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Petrographic Analysis of the Tel Mikhal (Tel Michal) Pottery

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Thirty-six vessels from the 1996 excavation season at Tel Mikhal were submitted for petrographic analysis.[1] Most types of Persian-period vessels and several MB II vessels from Kilns 466 and 481 in Area B1 were included in the sample. Several wasters from these kilns were analyzed as well.[2] The results show that the ceramic fabrics of these vessels fit into seven petrographic groups (Table 1; see below, Fig.1).

The Petrographic Groups

Ḥamra *Soil with Coastal Sand*

The matrix is ferruginous, silty, and non-carbonatic. The color of the clay ranges between different grades of dark brown under plane polarized light (PPL) and may exhibit a weak optical orientation. The non-plastic material is mostly quartz crystals (dominant, poorly sorted, mostly sand-sized and angular). Other minerals, including flint, zircon, hornblende and feldspar, appear in minor amounts. The raw material is *ḥamra*—red soil of the central littoral areas of Israel. This soil, typically a component of coastal formations, is spread along the Coastal Plain of Israel from the vicinty of Ashdod northward (Ravikovitch 1969:22–25; 1981:136–152).

This kind of soil is not a good raw material for potters. However, a well-attested phenomenon is its use in making cooking pots from the beginning of EB I to the end of the Iron Age. These cooking pots were made mostly of *terra rosa* with the addition of crushed calcite (Goren 1995:303). By the end of the Iron Age to the beginning of the Persian period, some kind of technological development seems to have taken place. Potters produced cooking pots using *ḥamra* tempered with coastal sand rather than *terra rosa* with crushed calcite (Goren 1995:303; 1996b:109). As a result of different rates of expansion between the hot surface and the cooler interior of the vessel, it may eventually break. Apparently, this change in fabric occurred for technical reasons, since it allows the vessel to better withstand repeated cycles of fast heating and cooling without cracking. This 'new' technique appears by the late Iron Age and early Persian period (Goren 1995:303; 1996b:109).[3]

The Material from the MB II Kilns.— The MB II vessels and wasters found in the Area B1 kilns show similar petrographic characteristics. The fabric is *ḥamra* soil with mostly coastal sand inclusions. This fact is not surprising, since the potential raw material available to the pottery manufacturers at Tel Mikhal includes abundant *ḥamra* soil.

The distance to resources is an important parameter in deciding where to locate a full-time craft. The potter certainly bears in mind the expenditure of energy necessary for such exploitation and the expected economic returns (Jarman 1972). Browman (1976) proposed a model called 'exploitable territory threshold', generalizing about distance to resources (in this case, hunting and gathering societies, which utilize an area of a given radius). His spatial theory assumes that exploitation of resources involves choices, which minimize energy expenses and maximize profits. Using similar models, other authors (e.g., Vita-Finzi 1978:23–31) suggested that an archaeological site occupies a position within an exploitable territory that has economic possibilities as a direct result of its location. Vita-Finzi called this model 'site catchment

Table 1. The Petrographic Families at Tel Mikhal with their Suggested Provenance

No.	Vessel Type	Reg. No.	Period	Petrographic Group	Suggested Provenance	Fig. No. (see Kapitaikin, this volume)
1	Cooking pot	4064/1	MB II	*Ḥamra*/Coastal sand	Local (from kiln)	15:3
2	Waster	4406/1	MB II	*Ḥamra*/Coastal sand	Local (from kiln)	
3	Jug	4089/1	MB II	*Ḥamra*/Coastal sand	Local (from kiln)	15:13
4	Juglet	4099/2	MB II	*Ḥamra*/Coastal sand	Local (from kiln)	15:14
5	Amphoriskos	4109/3	MB II	*Ḥamra*/Coastal sand	Local (from kiln)	15:10
6	Jar	1198	Persian	Phoenician coast	North Isr./Leb. littoral	7:20
7	Bowl	4197/1	Persian	Phoenician coast	North Isr./Leb. littoral	1:2
8	Jar flat shoulder	7186	Persian	Phoenician coast	North Isr./Leb. littoral	7:22
9	Jar flat shoulder	8153	Persian	Phoenician coast	North Isr./Leb. littoral	
10	Open oil lamp	1560	Persian	Phoenician coast	North Isr./Leb. littoral	11:7
12	Amphora	1372/1	Persian	Taqiya/Coastal sand	Shephelah	8:12
13	Bowl	7172/1	Persian	Taqiya/Coastal sand	Shephelah	1:1
14	Bowl	4271/1	MB II	Taqiya/Coastal sand	Shephelah	16:1
15	Amphora	1305/1	Persian	Micaceous clay	Southeastern Aegean	8:4
16	Bowl	4435/1	Persian	Micaceous clay	Southeastern Aegean	
17	Jar(?)	4217/1	Persian	Micaceous clay	Southeastern Aegean	
18	Amphora(?)	4448/1	Persian	Micaceous clay	Southeastern Aegean	8:5
19	Amphora	1550/1	Persian	Micaceous clay	Southeastern Aegean	8:9
20	Bowl	4116/1	Persian	Micaceous clay	Southeastern Aegean	12:4
21	Amphora	7243/1	Persian	Micaceous clay	Southeastern Aegean	12:14
22	Amphora	4072/1	Persian	Micaceous clay	Southeastern Aegean	8:1
23	Amphora	4036/1	Persian	Micaceous clay	Southeastern Aegean	12:15
24	Amphora	1147/1	Persian	Micaceous clay	Southeastern Aegean	
25	Amphora	1179/1	Persian	Micaceous clay	Southeastern Aegean	8:8
26	Amphora	4204/1	Persian	Micaceous clay	Southeastern Aegean	8:3
27	Amphora	4192/1	Persian	Micaceous clay	Southeastern Aegean	8:10
28	Amphora	7219/1	Persian	Micaceous clay	Southeastern Aegean	12:18
29	Bowl	4156/1	Persian	Micaceous clay	Southeastern Aegean	12:10
30	Amphora	4036/1	Persian	Moẓa silt clay	Judean Hills	12:15
31	Wedge vessel	7278	Persian	Rendzina	Carmel Coast?	11:1
32	Jug	7247	Persian	Rendzina	Carmel Coast?	9:10
33	Mortarium	4357	Persian	Ophiolites	Cyprus/Aegean	
34	Mortarium	7230	Persian	Ophiolites	Cyprus/Aegean	
35	Mortarium	4116	Persian	Ophiolites	Cyprus/Aegean	
36	Jug	3654	Persian	Ophiolites	Cyprus/Aegean	

analysis', a name that arose from an analogy to the area drained by a river and its tributaries, and conveys the concept of a region that supplies particular components drafted as raw material to the target site.

Since the ceramic industry can be considered as a living population in or close to an area that provides ceramic resources, the models of exploitable territory around the base (the pottery workshop) can be applied as well. One constraint deals with the distances to resources. Unfortunately, the distance to clay sources, temper, slip, paint and fuel outcrops are extremely important but rarely mentioned in the ethnographic literature (Arnold 1985:35 and see references therein). Ethnographic observations around the world (Arnold 1985:39–49, Tables 2.1, 2.2, 2.3) indicate that ceramic artisans in today's traditional societies walk up to a few kilometers to get raw material. Since not all clays may be suitable for pottery making (or not the first choice, like in Tel Mikhal), people could eventually avoid the local clays and walk greater distances to obtain preferable raw material.

At Tel Mikhal, despite the low quality of the local clay, the local potters manufactured vessels using the clays available nearby. Given the poor quality of the raw material, the vessels were certainly fragile. The same phenomenon occurs among vessels of this petrographic group retrieved in a kiln excavated on the northern bank of Naḥal Soreq (Singer-Avitz and Levy 1992a:12*–14*), as well as offerings in tombs from the Late Bronze Age at the Palmaḥim cemetery (Singer-Avitz and Levy 1992b:24*–25*).

Taqiya Marl with or without Vegetal Matter
The matrix is calcareous clay that contains sparsely distributed iron oxides. Under PPL the samples show a range of color from pale to strong orange, with some optical orientation. In one sample the voids from vegetal matter used as inclusions are evident, and well-sorted silty quartz was discerned as well. The non-plastic component includes few angular to sub-angular quartz crystals and rare occasional angular flints. Among the inclusions can be seen rounded and sub-rounded chalk and limestone. The raw material can be defined as marl originated in the Taqiya formation of the Paleocene Age (Bentor 1966:72–73).

This clay is suitable for ceramic manufacture and has been used by potters for centuries. Outcrops exist widely in the Levant. Exposures of the formation can be seen along the Northern Negev, the Judean Desert, the western section of the Judean Anticlinorium and in Samaria. The combination of Taqiya formation marl with chalk or coastal sand is typical of sites located in the inner Shephelah area (Bullard 1970:107–108). In Turkey and Morocco this formation appears, as well and as in Egypt, where it is called the Esna Shales formation (Bentor 1966:73). Unfortunately, its ubiquitous distribution precludes in many cases a definitive assessment of a vessel's provenance.

The use of this raw material seems to have been limited mostly to southern Israel (Goren 1996a:53). No outcrops exist in the close vicinity of Tel Mikhal. The nearest area that corresponds with this matrix is the northwestern Shephelah. The area near Gezer is tentatively proposed as the origin for this group.

The Phoenician Coast
The fabric of this group is carbonatic clay containing microfauna and iron oxides. In some cases *terra rosa* soil appears as rounded or elliptical balls, including silty quartz as inclusions. The color is pale to dark orange under PPL, and the occasional inclusions are angular quartz and limestone. In one case the sample completely lacks inclusions.

The most prominent characteristic of this group is the presence of the *Amphiroa* Sp. Algae, a *fossile directeur* of the bioclastic formations of the Quaternary Coast that occurs in Israel in the Ḥefer, Kurdane and Peleshet formations (Sivan 1996:48–53; Almagor and Hall 1980; Buchbinder 1975). To the north, similar components were observed in contemporary sands and beach rocks in the Lebanese Littoral (Sanlaville 1977:161–167; Walley 1997). This coralline fossil algae is common in beach rock formations, where it can be observed *in situ* (Sivan 1996:99), pointing to a coastal origin for this group.

Yet, a small amount of coastal sand (quartz grains) was discerned in the samples. Since quartz is abundant along the Israeli littoral, and decreases rapidly from the area of Haifa and 'Akko northward (Nir 1989:12–15; Cohen-

Weinberger and Goren 2004:73), the presence of quartz suggests a more northern coastal origin at the Phoenician Coast, such as the Northern Israel and Lebanese Littoral. In Israel, Persian-period vessels attributed to this family were retrieved in neighboring coastal sites like Apollonia-Arsuf (Gorzalczany 1999:189) and Yavne-Yam (Gorzalczany 2005).

Interestingly, the petrographic fabric of this group looks similar to the fabric of several types of vessels from Egypt. A group of clay letters from the Egyptian Amarna archive, sent by a certain Aziru of ʻAmurru, were examined petrographically and attributed to the city of Sumur (identified as Tel Kazel in the Akkar Plain; see Goren, Finkelstein and Na'aman 2004:115–116). In addition, among the Canaanite pottery retrieved at Tell ed-Daba in Egypt and checked by petrographic analysis, over half of these vessels belong to this particular group (Cohen-Weinberger and Goren 2004:69–73). The petrographic fabric of a group of Late Bronze amphorae found at Memphis and ʻAmarna (labeled there as Group 5) are currently under review by the New Kingdom Canaanite Memphis and ʻAmarna project (NKCMA). Preliminary reports of this project indicate that this fabic correlates very well with the fabric of the Tel Mikhal Persian-period vessels (Smith and Goren, forthcoming). In Sarepta (Lebanon), vessels found *in situ* at pottery workshops were defined as belonging to different sub-families of this petrographic group (Bettles 2003:67–70).

Ophiolites

This matrix is rather carbonatic, and is pale pink to yellowish under PPL. Few calcite crystals are discernable, together with silty-sized heavy minerals, such as oxyhornblende, olivine, pyroxene, feldspar and mica minerals. Carbonatic oolites are present both in the matrix and among the inclusions. The non-plastic components, which are coarse, include a wide range of minerals and rock fragments: quartz, limestone, schist, and rock fragments including schist and volcanic-originated minerals, such as hypersthene. Other igneous rocks and their derived minerals are gabbro, serpentine, dolerite and peridotite.

The lithic combination described above is foreign to the Levant south of Latteqiyeh. According to the plate tectonics model of the earth's crust, ophiolites are oceanic crust that has been pushed, pressed and thrust against a continental plate. At the end of this long process an ophiolite eventually includes a thin layer of oceanic sediments such as radiolarian chert, clay, plus basalts, dolerite complexes, gabbros, peridotites and pyroxenites. Some ophiolites metamorphize into green schist and amphibolite facies. Ophiolite outcrops are known in Cilicia, Northwest Syria and Cyprus (Whitechurch, Juteau and Montigny 1984). Further west, ophiolites are common in the Aegean.

This group of samples at Tel Mikhal includes heavy bowls and mortaria. Studies of similar vessels were carried out at Tell el-Ḥesi by both petrographic and neutron activation analyses (NAA). The results of these analyses showed that the vessels were made from limestone—ophiolitic outcrop environments (Bennett and Blakely 1989:199–203). Similar Persian-period vessels have been checked petrographically in several sites: Apollonia-Arsuf (Gorzalczany 1999:186); Yavne-Yam (Gorzalczany 2005) and Tel Yaʻoz (Segal, Kletter and Ziffer, this volume).[4] In all these sites the lithological evidence is homogeneous and almost identical to this group at Tel Mikhal. This fact points toward Western Cyprus as the source for raw material for Tel Mikhal.[5]

Rendzina

Two vessels, a wedge vessel and a jug belong to this group at Tel Mikhal. The fabric is silty, carbonatic and pale brown to gray under PPL, showing a very weak optical orientation. Twenty to thirty percent of the matrix is rounded and poorly sorted chalk particles of up to sand-sized grains. Quartz grains make up to 5% of the matrix. Small, worn-out calcite crystals are rare. In some examples the matrix is rich in *foraminifers* and ore minerals.

The temper includes rounded to sub-rounded chalk (40%–60% of the matrix), and *foraminifers*, in a wide range of sizes. Limestone is rare. Among the inclusions are round *terra rosa* balls, containing silty-sized heavy minerals and quartz grains. These ferruginous balls appear in a wide range of sizes, are silty and non-carbonatic, and are characterized by an almost isotropic dark reddish-brown color.

The raw material can be identified as *rendzina* soil (Goren 1995:303), which occurs mainly by erosion and attrition of Eocene and Senonian chalk rocks and marly chalk in Mediterranean climate areas, where the average pluvial precipitation is 500–700 mm/year. In Israel the *rendzina* soils are mostly concentrated in the north, in the Upper Galilee, around Naẓerat and especially Ẓefat (Ravikovitch 1969:87–88; 1981:19–20). Often both *rendzina* and *terra rosa* outcrops exist side by side in very close intercalation. The coastal area of the Carmel is proposed tentatively as a provenance for this group.

Moẓa Silty Clay

The fabric is light brown under PPL, calcareous with sparsely distributed iron oxides. Angular silty-sized dolomite crystals compose up to twenty percent of the matrix, one of the outstanding characteristics of this group. The temper consists mostly of few dolomite crystals (>5% of the matrix, 120μ in size) exhibiting a typical rhomboid shape. Other temper components are rare quartz angular crystals (>2% of the matrix) and occasional calcite. Voids due to burned-out vegetal material added to the clay are discernible as well. The condition of the dolomitic sand suggests that no significant process of translocation took place, and the sand developed *in situ.* Such processes are known in the Judean Hills (Arkin, Braun and Starinsky 1965). This group can be identified as originating from clay from the upper Moẓa formation, and the dolomitic sand was most probably supplied from the nearby ‘Amminadav formation. Since the sand in its natural outcrops tends to appear much less well sorted than in the pottery, it seems that the temper has been sieved by the potter in order to get the needed grain size.

This petrographic family is well known from different ceramic assemblages dated to several periods throughout the Judean and Samarian Hills (Glass et al. 1993:272; Goren 1995 and see references therein).

Dolomitic sand can be found in other parts of Israel, but as far as we know its use as temper was limited to the Judean Hills. Neutron activation analyses confirmed that pottery of this group found in the Negev and Sinai (Be’er Sheva‘, Kuntillet ‘Ajrud) should be attributed to the Judean Hills and more specifically to the Jerusalem area (Gunneweg, Perlman and Meshel 1985:283). On the grounds of the clear identification of the raw material as originating in the Judean Hills, this is the provenance suggested for vessel No. 30.

Micaceous Clay

Fifteen vessels, most of which are amphorae and jars and a few bowls, belong to this group. The matrix is pale to dark brown under PPL, and characterized by a large amount of silty-sized metamorphic minerals and micas (mostly biotite). The group can be divided into three sub-groups.

Sub-Group MC.1.— Micaceous clay, almost lack of temper. When it appears, is mostly very rare sub-angular to sub-rounded quartz, or rounded limestone, very rare as well. This group includes six amphorae, a torpedo jar and three Eastern Greek bowls.

Sub-Group MC.2.— As the former, but with more carbonates in the matrix. Two amphorae are in this group.

Sub-Group MC.3.— As the first sub-group, but includes larger micas in the matrix and exhibts temper, which consists of rare rock fragments (mostly angular schist), angular biotite and sub-rounded serpentine. This group consists of three amphorae.

All the above matrix descriptions are alien to the area of Tel Mikhal and the Eastern Coast of the Mediterranean. Yet, they correspond to the volcanic and metamorphic outcrops in the region of the Eastern Aegean Sea (Whitbread 1995).

CONCLUSIONS

The results of this analysis allow a comparison of the specific clays of the ceramic assemblage from Tel Mikhal to other petrographic groups in the Levant and the Mediterranean coasts. Since vessels sharing affinities both in clay and temper can be linked to geological environments in the Levant, we can therefore assess the provenance of a particular vessel (Porat 1986–7; 1989; Goren 1992; Greenberg and Porat 1996).

The Persian-period ceramic assemblage from Tel Mikhal is varied. Petrographically, there are seven groups (Fig. 1). A local group *(ḥamra)* fits the geological profile of the site. Three groups, those of the Taqiya, Moẓa and Rendzina profiles should be regarded as imports, from short distance to medium range (Browman 1976; Jarman 1972; Vita-Finzi 1978).

The Phoenician coastal, micaceous clay and ophiolites are alien fabrics, and are clearly long-distance imports. The appearance of these clays at Tel Mikhal indicates a well-defined pattern of exchange. The high proportion of Phoenician coastal fabric adds weight to Stern's suggestion that during the Persian period Tel Mikhal was a Sidonian stronghold (Stern 1978:79–83; 1990:147–149). The micaceous clay group and ophiolites group indicate Cypriot and Aegean trade was widespread in this period.

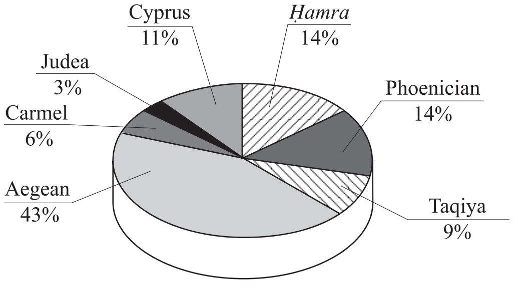

Fig. 1. Provenance of the vessels from Tel Mikhal.

What kind of fabrics were not found among the pottery of Tel Mikhal? Very little inland clays, and meager amounts from the Western Coastal Negev or the Central Hills area group were discovered. This pattern is typical of other coastal sites too, including Apollonia-Arsuf, Tel Ya'oz, and Yavne-Yam. Interestingly, contemporary inland sites, such as Jerusalem, Be'er Sheva', Kh. Malta and Kh. Nessibah, also have similar imported vessels in fairly noticeable amounts, together with local petrographic groups (Gorzalczany 2003).

The situation described above corresponds well with recently-proposed models (Lehmann 1998:30–32 and references therein), in which the Persian-period coastal and imported production dominated the local pottery market in Syria and northern Palestine. This was due to a general process of standardization in pottery production. This process was a condition in the development of an administrative mechanism flexible enough to allow the Achaemenids to rule a territory much larger than their predecessors, the Assyrians.

In the Late Iron Age, and increasingly during the Persian period, we find coastal types fairly distributed in inland Syria, with small amounts of inland pottery at littoral sites. As for the Cypriot and Greek imports, both seem to share similar distribution patterns, and both appear mostly at coastal sites (Lehmann 1998:28: Fig. 14). The natural environment of the Coastal Levant, characterized by a series of seasonal river systems, provides an ideal framework for the application of the dendritic models articulated by Bronson. In his model a major market would be situated on the coast and subsidiary markets would be in the inland area, spaced regularly along the wadi system. Local markets in areas of low population density, still dependent on the ports, would clarify the distribution pattern (Millar Master 2001:15–16, and see references and discussion therein). Stager (2001) defined this concept as "port power" and applied it to the Late Bronze Age. In fact, his model is a useful tool in all periods of significant Mediterranean trade (Millar Master 2001:16; Stager 2001:633).

During the Persian period at southern coastal sites, such as Apollonia-Arsuf (Gorzalczany 1999), Tel Ya'oz (Gorzalczany, this volume [b]), Yavne-Yam (Gorzalczany 2005) and Tel Mikhal, the distribution pattern seems to be much the same as in the Northern Mediterranean littoral, where an overwhelming amount of imported pottery is extensive in the local markets. This evidence suggests that the ruling Achaemenid kingdom and their Phoenician emissaries settled mainly on the littoral, despite their constant search for inland resources (Stager 2001:635; Gorzalczany 2003:136–137).

NOTES

[1] This study was part of my M.A. thesis (Gorzalczany 2003), concerning petrographic aspects of the Persian-period ceramic industry in the Near East. My thanks are due to my supervisor, Yuval Goren, who kindly assisted me during all stages of this present study.

[2] Thin sections were prepared following standard procedures (e.g., Goren 1995; 1996a; 1996b; Whitbread 1995:365–396). The results were compared with previous analyses of pottery at the site (Goldberg, Singer-Avitz and Horowitz 1989), as well as to pottery samples from Kh. Malta, Kh. Rogem and Meẓudat Ha-Ro'a, Naḥal Tut (Site 8), Yavne-Yam and Apollonia (Gorzalczany 1999; 2004; this volume [a]; in press) and to the local geology (Gifford and Rapp 1989; Horowitz 1979:13; Bakler 1989), as well as to the sample collection held at the Petrographic Laboratory of Comparative Microarchaeology at the Tel Aviv University Institute of Archaeology.

[3] New evidence arises from excavations at Site VIII at Naḥal Tut. There, both kinds of cooking pots appear together. Since the site is well dated to the very end of the Persian period on the grounds of the numismatic evidence, it is conceivable that this technological development took place later than previously thought (Gorzalczany, this volume [b]). Thanks are due to the excavator Yardenna Alexandre who kindly allowed sampling of the material from her excavation at Naḥal Tut.

[4] Petrographic analysis of the Persian-period vessels from Tel Ya'oz (Gorzalczany, this volume [a]) shows a remarkable similarity between the fabrics of mortaria bowls in all of the sites. A Cyprus/Aegean provenance is suggested for all these vessels. The author thanks Raz Kletter for his kind assistance in sampling the assemblage from Tel Ya'oz, as well as for his useful comments.

[5] These characteristics are shared not only by the mortaria in the littoral sites but also at inland sites. Mortaria vessels examined by the author from Jerusalem (City of David), Be'er Sheva' and Kh. Malta at the southern bank of the Ẓippori River showed an identical lithological configuration, indicating the same provenance for all. I am grateful to Alon de Groot, Zeev Herzog and Karen Covallo-Paran for kindly allowing me to sample these assemblages.

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