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Holocene Sea-Level Change and Early Human Utilization of Deltas

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ABSTRACT

Thirty-four documented archaeological sites, dated >5000 yr B.P. and located in and adjacent to marine deltas, are identified to evaluate early occupation of Holocene deltas worldwide. Modern marine deltas began to form from ~8500 to 6500 yr B.P., and our survey distinguishes at least 16 archaeological sites dated to ≥7000 yr B.P., which indicates that these resource-rich ecosystems were used by humans soon after their development. The model presented here links deceleration in rate of Holocene sea-level rise with the near-synchronous development of deltas and human occupation of these fertile plains. The integrated geological and archaeological database shows that conditions in and around deltas (accumulation of fertile soil, reliable water supply, perennial aquatic food sources, ease of travel and trade) were attractive to human immigration and settlement. Currently, rising sea level and land subsidence are principal natural phenomena affecting use of deltas, and humans remain vulnerable to these factors as well as to extensive ecological degradation caused by increased population pressures. The integrated geoarchaeological approach serves to refine long-term rates of change in delta evolution and thereby gauge human impact on these depocenters. Moreover, the model presented here provides insight into environmental conditions during the early to mid-Holocene transition from hunter-gatherers to sedentary communities, a major turning point in human history.

INTRODUCTION

During most of the past four million years, hominids sustained themselves by gathering wild plants and hunting and

Deltas *continued on p. 2*

Background photo: Wax Lake (left) and Atchafalaya (right), nascent deltas of the Mississippi River prograding into Atchafalaya Bay, Gulf of Mexico. Image shows characteristic features of newly formed deltas, which would have been typical during the early Holocene, including low-lying islands isolated by channels. During early phases of delta occupation, humans would have had to overcome challenges such as isolation and periodic inundation in this setting. This color infrared image was taken in February 1980 (courtesy of I. van Heerden, Louisiana State University).

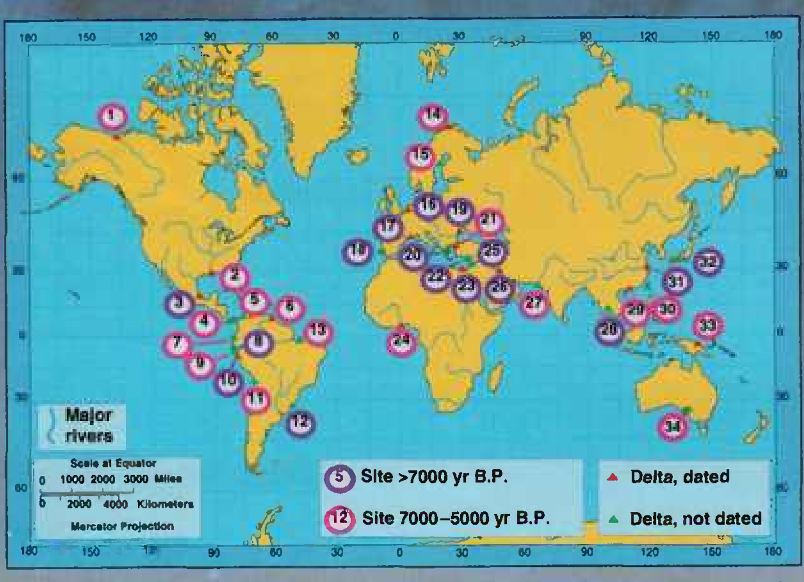

Figure 1. Documented archaeological sites, dated from >7000 to ~5000 yr B.P., on and adjacent to 34 delta sequences compiled in this preliminary survey (Table 1). Sixteen of the 34 delta sequences have been dated (Table 1). Of note are eight sites >7000 yr B.P. (purple circle) positioned on deltas that are dated to >7000 yr B.P. (red triangle), indicating early occupation of these depocenters.

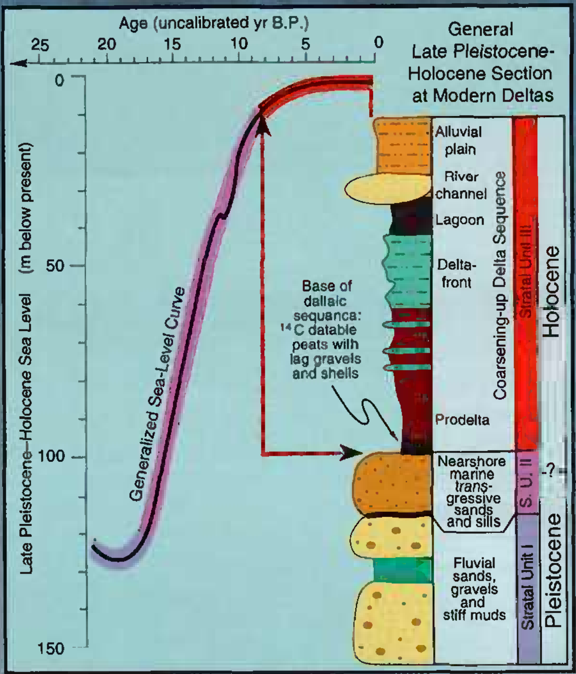

Figure 2. Generalized stratigraphic section depicting the late Pleistocene to Holocene subsurface geology at diverse marine delta localities (no thickness scale shown or implied). Particular focus in this study is on stratal unit III, characteristically a coarsening-up delta sequence comprising diverse lithofacies dated from ~8500 yr B.P. to present. The start of deltaic sequence formation in the early Holocene was fundamentally controlled by the decelerating rate of sea-level rise, as noted on the generalized world sea-level curve (after Warne and Stanley, 1995).

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In Memoriam

Ralph J. Bernhagen
Worthington, Ohio
October 24, 1997

John W. Butler, Jr.
Coos Bay, Oregon
September 27, 1996

Henry R. Cornwall
Concord, Massachussetts
September 8, 1997

Melvin Friedman
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January 2, 1997

Wilson M. Laird
North Potomac, Maryland
October 1997

Thomas A. Oliver
Calgary, Alberta
October 1997

CORRECTION

The U.S. Geological Survey and the National Science Foundation were among the sponsors of the 1997 GSA Presidential Conference "Ethics in the Geosciences" ("Conferees Tackle Ethics Questions," October *GSA Today*, v. 7, no. 10, p. 18).

Deltas *continued from p. 1*

fishing, typically in small mobile groups (Gebauer and Price, 1992; Feibel, 1997). The latest Pleistocene to mid-Holocene transition from hunting and gathering to a more settled way of life, referred to by some as the Neolithic Revolution, is a turning point in human history and has long been a keystone to archaeological research and debate. The change from foraging to sedentariness, and in some cases agriculture, which took place from about 10,000 to 5000 years ago, apparently occurred independently in different parts of the world.

Archaeologists generally attribute this widespread modification in human behavior to one or more of three principal factors: population pressure, altered social behavior, and/or climatic and environmental change (Price and Gebauer, 1995). Even though there have been extensive discussions during the past century regarding the relative importance of these three factors, there remain widely differing explanations for the remarkable transition from foraging to farming. However, most archaeologists agree that there is a close link between environment and human activity. Proponents of the climatic and environmental impetus have typically emphasized meteorological changes, especially transitions from cool to hot and wet to dry during the late Pleistocene and early Holocene (e.g., Childe's [1928] propinquity or desiccation theory). Associated with amelioration of climate in late stages of deglaciation (~8000 to 5000 yr B.P. [before present; herein all dates are uncalibrated]) are changes in vegetation communities worldwide (Adams and Faure, 1997).

In studies paralleling but generally independent of archaeological research, earth scientists are involved in identifying and measuring late Quaternary environmental changes, including those induced by anthropogenic activity. In this article, we present a new thesis that assimilates both the observed worldwide change in human settlement and subsistence behavior and near-synchronous environmental changes associated with a global deceleration in rate of sea-level rise that occurred between ~8500 and 6500 yr B.P. We propose that delta development, inextricably linked to deceleration in rate of sea-level rise (Stanley and Warne, 1994), provided newly formed, resource-rich environments conducive to occupation and subsequent development of sedentary human cultures worldwide (Fig. 1).

Deltas *continued on p. 3*

Deltas *continued from p. 2*

EARLY HOLOCENE INITIATION OF MARINE DELTAS WORLDWIDE

This study focuses specifically on deltas, although we recognize that other coastal environments, such as barrier islands that formed in the early to mid-Holocene, were extensively exploited by humans. Herein, the term delta is used in a broad sense and includes alluvial tracts of land deposited at or near the mouth of rivers near the sea. These depocenters include settings such as fan-, cuspate-, and bird-foot–shaped silty plains, coarse fan deltas, and river mouth alluvial plains located at heads of estuarine, bay, and fjord systems.

Radiocarbon-dated late Pleistocene to Holocene sections beneath modern delta plains typically contain three distinct stratigraphic units (Fig. 2). From base to top these units comprise: stratal unit I, late Pleistocene fluvial deposits (to as young as ~11,000 yr B.P.); stratal unit II, late Pleistocene to early Holocene shallow marine transgressive deposits (~18,000 to 8000 yr B.P.); and stratal unit III, Holocene deltaic deposits of variable lithologies (~8000 yr B.P. to present). Deltaic unit III, the focus of this article, is typically a coarsening-upward, prograding sequence with datable peats, shells, and lag gravels at its base. To determine the timing of initiation of world deltas, we identified the oldest radiocarbon age available at or near the dated base of documented Holocene deltaic sequences (Fig. 2).

Global survey of radiocarbon-dated sedimentary sequences in modern marine deltas reveals that many (>50) of these depocenters began to develop during the period ~8500 to 6500 yr B.P. in a variety of geographic and geologic settings on coastal margins of world oceans (Stanley and Warne, 1994; Warne and Stanley, 1995; additional dated delta sites available from the authors). Having considered all major controls (including climate, tectonic setting, isostasy, coastal hydrodynamics, fluvial and sediment discharge, and sediment accumulation rates), we conclude that sea-level change is the only process that could bring about the coeval worldwide initiation of Holocene deltas. Surveys of sea-level histories from diverse settings (cf. Pirazzoli, 1991) indicate a marked deceleration in sea-level rise at ~8000 to 7000 yr B.P. (Fig. 2). Recent investigations attribute this deceleration to abrupt changes in early Holocene atmospheric circulation (Alley et al., 1997; Stager and Mayewski, 1997). Holocene deltaic sequences began to accumulate as former incised river valleys filled with sediment to the point that the rate of fluvial sediment input exceeded the declining rate of sea-level rise along coasts. This threshold, from marine transgression and coastal erosion to sediment accretion and progradation at the mouth of rivers, took place on a worldwide basis within a span of ~2000 yr.

TABLE 1. EARLY TO MIDDLE HOLOCENE ARCHAEOLOGICAL SITES IN AND ADJACENT TO MARINE DELTAS

Delta seq. (Fig. 1)	Delta or lower plain*	Age (yr B.P.)	Dating method†	Reference
North and Central America				
1	*Mackenzie*	~5000	4	Clark (1991)
2	*Mississippi*	6220–5345	1	Russo (1996)
3	*Tecolutla, Veracruz*	7600	3A	Wilkerson (1980)
4	Santa Maria	6810	1	Ranere and Hansell (1978)
South America				
5	Magdalena	5050	1	Meggers (1979)
6	*Orinoco system*	~6000	1, 3A	Sanoja (1989)
7	Valdivia	5800	1, 3A	Stothert (1985)
8	Las Vegas	8250–6600	1, 3A	Stothert (1985)
9	Huaca Prieta	~5000	1	Quilter (1991)
10	Santa	~7000	4	Wells (1992)
11	Camiña	~6000	1	Martinez (1979)
12	Porto Alegre plain	~7000	1	Rodríguez (1992)
13	Near Amazon coast	5045	1, 3B	Meggers (1979)
Europe				
14	*Alta*	~5600	1, 3A	Nygaard (1989)
15	Ume	~5500	3A	Ramqvist et al. (1985)
16	*Rhine-Maas*	~7000	3A	Whittle (1996)
17	*Rhône*	8000–7000	4	Whittle (1996)
18	Tagus	~7000	4	Whittle (1996)
19	*Danube*	~7000	3C	Whittle (1996)
20	Dimini Bay–Seskolitis	8000–6400	1	Zangger (1991)
21	*Troy Bay–Scamander plain*	6800–6500	1	Kayan (1995)
22	Zyyi	8000–7000	3A	Ronen (1995)
Africa				
23	*Nile*	~7000	1, 3B	Stanley and Warne (1993)
24	*Niger*	~5000	4	Devisse and Vernet (1993)
Asia				
25	Oren	~8100–7500	1, 3A	Galili et al. (1993)
26	*Tigris-Euphrates*	7600–7000	1	Sanlaville (1992)
27	Indus	~5600	1	Mughal (1990)
28	Bang Pakong	~8000–7000	2, 3C	Higham (1989)
29	*Zhu Jiang (Pearl)*	6000	4	Lo (1990)
30	Peinan	~5600	3C	Lien (1993)
31	*Han Jiang (Yangtze)*	~7500	1	Stanley and Chen (1996)
32	Tokyo Bay	9450	4	Chard (1974)
33	*Ramu*	~5600	3B	Gorecki (1993)
Australia				
34	Murray	6020	1	Mulvaney (1969)

*Italics indicate deltas that have been radiocarbon dated.

† 1—Standard ^{14}C radiocarbon; 2—accelerator mass spectrometer (AMS); 3—artifact type: lithic = A, ceramic = B, other = C; 4—undefined.

DOCUMENTING EARLY HUMAN OCCUPATION OF DELTAS

Studies of the Nile and Yangtze deltas, where evidence for occupation extends to as early as ~7500 yr ago (Stanley and Warne, 1993; Stanley and Chen, 1996), were the catalyst for the present geoarchaeologic investigation. Findings from these two systems demonstrate that humans expanded onto the two depocenters within 500 yr of their development as fertile plains. We reviewed archaeological literature to identify and document prehistoric sites in and adjacent to these depocenters. Our aim was to determine if there is a worldwide correlation between early development of modern marine deltas (~8500–6500 yr B.P.) and human exploitation of these resource-rich environments shortly after their formation.

The focus of this survey is to determine timing of earliest recorded occupation, rather than the specific nature of human activity (foraging, sedentariness, plant cultivation, domestication, pottery-making, etc.) at the 34 identified sites. Thus, we do not discuss specific cultures, typologies, or other archaeological designations. To evaluate the timing of human occupation of deltas shortly after development of these new ecosystems, we selected sites for this study on the basis of the following: (1) only those with material older than 5000 yr B.P. (Table 1); and (2) availability of radiocarbon-dated material, such as charcoal, plant, and bone (20 sites),

Deltas *continued on p. 4*

Deltas *continued from p. 3*

and/or dated artifacts (lithic, ceramic) assigned a numeric age (14 sites). In this preliminary evaluation of the timing of early occupation of deltas, data are subdivided into two temporal categories (Fig. 1): sites known to be older than 7000 yr B.P., or shortly after delta development ($n = 16$); and those somewhat younger, between 7000 and 5000 yr B.P. ($n = 18$).

This preliminary survey, which is representative but not comprehensive, shows that sites we identified occur in a wide range of latitudes (Fig. 1). However, most are within tropic and northern temperate latitudes, primarily in northern South America, the circum-Mediterranean, and eastern-southeastern Asia. Our database records a near-equal number of sites dated >7000 and <7000 yr B.P., older sites being concentrated in European and Mediterranean areas. Sites occur on all continents except those at highest latitudes, and we found few documented early delta sites (>5000 yr B.P.) in North America (Coastal Environments, Inc., 1977), southern South America and Africa, Eurasia, and Australia. Also, our research did not identify documented early Holocene sites on some major world deltas, such as the Congo, Ganges, and Yellow, and those of northern Russian rivers.

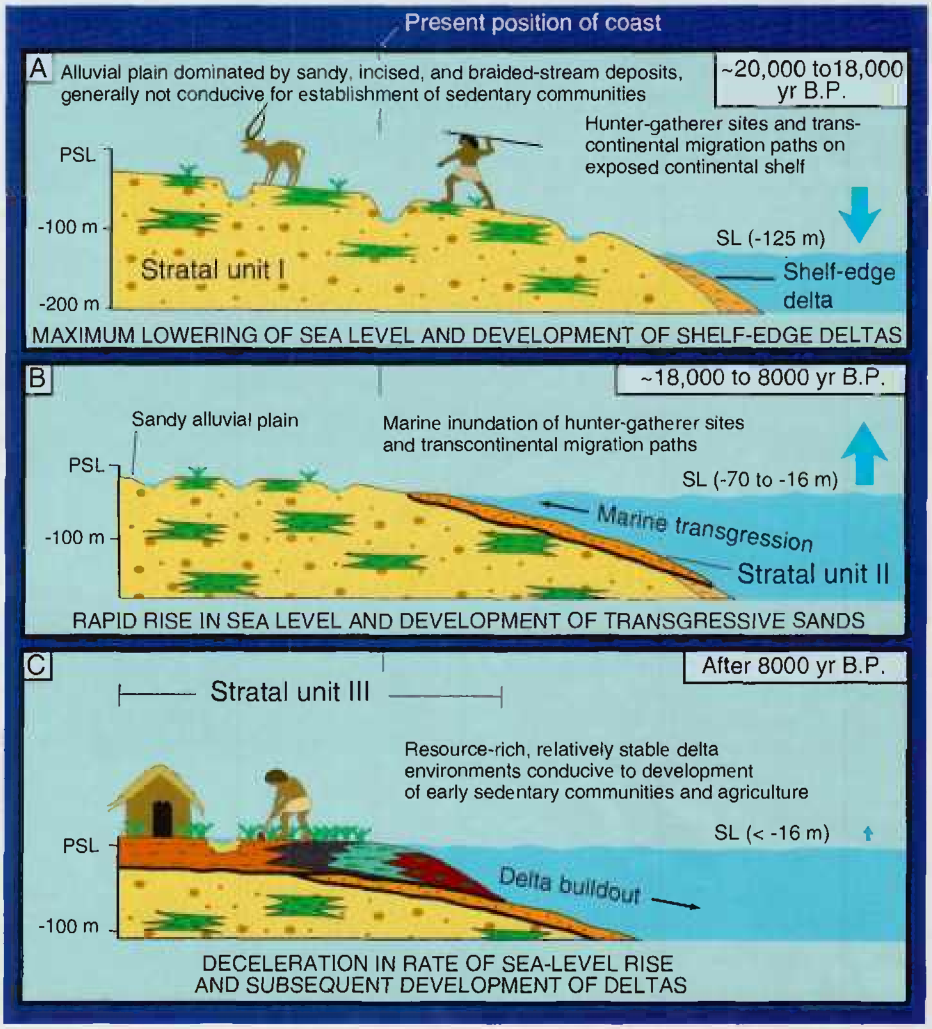

Figure 3. Integrated geological-archaeological model depicting the relations among late Pleistocene to Holocene sea-level change, coastal development near river mouths, and human migration and occupation. Formation of modern marine deltas and occupation of these fertile plains (part C) are inextricably linked to deceleration in the rate of sea-level rise. Facies correspond to those depicted in Figure 2.

LIMITATIONS OF CURRENT DATABASE

By early Holocene time, humans were widely dispersed in temperate and tropic regions. The majority of prehistoric sites are recorded on inland and upland landscapes rather than on the coast (Price and Gebauer, 1995). Current distributions of documented early settlement sites appear in marked contrast to modern demographics, where almost 80% of the world's population lives within 100 km of the coast. Thus, one might expect a larger number of sites positioned on or close to delta plains and submerged offshore (Stright, 1990) than are currently recorded.

There are several possible explanations for the relatively small number of recorded prehistoric sites on deltas. In many instances, artifacts and sites have been buried and obscured by thick sequences of Holocene deposits resulting from successive floods and generally high rates of deposition near river mouths (to 10 cm/yr). Land subsidence, which typically affects deltas (Stanley, 1997), would also lower early sites below present land surface and water table. Moreover, rise of sea level during this period submerged some coastal sites, such as the Neolithic settlement on the Oren delta (Fig. 1; Table 1), Israel (Galili et al., 1993). Hence, many deltaic sites are obscured and inherently difficult to discover and excavate (cf. Stright, 1990), and evidence of human occupation is most commonly found along more stable and somewhat higher margins and apices of these depocenters. In addition, subsequent anthropogenic activity may have further modified and obscured prehistoric sites.

It is possible that the irregular distribution of documented early delta sites is influenced by other factors, such as uneven intensity of archaeological exploration and access to literature and records. Other explanations for the uneven distribution of sites include increased logistical difficulty of exploration in areas such as densely vegetated tropics, climatically isolated (polar) regions, and submarine settings.

Additional challenges associated with the systematic worldwide survey of early and mid-Holocene archaeological sites on deltas pertain to dating. In some regions, sites are dated typologically—that is, by identifying characteristic lithic and ceramic manufacture method and/or style and correlating with sites elsewhere that contain similar artifacts that have been radiocarbon dated. Materials are now commonly dated by the standard radiocarbon method, but ages cited in the literature vary in format—e.g., in yr B.P., uncalibrated or calibrated, or in yr B.C.E. At this time, material at only a few delta sites has been dated using the accelerator mass spectrometer (AMS) method, and none that we reviewed in the literature incorporate reservoir corrections (cf. Stuiver and Brazunias, 1993).

INCIPIENT SETTLEMENT OF RESOURCE-RICH DELTA PLAINS

Humans occupied a broad spectrum of environments by the end of the Pleistocene, and the transition to agriculture was under way in widely different regions of the world between that time and the mid-Holocene. By identifying 34 delta sites occupied by at least 5000 yr B.P., our database suggests that delta environments may have been a component in this transition. Eight documented sites are dated to 7000 yr B.P. or earlier and are positioned on or adjacent to deltas that are known to have begun at least 7000 yr ago. These include (Table 1): Tecolutla (Mexico), Santa (Peru), Rhine-Maas (Netherlands), Rhône (France), Danube (Romania), Nile (Egypt), Tigris-Euphrates (Iraq, Kuwait), and Yangtze (China). These sites are in diverse geologic, geographic, and climatic settings along the lower stretches of rivers characterized by variable flow and sediment load. These localities, nevertheless, have the following common features: a generally prograding shoreline and increasing land area, permanent freshwater sources, high water table, aquatic habitats (fresh, brackish, marine), well-developed and relatively stable system of distributary channels, and fertile silt-rich soil.

Archaeological research indicates that sedentariness occurred in diverse geographic and climatic settings, but essential to site location was availability of a reliable water supply such that risks of drought were minimized. Other advantages associated with proximity to water sources include perennially available protein and other aquatic food sources and ease of regional travel and trade.

INTEGRATED GEOLOGICAL-ARCHAEOLOGICAL DELTA MODEL

A delta model that incorporates the geological and archaeological records emphasizes the near-synchronous development of resource-rich deltaic environments, which offered soil and water resources conducive to human immigration and settlement (Fig. 3). Although climate is the fundamental driving force for late Pleistocene and Holocene sea-level oscillations, as well as regional environmental and associated vegetation changes, our model identifies sea level as the principal worldwide mechanism that directly controls delta formation and early human occupation of these coastal environments.

From ~20,000 to 18,000 yr B.P. (Fig. 3A), when sea level was at least 120 m below present level (Fairbanks, 1989), river gradients were greater than those of today, braided-river systems incised preexisting coastal plains, and deltas formed seaward of present shorelines, near the present shelf edge. Late Pleistocene alluvial plain deposits on the subaerially exposed continental shelf (Fig. 2) served as habitat as well as land bridges between continents for forager groups.

From ~18,000 to 8000 yr B.P. (Fig. 3B), sea level rose rapidly (to as much as 1 cm/yr), while shelf-edge deltas and continental shelves were concurrently submerged. Coastlines retreated landward, and shelf sediments were extensively reworked by nearshore waves and currents

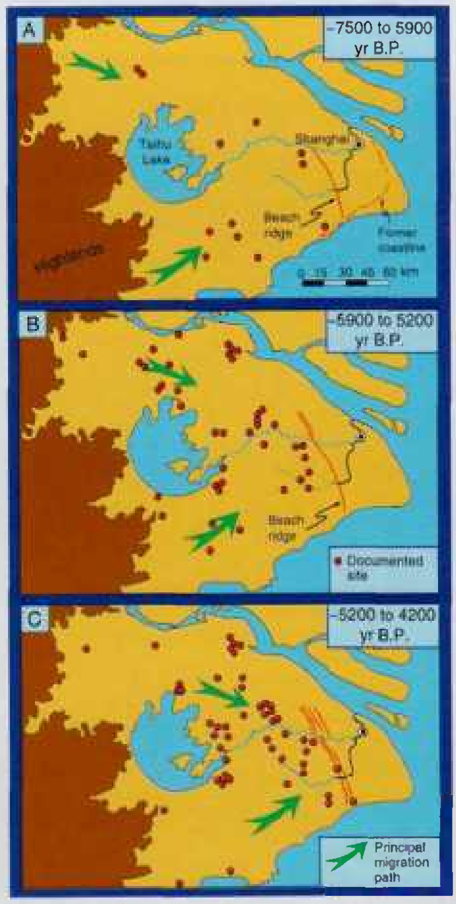

Figure 4. Yangtze delta of China, which contains the largest number of documented early sites (sedentary Neolithic cultures), provides evidence of human occupation shortly after delta-plain formation. Eastward migration through time is primarily related to the effects of early to middle Holocene sea-level rise on delta landform development (after Stanley and Chen, 1996).

forming widely distributed, shelly sand (transgressive) deposits (Fig. 2). Coastal processes associated with this marine transgression altered or destroyed coastal sites that had previously been located on the exposed shelf. Fluvial systems remained predominantly incised and braided. Although groups of hunter-gatherers continued to occupy alluvial plains near river mouths, these still-incised, rapidly shifting, sandy, braided-river environments were not conducive to long-term settlement.

From ~8500 to 6500 yr B.P. (Fig. 3C), the rate of sea-level rise decreased markedly (to as little as 1 mm/yr), yet landward displacement of most coastlines continued. However, decelerating sea-level rise induced infilling of incised river valleys and a change from marine erosion to fluvial deposition at river mouths, with accompanying accretion and progradation of silty, nutrient-rich delta plain deposits (Fig. 2). Moreover, as river gradients decreased there was a widespread change from ephemeral braided to more stable meandering river systems.

During initial stages of development, the seaward parts of deltas generally comprise a series of ephemeral lowlands and islands isolated by shallow distributaries (van Heerden and Roberts, 1980), as illustrated by the nascent Atchafalaya delta (see background photo). These frequently inundated lowlands compelled humans to overcome difficulties associated with isolation on islands, periodic inundation, and forced migration (Büdel, 1966). Technological advances during the early and middle Holocene enabled some humans to exploit these evolving coastal lowland environments. Abundant freshwater resources and access to inland settlements via rivers made deltas more attractive than other coastal areas to some prehistoric groups. In some deltas, such as the Nile and Yangtze, increasing technology and human manipulation eventually gave rise to well-developed hydraulic civilizations (Butzer, 1976).

The Yangtze in eastern China (Fig. 4) is the most extensively documented example that demonstrates the close relation between sea-level change and early human occupation of deltas. By integrating archaeological information and petrologic and radiocarbon data derived from cores, it has been shown that this depocenter was occupied by ~7500 yr B.P. or within five centuries of the beginning of delta formation (Stanley and Chen, 1996). Geoarchaeological studies reveal that positions of Neolithic settlements are related to geography (selection of topographic highs, which are less vulnerable to inundation) and advancing techniques in adapting to wetland occupancy, and that their distributions changed systematically through time in direct response to sea-level rise. The integrated record indicates a progressive eastward expansion of settlements as sea-level rise inundated former topographic lows, inducing relocation toward higher elevations associated with coastal ridges that served as protective barriers (Fig. 4).

RAMIFICATIONS OF THE INTEGRATED STUDY

This integrated geological and archaeological investigation of early to middle Holocene deltas can serve to refine the archaeological record for deltas and other coastal settings and to foster development of effective, long-term coastal protection strategies.

Systematic geological analyses of continuous borings in deltas and their lateral correlation define three-dimensional lithofacies distributions and associated environments of deposition. Such analyses provide a context for interpreting both

Deltas *continued on p. 6*

Deltas *continued from p. 5*

regional paleogeography and site-specific environmental settings. These paleoenvironmental reconstructions refine measurements of relative sea-level change that take into account land motion relative to sea level. Detailed study of the history of relative sea level enhances understanding of coastal landscape evolution and its influence on human migration, subsistence, and settlement patterns.

Augmenting the geologic record with dated artifacts and associated cultural material can help us establish a more accurate chronostratigraphic framework, allowing us to reconstruct delta environments and evaluate rates of change through time (Warne and Stanley, 1993). Geoarchaeological research incorporating nonintrusive subsurface exploration methods refines the relation among sea level, nearshore environments, and early occupation of deltas by humans. Enhanced use of remote sensing methods, such as ground penetrating radar (GPR), may be useful in identifying buried sites. Analysis of closely spaced cores by both geologists and archaeologists provides the most effective means to evaluate these buried sites (cf. Kayan, 1995).

Since the mid-Holocene, humans have increasingly exploited and altered deltaic environments. Yet most low-elevation delta-plain surfaces continue to be subject to natural factors, primarily rising sea level (Milliman et al., 1989) and subsidence (Stanley, 1997). These phenomena induce coastal erosion, salt-water incursion, and loss of habitable delta-plain surfaces; thus, humans remain vulnerable to sea-level rise (cf. French et al., 1995). The impact of sea-level rise on deltas is a critical concern because world population is projected to exceed 10 billion by 2060 (Rosenzweig and Parry, 1994). Humans are increasingly dependent on deltas as vital food resources. Moreover, the increasing population pressures are causing serious and extensive degradation of these environmentally sensitive regions.

The integrated geoarchaeological record provides the means to interpret deltaic conditions for the period prior to major human modification and thereby to establish a baseline to differentiate from anthropogenic activity long-term changes in delta environments induced by natural factors. By evaluating long-term delta changes, this interdisciplinary approach can be used to measure environmental change through time and formulate effective, long-term coastal protection strategies.

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Louisiana Transfers from Southeastern Section to South-Central Section

The management boards of the Southeastern and South-Central Sections of the Geological Society of America recommended in summer 1997 that GSA member affiliation in Louisiana be transferred from the Southeastern to the South-Central Section. The GSA Council approved the transfer pending member input, and in August, GSA solicited the opinion of members in Louisiana. An overwhelming majority of those who responded approved of the transfer, which will bring the South-Central Section population into proportion with that of other sections. In addition, professional geologists in Louisiana are generally more aligned with the activities of the South-Central Section than with those of the Southeastern Section.

Effective immediately, GSA members in the state of Louisiana will be affiliated with the South-Central Section, *unless they indicate otherwise.* **Please note that GSA members may choose to maintain affiliation with any GSA section, regardless of their residential area. However, members may affiliate with only one GSA section at a time.** Any member who wishes to affiliate with a GSA section outside of his or her residential area should specify this on his or her dues statement or contact Membership Services at (303) 447-2020 or member@geosociety.org.

The members of the GSA South-Central Section wish to welcome our new affiliates. We remind you that we have an active program of student support, including travel grants to meetings and research awards at both the undergraduate and graduate levels. Our section meetings will be in Norman, Oklahoma (1998), Lubbock, Texas (1999), and Fayetteville, Arkansas (2000). Plan to attend these and get to know us!

—Elizabeth Anthony, Chair, South-Central Section

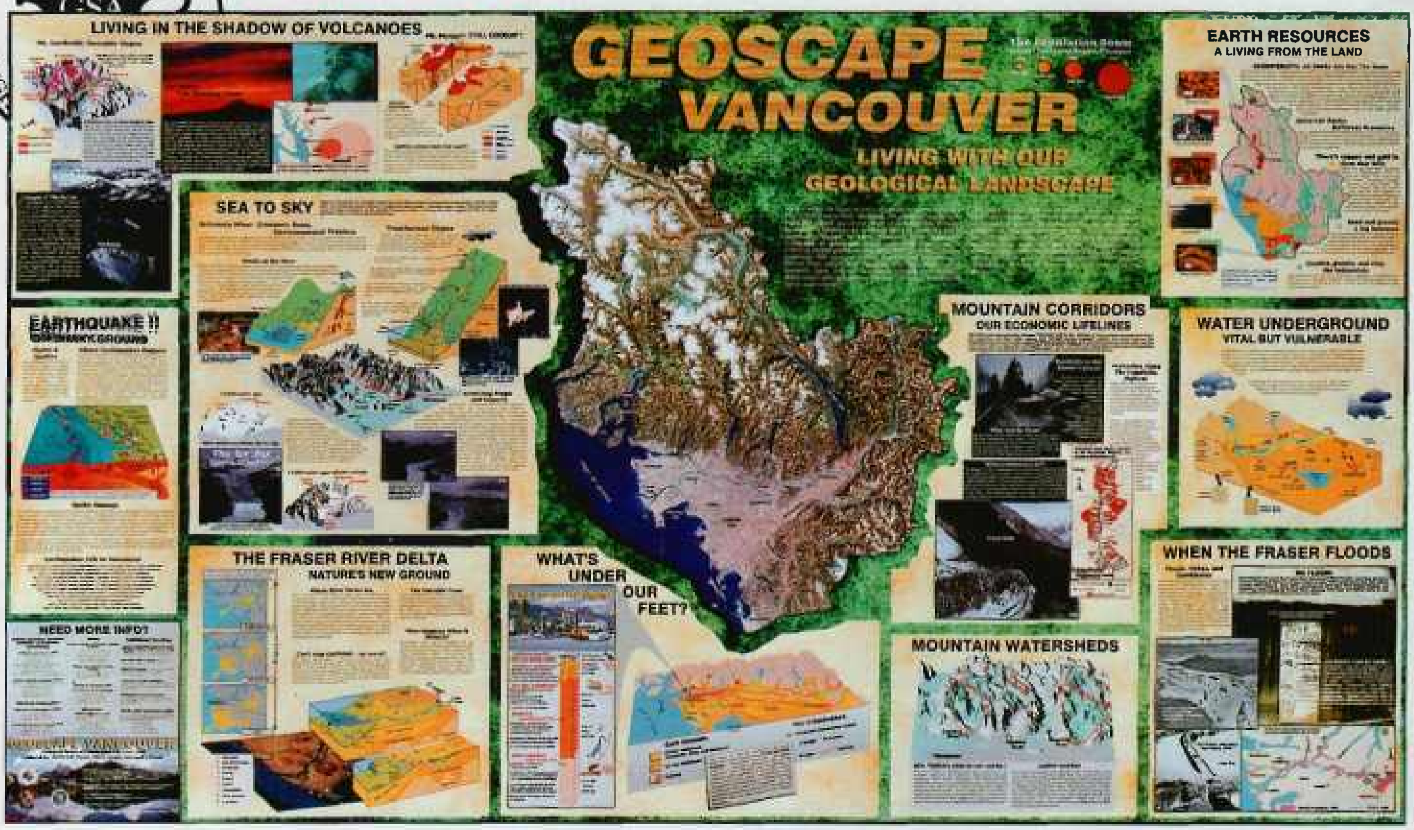

Figure 1. Geoscape Vancouver poster (published poster is 90 × 150 cm).

Raising Community Geoliteracy— The GEOSCAPE Vancouver Story

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OVERVIEW

The Geological Survey of Canada has recently launched a geoliteracy initiative in the Vancouver metropolitan region. Our first product is *Geoscape Vancouver*, a colorful, jargon-free, graphics-rich poster dealing with local geological issues. This poster has proven to be a powerful vehicle for educating the public, and we hope, through this article, to encourage the production of similar posters for other cities in North America.

THE LOCAL OPPORTUNITY

A great challenge facing geoscientists is to ensure that relevant earth science information is clearly communicated to the public, and through them to society's decision makers. To get people's attention, we must talk about what directly affects their lives. In large part that means explaining geological issues relevant to the places where people live and work. People are concerned with local geological hazards and are aware of land use debates in their community. They value understandable information on important issues such as quality of drinking water and resource development. They know best their own local landscape and are curious about what they have observed or experienced, be it flood or fossil, rockfall, or river stone.

Unfortunately, most geological information is highly technical, full of jargon, and therefore inaccessible to the public. What is produced specifically for the public is often aimed at a state, provincial, or national audience and is therefore rather generic. Excellent information is available for the geological "show pieces" of North America (e.g., Grand Canyon, Mount St. Helens, Niagara Falls), but rarely is there anything to explain the geology of a local watershed or ground-water supply, or nearby mountains or shorelines.

A deterrent to producing such locally oriented geological information is the possibility that the audience for such a product is so limited that the effort is difficult to justify. Large metropolitan centers, however, are ideal places for providing local geological information: A large population shares a small landscape; the large population places complex demands on earth and water resources, and any geological hazards affect many people. In addition, the geological database for most urban areas is large; thus the geoscientist can draw on a wealth of information. Further, metropolitan school systems can be important users and distributors of the geological product that is critical to its success. These circumstances provided the context for the development of the *Geoscape Vancouver* poster.

THE POSTER

Geoscape Vancouver is a large (90 × 150 cm), full-color, jargon-free, graphics-rich poster (Fig. 1). A central satellite image of the Vancouver area is surrounded by 10 panels, each of which discusses an important local geological issue: earthquakes; volcanoes;