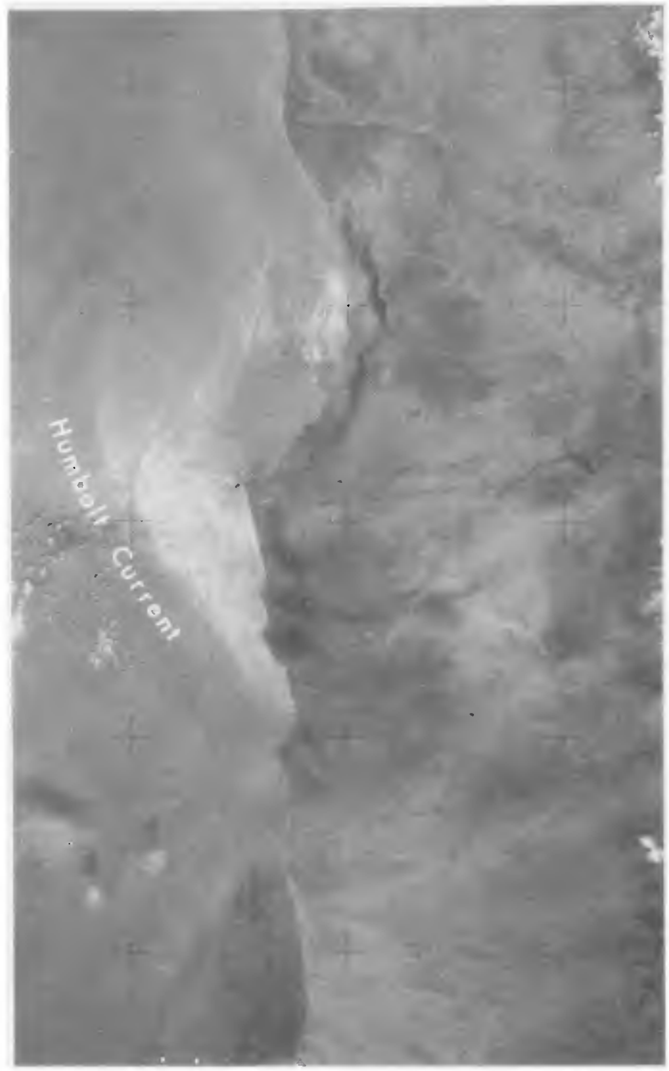
REV 134/135: CM3/SILVER/50/CX17(f6.7,1/500) 3FR,[NEXT SITE: 9M]

# SITE 7: NORTHERN SOUTH AMERICA



# 7A: HUMBOLDT CURRENT



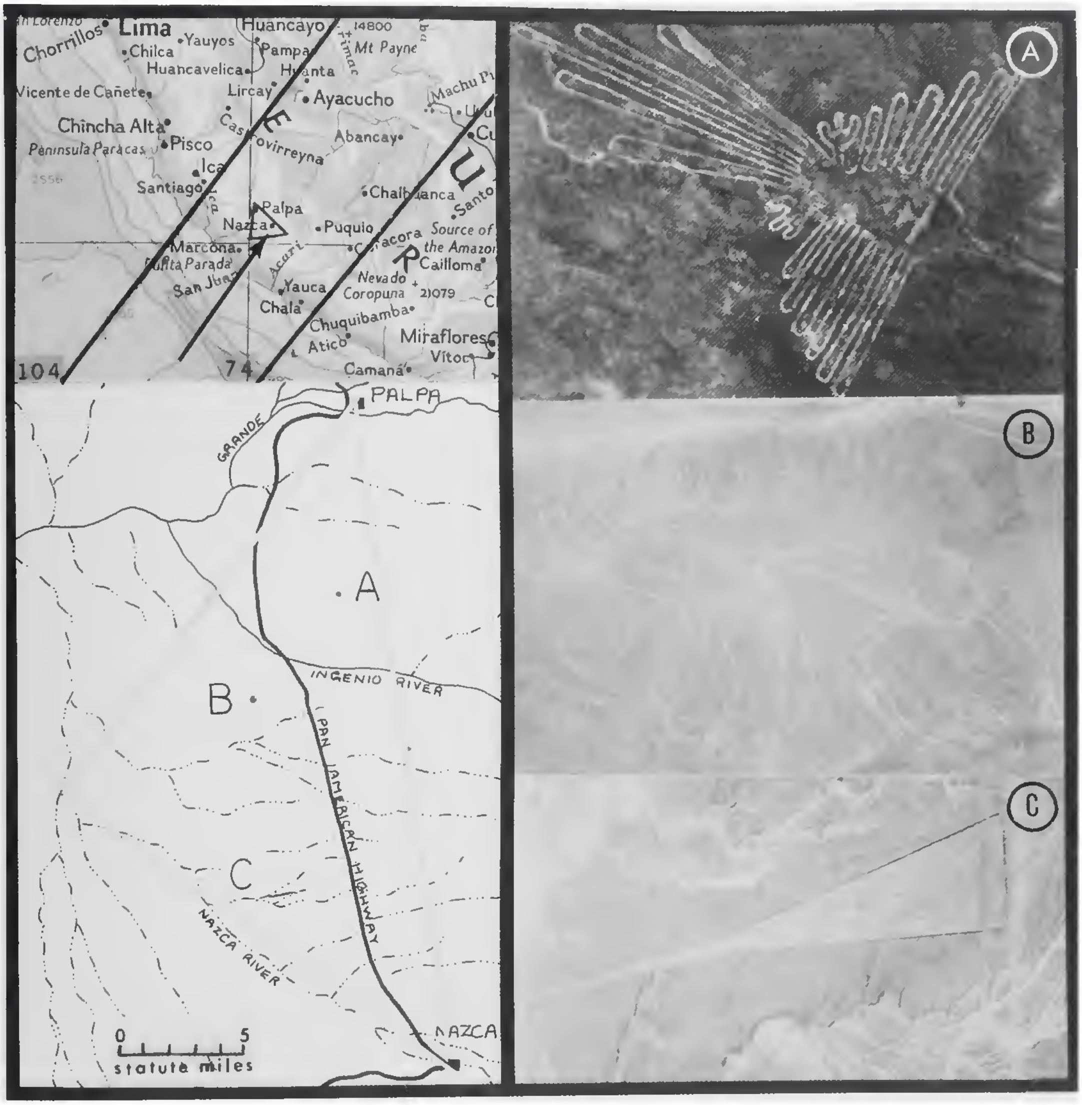

1. CAN YOU OBSERVE THE HUMBOLDT CURRENT?

2. ARE THERE ANY GYRES?

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

<u>REV 104</u>: CM3/SILVER/50/CX15(f5.6,1/500) 3FR,[NEXT SITE: 7D]

# 7B: NAZCA PLAIN

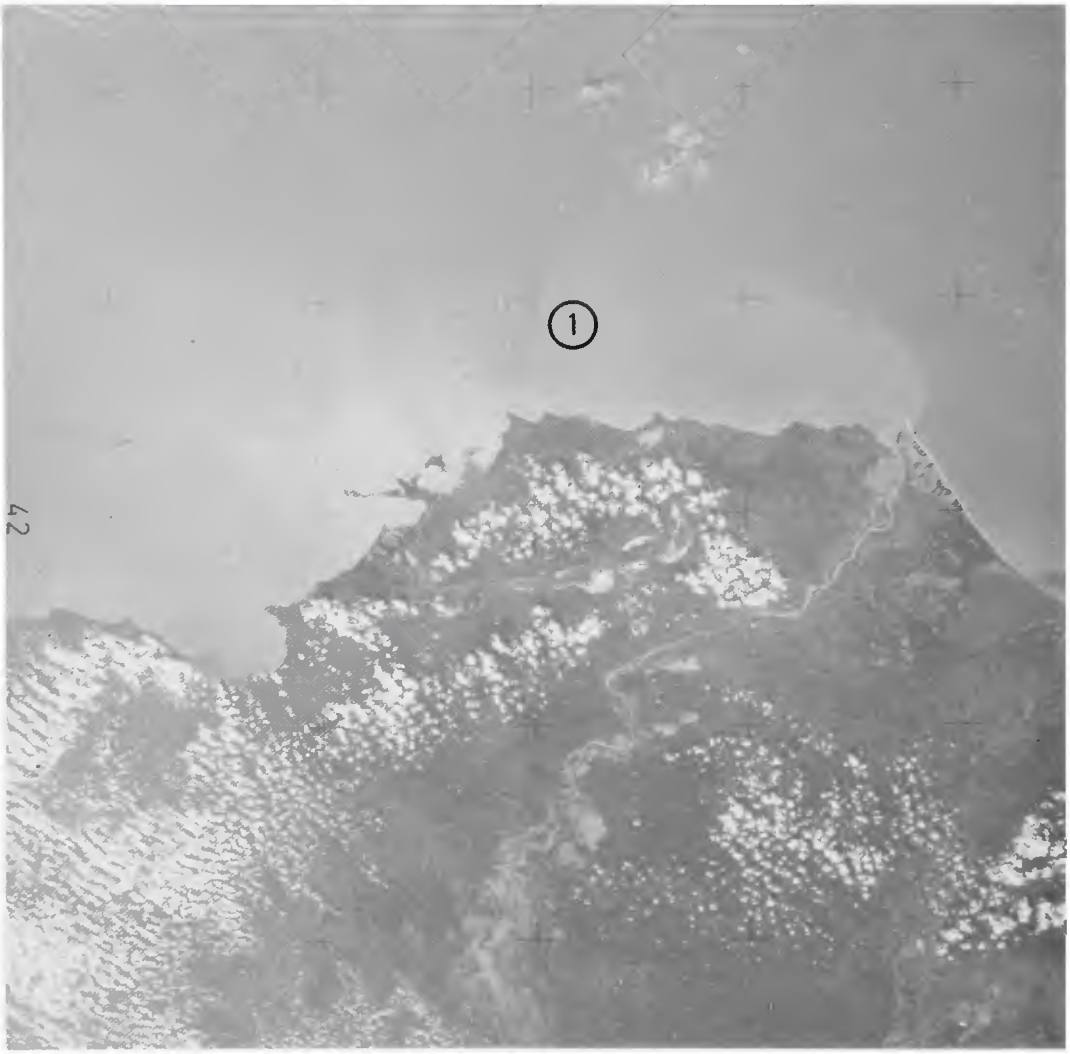



1. CAN YOU DISCERN THE NAZCA PLAIN MARKINGS? SCOPE MAY HELP.

2. IF NOT, OBTAIN 3 STEREO PHOTOGRAPHS OF PERUVIAN DESERT LANDFORMS.

REV 74: CM3/SILVER/250/CX14(f9.5,1/500) 3FR,[NEXT SITE: 7C]

# 7C: INTERNAL WAVES

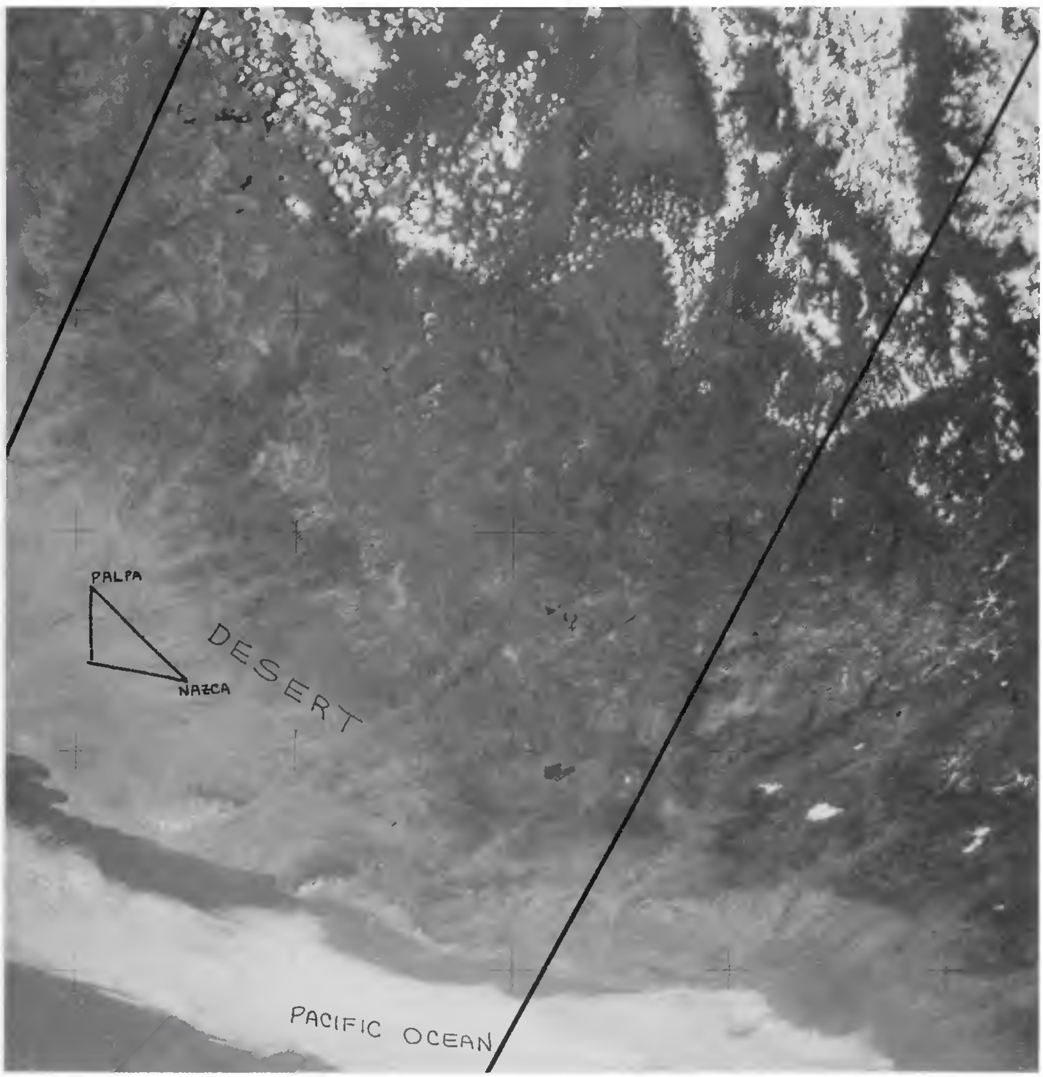



1. DO YOU SEE INTERNAL WAVES OFF THE COAST?

2. PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 74: CM3/SILVER/250/CX14(f8,1/250) 3FR,[NEXT SITE: 6A]

# 7D: PERUVIAN DESERT




104

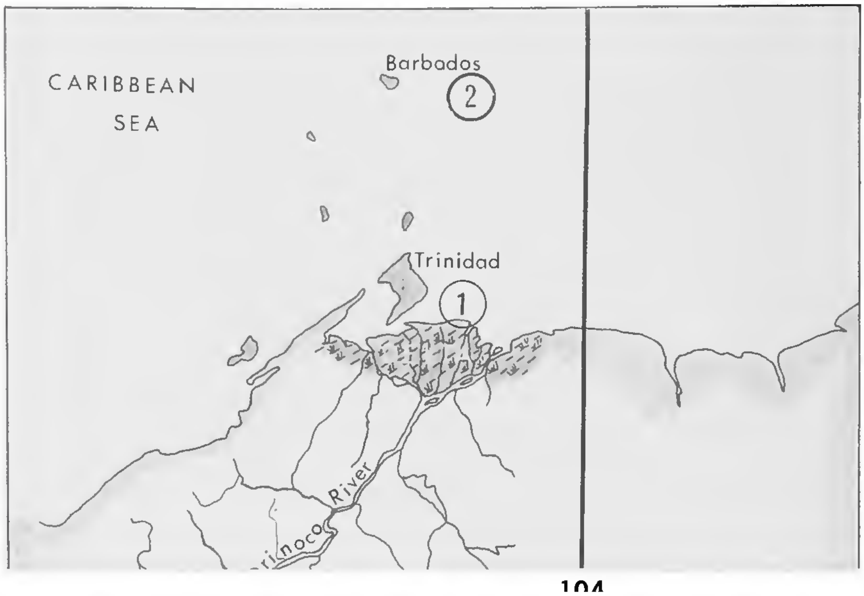
74

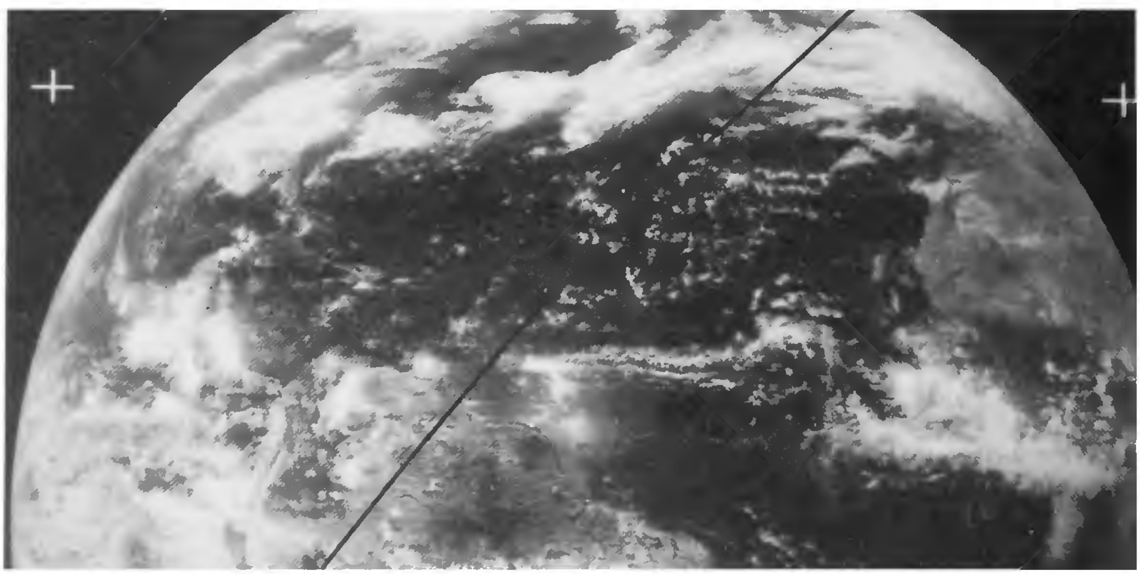
1. CAN YOU DISTINGUISH DUNE FIELDS IN THE PERUVIAN DESERT?
2. PHOTOGRAPH NAZCA PLAIN (SITE 7B).

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 104: CM3/SILVER/50/CX15(f8,1/500) 3FR,[NEXT SITE: 7E]

# 7E: ORINOCO RIVER DELTA



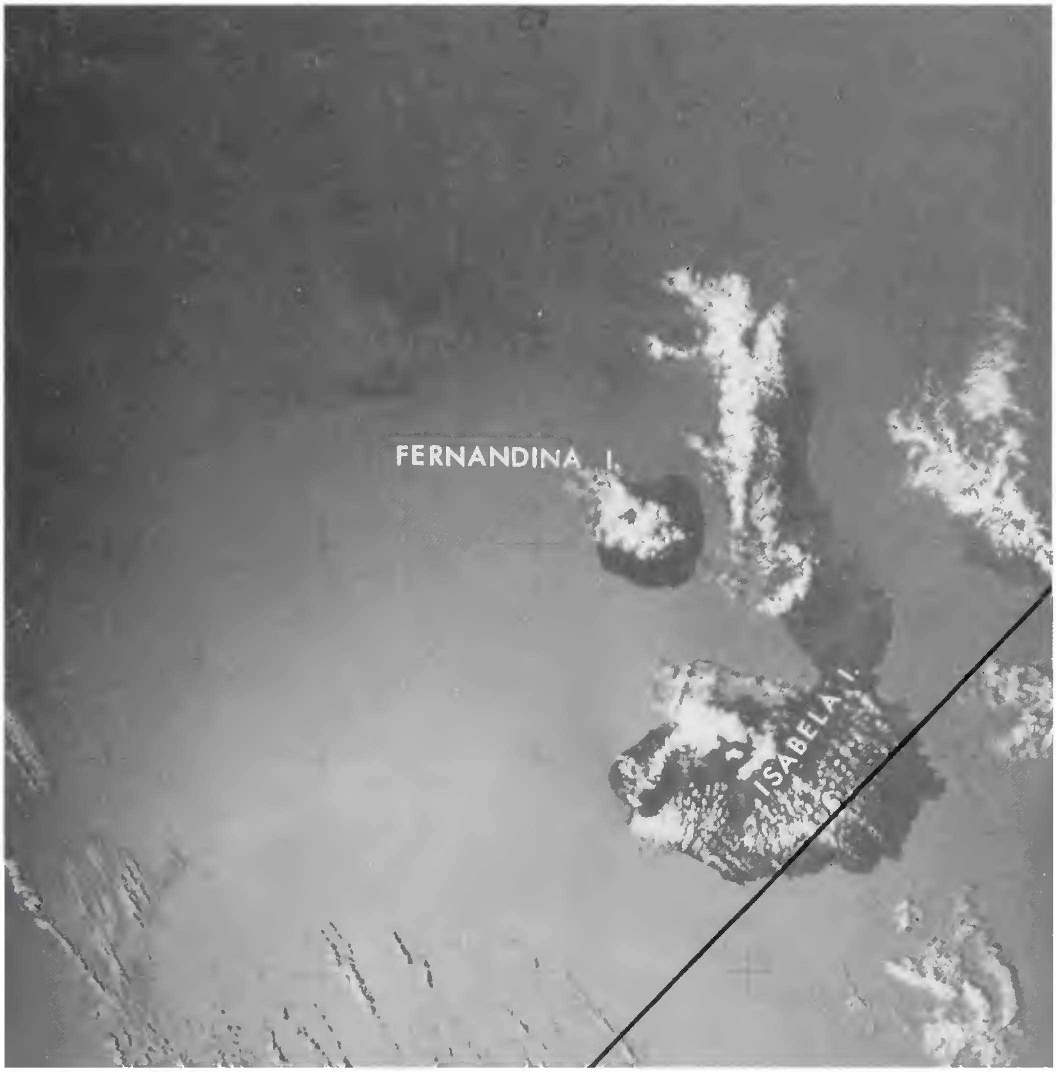



104

1. OBTAIN 3 STEREO PHOTOGRAPHS OF THE ORINOCO RIVER DELTA.
2. OBTAIN 3 STEREO PHOTOGRAPHS OF WATER NEAR BARBADOS.
3. USE COLOR CHART TO IDENTIFY WATER COLORS BETWEEN COAST AND BARBADOS.

REV 104: CM3/SILVER/50/CX15(f8,1/500) 6FR,[RECORD LAST FR NO: PAGE 5]

# 7F: GALAPAGOS ISLANDS



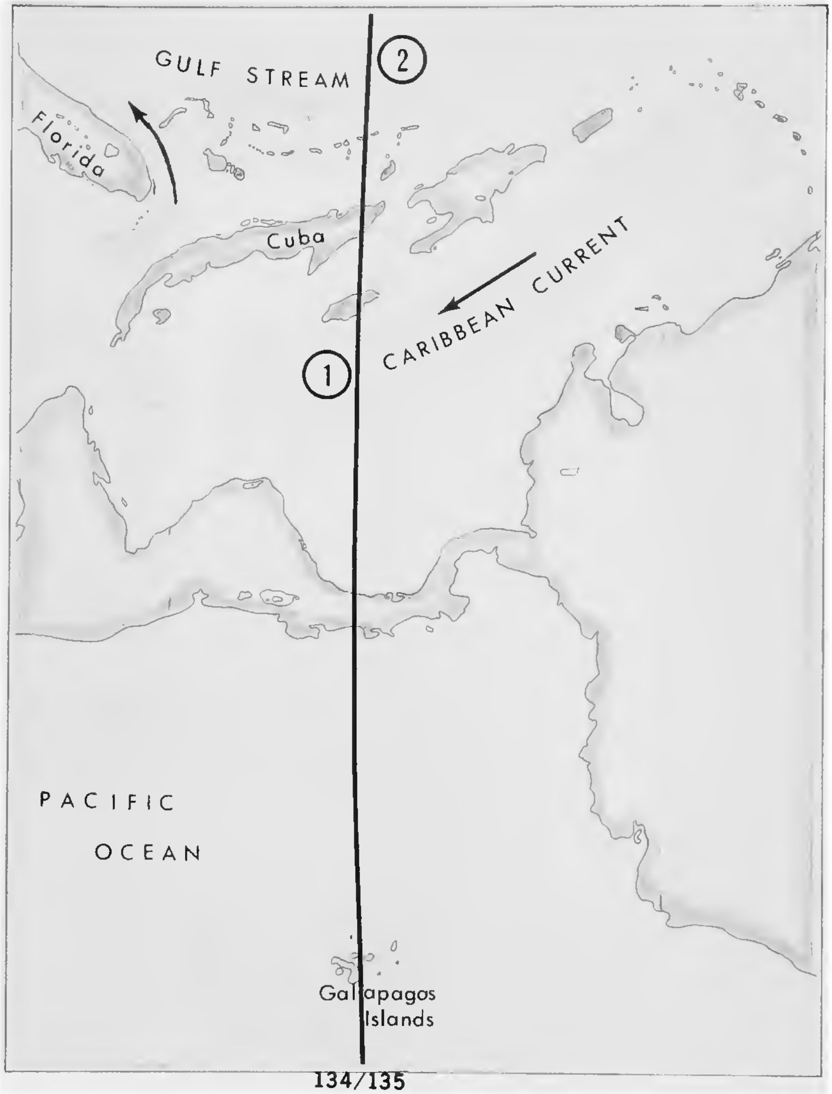

134/135

1. DESCRIBE UPWELLINGS, BOW WAVES, ISLAND WAKES, OR INTERNAL WAVES. (FERNANDINA IS AN ACTIVE VOLCANO)

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 134: CM3/SILVER/50/CX17(f9.5,1/500) 3FR,[NEXT SITE: 7G]

# 7G: CARIBBEAN SEA



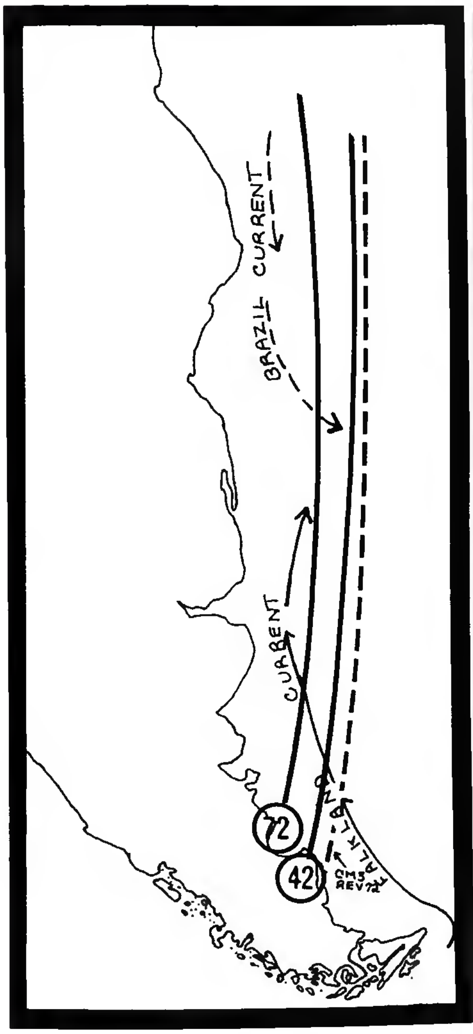

1. OBTAIN 3 STEREO PHOTOGRAPHS OF EDDIES IN THE CARIBBEAN SEA.

2. OBTAIN 3 STEREO PHOTOGRAPHS OF GULF STREAM BOUNDARIES.
   (IF CLOUDED, LOOK FOR TROPICAL STORM CENTERS [SITE 3B])

REV 134: CM3/SILVER/50/CX17(f9.5,1/500) 6FR,[NEXT SITE: 6A]

# SITE 8: SOUTHERN SOUTH AMERICA

# 8A: FALKLAND CURRENT



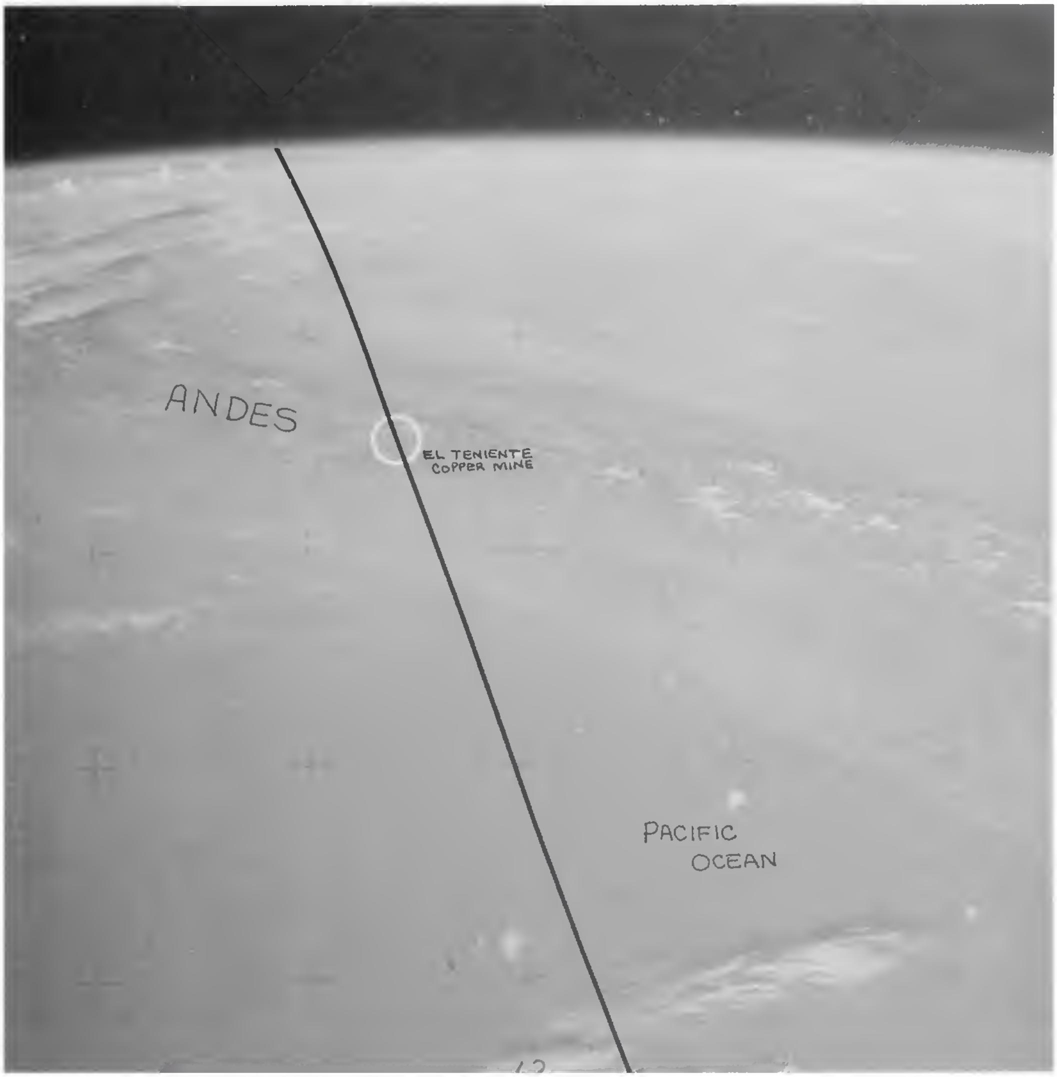


1. CAN YOU LOCATE THE FALKLAND CURRENT?
2. OBTAIN 3 STEREO FRAMES OF PLANKTON BLOOM OCCURRENCES.
3. TRACE THE FALKLAND CURRENT TO AREA OF CONFLUENCE WITH BRAZIL CURRENT. MARK G.E.T. AND OBTAIN 3 STEREO PHOTOGRAPHS.

REV 42: CM3/SILVER/50/CX11(f6.7,1/250) 6FR,[NEXT SITE: 3A]

REV 72: CM3/SILVER/250/CX12(f6.7,1/125) 6FR,[NEXT SITE: 9H - DAC STRIP]
[RECORD LAST FR NO: PAGE 4]

# 8B: CHILEAN ANDES



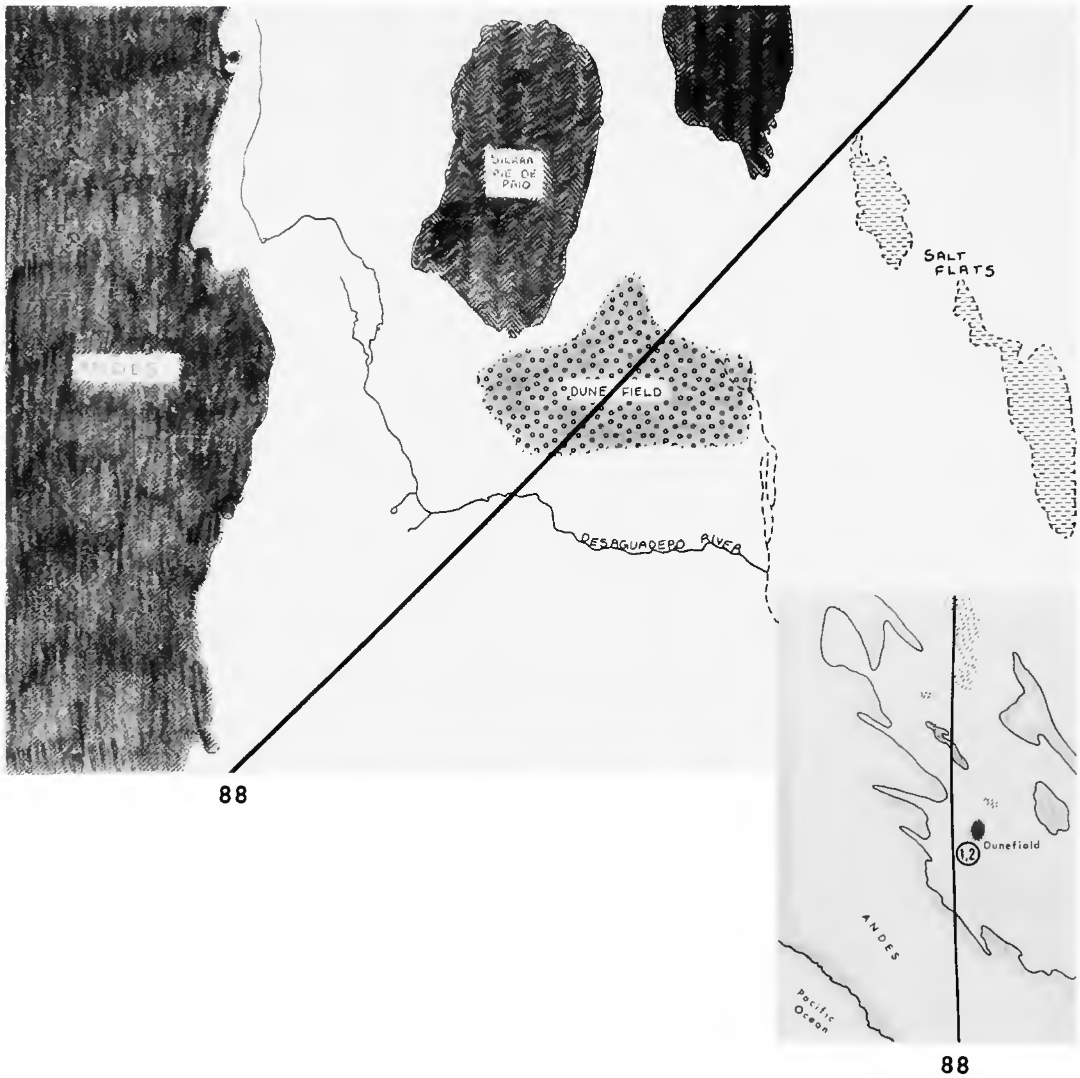

88

1. CAN YOU SEE ANY COLOR OXIDATION ZONES SIMILAR TO THOSE IN GREAT LAKES REGION (SITES 4C AND 4D)? IF SO, MARK LOCATION.

2. PHOTOGRAPH MAJOR STRUCTURES OR LINEAMENTS.

REV 88: CM3/SILVER/250/CX15(f6.7,1/250) 3FR,[NEXT SITE: 8C]

# 8C: DUNE FIELD




1. USE COLOR CHART TO IDENTIFY COLOR OF DUNE FIELD.

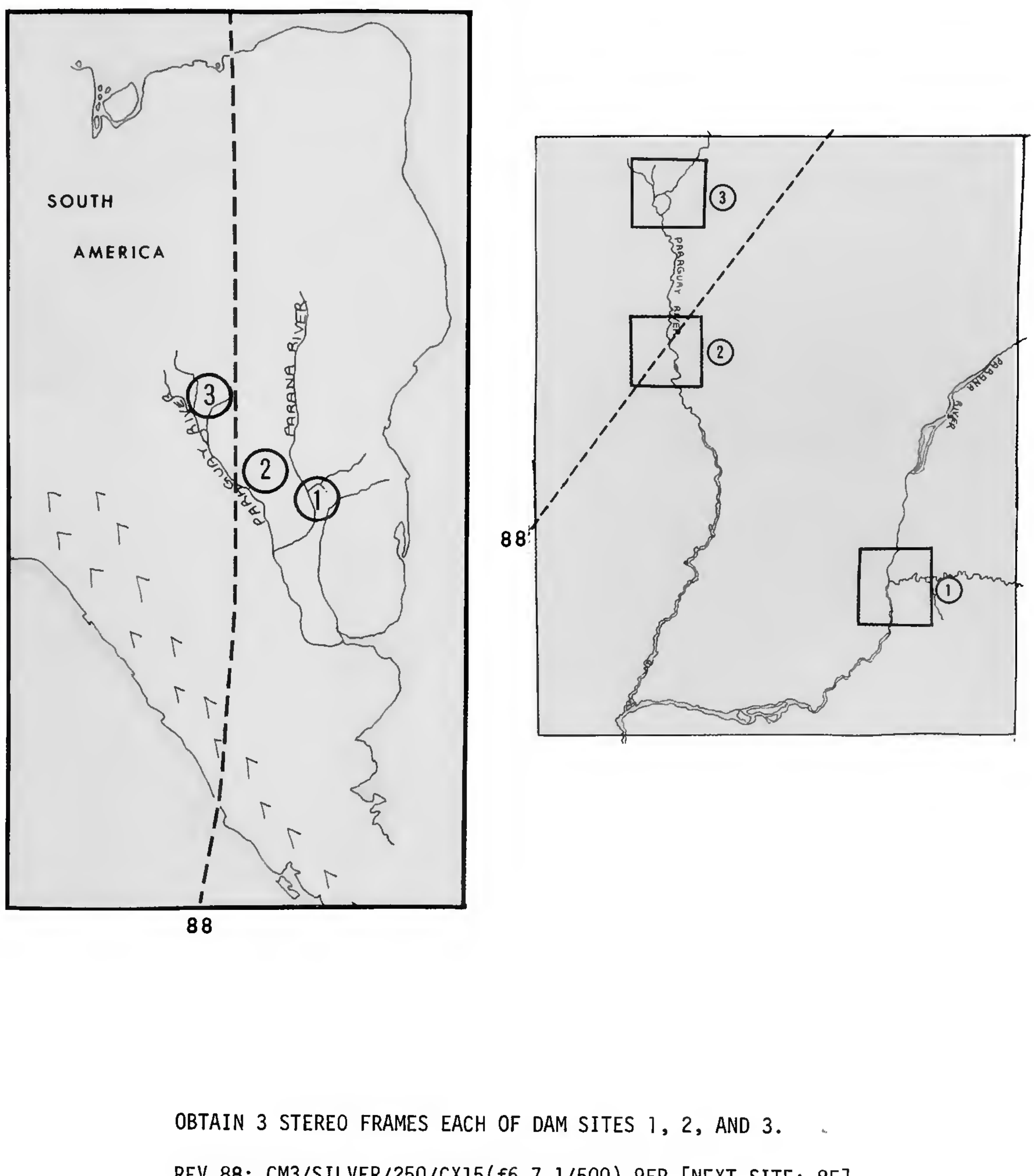
2. WHAT IS THE DUNE PATTERN AND HOW ARE THE DUNES ORIENTED?

3. IS THERE ANY RELATION BETWEEN THE DUNE FIELD AND ADJACENT MOUNTAINS?

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 88: CM3/SILVER/250/CX15(f6.7,1/250) 3FR,[NEXT SITE: 8D]

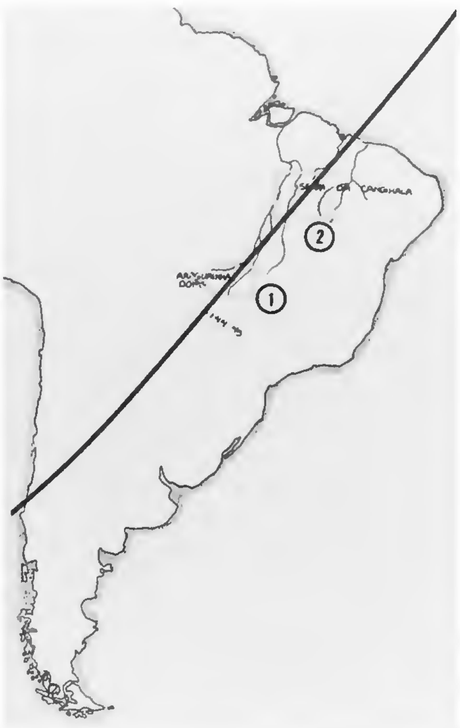
# 8D: PARANA RIVER

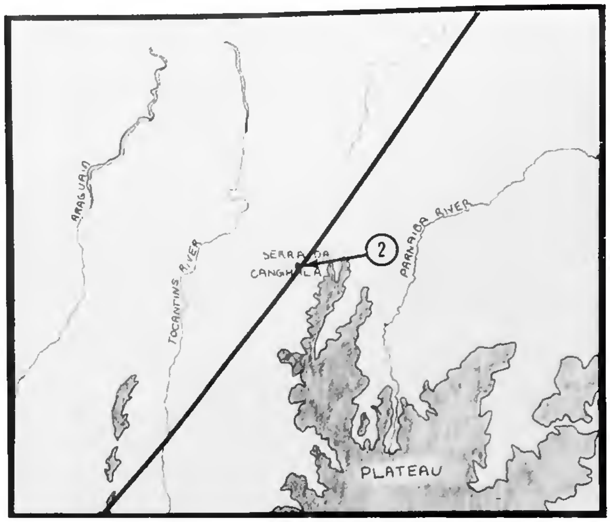


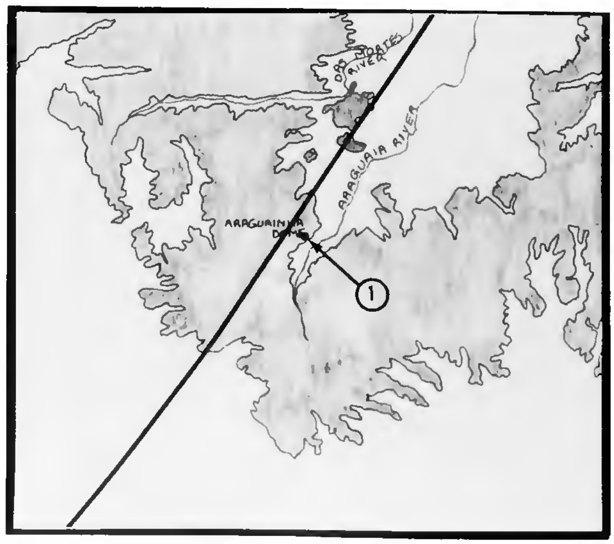

OBTAIN 3 STEREO FRAMES EACH OF DAM SITES 1, 2, AND 3.

REV 88: CM3/SILVER/250/CX15(f6.7,1/500) 9FR,[NEXT SITE: 8E]

# 8E: CIRCULAR STRUCTURES



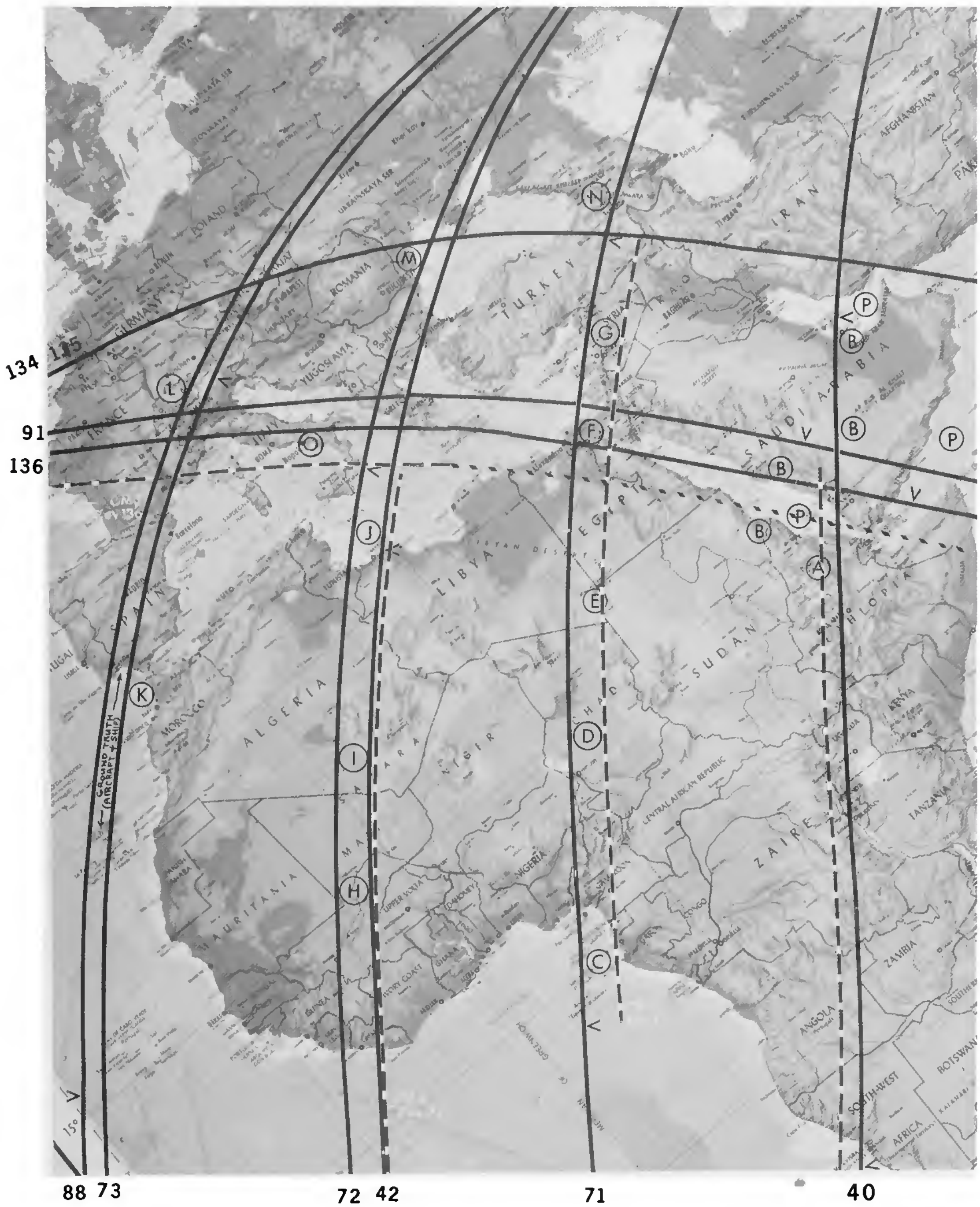



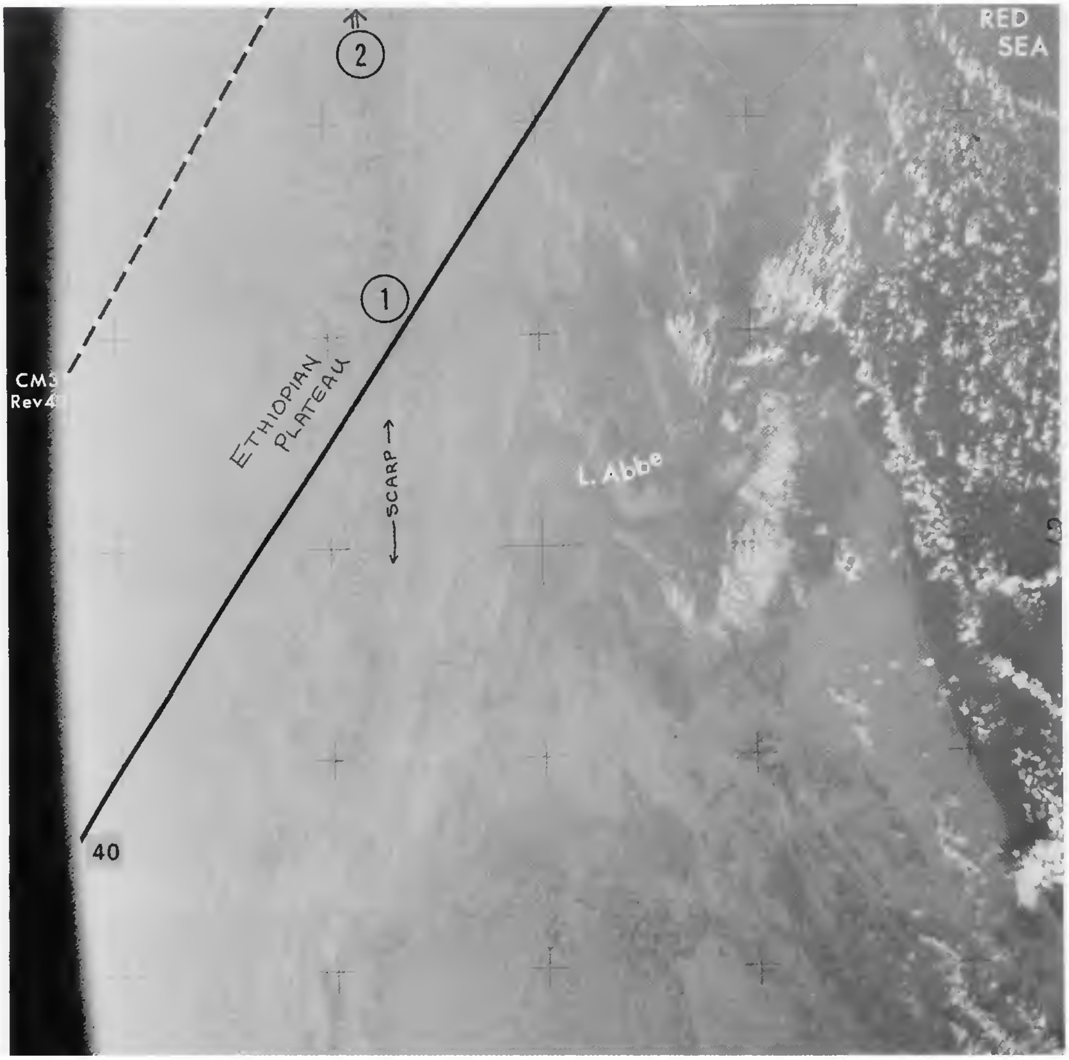

1. CAN YOU RESOLVE THE TWO CIRCULAR STRUCTURES 1 AND 2?
2. OBTAIN 3 STEREO FRAMES PER TARGET.

<u>REV 88</u>: CM3/SILVER/250/CX15(f6.7,1/500) 6FR,[NEXT SITE: 3A]

# SITE 9: AFRICA AND EUROPE



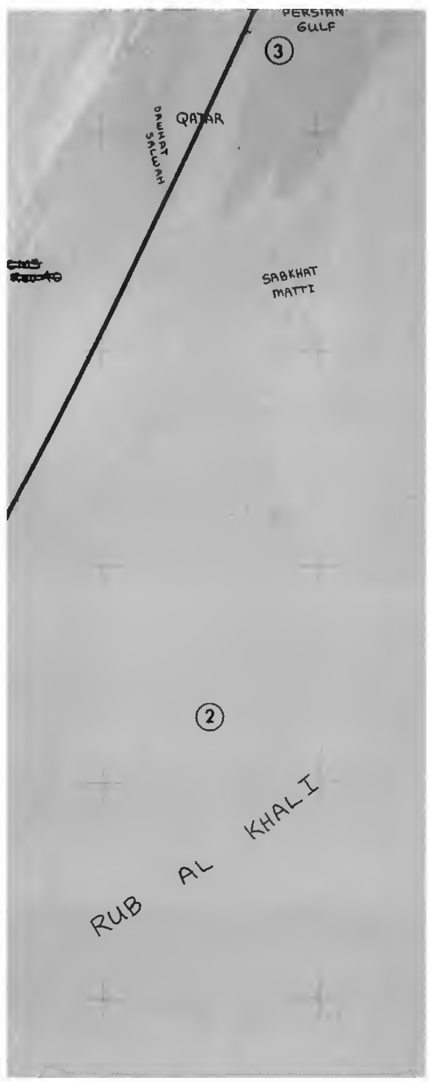
# 9A: AFAR TRIANGLE



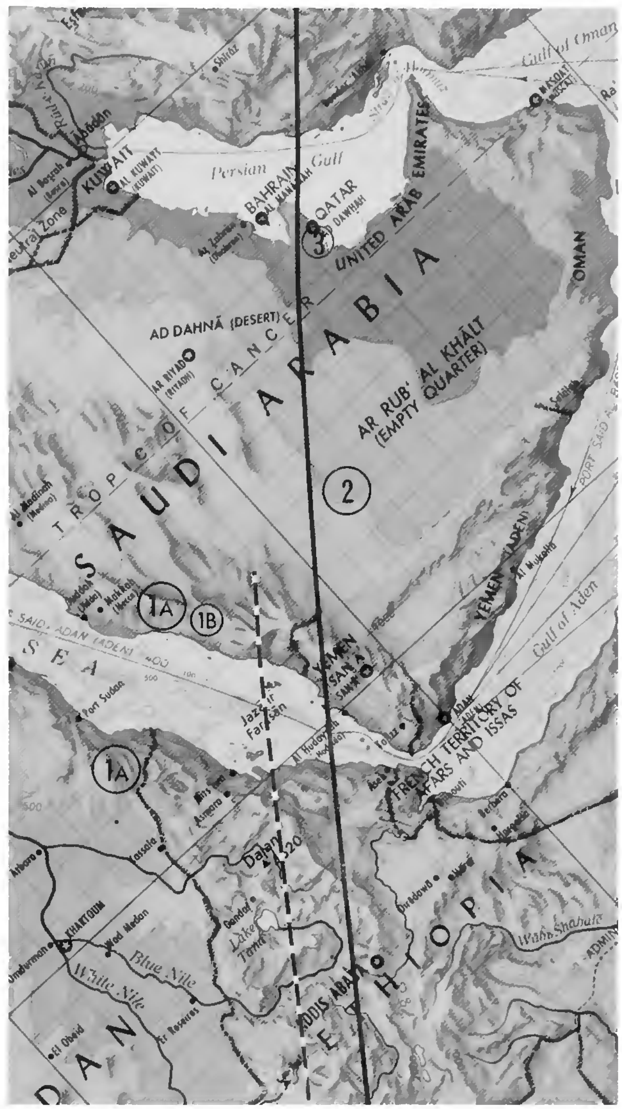

1. OBTAIN 3 STEREO PHOTOGRAPHS OF THE ETHIOPIAN PLATEAU SCARP.
2. OBSERVE MOUNTAINOUS REGION TO THE NORTH.

REV 40: CM3/SILVER/50/IF01/ORANGE FILTER(f6.7,1/500) 3FR,[NEXT SITE: 9B]

# 9B: ARABIAN PENINSULA




40




40

CM3

1A. COMPARE MOUNTAINOUS REGION ON EACH SIDE OF THE RED SEA.
B. OBTAIN 3 STEREO PHOTOGRAPHS OF STRUCTURES THAT NEARLY PARALLEL GROUNDTRACK.

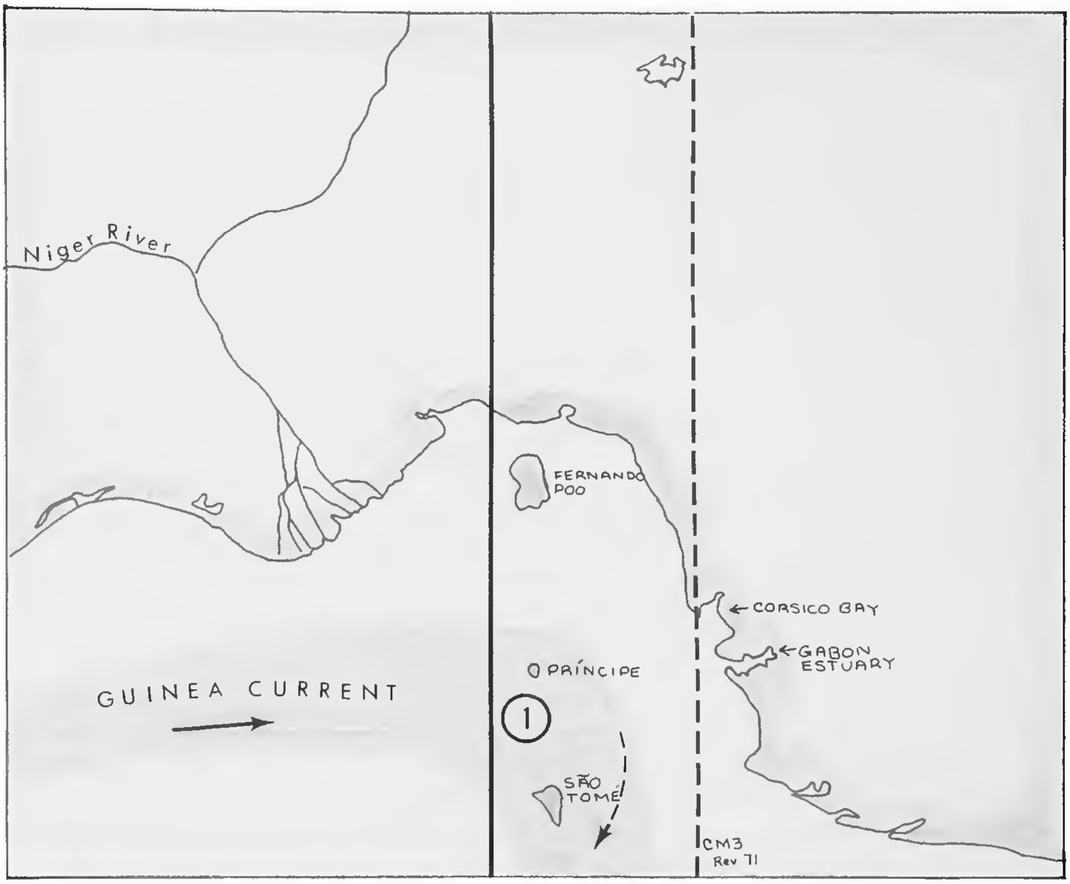
CM5

2A. USE COLOR CHART TO DEFINE DESERT COLOR TRANSITIONS.
B. IS COLOR RELATED TO DUNE TYPE OR ORIENTATION?

3. OBTAIN 3 STEREO PHOTOGRAPHS OF THE WATER-LAND INTERFACE AT DOHA, QATAR.

REV 40: CM5/SILVER/50/IF01/ORANGE FILTER(f9.5,1/500) 9FR,[RECORD LAST FR NO: PAGE 4]

# 9C: GUINEA CURRENT

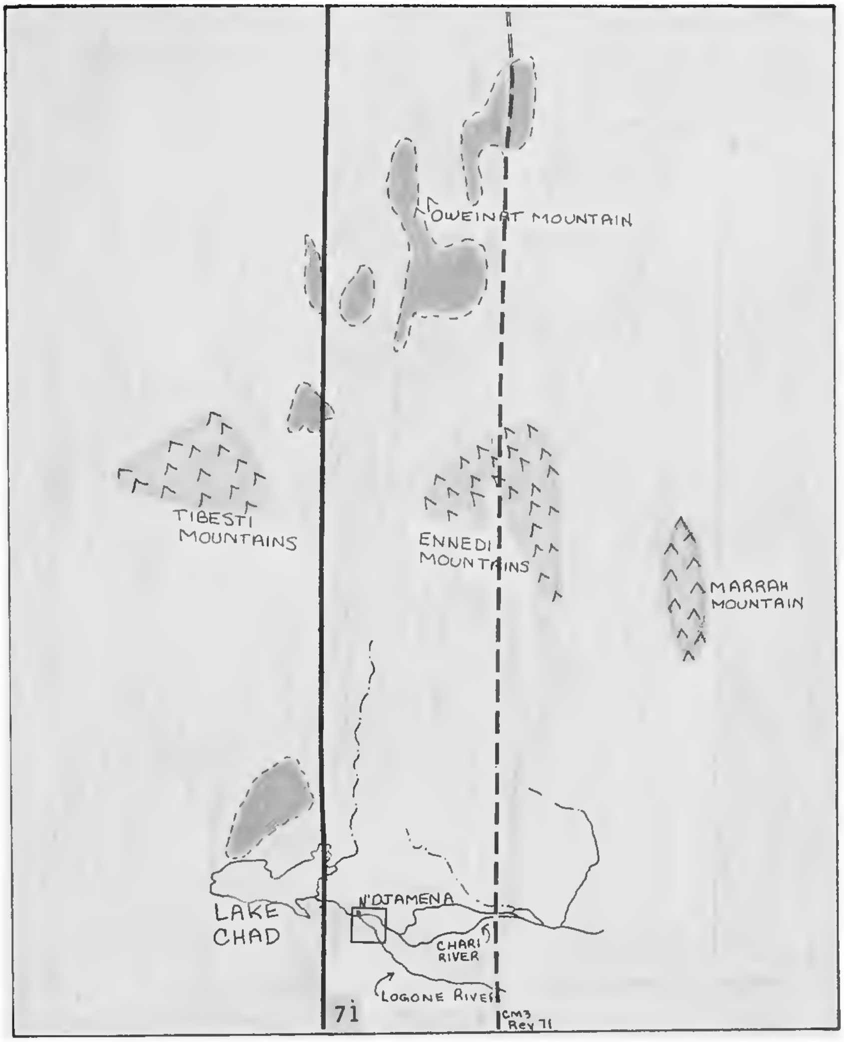



71

1. CAN YOU SEE ANY TRACES OF THE GUINEA CURRENT?
2. ARE THERE ANY GYRES IN THE AREA, IF SO MARK ON MAP.

REV 71: CM3/SILVER/250/CX12(f8,1/250) 3FR,[NEXT SITE: 9D]

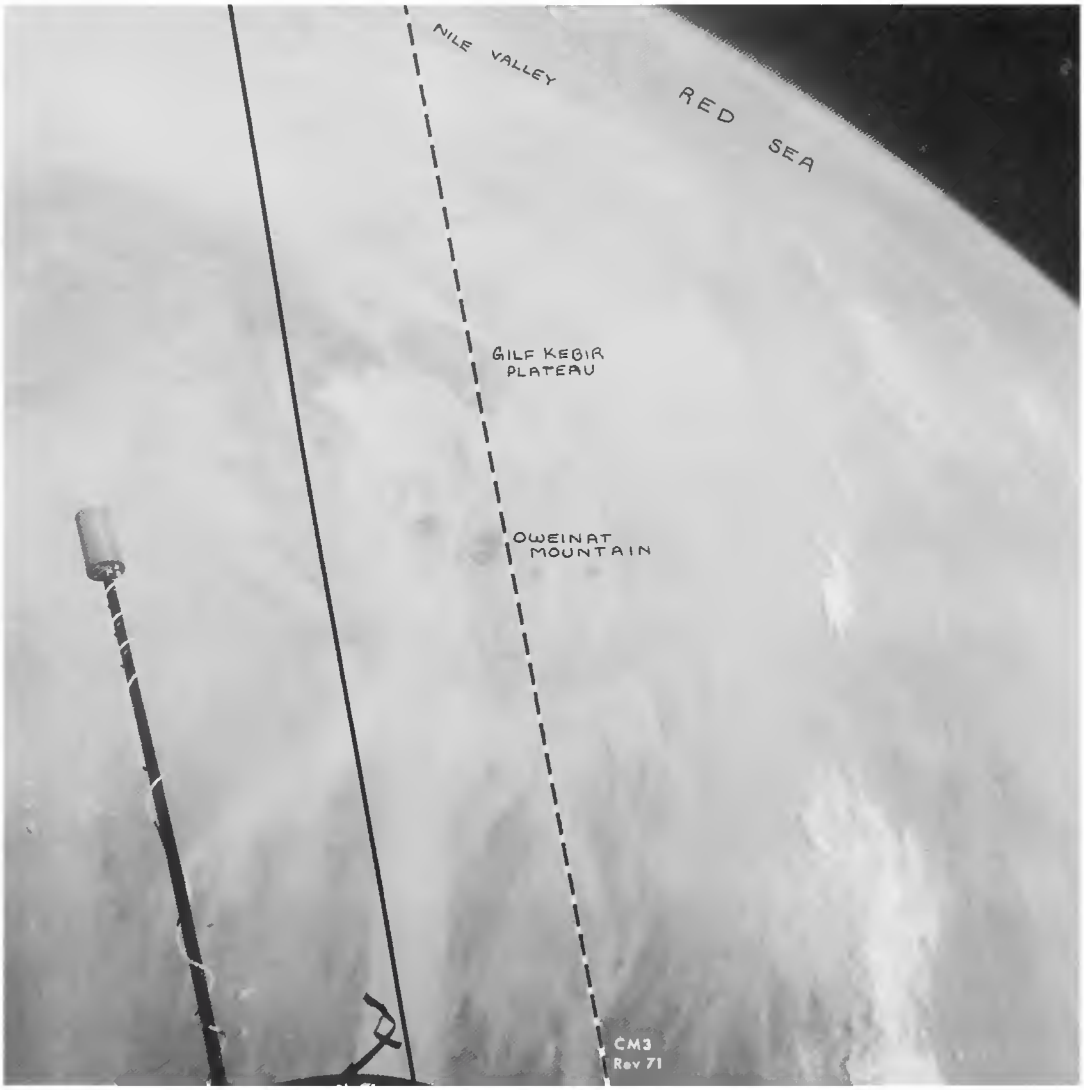
# 9D: DESERT COLORS




1. OBTAIN 3 STEREO PHOTOGRAPHS OF AREA SOUTHEAST OF N'DJAMENA. (Indicated by square)
2. USE COLOR CHART TO DEFINE DESERT COLORS, NORTH OF LAKE CHAD.
3. WHAT DUNE PATTERNS CAN YOU OBSERVE; DO THEY HAVE DIFFERENT COLORS?

REV 71: CM3/SILVER/250/CX12(f11,1/500) 6FR,[NEXT SITE: 9E]

# 9E: OWEINAT MOUNTAIN




71

1. OBTAIN 3 STEREO PHOTOGRAPHS OF OWEINAT MOUNTAIN AND ADJACENT DUNEFIELDS.
2. CAN YOU RESOLVE ANY STRUCTURES IN THE MOUNTAIN?
3. ARE THERE ANY COLOR OXIDATION ZONES ON THE MOUNTAIN?

REV 71: CM3/SILVER/250/CX12(f11,1/500) 3FR,[NEXT SITE: 9F]

# 9F: NILE DELTA

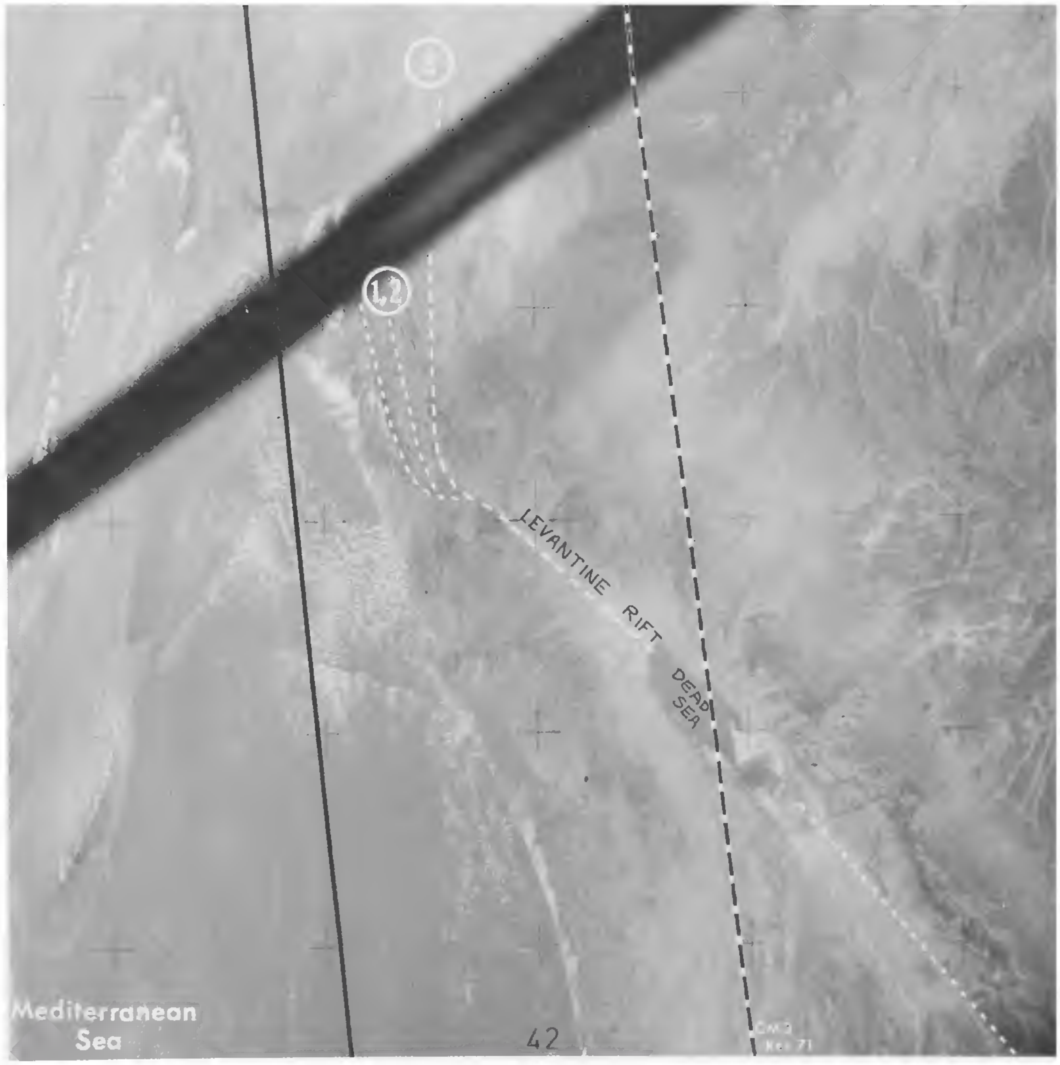

1. CAN YOU RESOLVE THE PYRAMIDS WITHOUT SCOPE?

2. OBTAIN 3 STEREO PHOTOGRAPHS OF CAIRO.

3. OBTAIN 3 STEREO PHOTOGRAPHS LOOKING SOUTHWARD ALONG THE GULF OF SUEZ.

REV 71: CM3/SILVER/250/CX12(f8,1/500) 9FR,[NEXT SITE: 9G]

# 9G: LEVANTINE RIFT




1. OBTAIN 3 STEREO PHOTOGRAPHS OF THE ARCUATE TERMINATIONS OF THE LEVANTINE RIFT.
2. CAN YOU DISTINGUISH RELATED GROUPS OF FAULTS?
3. WHERE IS THE NORTHERNMOST TERMINATION OF THIS FAULT COMPLEX?

REV 71: CM3/SILVER/250/CX12(f8,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

# 9H: NIGER RIVER DELTA


1. IN AREA OF FOSSIL DUNES, CAN YOU DISTINGUISH YOUNGER DUNE GENERATIONS? DELINEATE THEIR ORIENTATIONS ON PHOTOGRAPH, MARKING THEM FROM OLDEST TO YOUNGEST.

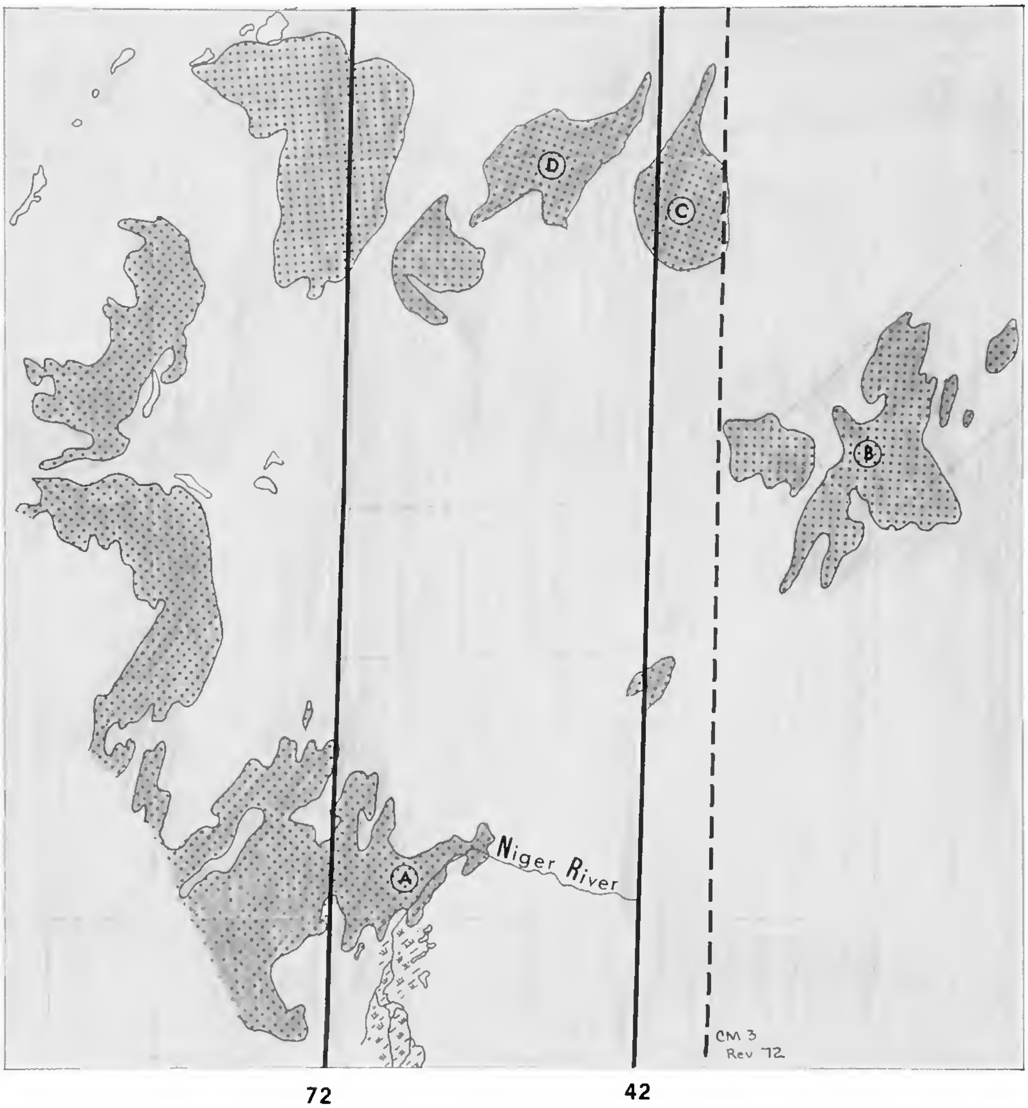
2. WHERE DO YOU SEE VEGETATION PATTERNS?

3. OBTAIN 3 STEREO PHOTOGRAPHS OF INTERESTING FEATURES.

REV 42: CM3/SILVER/50/IF01/ORANGE FILTER(f9.5,1/500) 6FR,[NEXT SITE: 9I]

REV 72: CM3/DAC/25/CT01/6fps(f8,1/125) 11 MINUTES TOTAL STRIP
[MAKE GENERAL COMMENTS ONLY]

# 9I: ALGERIAN DESERT




1. USE COLOR WHEEL TO DEFINE DESERT COLORS.

2. IS COLOR RELATED TO OBSERVABLE DUNE PATTERNS? OBTAIN 3 STEREO PHOTOGRAPHS.

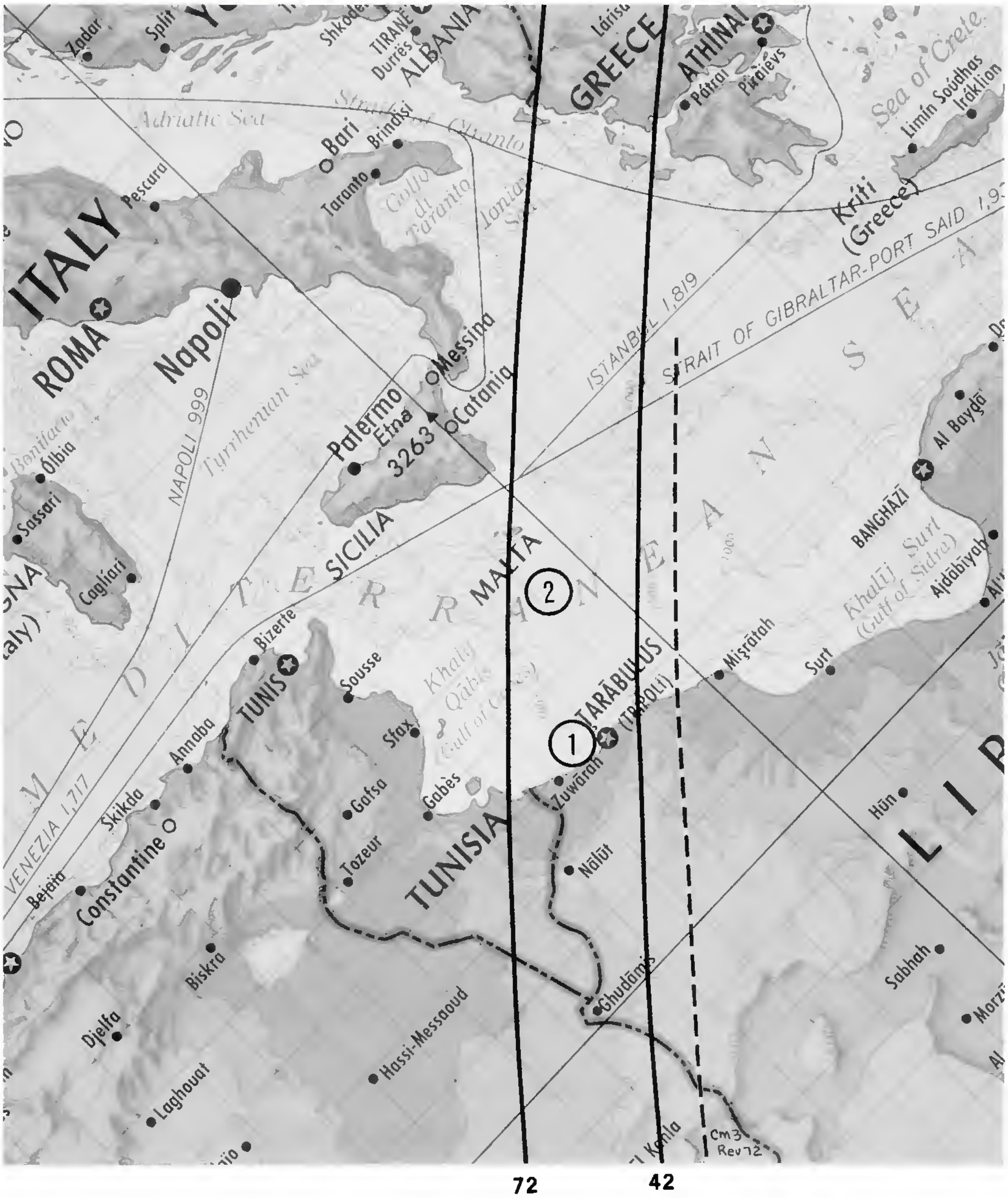
3. DESCRIBE INTERDUNE AREAS AND RELATIONSHIP BETWEEN DUNES AND ADJACENT HILLS.

4. DESCRIBE TRANSITION ZONES BETWEEN DESERT AND ANY VEGETATED LAND.

REV 42: CM3/SILVER/50/IF01/ORANGE FILTER(f9.5,1/500) 6FR,[NEXT SITE: 9J]

REV 72: CM3/DAC/25/CT01/6fps(f8,1/125) 11 MINUTES TOTAL STRIP
[MAKE GENERAL COMMENTS ONLY]

# 9J: TRIPOLI



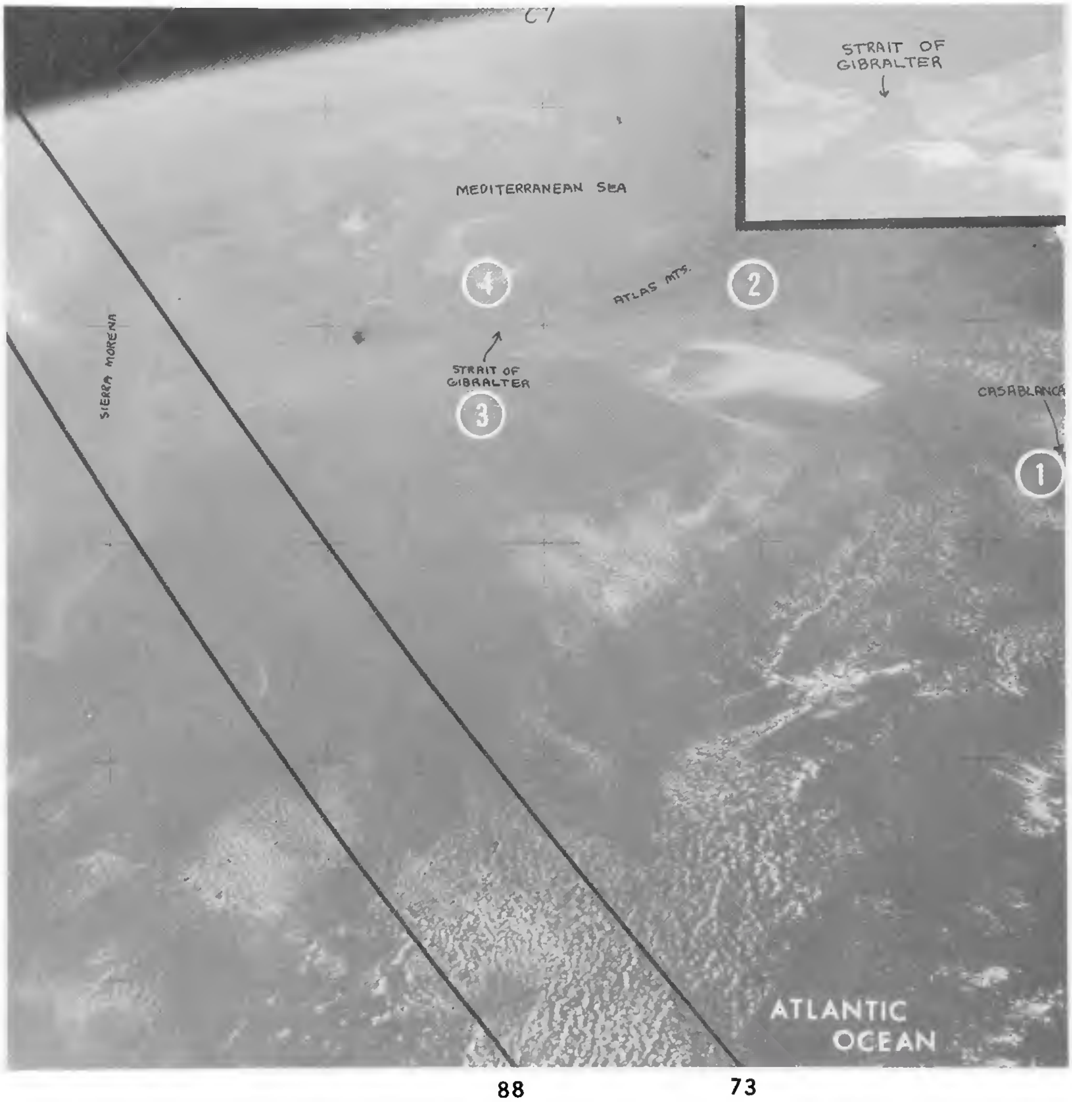

1. OBTAIN 3 STEREO PHOTOGRAPHS OF WATER-LAND INTERFACE AT TRIPOLI.

2. BETWEEN TRIPOLI AND SICILY, CAN YOU SEE: EDDIES OR GYRES? CURRENT BOUNDARIES? INTERNAL WAVES? PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 42: CM3/SILVER/50/IF01/ORANGE FILTER(f9.5,1/500) 6FR,[RECORD LAST FR NO: PAGE 4]

REV 72: CM3/DAC/25/CT01/6fps(f8,1/125) 11 MINUTES TOTAL STRIP [MAKE GENERAL COMMENTS ONLY]

# 9K: STRAIT OF GIBRALTAR




1. OBTAIN 3 STEREO PHOTOGRAPHS OF WATER-LAND INTERFACE AT CASABLANCA.

2. OBTAIN 3 STEREO PHOTOGRAPHS OF ATLAS MOUNTAINS.

3. CAN YOU SEE CURRENT BOUNDARIES WEST OF THE STRAIT OF GIBRALTAR?

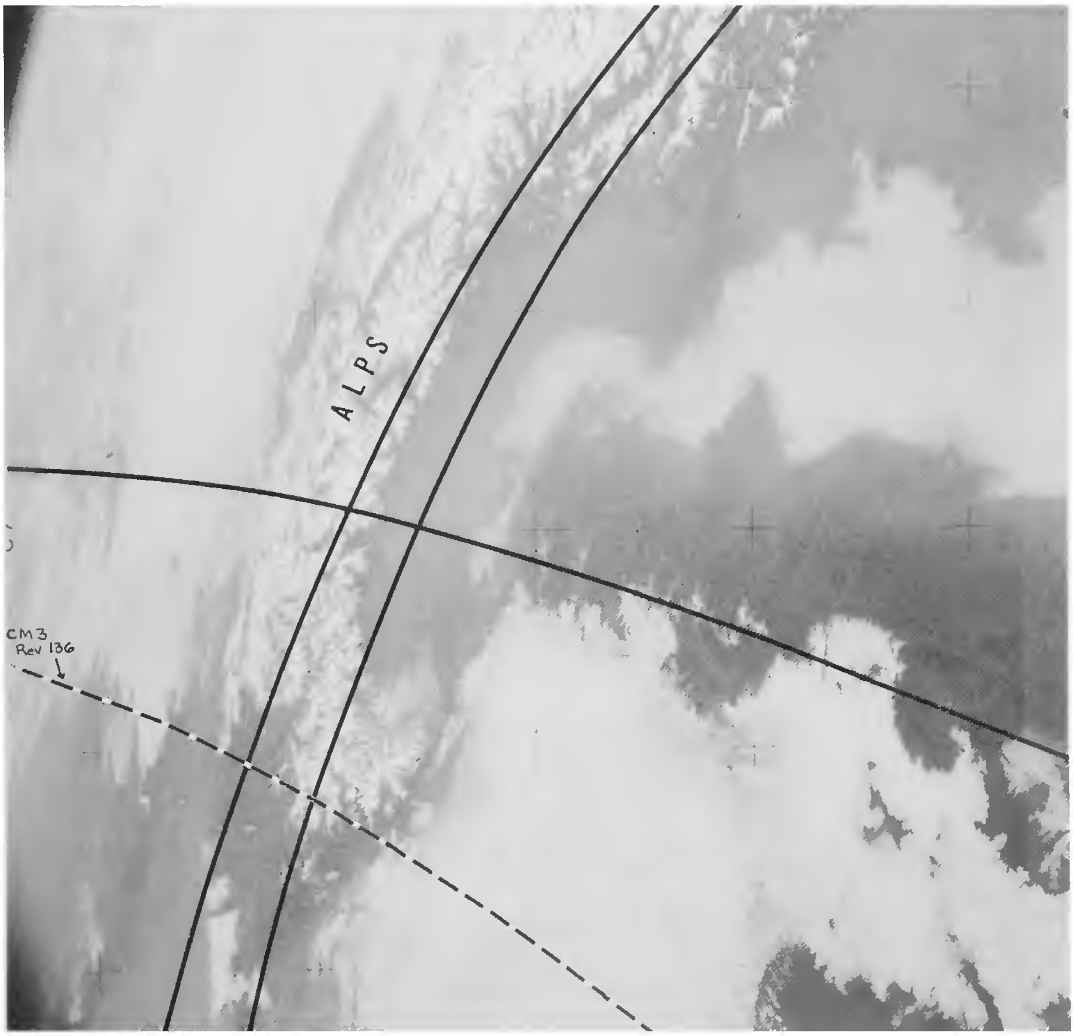
4. DESCRIBE TURBULENCE OR INTERNAL WAVES EAST OF THE STRAIT OF GIBRALTAR.

PHOTOGRAPHS: 3 STEREO FRAMES PER TARGET.

REV 73: CM3/SILVER/50/CX14,(f9.5,1/500) 9FR,[NEXT SITE: 9L]

REV 88: CM3/SILVER/250/CX15(f9.5,1/500) 9FR,[NEXT SITE: 9L]

# 9L: ALPS




1. OBTAIN 3 STEREO PHOTOGRAPHS OF SNOW COVER PATTERNS.

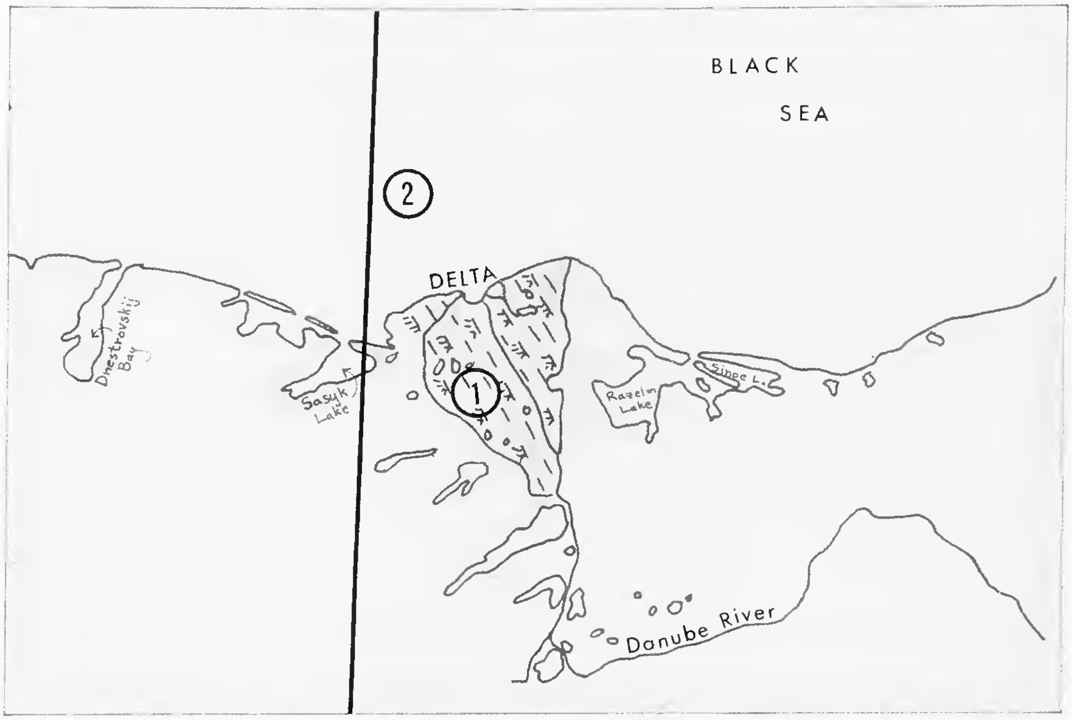
2. CAN YOU DISTINGUISH ANY GLACIERS OR FIRN LINES?

REV 73: CM3/SILVER/50/CX14(f9.5,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

REV 88: CM3/SILVER/250/CX15(f9.5,1/500) 3FR,[RECORD LAST FR NO: PAGE 5]

REV 136: CM3/SILVER/250/IF02/ORANGE FILTER(f5.6,1/250) 3FR,[NEXT SITE: 90]

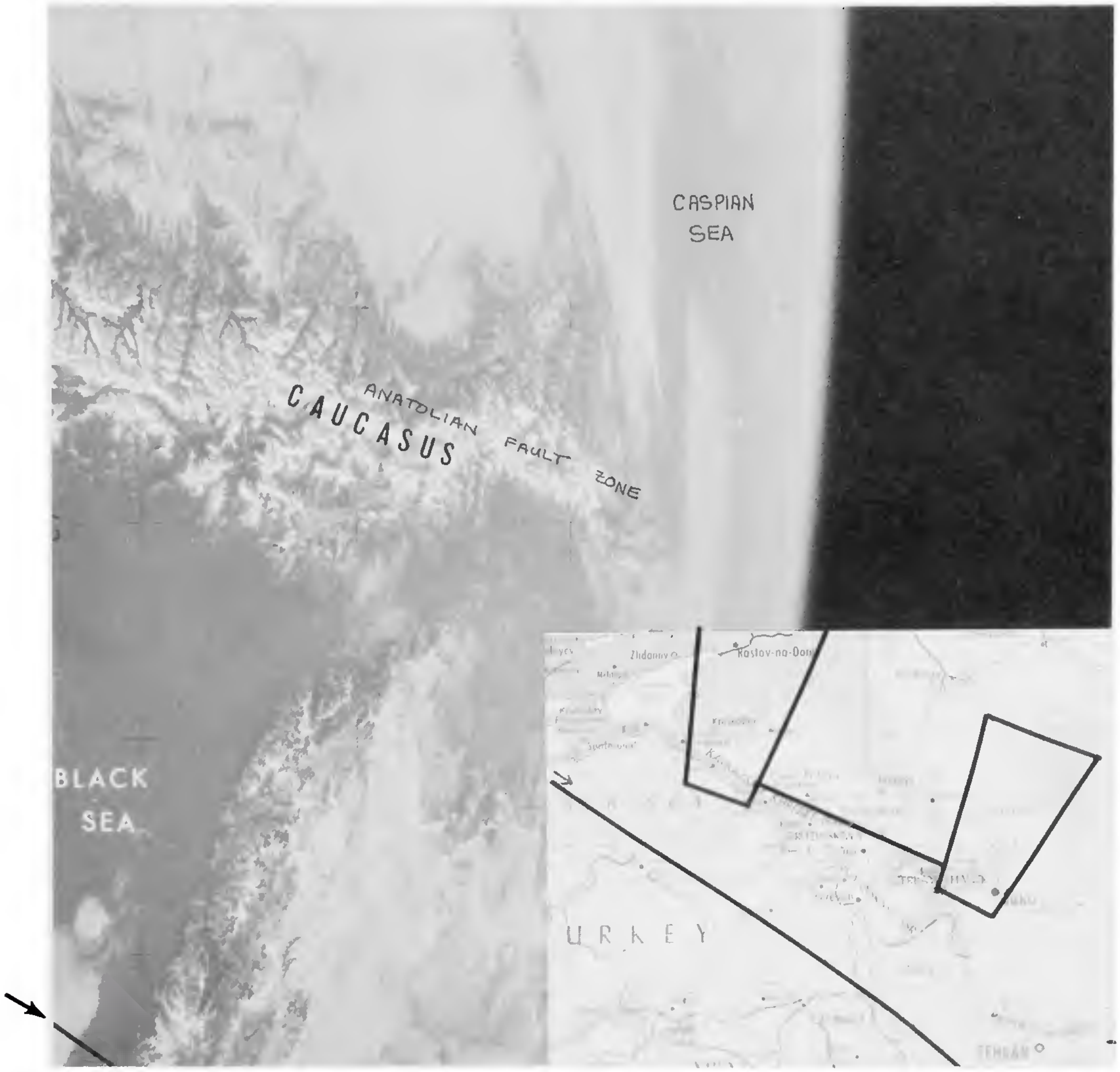
# 9M: DANUBE DELTA




1. OBTAIN 3 STEREO PHOTOGRAPHS OF DANUBE DELTA.
2. CAN YOU SEE ANY SEDIMENT PLUMES IN THE BLACK SEA?

REV 135: CM3/SILVER/50/CX17(f5.6,1/500) 3FR,[NEXT SITE: 9N, CHANGE TO CM5]

# 9N: ANATOLIAN FAULT



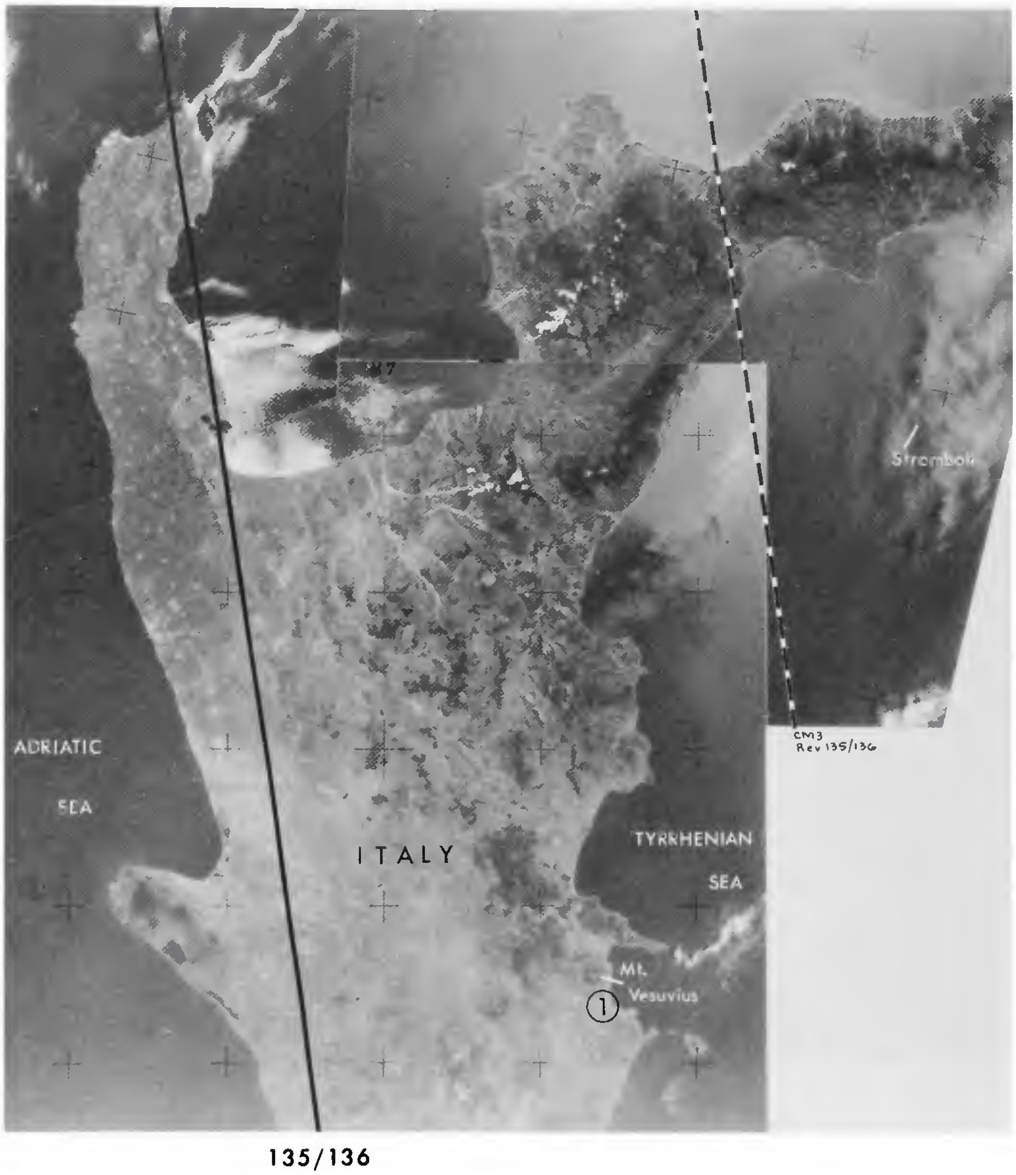

134/135 135

1. OBTAIN 6 STEREO PHOTOGRAPHS OF THE ANATOLIAN FAULT ZONE. (FRAME INTERVAL: 6 SECS)

2. CAN YOU SEE ANY SNOW COVER ON TOP OF THE PEAKS?

REV 135: CM5/SILVER/50/CX17(f5.6,1/500) 6FR,[NEXT SITE: 9P]

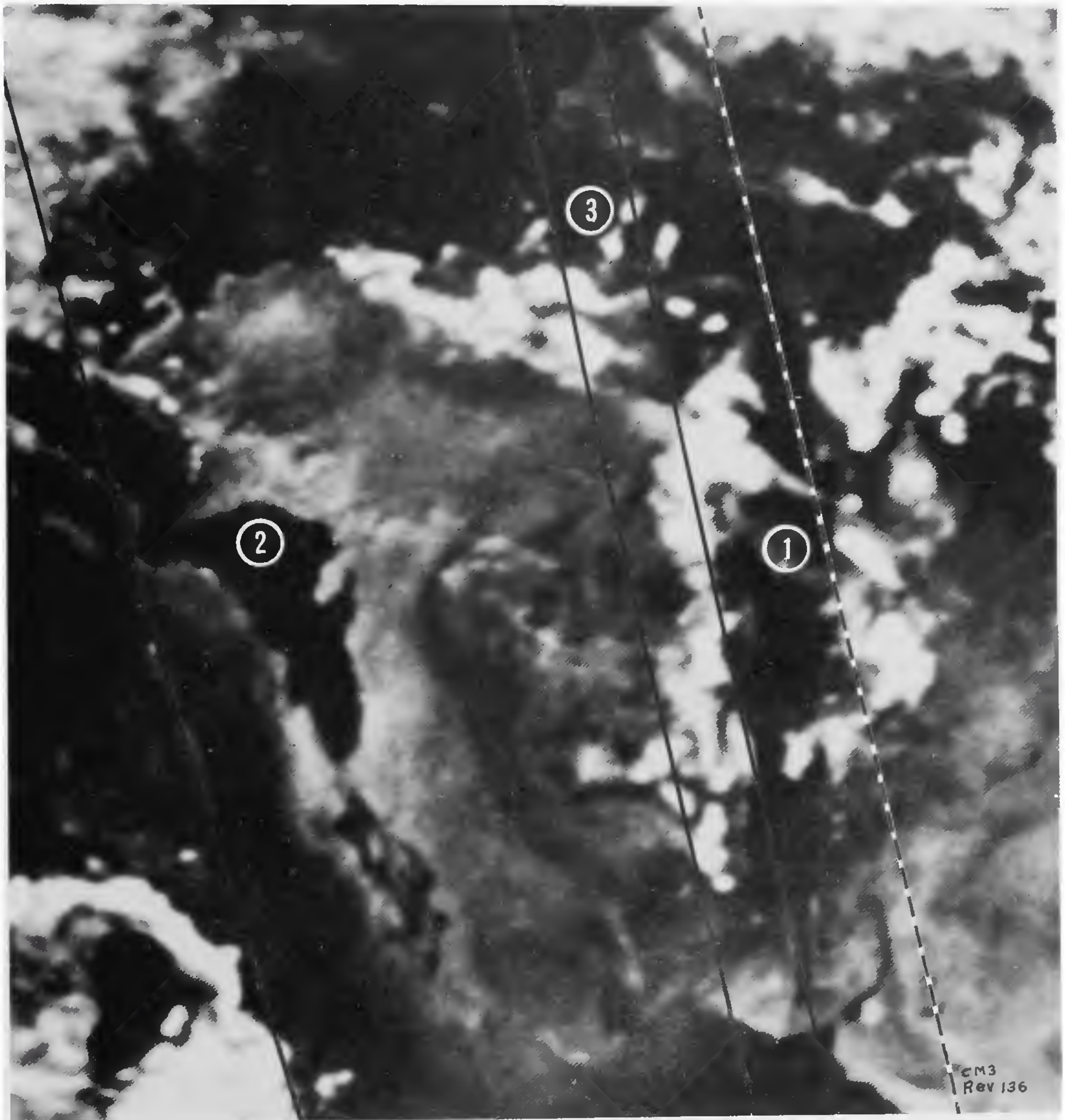
# 90: VOLCANICS




1. OBTAIN 3 STEREO PHOTOGRAPHS OF VESUVIUS AND OTHER DARK-COLORED VOLCANIC ROCKS.

REV 136: CM3/SILVER/250/IF01/ORANGE FILTER(f5.6,1/125) 6FR,[NEXT SITE: 9P]

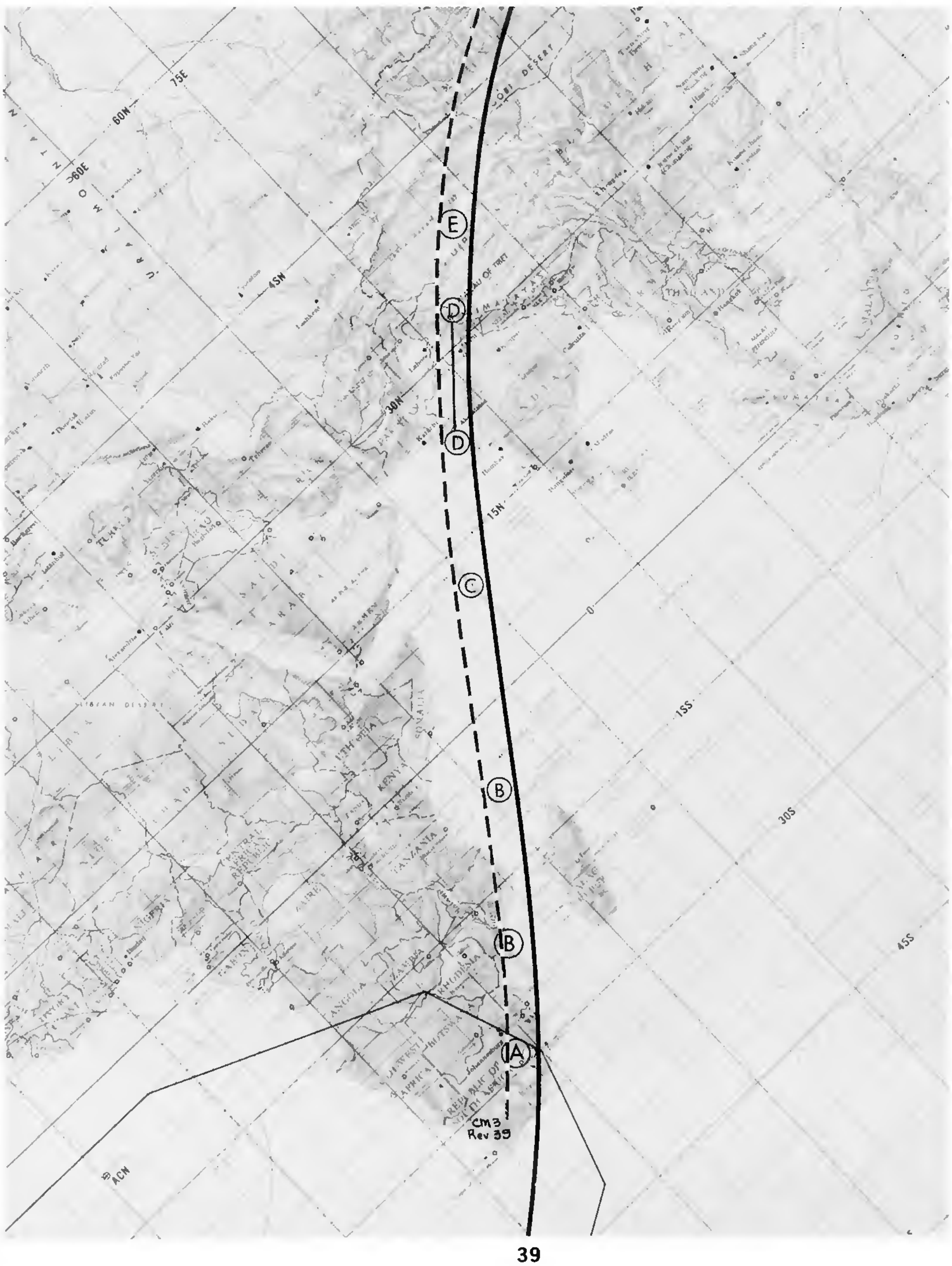
# 9P: BIOLUMINESCENCE




MARK G.E.T. IF YOU SEE ANY FLICKERS OF LIGHT THAT MAY BE DUE TO BIOLUMINESCENCE IN:

1. REV 91: CM3/RED SEA [RECORD LAST FR NO: PAGE 5]
2. REV 135: CM3/PERSIAN GULF AND ARABIAN SEA [RECORD LAST FR NO: PAGE 5]
3. REV 136: CM3/RED SEA AND GULF OF ADEN [RECORD LAST FR NO: PAGE 5]

# SITE 10: AFRICA AND INDIA

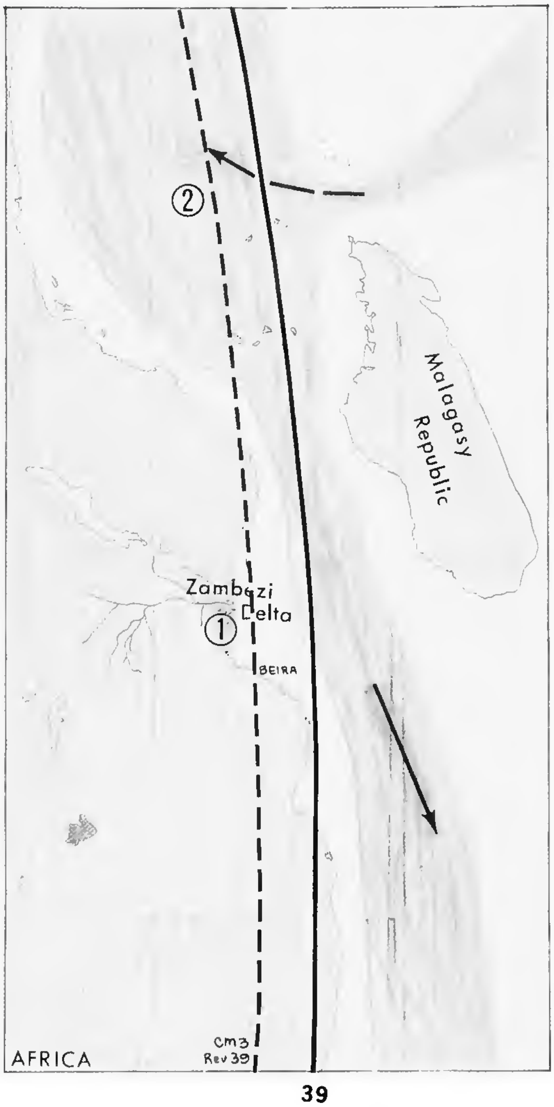


# 10A: GREAT DIKE


1. COMPARE THE COLOR OF THE GREAT DIKE TO THAT OF THE SURROUNDING ROCK.
2. OBTAIN 3 STEREO PHOTOGRAPHS OF THE DIKE.

REV 39: CM3/SILVER/50/IF01/ORANGE FILTER(f5.6,1/500) 3FR,[NEXT SITE: 10B]

# 10B: SOMALI CURRENT

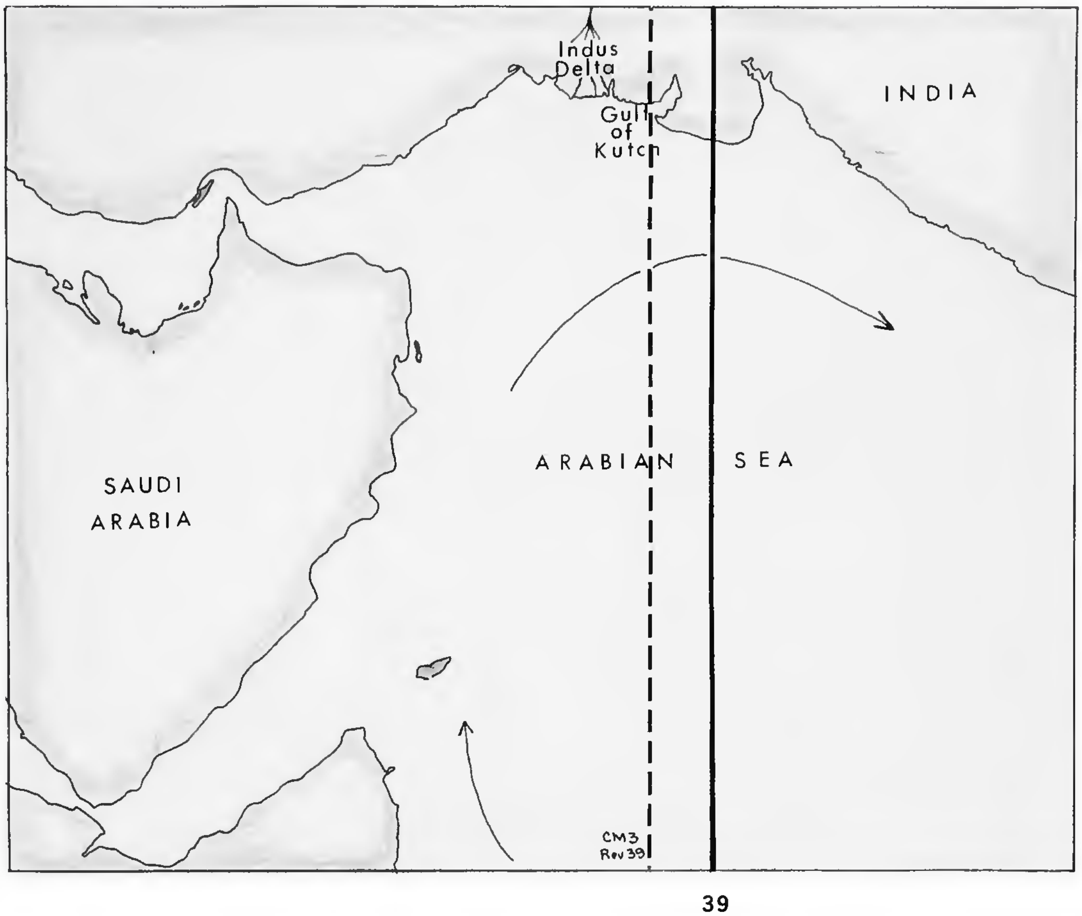



1. OBTAIN 3 STEREO PHOTOGRAPHS OF ZAMBEZI RIVER DELTA.

2. OFF THE COAST OF AFRICA, CAN YOU SEE: SEDIMENT PLUMES?
   CURRENT BOUNDARIES?
   INTERNAL WAVES?

REV 39: CM3/SILVER/50/IF01/ORANGE FILTER(f6.7,1/500) 3FR,[NEXT SITE: 10C]

# 10C: ARABIAN SEA

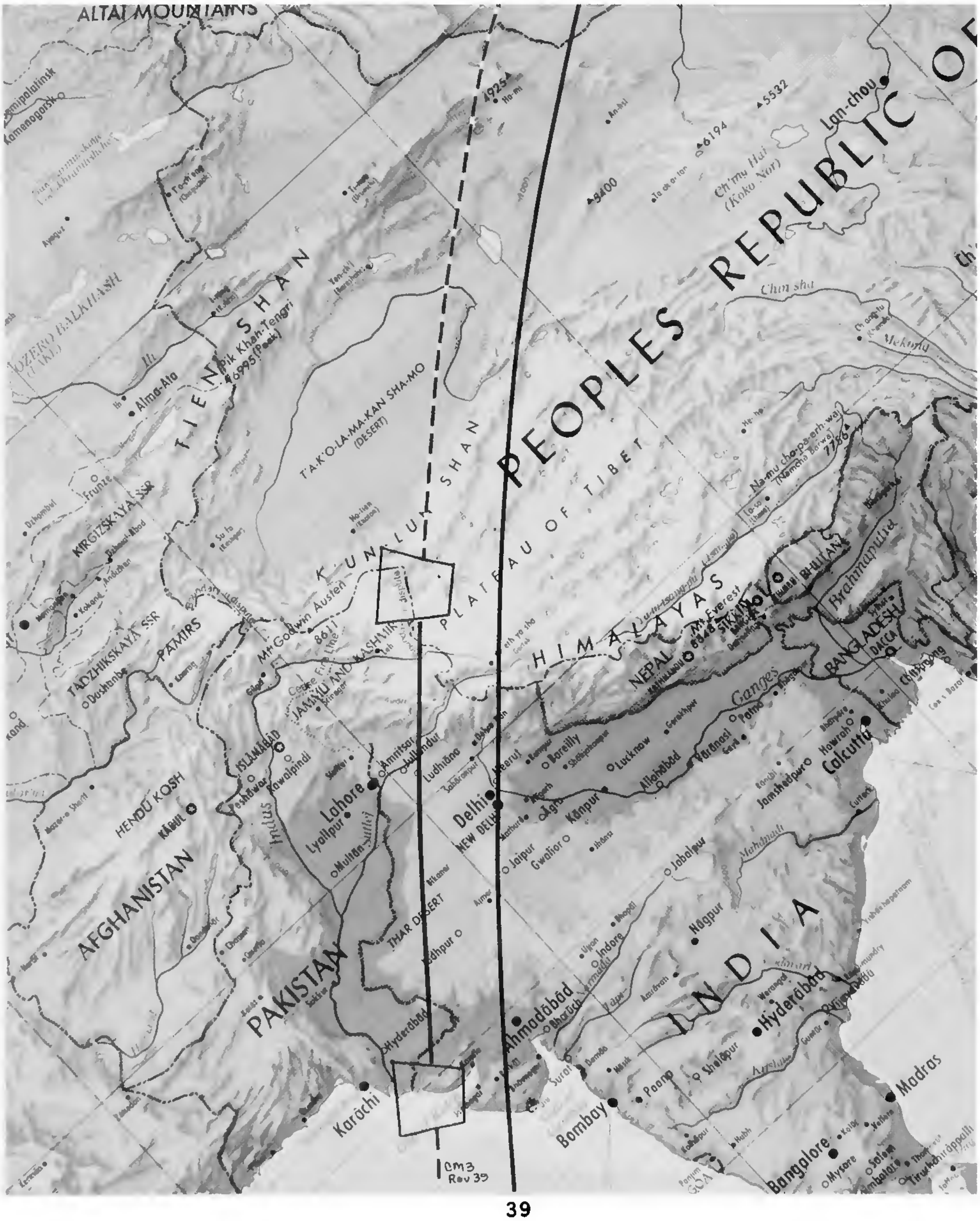



1. CAN YOU SEE CURRENT BOUNDARIES IN THE ARABIAN SEA?

2. OBTAIN 3 STEREO PHOTOGRAPHS OF INTERESTING FEATURES.

REV 39: CM3/SILVER/50/IF01/ORANGE FILTER(f6.7,1/500) 3FR,[NEXT SITE: 10D]

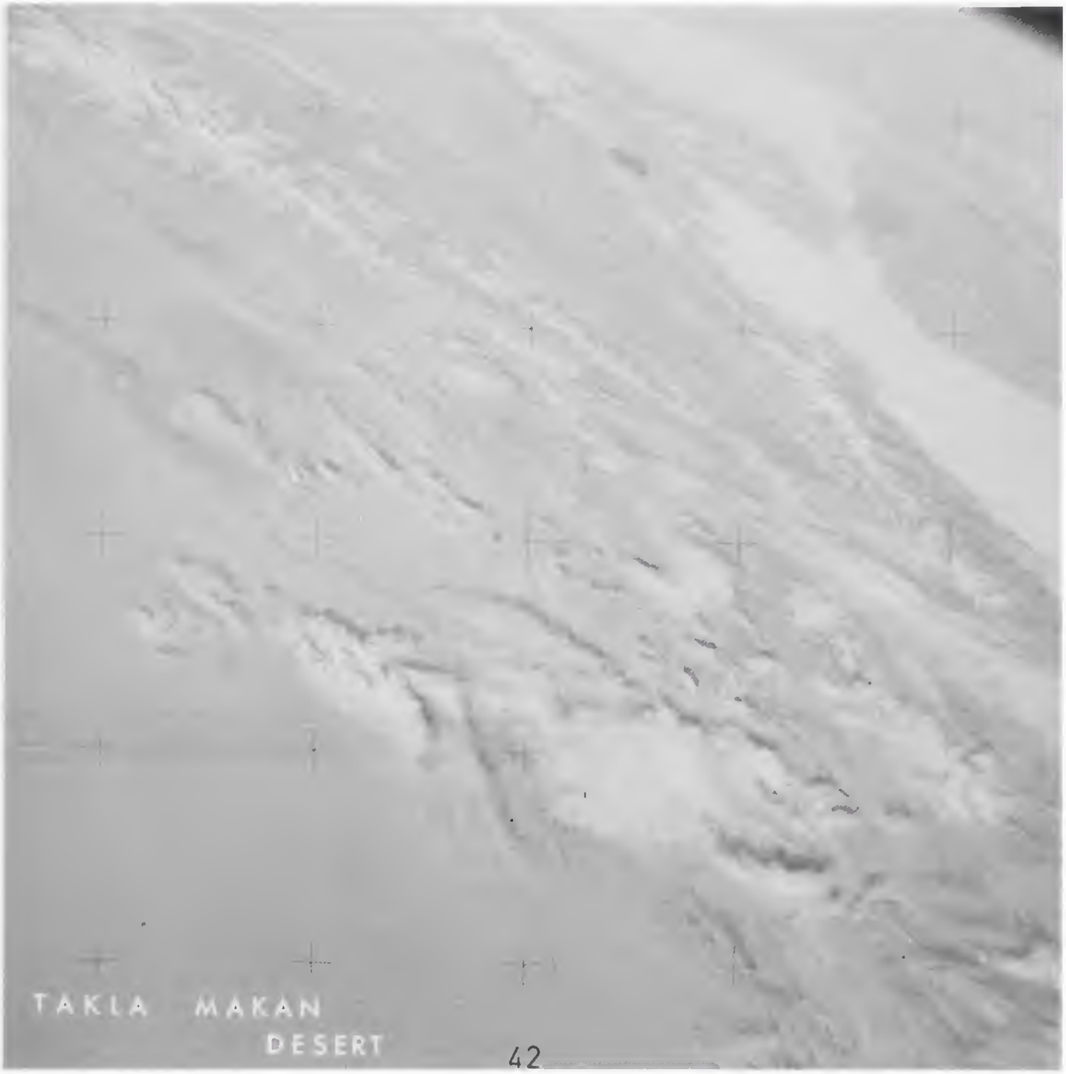
# 10D: HIMALAYA MOUNTAINS




OBTAIN 20 PHOTOGRAPHS THROUGH CENTER OF CM3 ALONG SOLID BLACK LINE.
(FRAME INTERVAL: 10 SECS)

REV 39: CM3/SILVER/50/IF01/ORANGE FILTER(f8,1/500) 20FR,[NEXT SITE: 10E]

# 10E: TAKLA MAKAN DESERT



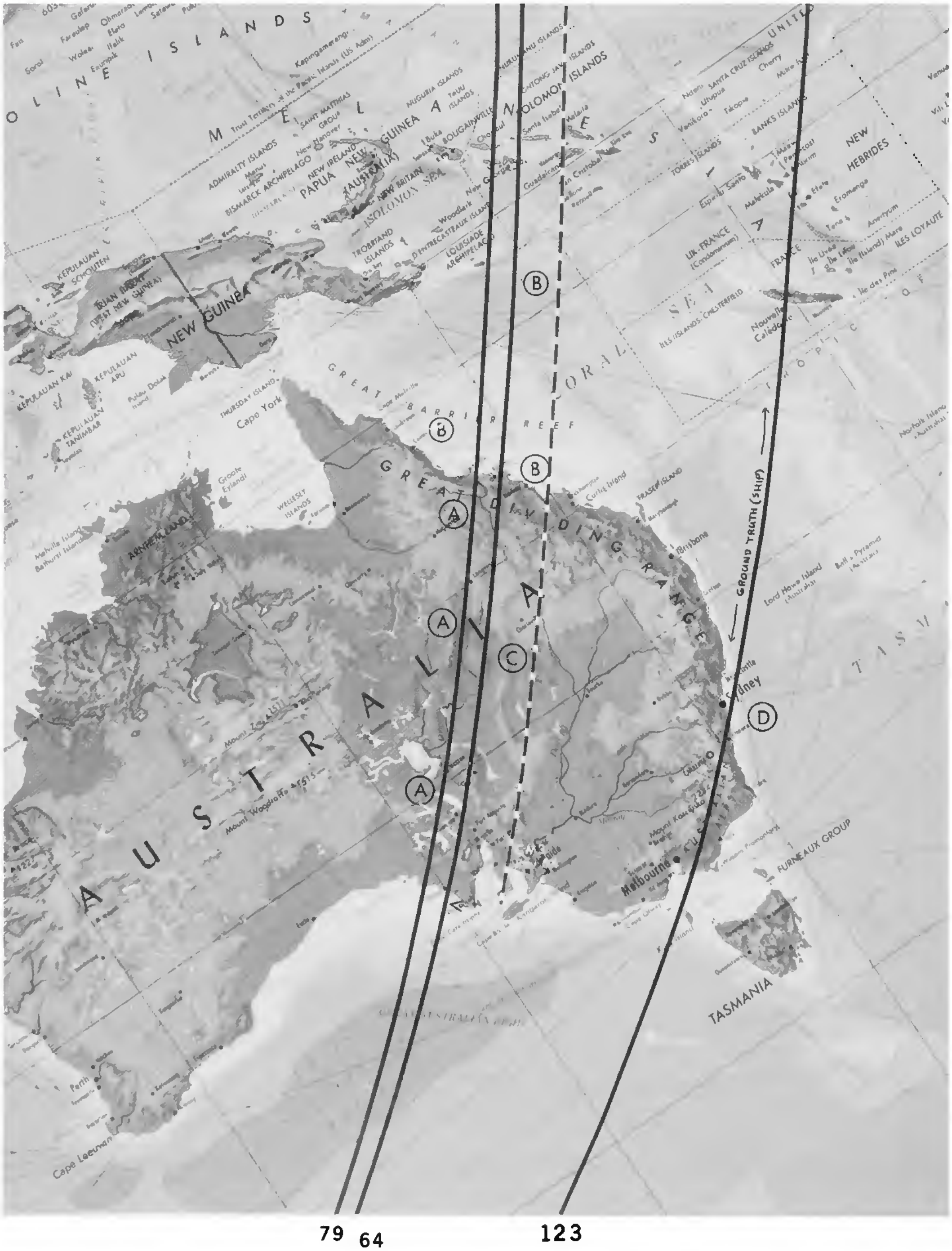

1. USE COLOR CHART TO DEFINE DESERT COLORS.

2. WHAT DUNE PATTERNS ARE PREDOMINANT AND DOES COLOR DEPEND ON DUNE PATTERNS?

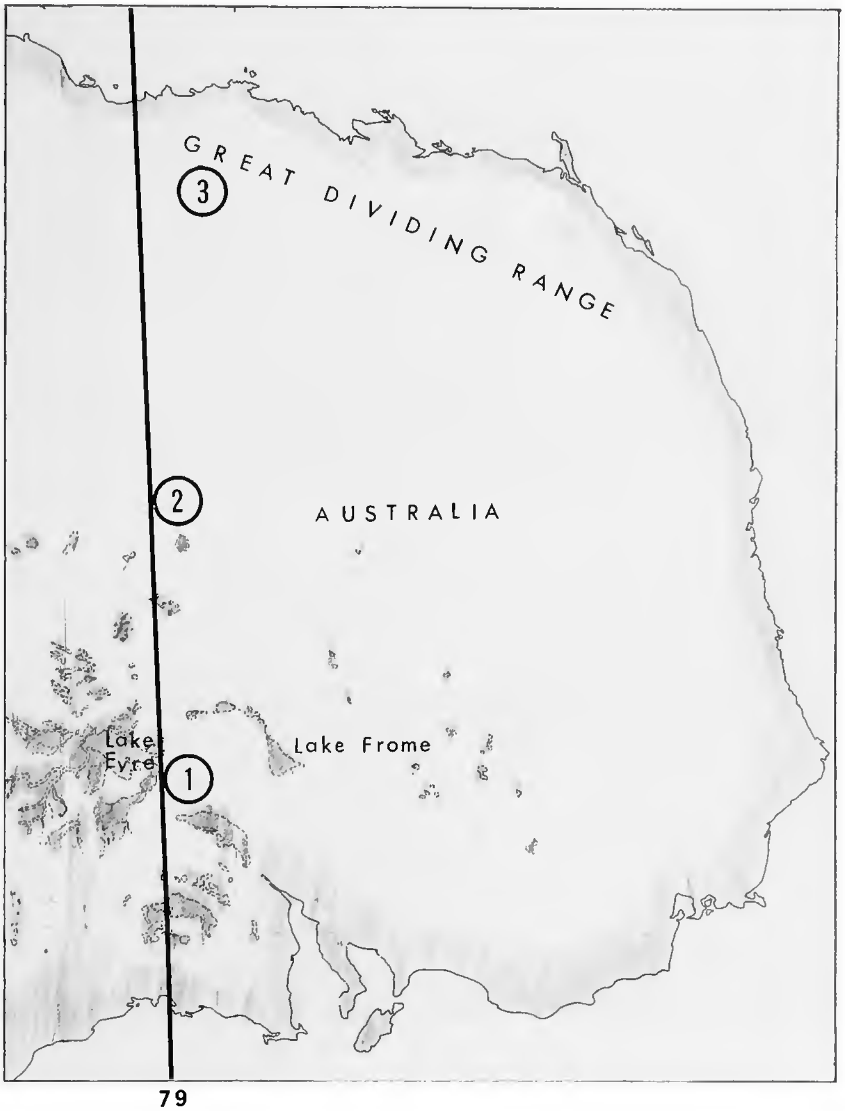
PHOTOGRAPHS; 3 STEREO FRAMES PER TARGET.

REV 39: CM3/SILVER/50/IF01/ORANGE FILTER(f8,1/500) 3FR,[RECORD LAST FR NO: PAGE 4]

# SITE 11: AUSTRALIA



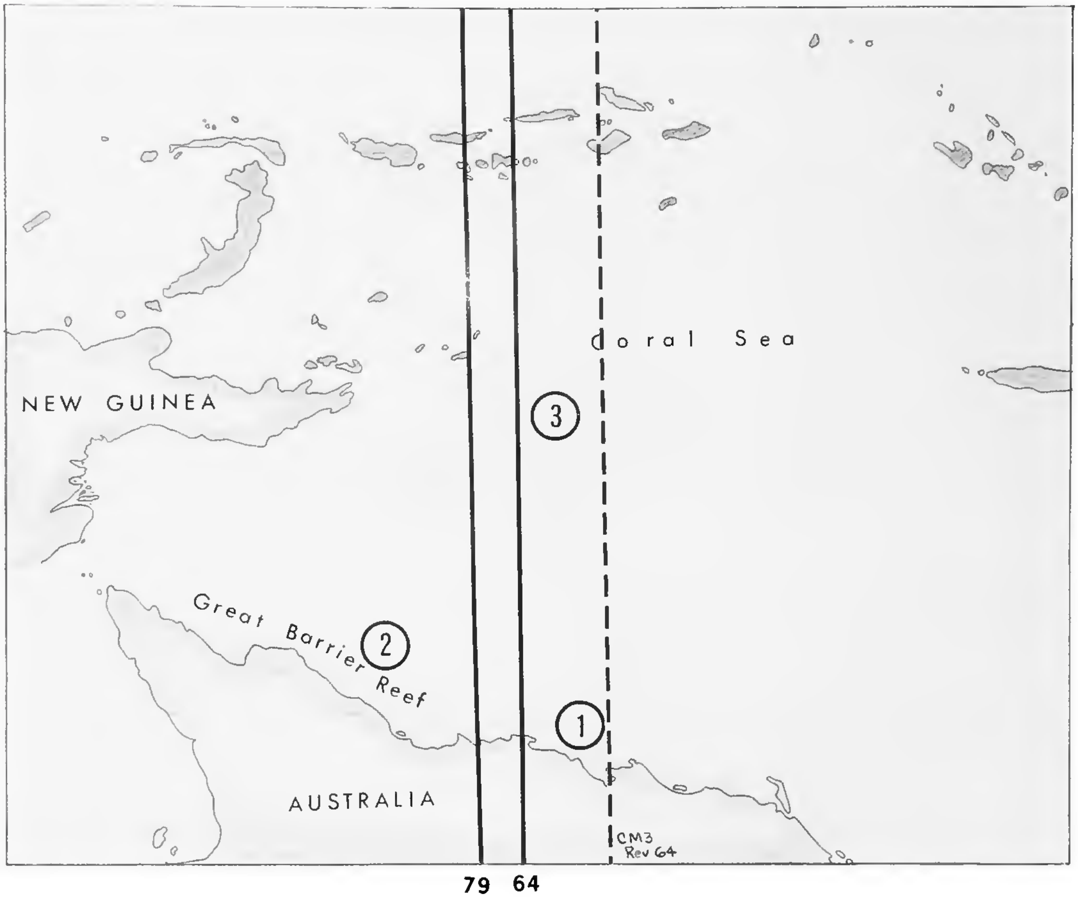
# 11A: PLAYAS




1. STUDY THE LAKE EYRE REGION AND COMPARE TO THE NIGER RIVER FALSE DELTA (SITE 9H).
2. DESCRIBE AND OBTAIN 3 STEREO PHOTOGRAPHS OF DESERT EROSION AND DUNE PATTERNS.
3. OBTAIN 3 STEREO PHOTOGRAPHS OF MAJOR LINEAMENTS IN THE GREAT DIVIDING RANGE.

REV 79: CM3/SILVER/50/CX14(f9.5,1/500) 6FR,[NEXT SITE: 11B]

# 11B: CORAL SEA




1. ARE THERE ANY SUSPENDED SEDIMENTS OFF THE COAST?

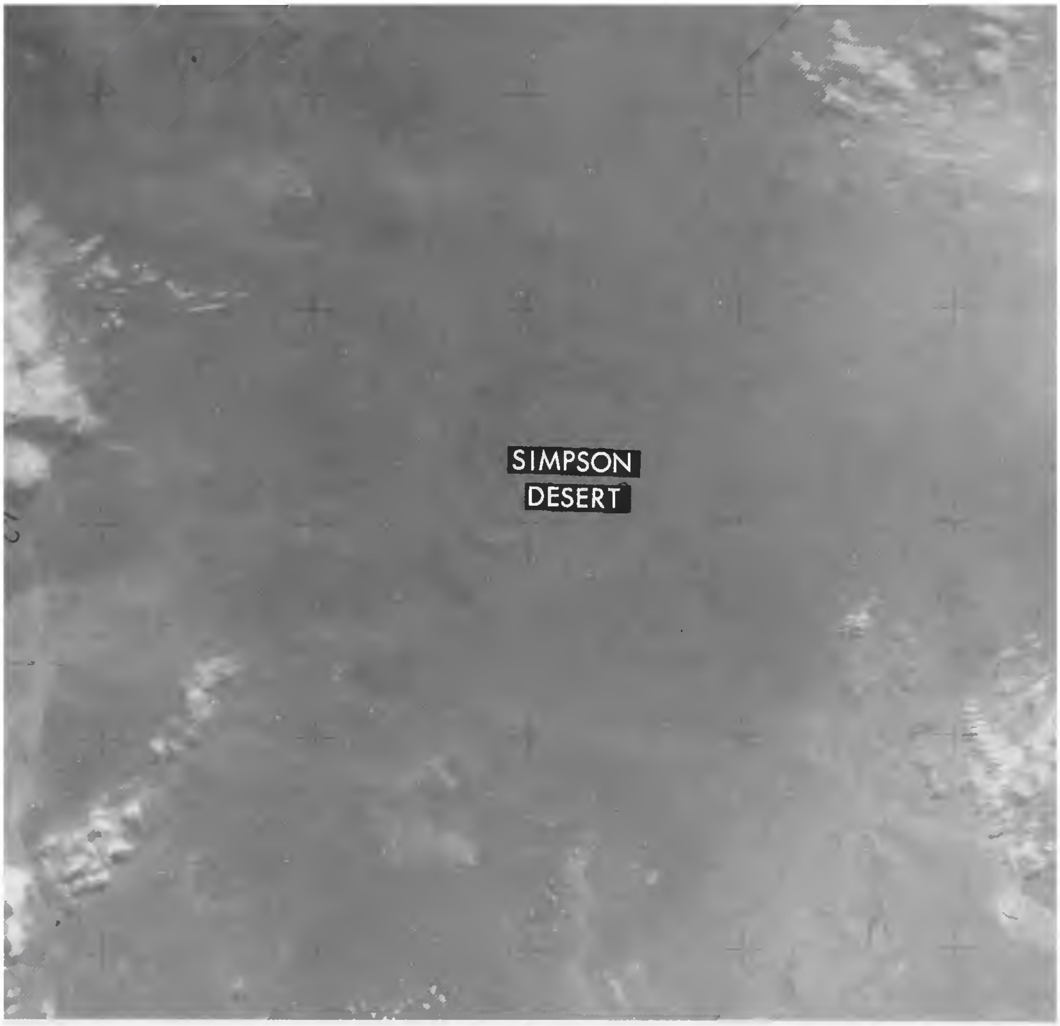
2. OBTAIN 3 STEREO PHOTOGRAPHS OF THE BARRIER REEF.

3. DO YOU SEE ANY WATER EDDIES IN THE CORAL SEA? (CLOUD PATTERNS MAY BE USEFUL IN LOCATING EDDIES)

REV 64: CM3/SILVER/250/CX12(f8,1/500) 6FR,[NEXT SITE: 3A]

REV 79: CM3/SILVER/50/CX14(f8,1/500) 6FR,[NEXT SITE: 3A]

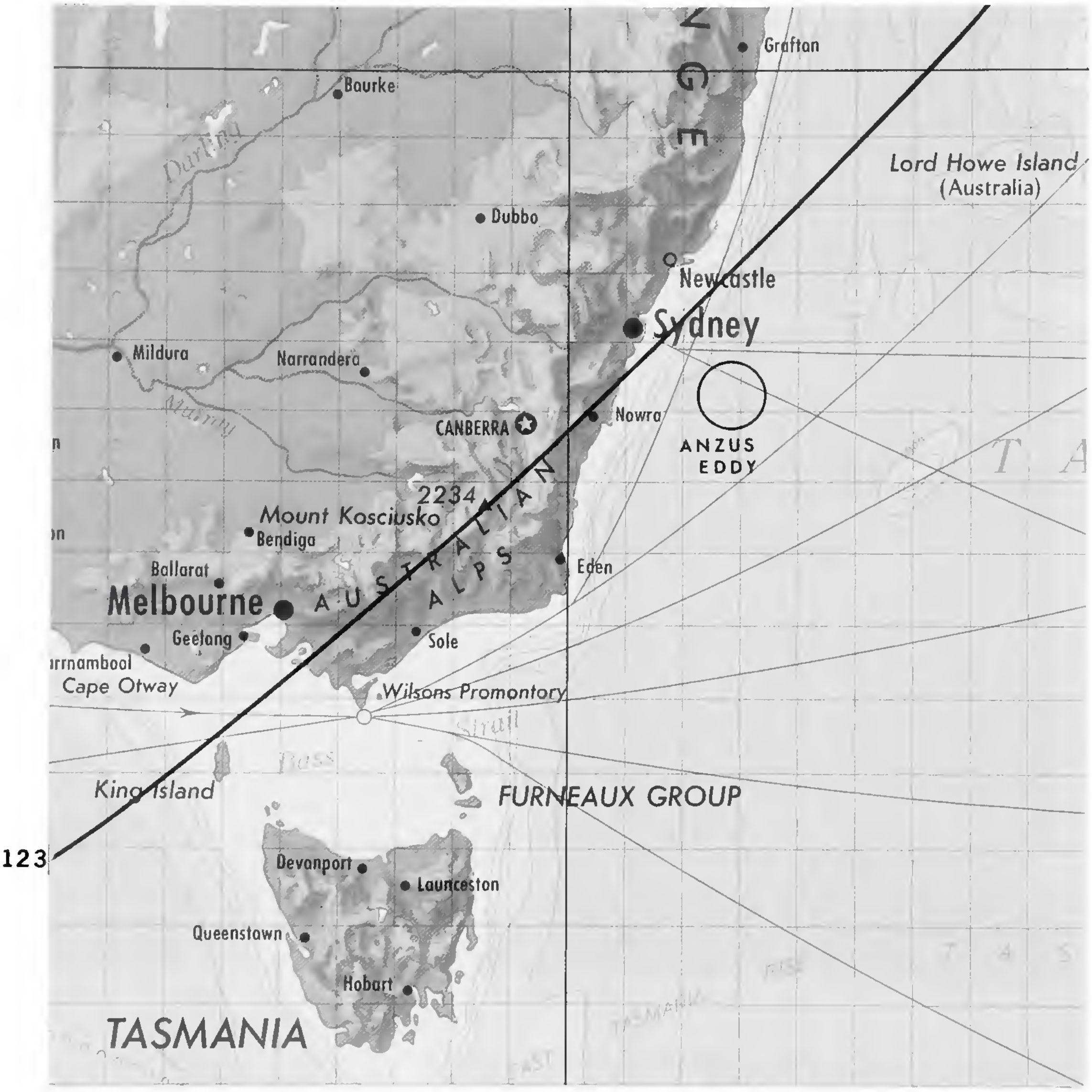
# 11C: SIMPSON DESERT




1. USE COLOR CHART TO DEFINE DESERT COLORS.
2. ARE THERE ANY DISTINCT DUNE FIELDS?
3. IS COLOR RELATED TO DUNE TYPE, ORIENTATION OR PROBABLE SOURCE?

REV 64: CM3/SILVER/250/CX12(f8,1/250) 3FR,[NEXT SITE: 11B]

# 11D: ANZUS EDDY

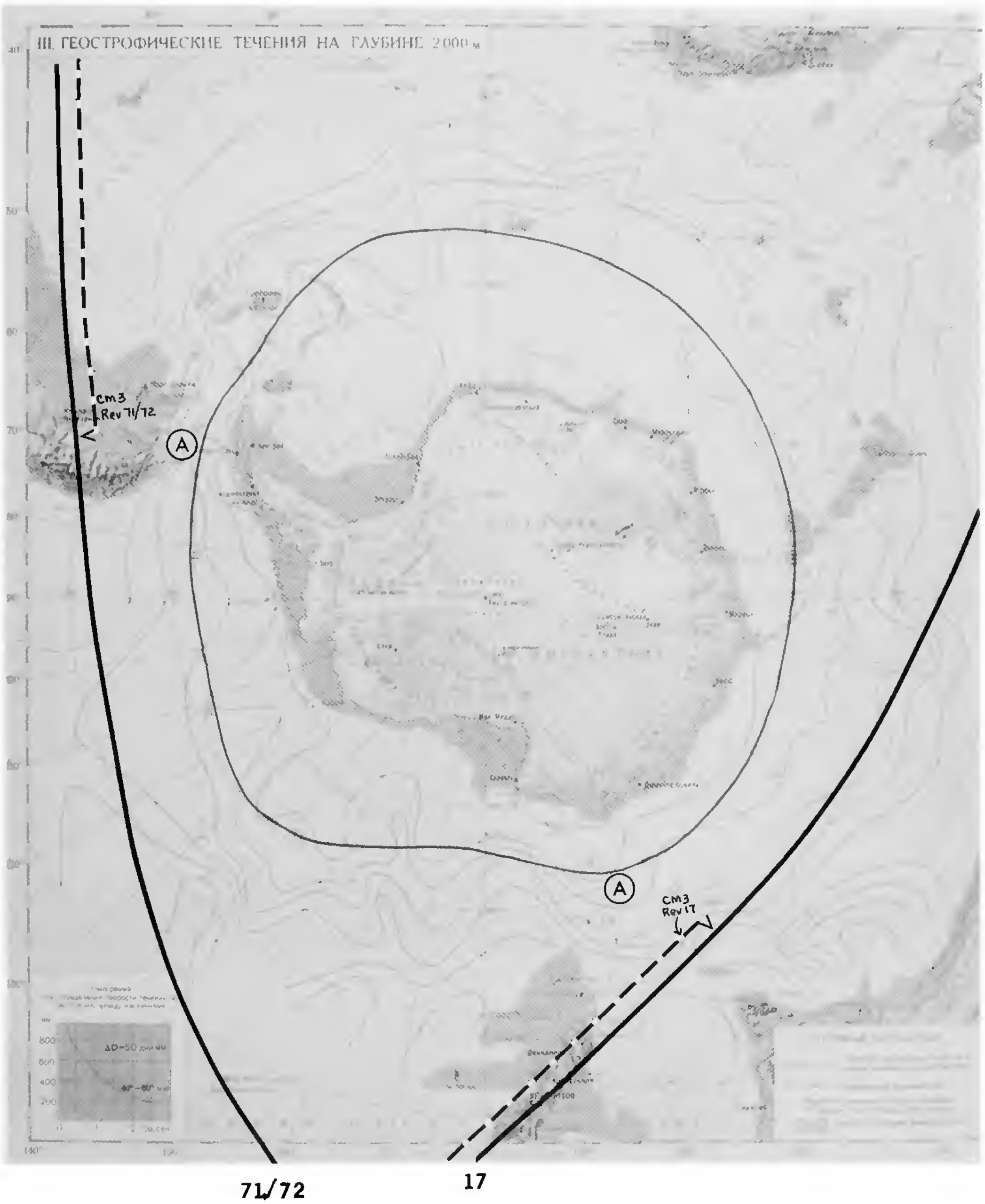



1. CAN YOU OBSERVE ANY MANIFESTATIONS OF THE "ANZUS EDDY"? (LOOK FOR WATER COLOR, CLOUD PATTERNS OR SEA STATE)

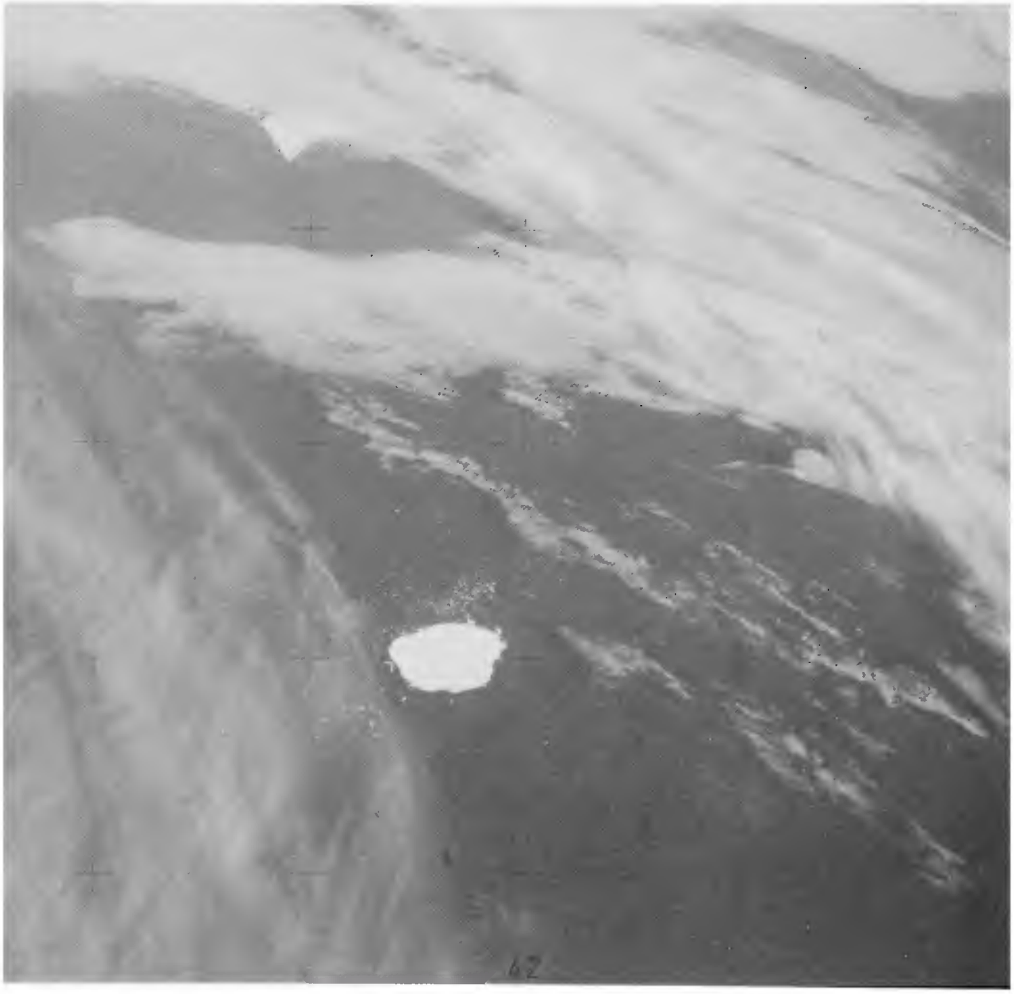
2. OBTAIN 3 STEREO PHOTOGRAPHS OF AREA.

REV 123: CM3/SILVER/50/CX16(f4.7,1/250) 6FR,[RECORD LAST FR NO: PAGE 5]

# SITE 12: ANTARCTICAN ICE



# 12A: ICEBERGS

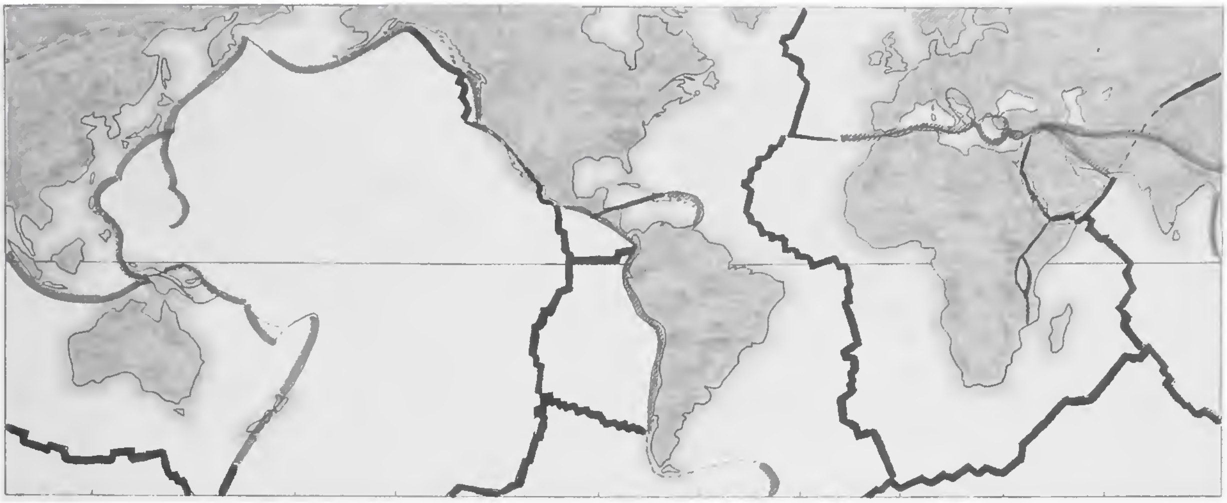



1. PHOTOGRAPH ICEBERGS AND ASSOCIATED SWARMS.
2. IS THERE ANY EVIDENCE OF BERG ROTATION?
3. IF YOU CAN SEE THE EDGE OF ANTARCTICA, OBTAIN 3 STEREO PHOTOGRAPHS.

REV 17: CM3/SILVER/250/CX10(f6.7,1/250) 6FR,[NEXT SITE: 1]

REV 72: CM3/SILVER/250/CX12(f6.7,1/250) 6FR,[NEXT SITE: 8A]

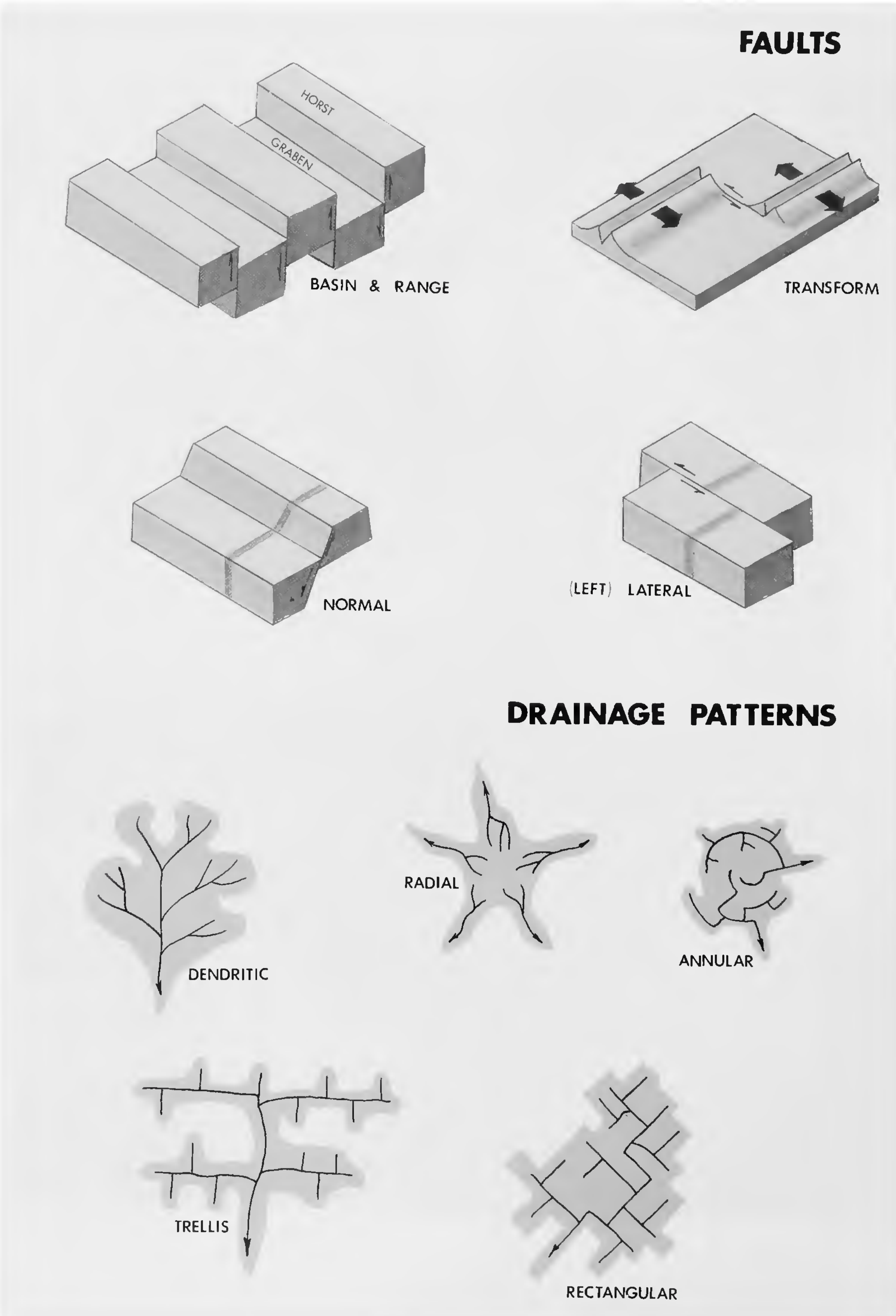
## PLATE TECTONICS



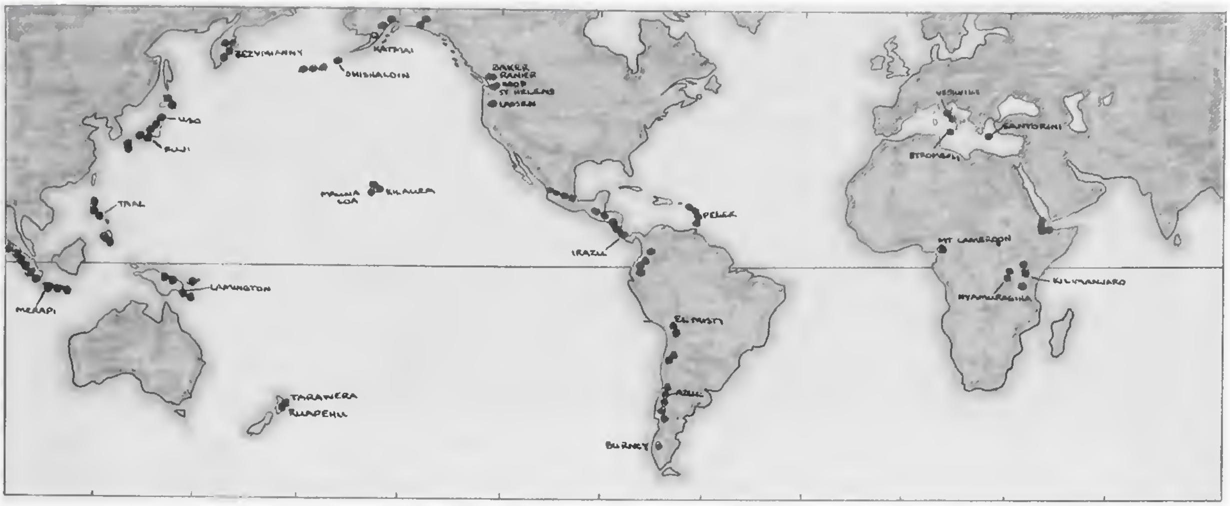
RIFTS, RIDGES & TRANSFORM FAULTS

SUBDUCTION ZONES

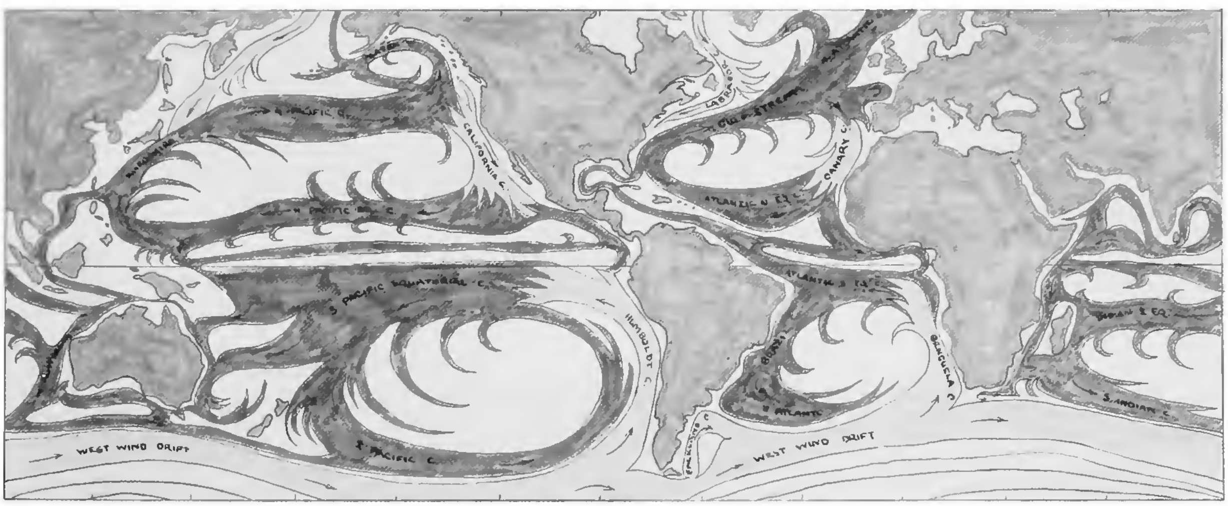
## OCEAN FLOOR

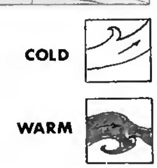

FAULTS
HORST
GRABEN
BASIN & RANGE
TRANSFORM
NORMAL
(LEFT) LATERAL
DRAINAGE PATTERNS
DENDRITIC
RADIAL
ANNULAR
TRELLIS
RECTANGULAR

## VOLCANOES

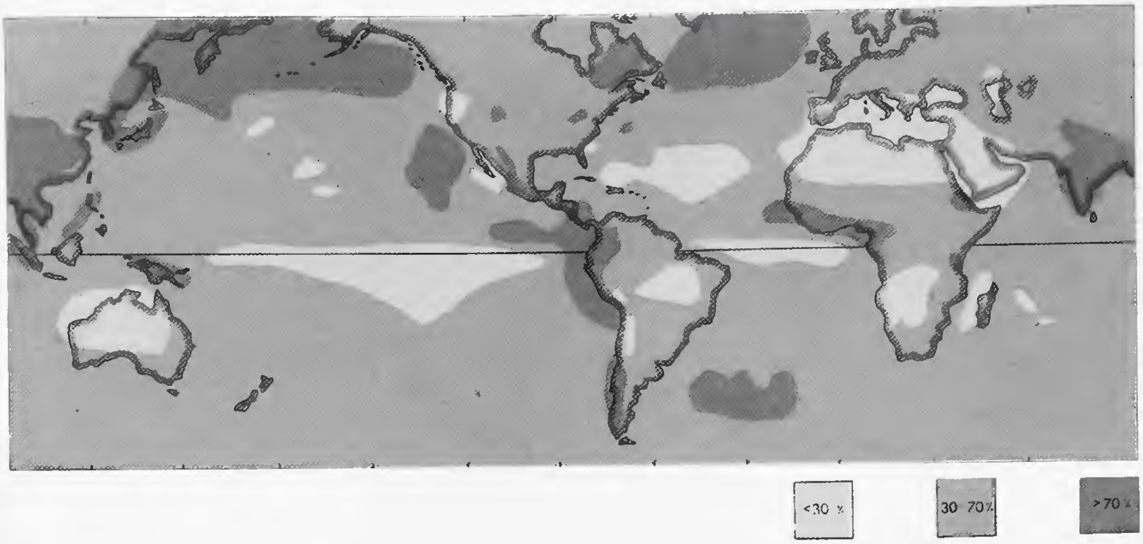



## OCEAN CURRENTS

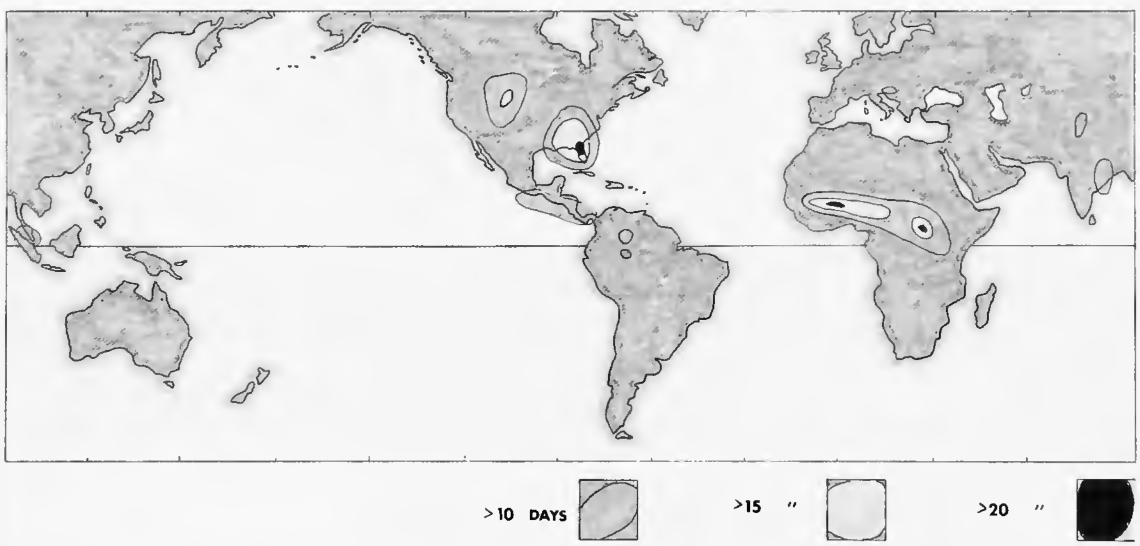


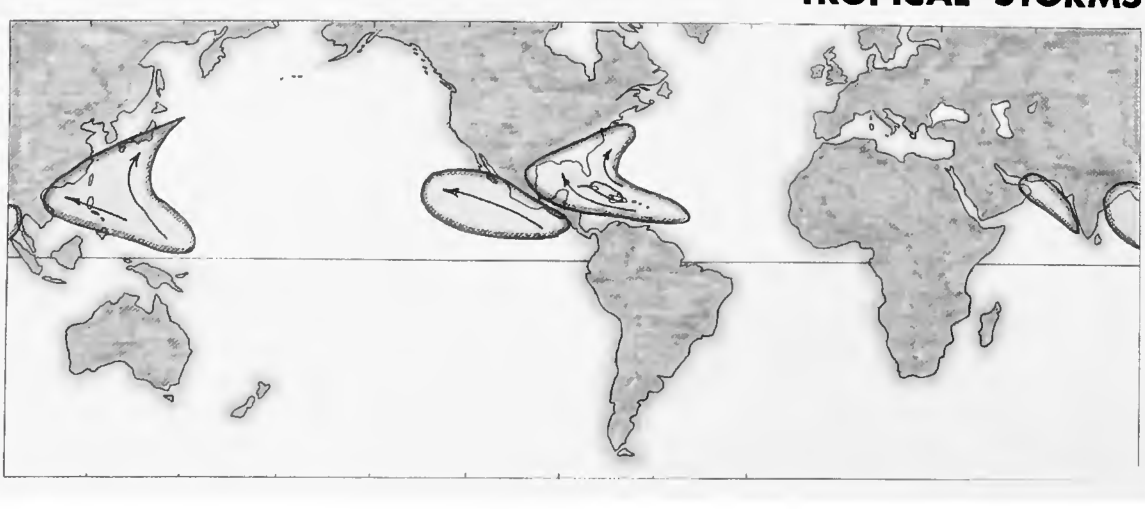
## JULY CLOUD COVER



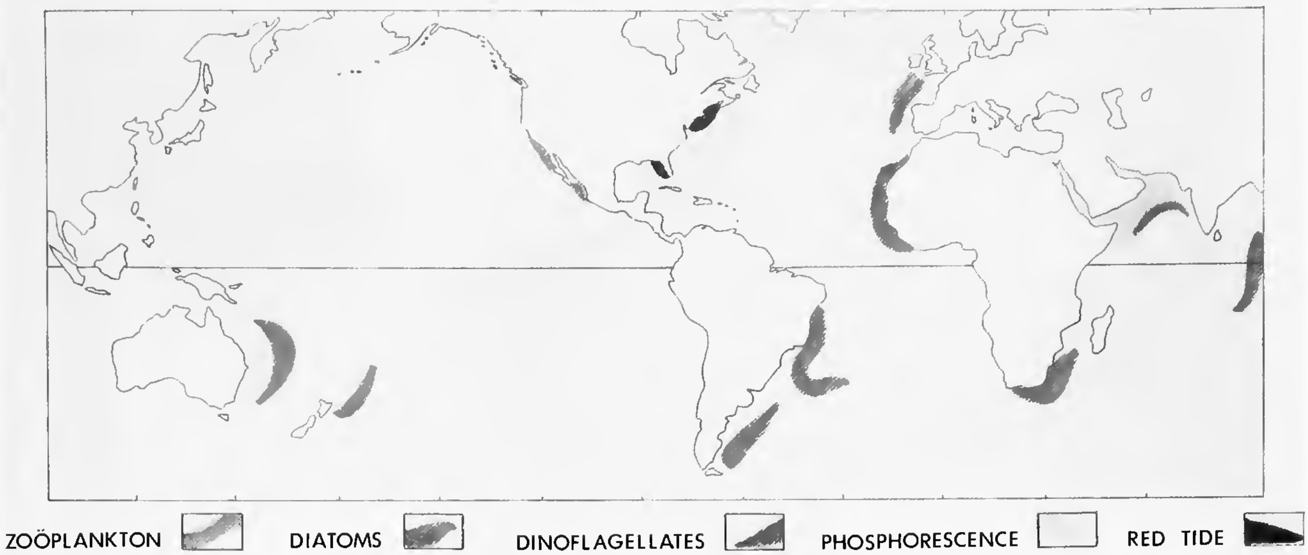

## JULY THUNDERSTORMS



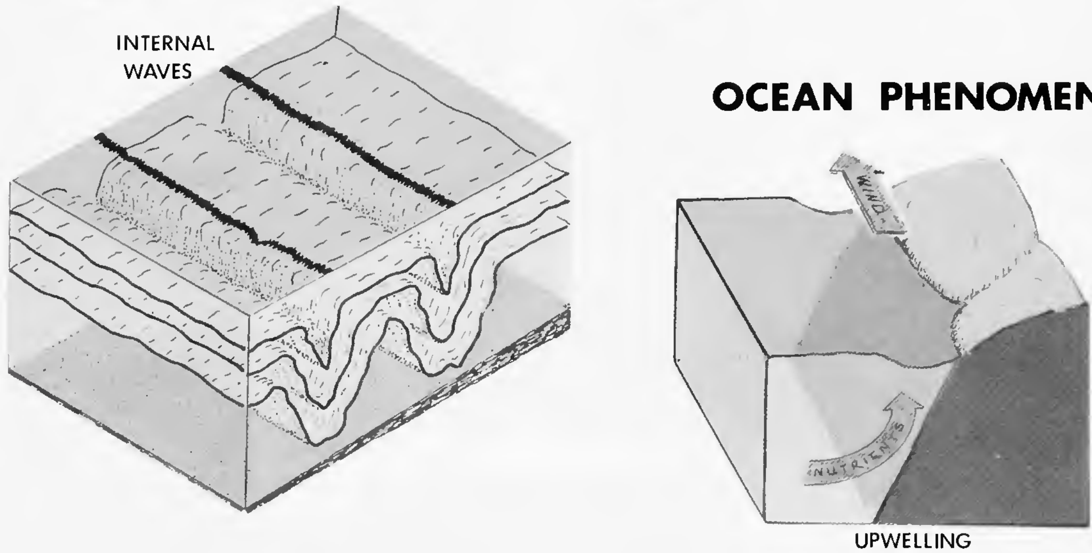

## TROPICAL STORMS



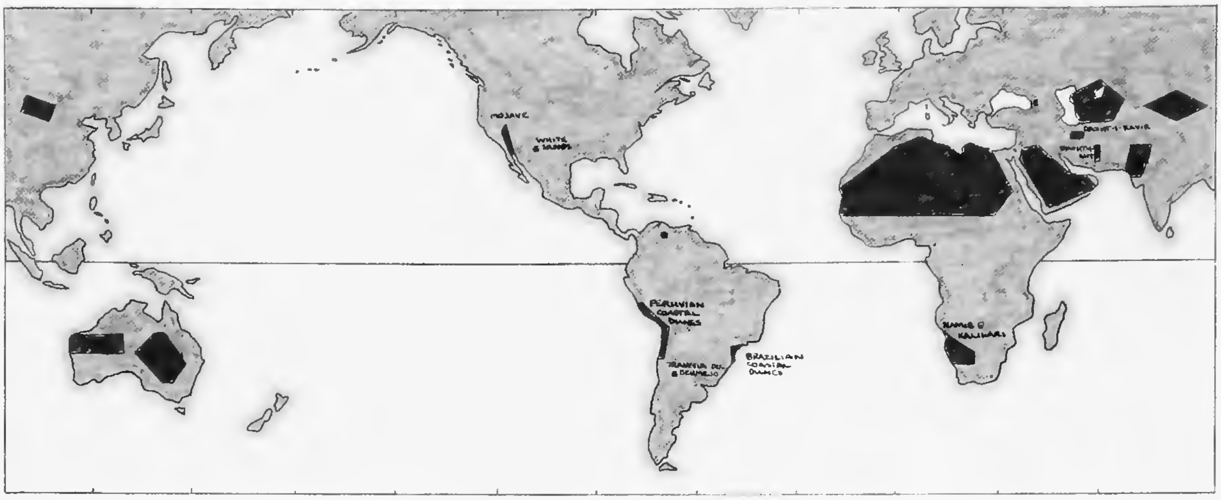
## OCEAN BIOCOLORS



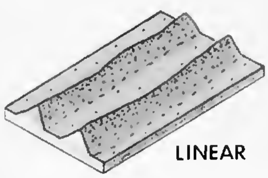

## OCEAN PHENOMENA

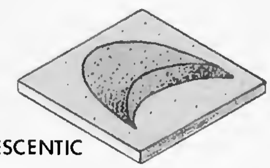


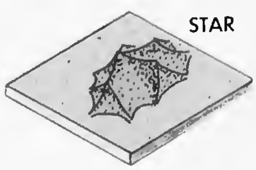

## SAND SEAS

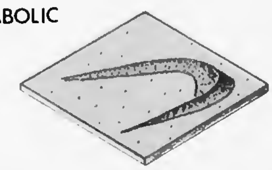



## DUNES


LINEAR


CRESCENTIC

STAR


PARABOLIC


☆U.S. GOVERNMENT PRINTING OFFICE: 1977 O—232-501