Production and Exchange of Ceramics on the Oman Peninsula from the Perspective of Hili

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Analysis was conducted for purposes of defining provenience of the raw material for three ceramics types: "domestic," "black-on-red," and Emir grey wares selected from Periods I and II at Hili 8 settlement and Hili North Tomb A on the Oman Peninsula of the 3rd millennium B.C. Combined thin section petrography and neutron activation analysis indicated that the "domestic" and "black-on-red" fine wares conform to the geological setting of the Oman Peninsula and the Emir grey ware probably comes from SE Iran. The cultural implications are discussed.

Introduction

The Oman Peninsula captured the interest of Near Eastern archaeologists when it first became identified with Magan, a land referred to in Mesopotamian texts of the 3rd millennium B.C. (Peake 1928). In those texts references are made to the extensive trade contacts between Magan and Mesopotamia. Systematic archaeological exploration in the region, which now includes the United Arab Emirates and the Sultanate of Oman, was begun in the early 1960s by the Danish Archaeological Mission and was followed by a number of projects designed to round out the picture provided by the textual sources. As a result of this research, archaeologists have become increasingly aware that protohistoric groups on the Oman Peninsula not only engaged in trade with Mesopotamia but also had established links with other neighbors: the Indo-Iranian Borderlands to the north (Lamberg-Karlovsky and Tosi 1973; Cleuziou and Tosi in press) and the Indus Valley civilization to the east (During-Caspers 1972; Cleuziou and Vogt 1985). Figure 1 shows the location of some key sites of the Oman Peninsula, the Indo-Iranian Borderlands, and the Indus Valley civilization.

This paper presents the results of research undertaken to investigate the nature of these contacts through the analysis of ceramics from excavations at Hili, one of the best known sites on the Oman Peninsula (FIG. 1). The methodology, involving macroscopic, petrographic, and chemical analyses, was designed to establish the provenience of the ceramics, to investigate their production and distribution, and to delineate the context of the interaction among groups both within and outside of the Oman Peninsula (Mery 1985). Our principal goal will be to determine whether contacts were based upon a shared style or technology or, conversely, on the exchange of products (Wright 1984; Wright and Blackman 1985; Mery in press).

In the sections that follow, we first provide a background to the site of Hili and to the methods of analysis used in the study. These sections are followed by a presentation of the results of the analyses and our interpretation of their implications.

Study Area

Hili, located on the Oman Peninsula, is 150 km east of Abu Dhabi, United Arab Emirates (FIG. 1). Situated at the al-Ain Oasis in the western foothills of the Jebel Hajjar mountains, Hili is a complex of sites including both settlements and tombs. The ceramics analyzed in this research are from the settlement at Hili 8 and from Tomb A at Hili North.

Hili 8 is one among several sites scattered over an area of at least 25 ha. To date, it is the only site excavated on the Oman Peninsula with a continuous occupation during the 3rd millennium B.C., a sequence that has been divided into the following periods and phases (Cleuziou in press a, b):

Period I, 3000 to 2700 B.C.
Period II, phases a–c_1, 2700 to 2450 B.C.
Period II, phases c_2–f, 2450 to 2100 B.C.

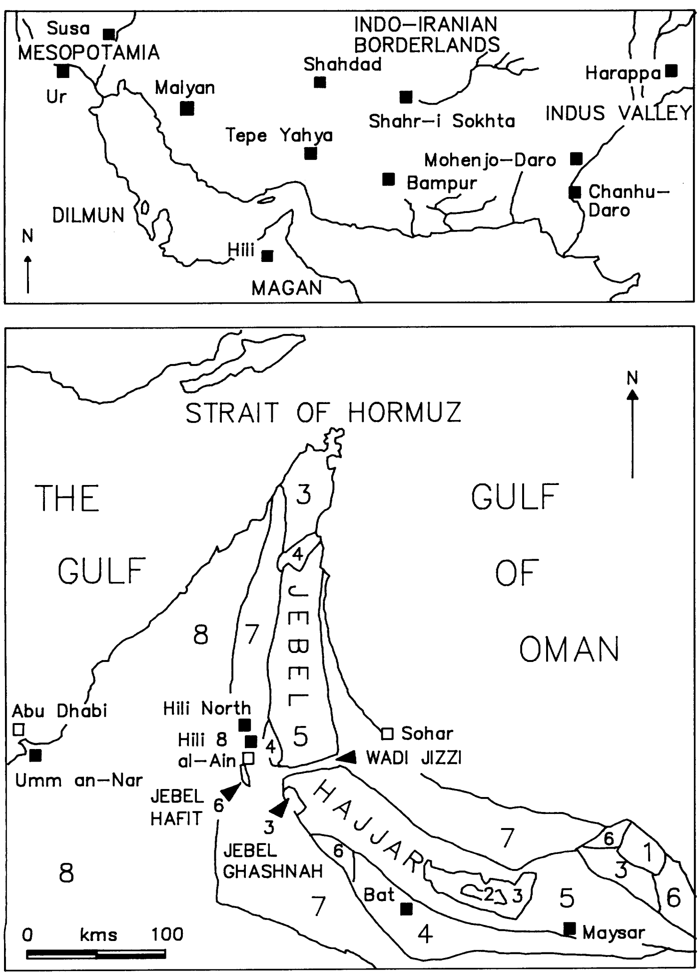


Figure 1. Map of the geology of the Oman Peninsula and archaeological sites referred to in the text. Solid squares represent 3rd millennium B.C. sites and open squares represent modern towns. 1) Autochthonous Precambrian quartzites; 2) Autochthonous Precambrian granites; 3) Autochtonous Mesozoic-Permian limestones and dolomites; 4) Hawasina upper Cretaceous limestones; 5) Semail Nappe upper Cretaceous ophiolites; 6) Tertiary limestones; 7) wadi sediments; and 8) dune sands.

The principal architectural remains consist of the base of a solid, compartmented mud-brick tower (FIG. 2), rebuilt three times during phases Ia, IIa, and IIf. At least four towers existed at Hili by the end of the 3rd millennium B.C., and they are similar to others at several sites in interior Oman, including Bat (Frifelt 1976) and Maysar (Weisgerber 1984). Subsistence and settlement were based on a well-controlled and complex system of irrigation that began in Period I. At Hili 8 there are vestiges of features (ditches, wells, canals) associated with irrigation (Cleuziou 1982) and ethnobotanical evidence for plant domesticates cultivated in different seasons (Cleuziou and Costantini 1980).

Tomb A at Hili North is 2 km NNW of Hili 8 and consists of a multi-chambered collective burial tomb. Used for a period of no more than 200 to 300 years, it is contemporaneous with phases IIf–g at Hili 8 (Cleuziou and Vogt 1985). Tomb A is one of the largest known examples of "Umm an-Nar" type tombs, which are widespread throughout the Oman Peninsula during the second half of the 3rd millennium B.C. (Frifelt 1975a, 1975b; Vogt 1986). Built of stones and faced with large ashlars and a single doorstone, Tomb A measures 10.7 m in diameter and contains four parallel chambers in which more than 80 individuals were buried. In one of the chambers, bodies were superimposed in two layers and arranged side-by-side, in a flexed position.

Proposed Interaction

As noted above, numerous scholars have proposed that during the 3rd millennium B.C. contacts between the Oman Peninsula and the surrounding areas (i.e., Persian Gulf, Mesopotamia, southern and eastern Iran, and the Indus Valley) were taking place. While some indications of these contacts are based upon Mesopotamian textual sources, many rest on inferential evidence, including parallels in artifacts or raw materials, such as soft-stone vessels, use of carnelian, and evidence for the use of Omani ores to manufacture artifacts found in Mesopotamia and Susa (Berthoud 1979).

By far the most relevant evidence for contact rests on ceramic parallels. Comparative studies based upon similarities of form and design motifs suggest wide-ranging contacts between Oman and other parts of the Near East, beginning at the end of the 4th millennium B.C. Between 3000 and 2700 B.C., the predominant relationships were oriented toward Mesopotamia. Small, painted or unpainted, double-carinated jars associated with a fine mineral-tempered ware were used as grave goods in cairns (e.g., at the Jebel Hafit [south of al-Ain Oasis]). They

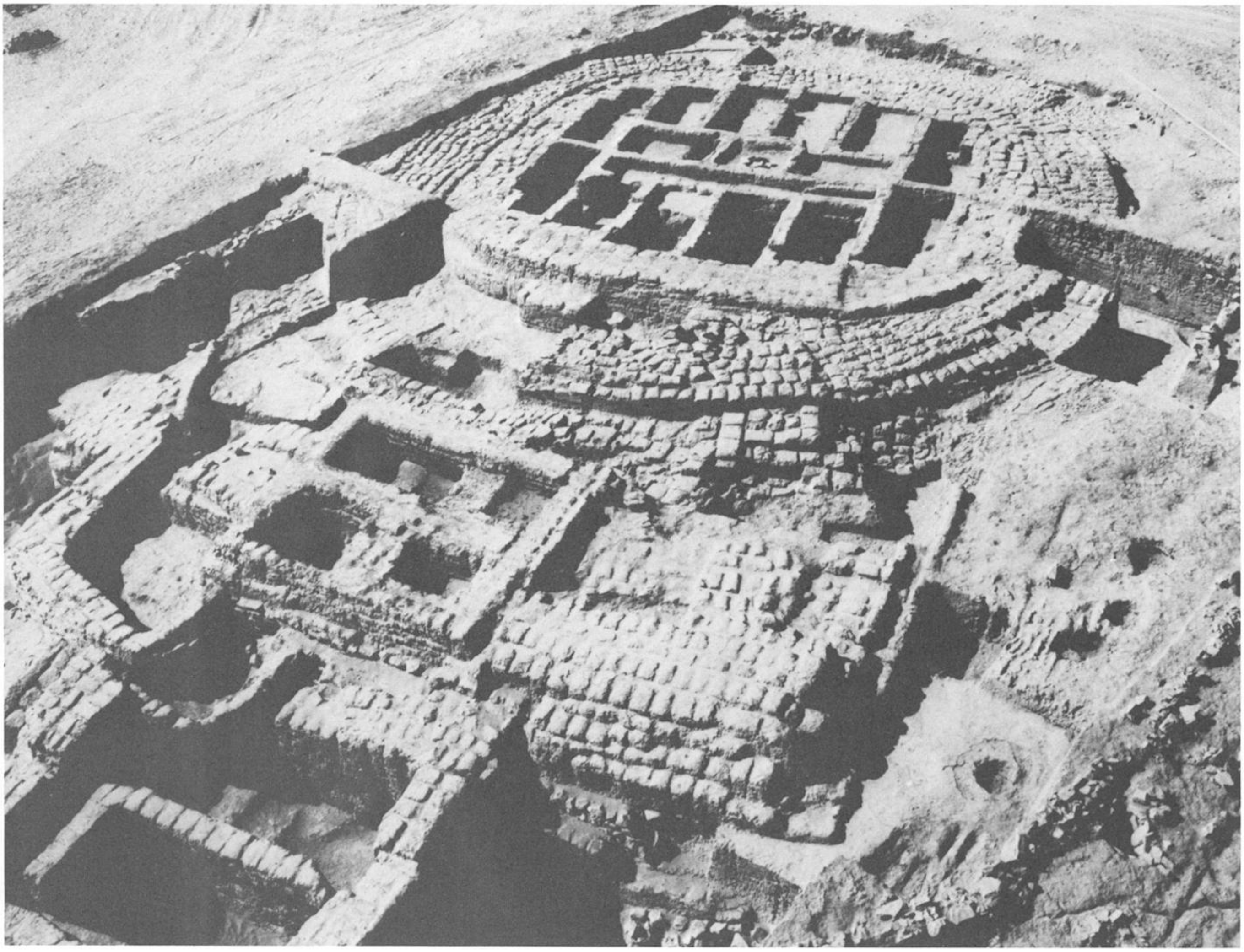


Figure 2. Hili 8 settlement, general view of the site.

have parallels in the Jemdet Nasr-Early Dynastic ceramics from Mesopotamia (Frifelt 1970; Potts in press). After 2700 B.C. other Mesopotamian-like ceramics appeared at Hili 8, phases IIa–c_1, and at the tombs at Umm an-Nar near Abu Dhabi (Frifelt 1975b; al-Tikriti 1981). Mynors (1982), using petrographic and chemical data, has documented the movement of southern Mesopotamian ceramics onto the Oman Peninsula.

From as early as Period I and throughout the 3rd millennium, the Oman Peninsula shows several ceramic parallels with southern and eastern Iran. Parallels have been suggested (Cleuziou 1984, in press b; Cleuziou and Tosi in press; Tosi 1986) between the two regions based on similarities in traditions of black-on-red fine wares. During the second half of the 3rd millennium B.C., two new ceramic types appear in the ceramic corpus of the Oman Peninsula: black-on-grey wares and incised grey wares.[1] Both types have been found in southern and eastern Iran (de Cardi 1970; Lamberg-Karlovsky and Tosi 1973). The black-on-grey ware falls within the type Emir 2, as described by Wright (1984, 1985).

At the end of the 3rd millennium, ceramics from both settlements and tombs indicate that the direction of contact shifted toward the Indus. Identification with the Indus is based upon rims and/or body sherds from large, black/slipped storage jars that are made with a distinctive red micaceous paste and are found throughout the Oman Peninsula (Cleuziou in press b). Other Indus-type ceramics at Hili North Tomb A are a series of bottles of fine

1. The incised grey ware and other ceramic types that show external relations between the Oman Peninsula and Iran are currently under study.

red ware decorated with black designs known from the Indus sites of Harappa, Mohenjo-daro, and Chanhu Daro (Cleuziou and Vogt 1985).

The similarities in pottery cited above suggest that interaction was taking place among diverse cultures and that contacts shifted over time. In the remainder of this paper, we will test one aspect of these proposed contacts through an integrated program of ceramic typology, petrography, and neutron activation analysis of the "black-on-red" fine wares and Emir grey wares of Hili sites that have been linked to the Indo-Iranian borderlands.

Methods of Analysis

Three techniques were employed. Macroscopic and low/power microscopic examination was used initially to classify the fabrics and the ware types. Petrographic thin section analysis was used to classify the micro-facies, and instrumental neutron activation analysis (INAA) to characterize the bulk chemical composition of the ceramics. Each of these techniques supplies unique but complementary data, which when integrated provide a complete picture of ceramic production and exchange on the Oman Peninsula.

The ceramic assemblage at Hili 8 consists of 2764 diagnostic sherds (Cleuziou in press b) and at Hili North Tomb A, of 384 complete pots. All were initially sorted and classified as to fabric and ware type by macroscopic and binocular microscopic examination. The fabric and ware types identified were then subsampled to provide a representative selection of each type for further, more detailed study. The macroscopic examination proceeded on two levels. The first level aimed at identifying and defining different groups based upon shape and decoration, surface treatment, and forming techniques. The second level involved the detailed description of the paste (walls and core), the pores, and the inclusions (color, shape, dimension, frequency, distribution) to establish a precise ceramic typology.

Petrographic Thin Section Analysis

This technique was used to describe and classify different micro-facies in the ceramic pastes. Micro-facies are here defined as identical associations of a variety of features described as follows. Observational data are collected on the matrix (the original clay minerals, now thermally altered, and all the non-plastic inclusions smaller than 5 microns), the coarse fraction (non-plastics larger than 5 microns, principally minerals and rock fragments), and the pores. Thin section analysis is well suited to the identification of minerals and rock fragments and to the description of their granulometric and morphological features. Secondary components also can be identified in thin section (Courtois 1976), and they yield information on the post-depositional environment. When taken together, these data enable the reconstruction of the original environment of the raw materials used to prepare the ceramic body (Maggetti 1982; Echallier 1984).

Other observations that can be made with thin section petrography relate to manufacturing methods (Shepard 1954). They include the identification of vegetal or animal fragments and man-made materials such as grog (crushed ceramics). In addition, firing temperature can be determined from the kind and degree of alteration of the mineral components. Forming technique may be inferred from microstructural data (pore and grain distribution and alignment).

Instrumental Neutron Activation Analysis (INAA)

This analytical technique is a precise and accurate method of chemical analysis, which allows the determination of up to 36 major, minor, and trace elements simultaneously. In this study, 26 elements were quantified. Table 1 presents the elements sought, the radionuclide and associated photopeak used in the quantification, the elemental concentrations in the comparator standard, and the estimated precision of the analysis. The analytical parameters are described in Blackman (1984). The estimate of precision is based on the analysis of 56 aliquots of a check standard, NBS SRM 678, a brick clay (Blackman 1986). The data provided by this technique represent the bulk chemical composition of the ceramic body, including both matrix and coarser inclusions. As such, the data reflect the relative homogeneity of the paste composition. Coarse ceramic wares, with a variety of mineralogically different grain types, can be expected to display greater heterogeneity than fine ceramic wares.

The basic premise of the compositional characterization (as well as for the petrographic analysis) is that ancient potters will select their clays from those available within a reasonable distance of the site of manufacture and that, although firing alters the original mineralogy of the matrix, it will not affect the chemical composition (Bieber et al. 1976). The chemical data are used to isolate ceramic groups of similar chemical composition and to statistically test the validity of these groups. The chemical composition groups are then tested against the typological and mineralogical data for consistency. These combined data may then be used to test a variety of propositions concerning, for example, exchange or aspects of the ceramic technology. The relative chemical (as well as the mineralogical)

Table 1. I.N.A.A. experimental parameters.

Element	*Nuclide*	*Gamma ray energy (Kev)*	*Conc. in standard SRM 1633**	*Count†*	*Analytical precision‡ SRM 679*
Na	Na-24	1369	0.32%	1	2.3%
K	K-42	1525	1.61%	1	8.2%
Ca	Ca-47	1297	4.70%	1	n.d.§
Sc	Sc-46	889	27 ppm	2	1.4%
Cr	Cr-51	320	131 ppm	2	3.1%
Fe	Fe-58	1099 and 1292	6.20%	2	2.9%
Co	Co-60	1173 and 1333	41.5 ppm	2	1.5%
Zn	Zn-65	1115	213 ppm	2	3.5%
As	As-76	559	61 ppm	1	6.0%
Br	Br-82	554	8.6 ppm	1	n.d.
Rb	Rb-86	1077	125 ppm	2	9.1%
Sr	Sr-85	514	1700 ppm	2	n.d.
Zr	Zr-95	757	301 ppm	2	n.d.
Sb	Sb-122	564	6.9 ppm	1	9.9%
Cs	Cs-134	796	8.6 ppm	2	2.7%
Ba	Ba-131	496	2700 ppm	1	13.2%
La	La-140	1596	82 ppm	1	1.4%
Ce	Ce-141	145	146 ppm	2	1.8%
Nd	Nd-147	91	64 ppm	1	n.d
Sm	Sm-153	103	12.9 ppm	1	1.6%
Eu	Eu-152	1408	2.5 ppm	2	2.2%
Tb	Tb-160	879	1.9 ppm	2	12.9%
Yb	Yb-175	396	6.4 ppm	1	4.8%
Lu	Lu-177	208	1 ppm	1	6.7%
Hf	Hf-181	482	7.9 ppm	2	3.5%
Ta	Ta-182	1221	1.8 ppm	2	7.0%
Th	Pa-233	312	24.8 ppm	2	2.2%
U	Np-239	106	11.6 ppm	1	15.9%
W	W-187	686	5.5 ppm	1	n.d.

*Ondov et al. (1975) and Certificate of Analysis SRMs 1632 and 1633, National Bureau of Standards.
†Count 1: 1 hour after a 5-day delay; count 2: 2 hours after a 30-day delay.
‡Blackman (1985).
§Not determined.

homogeneity of typologically-coherent ceramic groups can provide information on clay preparation techniques, the geographic extent and variability of the raw materials, and even the number of production sites. The absolute concentration of the elements and their ratios to one another can provide information on exchange of ceramics as well as clues to the geochemistry of formation of the clay deposits.

Petrographic or chemical analysis, used separately, provides powerful tools to further the understanding of ancient ceramic production and distribution, and when used together can test the validity of the results derived from each technique. In addition, they provide information that is not accessible by either technique alone. Optical microscopy permits the identification of micro-structures and inclusions, but since the minerals below 5 microns are not identifiable, the analysis of the matrix is only partial. The neutron activation provides a total compositional analysis, although it does not permit differentiation of the metaphases, the coarse fraction, and the post-depositional alteration.

The Oman Peninsula is a perfect setting in which to develop a program of joint petrographic-chemical analysis. The combination of chemical and mineralogical data makes it possible to reconstruct both the original parent rocks from which the clays were formed and their later alteration products. Moreover, due to the abrupt changes in geology throughout the Oman Peninsula, it is possible to pinpoint specific areas as probable resource-procurement zones and to exclude others.

Ceramic Typology

Three ceramic wares were studied. Two wares, "black-on-red" fine ware and the Emir grey, are discussed in the context of interaction between the Oman Peninsula and the Indo-Iranian Borderlands. A third type, the local "domestic" ware, is included for purposes of comparison.[2]

"Domestic" Ware

The most typical forms (FIG. 3) at Hili 8, phases IIf–g, and at Hili North Tomb A are globular jars without necks. Decoration consists of black paint on a red slip/paint, the latter covering all or part of the external wall and sometimes the inside of the rim. Painted patterns are always geometrical, and the most frequent motif is the association of straight and/or undulating lines. The fabric is easily recognizable macroscopically because of its sandy, porous appearance. The color is that of a siliceous clay, ranging from buff to orange, light red, and brown. The thickness of the wall varies between 3 mm and 9 mm.

The "domestic" ware is considered to be "a local product made for everyday purpose and it would not be expected to be found on the other side of the straits of Hormuz" (Cleuziou and Vogt 1985: 7). This ware is found in abundance in the Hili area. At Hili 8 it occurs for almost a 400-year period, and its percentage increases regularly from 85% of the total ceramic assemblage in phases IIc_2–d to 95% in phases IIf–g. At Hili North Tomb A it represents 50% of the assemblage. Stylistic parallels to the "domestic" ware at Hili are found at other sites on the Oman Peninsula, for example at Bat (Frifelt 1976) and Maysar (Weisgerber 1980, 1981).

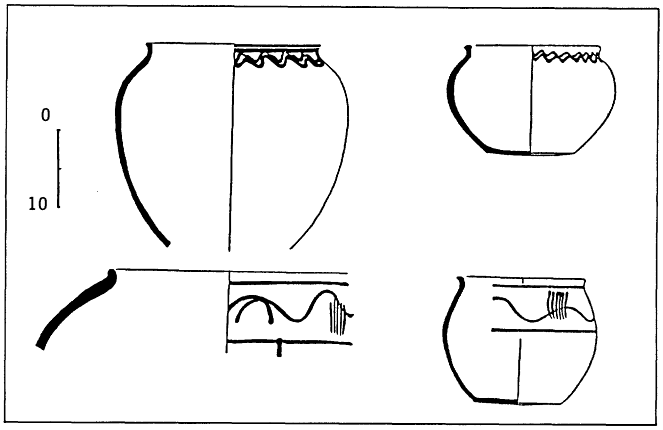


Figure 3. Examples of "domestic" ware from Hili 8. Scale in cm.

"Black-on-Red" Fine Ware

At Hili this ceramic is a homogeneous, technological, and typological tradition that covers a time span from 3000 to 2100 B.C. The principal shape (FIG. 4) at Hili 8, phases IIf–g, and Hili North Tomb A is a short-necked jar, decorated with motifs painted in black applied over a red slip/paint. The slip/paint covers the entire external surface of the vessels. The motifs are geometric, principally horizontal, and wavy lines or friezes of slanted strokes and chevrons. The paste is extremely fine, smooth, and nonporous, with few visible inclusions. Color varies between buff and red. The wall thickness is between 3 mm and 4 mm.

"Black-on-red" fine ware is widely distributed in the Hili area and throughout the Oman Peninsula (de Cardi, Collier, and Doe 1976; Hastings, Humphries, and Meadow 1975), notably at Umm an-Nar (Thorvildsen 1962; Frifelt 1975b; al-Tikriti 1981) and Bat (Frifelt 1976). This type is closely correlated with funerary contexts, as at Hili North Tomb A where it represents 30% of the ceramic assemblage. Although "black-on-red" fine ware is found in settlements, it appears only in small percentages in this context. Stylistically similar black-on-red wares are present at numerous sites in southern and eastern Iran, and it has been proposed that these ceramics were exported to Oman, at least in the first half of the 3rd millennium B.C. (Tosi 1986: 469).

Emir Grey Ware

The principal shapes and forms of Emir ware found at Hili North Tomb A are miniature jars, less than 7 cm in height. They fall within the Emir type 2, as described in Wright (1984, in press). There are variations within this ware at Hili (Cleuziou and Vogt 1985) as indicated in Figure 5. The most common variant is a globular, miniature jar with a flat or concave base, short neck, and simple everted lip. The jars are decorated with black-painted motifs of slanted or vertical lines enclosed by single lines.

Based on the Hili chronology, Emir grey ware appears in Oman in the last centuries of the 3rd millennium B.C. It is restricted almost entirely to funerary contexts, as at Hili Tomb 1059, Hili North, and Umm an-Nar graves and is extremely scarce at Hili 8 settlement (1 sherd in phase IIe and 12 in phase IIf). On the other side of the Gulf, Emir (type 2) ceramics are distributed principally in eastern Iran where they occur both in settlements and graves, as at Bampur, Shahr-i Sokhta, and Damin. At Bampur and Shahr-i Sokhta, the two sites at which there are stratified sequences, Emir ceramics appear by the beginning of the 3rd millennium B.C. (Wright 1984).

2. This summary is based upon the preliminary studies of Hili ceramics (Cleuziou 1984, in press a, b; Cleuziou and Vogt 1985; Mery 1986). Although the typology for the "domestic" and the "black-on-red" fine wares is well developed, no formal designations have been made for the types. Consequently, these ceramics will be referred to as "domestic" ware and "black-on-red" fine ware.

Thin Section Analysis

A total of 75 sherds (36 "domestic", 24 "black-on-red" fine ware, and 15 Emir grey ware) were studied in thin section. Selection of samples for thin section examination was based upon the paste compositional groups described above. In addition, 10 samples of earth, sand, and rock from the immediate area of Hili were studied.

"Domestic" Ware

Of the 36 "domestic" ware samples, 27 were selected from Hili 8, phases IIc_2–f, and 9 from Hili North Tomb A (Mery 1986). All the samples analyzed have the same micro-facies, indicating a single clay source. The matrix is phyllitic (FIG. 6A). Numerous elongated pores are oriented parallel to the walls of the sherds, resulting in a characteristic corded structure. Visible inclusions are abundant, with a size range between 10 microns and 0.5 mm. They are a mixture of detrital quartz, some granito-gneissic rock fragments, and small quantities of basic and ultrabasic grains (pyroxenes, amphiboles, olivines, and serpentines). No primary carbonate minerals are present. Many of the inclusions are angular or splintered, including minerals and rock fragments such as feldspars and quartz/biotites that do not stand up well to long-distance erosional transport.

The geology in the area of al-Ain provides information on the provenience of the clay used for the "domestic" ware (FIG. 1). It is dominated by sedimentary rocks composed of calcareous ridges such as the Jebel Hafit. The substratum consists of limestones, dolomites, marls, and shales. Sand-dune deposits contain about 50% fossiliferous calcareous debris. The first chains of gabbros and peridotites of the Semail Nappe are located about 30 km east of Hili. Based on the thin section analysis, the immediate environment of Hili can be excluded as a possible source of the clay used for "domestic" ware, since these ceramics do not contain primary carbonates. On the other hand, the source of the clay was not in direct contact with the ophiolite ridges (Semail Nappe) east of al-Ain, since

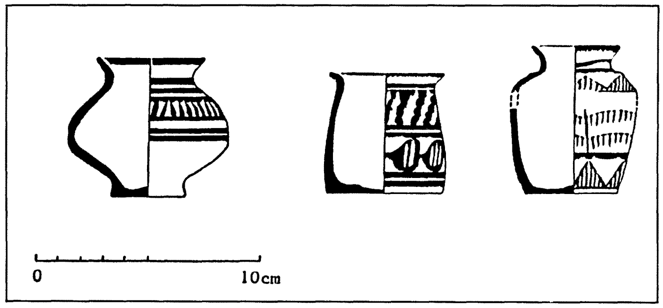


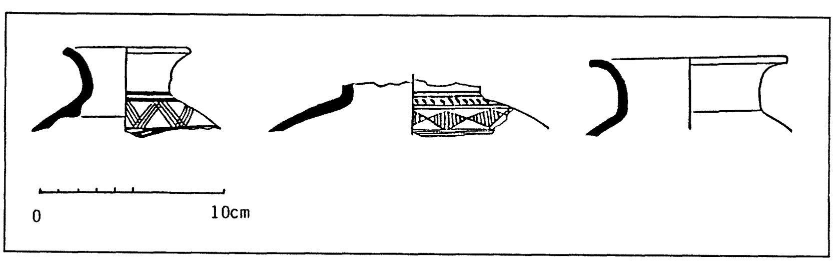
Figure 5. Examples of Emir grey ware from Hili North Tomb A.

the ceramic sample contained few basic and ultrabasic minerals. The Semail Nappe is a very compact magmatic range extending over 600 km throughout the Oman Peninsula.

As Figure 1 indicates, the two nearest mapped areas (Glennie et al. 1974) that are petrographically compatible with the mineralogical composition of the "domestic" ware are located in the Jebel Hajjar mountains about 60 km from Hili. It is only at these places that we can find acid rocks such as muscovite-quarzite and schist close to the gabbros and peridotites of the Semail Nappe. The first zone of provenience is located east of Hili at the mouth of the Wadi Jizzi, one of the three major valleys that cross the Jebel Hajjar from east to west. The Wadi Jizzi, which connects the Hili area with Sohar on the Gulf of Oman, has long been an important route, probably in use during the 3rd millennium B.C. (Frifelt 1975a). The second potential zone of provenience is located on the western piedmont of the Jebel Hajjar, near Jebel Ghashnah. Without additional fieldwork, both of these potential locations remain hypothetical.

To summarize, the weight of the evidence points to the production of "domestic" ware close to an acid rock source such as one or both of the areas described above. Our conclusions are based upon the following four factors: 1) the presence of a major acid rock fraction; 2) the small, but persistent, fraction of basic and ultrabasic elements; 3) the absence of a primary carbonate component; and 4)

Figure 4. Examples of "black-on-red" fine ware from Hili 8.



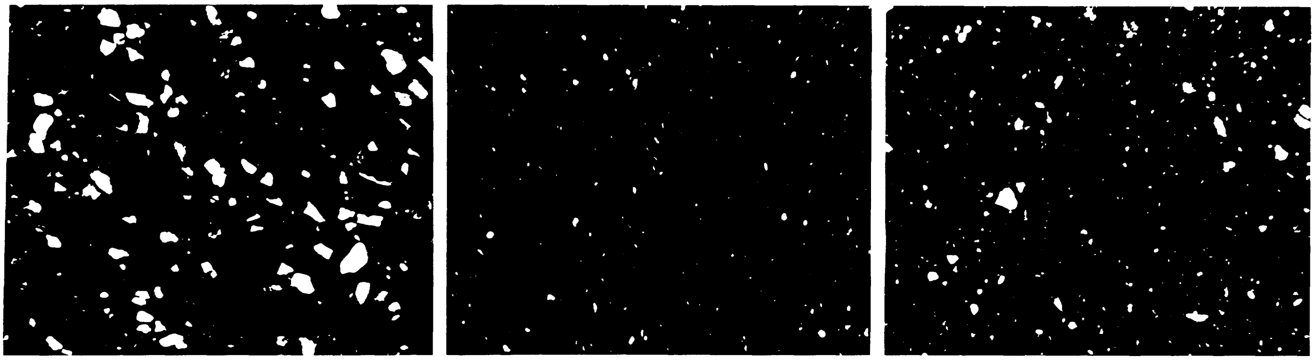


Figure 6. Thin sections, cross-polarizers, × 40. a) "Domestic" ware. Numerous mineral inclusions between 5 and 400 microns: numerous angular quartz, some plagioclases, automorphic amphiboles, fragments of rocks with quartz associated or not with amphiboles, biotites, and muscovites. Few isolated muscovites, biotites, fibrous epidotes, altered olivines, and sub-automorphic pyroxenes. Scarce tourmalines and radiolarians. b) "Black-on-red" fine ware. Phyllitic matrix, sub-isotropic. Scarce mineral inclusions, between 5 and 100 microns: quartz, biotites, muscovites, amphiboles, iron oxides, few plagioclases, and fragments of basalt or andesite. c) Emir grey ware. Isotropic matrix. Few mineral inclusions: 95% angular or splintered quartz, some altered feldspars, plagioclases, microclines, and muscovites, between 5 and 150 microns.

the angularity of the grains and presence of minerals easily altered by mechanical agencies and of rock fragments indicating short-range depositional transport.

"Black-on-Red" Fine Ware

Twelve sherds of "black-on-red" fine ware, from all periods at Hili 8, and 12 sherds from Hili North Tomb A were analyzed. The paste composition (FIG. 6B) is consistent with a clay containing a rare non-plastic, silt fraction. Most of this fraction consists of small, angular quartz (5–100 microns) associated with biotites, fractured amphiboles, and rare fragments of effusive rocks, possibly basalt. Carbonates are totally absent from the silt fraction and, as with the "domestic" ware, this fact effectively excludes the immediate area around Hili as a possible source for raw material. The occurrence of minerals such as biotites and amphiboles indicates the proximity of basic formations, which are numerous, although not predominant, in the Semail Nappe. The absence of ultrabasic rock types, which are predominant on the Semail Nappe, further narrows the possible source area.

The "black-on-red" fine ware is produced from a different clay source than the "domestic" ware. The major difference between the two is the presence of small amounts of effusive rocks in the "black-on-red" fine ware and their absence in the "domestic" ware. The chemical composition of the rare earth elements, discussed below, confirms this conclusion. Although the evidence points to two separate sources for the clays of the "domestic" and "black-on-red" fine wares, these sources need not be at great distances from one another. The great diversity of the geology of the Omani Mountains provides a number of petrographically possible sources in close proximity; for example, there are extrusive rocks at a distance of only 5 km from the acid metamorphics in the Wadi Jizzi.

Emir Grey Ware

Three sherds of Emir grey ware from phases IIe–g at Hili 8 and 12 sherds from Hili North Tomb A were analyzed. In thin section (FIG. 6C) the paste is very different from the "black-on-red" fine ware and consists of an argillaceous matrix with silt-sized, fractured quartz, plagioclase, and microclines. Carbonates as well as basic or ultrabasic minerals are absent. The angularity of the quartz grains could be preserved during short-distance aeolian transport; however, the lack of rounding and the absence of significant admixtures of other rock types would exclude long-range transport. For the same reasons, as outlined above for the "black-on-red" fine and "domestic" wares, the immediate vicinity of Hili can again be excluded as a possible source of raw materials. Moreover, as the Oman Peninsula is a region dominated by calcareous and dolomitic formations in its western and northern parts and by basic and ultrabasic formations in the eastern part, the total absence of carbonate, basic, and ultrabasic components makes the peninsula an improbable source for the clays used in producing the Emir grey ware.

Chemical Analysis

Seventy samples (29 "domestic" ware, 21 "black-on-red" fine ware, and 20 Emir grey ware) were analyzed by instrumental neutron activation analysis. The chemical data for all of the 70 samples were first subjected to cluster analysis using the hierarchical aggregative clustering algorithm, AGCLUS (Bieber et al. 1976). The clustering employed a mean euclidean distance matrix and "average link" cluster type. The elements selected for clustering included alkali, transition metal, and rare earth elements (K, Rb, Sc, Cr, Fe, Co, La, Ce, Sm, Yb, Hf, Ta, and Th) that were expected to be the most discriminating given the geological environment of the Oman Peninsula. The results of the cluster analysis showed that 94% (66) of the samples were classified into one or another of three large clusters and one small, more loosely-defined, cluster. The three large clusters contained 87% of the samples and corresponded closely to the typologically-assigned wares. The "domestic" ware compositional group consisted exclusively of "domestic" ware samples containing 25 (86%) of the 29 samples studied. The Emir grey compositional group contained 17 (85%) of the 20 studied. The "black-on-red" fine ware compositional group contained 15 (72%) of the 21 samples studied.

The statistical validity of the three large compositional groups was tested using Mahalanobis distance and Hotelling's T^2 statistic. Each of the groups retained their integration at the 99% confidence level. Moreover, when members of each compositional group were tested for inclusion in a group other than their assigned groups, all were rejected at the 99% confidence level. The three large typologically-defined groups, therefore, represent readily identifiable chemical compositions. The fourth, smaller group contained too few samples (five) for multivariate statistical evaluation with the techniques used here. Members of this group, however, were rejected at the 99% confidence interval from inclusion in any of the three larger groups. Pending an extensive evaluation of the typology of the black-on-red wares and the analysis of additional samples, the validity of this particular group remains in contention. Only four samples (6%) remain unassigned and three of these showed unique characteristics upon petrographic examination.[3] Table 2 presents the group means, standard deviations, and 95% confidence interval for the three chemical compositional groups. Inspection of this table shows that the alkali earth elements (sodium, potassium, rubidium, and cesium) in each of the compositional groups have coefficients of variation of 15% or less. The transition metals, rare earth elements, and thorium, however, display quite low variability in each group. Coefficients of variation in the range of 3% to 5% for the "black-on-red" fine ware group and 5% to 10% for the "domestic" and Emir grey ware groups document extreme homogeneity for the ceramic groups. In fact, the coefficients of variation calculated for the "black-on-red" fine ware compositional group are only about twice those measured for the check standard (TABLE 1), a material especially selected and processed for maximum homogeneity. Such a degree of homogeneity as that displayed by the "black-on-red" fine ware, the "domestic" ware, and probably also the Emir grey ware, strongly indicates either a very uniform treatment of the raw materials, a very homogeneous and probably geographically-circumscribed resource procurement area, or both.

The alkaline earth elements (calcium, strontium, and barium), on the other hand, display a high amount of variability in all three groups. This variability is due, at least in part, to the minor post-depositional precipitation of secondary calcite identified in petrographic examination. Even with the inclusion of the secondary calcium contribution, however, the calcium concentrations are low. The raw materials of all three compositional groups were, therefore, low-calcium clays that effectively exclude the carbonate-rich Hili area as the source of these clays.

The geochemical differences among these three compositional groups can be graphically displayed using selected binary plots of the elemental concentrations summarized in Table 2. Figure 7, a plot of the mafic elements Co vs. Cr, shows that the three groups are completely separate populations at the 99% confidence interval. The "domestic" ware group (open diamond) has a chromium content three to four times that of the other two ware groups. "Domestic" ware, a moderately coarse ceramic, has a coarse fraction (identified petrographically) that is predominately quartz with minor mafic inclusions, including rare spinels (chromite). The sampling technique used for the INAA yields a bulk analysis of paste and inclusions. Since quartz is usually relatively "clean," with low concentrations of minor and trace elemental contents, the net effect of the quartz inclusions in the "domestic" ware is to act as a diluent depressing the apparent concentrations of other elements. The exception is chromium; its high concentrations are due to the minor mafic inclusions, particularly chromite.

Both the "black-on-red" fine ware and Emir grey have fine pastes with few inclusions over 5 microns and, therefore, are unaffected by this type of dilution. Figure 7 and Table 2 show the mafic element, cobalt, in "black-on-red"

3. Eight of the 70 samples analyzed (two "domestic" ware, three Emir grey ware, and three "black-on-red" ware samples) were petrographically classified as unique in thin section. Both of the petrographically unique "domestic" ware samples and one of the Emir grey ware also showed chemically anomalous compositions. Two of the three petrographically unique Emir grey ware samples, however, and all three of the unique "black-on-red" fine ware were chemically classified in groups consistent with their typological assignation. The significance of the small, enigmatic number of samples is currently under study.

Table 2. Means, standard deviations, and 95% confidence intervals for the three Hili ceramic groups.

	Ca %	*Sr* *ppm*	*Ba* *ppm*	*Na* %	*K* %	*Rb* *ppm*	*Cs* *ppm*	*Sc* *ppm*	*Cr* *ppm*	*Fe* %	*Co* *ppm*
"domestic" ware (N = 25)											
Mean conc.	4.76	632	248	1.30	1.51	70.1	3.52	12.2	795	3.43	20.3
Group std. dev. (%)	54.2	50.7	25.9	15.5	18.4	17.8	15.4	5.6	5.6	5.2	6.2
Upper 95% limit	10.1	1294	384	1.71	2.09	95.9	4.65	13.6	1052	3.8	22.9
Lower 95% limit	0.00	0.0	113	0.88	0.94	44.4	2.39	10.8	538	3.06	17.7
"black-on-red" fine ware (N = 17)											
Mean conc.	6.23	505	219	1.43	2.14	93.3	6.19	22.0	282	5.40	31.5
Group std. dev. (%)	23.4	44.9	38.1	12.7	10.5	10.9	10.9	4.5	7.9	3.6	2.5
Upper 95% limit	9.33	986	404	1.81	2.62	115	7.62	24.1	330	5.81	33.1
Lower 95% limit	3.14	24	33	1.04	1.67	71.7	4.76	19.9	235	4.99	29.8
Emir grey ware (N = 19)											
Mean conc.	3.01	276	260	1.11	2.55	168	13.2	18.0	192	5.01	23.2
Group std. dev. (%)	44.4	53.9	37.6	13.1	4.6	9.8	45.5	6.1	14.6	7.5	6.9
Upper 95% limit	6.28	539	477	1.41	2.80	202	25.8	20.4	251	5.80	26.5
Lower 95% limit	0.00	13	42	0.80	2.30	133	0.58	15.7	133	4.21	19.8

	Zn *ppm*	*La* *ppm*	*Ce* *ppm*	*Sm* *ppm*	*Eu* *ppm*	*Yb* *ppm*	*Lu* *ppm*	*Hf* *ppm*	*Ta* *ppm*	*Th* *ppm*
"domestic" ware (N = 25)										
Mean conc.	72.0	20.4	37.3	3.42	0.778	1.76	0.258	4.03	0.678	5.56
Group std. dev. (%)	9.8	4.1	4.7	4.1	4.4	8.1	13.2	13.1	9.8	6.4
Upper 95% limit	86.6	22.1	40.9	3.71	0.848	2.06	0.328	5.12	0.815	6.29
Lower 95% limit	57.3	18.7	33.7	3.14	0.707	1.47	0.188	2.94	0.541	4.83
"black-on-red" fine ware (N = 17)										
Mean conc.	104	21.7	40.4	4.08	0.938	2.33	0.353	3.55	0.674	7.47
Group std. dev. (%)	8.0	3.2	3.4	2.8	3.2	7.1	11.2	3.6	9.3	4.6
Upper 95% limit	121	23.2	43.4	4.33	1.00	2.68	0.437	3.82	0.807	8.19
Lower 95% limit	86.1	20.2	37.5	3.84	0.875	1.97	0.270	3.27	0.542	6.74
Emir grey ware (N = 19)										
Mean conc.	116	36.5	66.2	5.14	1.03	2.75	0.429	4.91	0.955	13.3
Group std. dev. (%)	7.0	8.0	7.9	8.6	8.9	8.5	9.2	4.9	10.0	6.8
Upper 95% limit	133	42.6	77.2	6.07	1.23	3.24	0.512	5.41	1.16	15.2
Lower 95% limit	98.6	30.4	55.2	4.21	0.839	2.26	0.346	4.40	0.754	11.4

fine ware to be significantly higher than in either the "domestic" or the Emir grey ware groups. The "black-on-red" fine ware group also has significantly higher concentrations of iron and scandium.

The rare earth elements and thorium, usually associated with more acid igneous rock types, have their highest concentrations in the Emir grey ware. The "domestic" and the "black-on-red" fine wares have significantly lower rare earth and thorium concentrations and are nearly identical in lighter rare earth concentrations (La and Ce; TABLE 2). These two groups vary significantly, however, in the content of their intermediate rare earths (Sm and Eu) and thorium. The same may also be true for the heavy rare earths (Yb and Lu), but the lower precision of the measurement of these two elements obscures the distinction. Figure 8 shows the La vs. Sm plot with complete separation at the 95% confidence interval among the three groups. Most significant is the relationship of the rare earth element distributions noted between the "domestic" ware group (open diamond) and the "black-on-red" fine ware group (solid square). Correction for quartz dilution in the "domestic" ware group would affect all the rare earth elements equally. To account for the difference in distribution shown in Figure 8, samarium (and all heavier rare earths) must be selectively added (or depleted) without changing the lanthanum (and cerium) concentration, an effect difficult to achieve naturally or with human treatment. The separation shown by the La vs. Sm plot is, therefore, a strong indication that two different rare earth populations are present and that the clays utilized in these two ceramic types are from different sources rather than the result of manipulation of the same clays by the potters.

The Emir grey ware group shows the highest concentrations of the alkali elements (potassium, rubidium, and cesium). The Rb and Cs, in trace amounts, most frequently substitute for the major element, potassium. The elevated alkali element concentrations in this group may be indicative of K-feldspar or mica inclusions in the clay or a parent material with a larger acid rock component.

In summary, the chemical data indicate the presence of three quite homogeneous and chemically distinct compositional groups, which strongly parallel the typological and the mineralogical group assignments. Each compositional group represents the use of different clay sources, and no compositional group can have been altered by human or natural intervention to produce the composition of another group. The Emir grey ware group, with relatively high alkalis, rare earths, and thorium and relatively lower mafic elements (Cr and Co), is more compatible with an environment containing a higher acid rock component. The "black-on-red" fine ware group, with higher concentrations of calcium, cobalt, and iron and lower alkali and rare earth components, is more compatible with a basic rock environment.

Conclusions

Analytical Results

The typological, mineralogical, and chemical homogeneity of the "domestic" and "black-on-red" fine wares not only documents a standardized production but strongly suggests a restricted geographical distribution for sources of each clay used. The Emir grey ware is chemically slightly less homogeneous and may have been produced from clays of a broader resource zone. The absence of primary carbonates in all three wares indicates that the raw materials could not have been procured from the immediate vicinity of Hili. For both the "domestic" and the "black-on-red" fine wares, however, the overall mineralogy and chemistry are compatible with raw material sources somewhere on the Oman Peninsula in or close to the Omani mountains. The raw materials for the Emir grey ware, on the other hand, are not compatible with the geology of the Oman Peninsula and are most likely imports from southern or eastern Iran. The arguments supporting these conclusions can be summarized as follows.

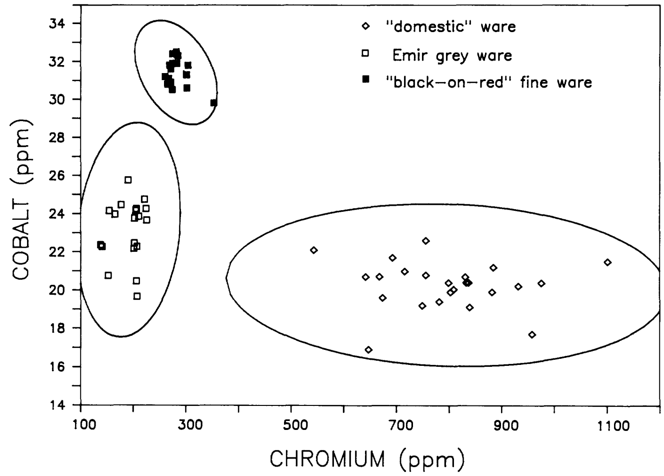


Figure 7. Plot of chromium vs. cobalt (concentrations are in parts per million and the 99% confidence ellipses are enclosed by the solid lines).

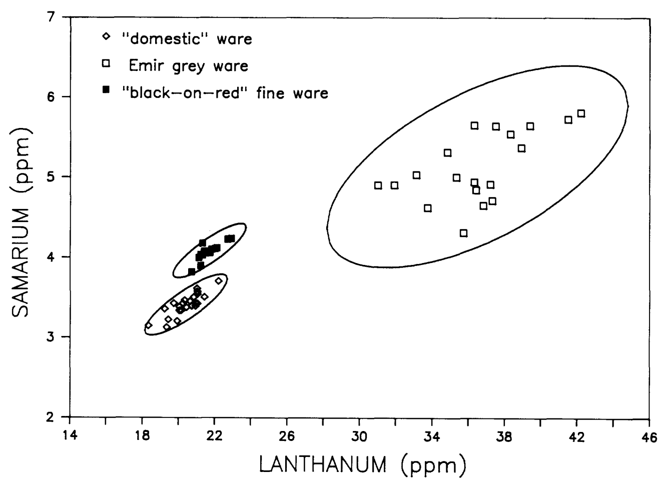


Figure 8. Plot of lanthanum vs. samarium (concentrations are in parts per million and the 95% confidence ellipses are enclosed by the solid lines).

All of the data demonstrate that the three ceramic types, the "domestic," the "black-on-red" fine ware, and the Emir grey ware, were produced from distinctively different raw materials. Emir grey ware is, therefore, not merely a specialized variant of the "black-on-red" fine ware created by altering the kiln atmosphere. Moreover, the "domestic" and the "black-on-red" fine wares were not simply variants produced by levigation or tempering of the same clay. The presence of basic rock and mineral fragments in the "black-on-red" fine ware and their absence in the "domestic" ware, coupled with the chromium concentration and differences in rare-earth element ratios, demonstrates that the two ware types were formed from clays with different parent rocks and sedimentary histories.

Both of these wares are extremely homogeneous, showing no changes in mineralogy or chemistry through time. The "domestic" and "black-on-red" fine wares both are present during the 3rd millennium B.C. on the Oman Peninsula. At Hili 8, the site with the best-developed stratigraphic sequence, "black-on-red" fine ware is present throughout the sequence (ca. 900 years), and "domestic" ware is present from phase IIc_2 to phases IIf–g (ca. 400 years). Typologically both wares are homogeneous, showing a slow evolution of form and design motifs throughout the long time periods during which they were produced (Mery 1986). The relative abundance of the "domestic" and "black-on-red" fine wares, standardized production, and time depth argues for production on the Oman Peninsula.

Although the sources of the clays used to make either the "domestic" ware or the "black-on-red" fine ware have not been precisely located, there is nothing in their mineralogical or chemical makeup that excludes their production on the Oman Peninsula. As indicated, the geological environment of the Oman Peninsula is diverse and distinctive (FIG. 1). The western and northern parts of the Oman Peninsula, including the immediate vicinity of Hili, comprise an essentially calcareous environment consisting of limestone and dolomite formations. The mountainous regions of the eastern peninsula consist primarily of basic and ultrabasic formations readily accessible from Hili. None of the ceramics studied are mineralogically or chemically compatible with the calcareous environment surrounding Hili; however, the mineralogy and chemistry of the "domestic" and the "black-on-red" fine wares are compatible with microenvironments in the eastern mountains. In fact, the most reasonable geological zones for the exploitation of clays with compatible mineralogy and chemistry are close to or in the mountains to the east of Hili (FIG. 1). As is summarized in Figure 9, all lines of evidence argue for an indigenous Omani tradition for both the "domestic" and the "black-on-red" fine wares.

The Emir grey ware from Hili presents an entirely different set of evidence. This ceramic is chemically and mineralogically compatible with an area where acid igneous rocks are present and where basic to ultrabasic rocks and carbonate rocks are absent. This is not the geological environment of the Hili area or, indeed, of the Oman Peninsula. The evidence strongly suggests a location outside of the Oman Peninsula as the source of the raw materials. From an archaeological perspective, the probable source for the Emir grey ware would seem to be in eastern Iran, where this ware is found in highest concentrations and where it is present from the beginning of the 3rd millennium B.C. (Wright 1984, in press).

The results of our analyses of Emir grey ware at Hili are wholly compatible with previous studies in which several different resource zones were delimited in eastern Iran (Wright 1984, in press). Although it is not possible to directly link a specific Iranian site with the Emir grey ware found at Hili, the high concentrations of rubidium and cesium and the lower concentrations of chromium in the Hili Emir ware are compatible with southern and eastern Iranian sources. Based upon the present evidence, these data, summarized in Figure 10, support the conclusion that the Emir ceramics found at Hili were produced in southern or eastern Iran.

Methodologically, the analysis of the Hili ceramics demonstrates the importance of merging several types of analytical data into a single, integrated research program. As presented here, we now have a new and more precise data base with which to test archaeologically-derived hypotheses. As our research program develops to include additional types of ceramics from Oman and Iran, the database will provide a broadened perspective on which to infer local production and exchange relations.

Cultural Implications

Until recently, it was generally accepted that the Oman Peninsula was a cultural backwater that lagged behind the greater centers that flanked it on the west (Mesopotamia), the north (Elam), and the east (Indus Valley). The region was viewed as a conduit for communication and commodities that flowed between the major civilizations. Any detectable manifestation of cultural development was ascribed to stimulus diffusion.

This interpretation has been altered in the most recent syntheses (Tosi 1986; Cleuziou and Tosi in press) in which two "interacting trends" have been identified. First, the indigenous development of distinctively Omani traits such as "specialized subsistence technology, funerary rituals, settlement types, waterworks . . ." (Cleuziou and Tosi in press) is cited. The second trend is traced through the increased development of contacts with polities in other regions of the Near East and South Asia. The bases for identifying this second trend pertain to the demand for Omani products known from Mesopotamian texts and the importation of Mesopotamian and Iranian ceramics.

The results of our study contradict the contention that contact with Iran during the first half of the 3rd millennium B.C. was based upon the "importation" of "black-on-red" fine ware and that pottery remained "a rare imported commodity . . . until 2500 B.C." (Tosi 1986: 469). On the contrary "black-on-red" fine ware production de-

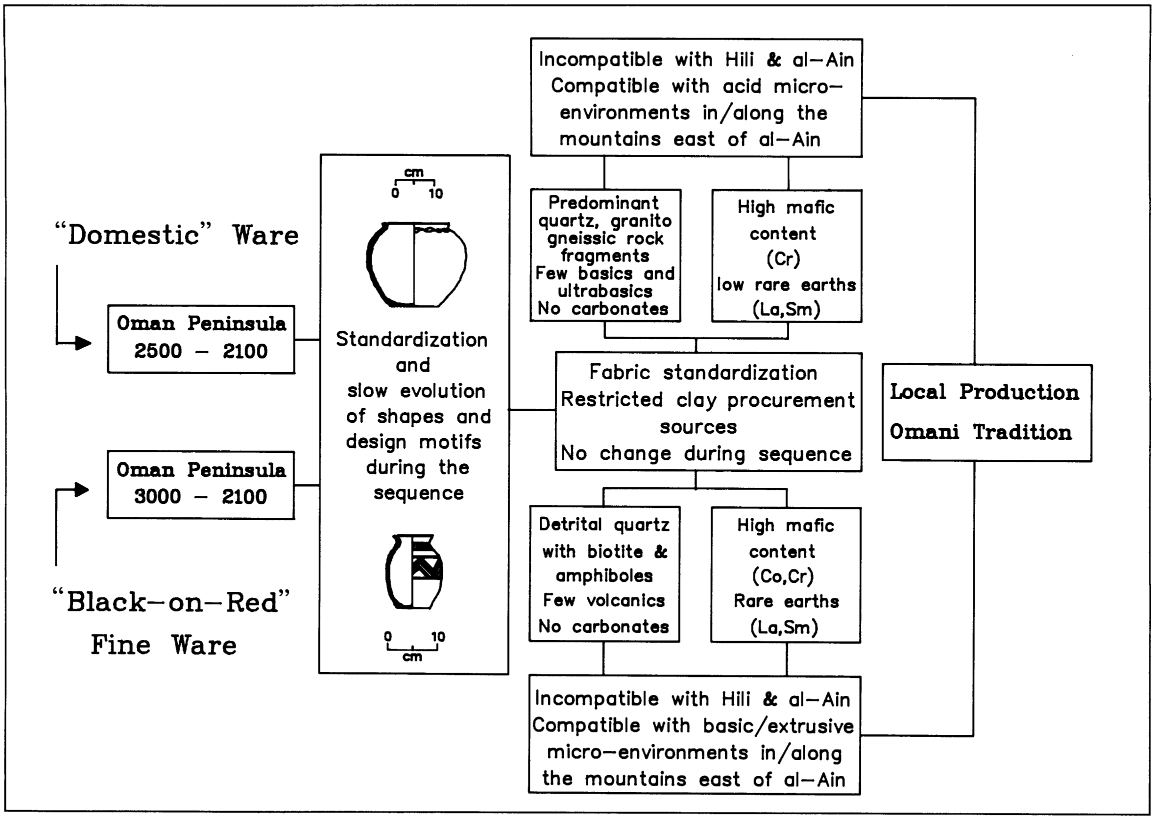
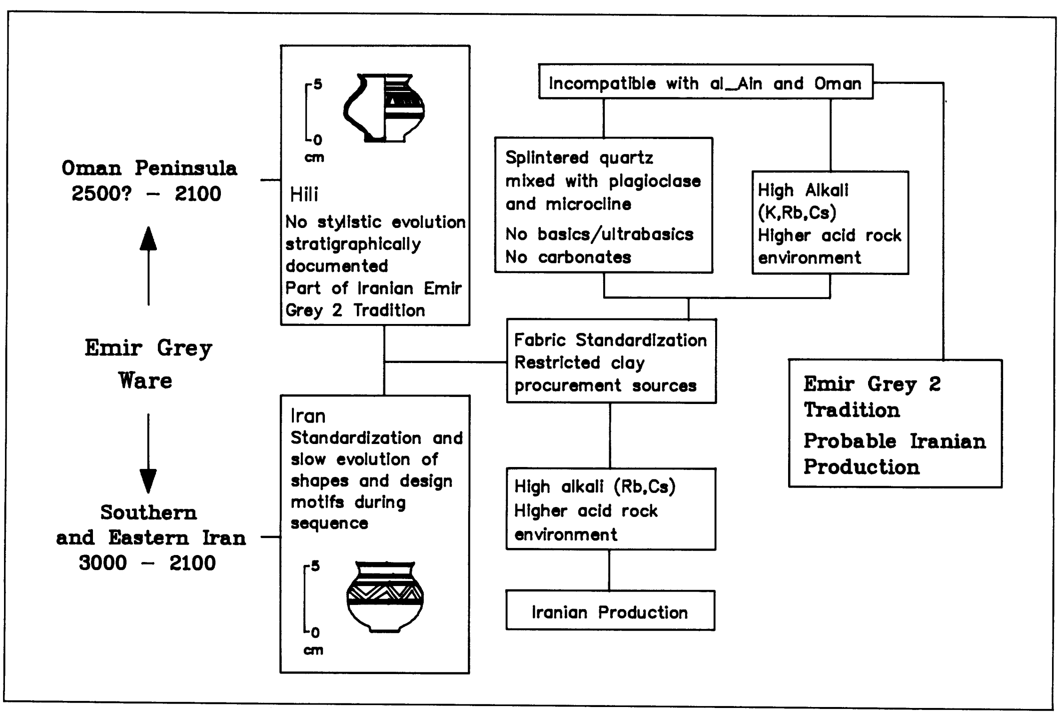


Figure 9. Summary of typological, mineralogical, and chemical analyses of "domestic" and "black-on-red" fine wares.

Figure 10. Summary of typological, mineralogical, and chemical analyses of Emir grey ware.



veloped indigenously and its local manufacture continued throughout the 3rd millennium. It is, in fact, one of the distinctive markers of a local Omani tradition. The obvious implication is that while some ceramics were imported from Mesopotamia, as has been documented by Mynors (1982), a thriving ceramic industry was present on the Peninsula itself from the early 3rd millennium and the bulk of the ceramic assemblage is represented by these local types.

This investigation makes it possible to trace the development of the local ceramic industry on the Oman Peninsula. While the first identified product of this industry, "black-on-red" fine ware, is technologically sophisticated, there is little change stylistically or technologically throughout the 3rd millennium. In mid-millennium a new type of specialized ceramic product, "domestic" ware, appears, with virtually no parallels outside the Oman Peninsula. This ware represents a major departure from the "black-on-red" fine ware, as different production techniques and raw materials were used. Whether the two ceramic wares were produced at the same site or at different sites awaits further study. The appearance of "domestic" ware, however, documents the continuation of a general trend in the development of crafts on the Oman Peninsula.

The presence of a local ceramic industry indicates that craft technologies developed alongside the subsistence technologies and maritime economic adaptations cited by Cleuziou and Tosi (in press). Furthermore, it indicates that changes were occurring in Omani society in which an internal division of labor and presence of specialists developed parallel with external exchange relations. In addition, the local production of "black-on-red" fine ware calls into serious question the nature of proposed relationships with Iran in the first half of the 3rd millennium B.C. The degree to which similarities in stylistic traits of ceramics between Iran and Oman can now be ascribed to "emulation" by the inhabitants of Oman is an open question requiring more systematic investigation.

The first ceramic evidence for direct contact with Iran is now in the mid-third millennium B.C., when the Emir grey ware from southern and eastern Iran appears in the ceramic assemblage as imports. This occurrence implies an expansion of relations and documents a direct form of contact.

To summarize, during the first half of the third millennium, inhabitants of the Oman Peninsula maintained direct contact with southern Mesopotamia. This contact is documented in Periods I through II (phases a–c_1) by the presence of Mesopotamian and Mesopotamian-like ceramics, some of which were produced in southern Mesopotamia (Mynors 1982). We should emphasize that, up to this point, the only indication of imported pottery is from Mesopotamia and the amount is limited. A contemporary development of new technologies related to subsistence and maritime economic adaptations has been documented elsewhere. In this paper, we have identified the presence of a local ceramic industry that grew up alongside these other technologies. The standardization of vessel forms and motifs, as well as the uniformity of technology, suggests that they were produced by craft specialists. The development of a new technology and a specialized group of craft workers, as well as the creation of impressive waterworks and control of imported ceramics by a local elite, contributed to the emergence of a social hierarchy. In phase IIc_2, dating to mid-millennium, exchange with Mesopotamia continued, but there is evidence of a widening circle of contact. During this period, and perhaps earlier, a variety of commodities, such as metal, marine products, and pearls (Cleuziou and Tosi in press) were exported from the Oman Peninsula. At this time, the inhabitants of the Oman Peninsula also began to import Emir ceramics from southern and eastern Iran. Later, the presence of a ceramic type known as Incised Grey ware shows a continued contact with Iran, and by the end of the millennium "typical" Harappan type pottery also is found.

The broader significance of these interpretations has implications for the general discussion of Near Eastern interactions during the third millennium B.C. During this period, the people of the Oman Peninsula experienced rapid internal growth in socioeconomic complexity and external interaction with numerous peoples and polities, of which at least two (the Sumerians and the Harappans) were politically and economically more advanced. There are, however, few indications of foreign dominance in these exchange relations; rather, the present evidence favors the cultural autonomy of the people of the Peninsula. This autonomy is demonstrated by the indigenous developments outlined above, while at the same time shifting relations with several of their more powerful neighbors were maintained. There is no indication of dominance by the larger polities.

This interpretation is in accord with studies from other regions, peripheral to the Sumerian and Harappan civilizations. Recent work by Kohl (1987) on the NE frontier, Possehl (1986) in southern Baluchistan, and Wright (1987) on the Kachi Plain in northern Baluchistan suggest that exchange relations during the third millennium were not based upon inequality or physical or cultural dominance. Rather, exchange relations and internal developments during the period may be better characterized as a "patchwork" of culturally autonomous peoples who, although outflanked by politically and economically better-organized neighbors and possibly stimulated by contacts with them, controlled their own socioeconomic activities.

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