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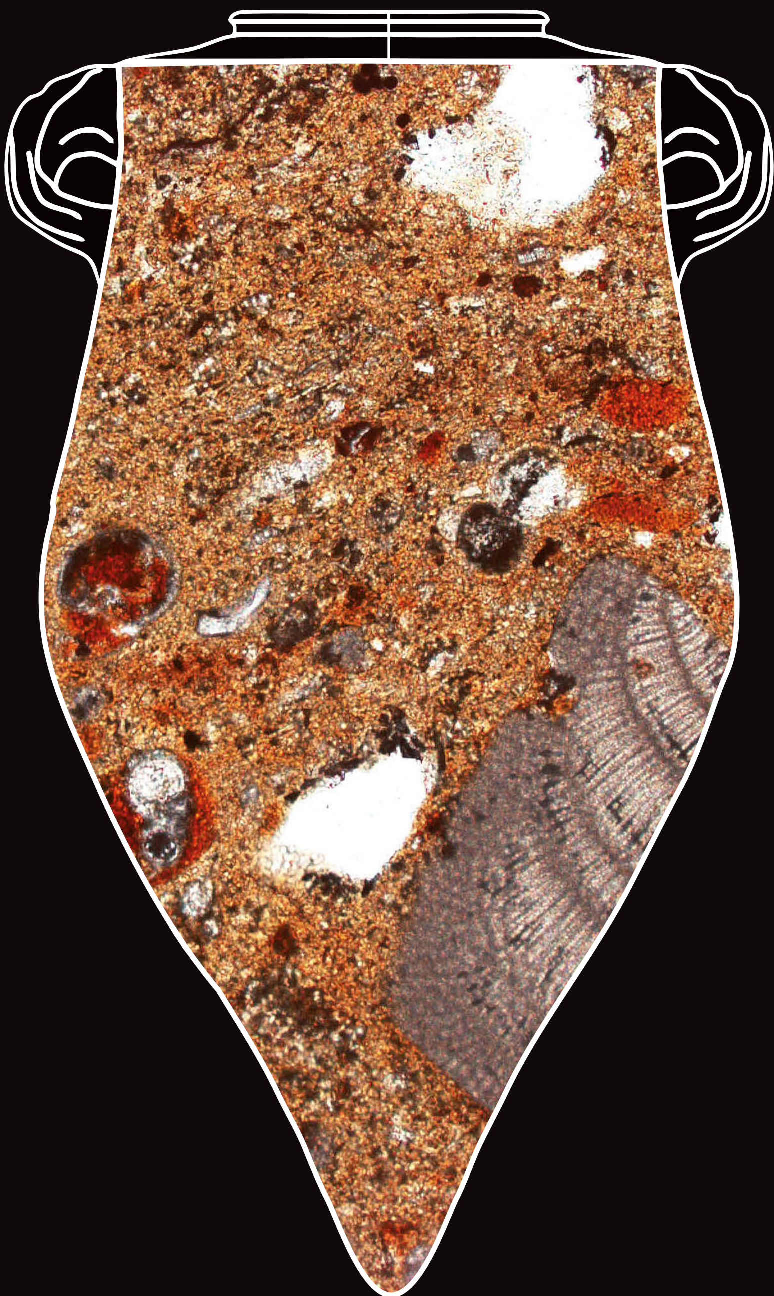

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Contents

1. Introduction

1.1. The study subject

The vine was considered as the most profitable crop of ancient Palestine.[1] Even if in the Galilee "the vine was cultivated to a much lesser extent than in Judaea" and the main Galilean crop was rather olives, in general (as specified by the Mishna) the consumption of wine in terms of the volume was three times that of oil.[2] Differences in the shape of the wine containers found in this region not only reflect chronological sequences, but also are indicative of the origin of their individual models, that is, of "coastal" Phoenician *versus* "inland" non-Phoenician pottery-making tradition respectively.

These two basic types and their derivatives were developing throughout many centuries, resulting in several typo-chronological variants of the vessels in question (see below). The jars[3] of the Phoenician tradition, characterized by carinated shoulder and the lack of neck (sometimes described also as "hole-mouth", "neckless", "shouldered", "waisted" or "torpedo" jars), were popular not only on the coastal Phoenician sites, but also in the Carmel area and the plain of Zevulun (the Haifa/Akko bay); in general, they may have occurred at any site located along the trade routes. This "Phoenician" type was much used in a maritime trade, especially along the Syro-palestinian coast. The other basic shape, jar with a bag-shaped body and short concave neck, was common in Judea, Sharon plain, Samaria and the Galilee. Unlike the carinated-shoulder jar, it was mostly used in the local storage of wine/oil rather than in the trade.

Although both shapes of the jars originated roughly at the same time during an earlier part of the Iron Age II, the Phoenician jar in its "classical" form was used till the 3rd /2nd century BC only, after which it was followed by a related "hole-mouth" jar; in a modified form, the latter continued into the Roman period, to as late as the 2nd (and into 3rd) century AD. The bag-shaped form continued till the 8th century AD at least, its Hellenistic version followed by the Roman and Byzantine/Early Islamic variety.

It is logical to assume that the areas of the grape-vine cultivation must have neighboured on the pottery workshops necessary to provide supplies in wine containers. The trade in pottery was by its nature regional; thus, for instance, in the Roman period Kefar Hananya cooking vessels[4] were sold within 20 km or so of that settlement (although it should be remembered that usually they were not sizeable vessels, hence easy to carry). Jars were used for transporting the wine from the place of its production to the place of consumption, after which they may have been recycled with different contents.

The major obstacle in identifying the pattern of the jar-making workshops is a poor state of preservation of their archaeological remains. However, also some indirect methods can be employed to indicate the potential places of manufacture of the vessels in question. These are:

1) studying of the distribution pattern combined with the frequency of occurrence of finds of a particular ware or fabric; one example is the occurrence of the "Phoenician Semi-Fine ware", traced from its homeland on the south Lebanese coast to the Hula valley[5].
2) potential confirmation by the archaeometry which calls for in-depth analyses of the mineral composition of the raw material used in the production of vessels, often termed "fingerprints" of individual workshops. Such a study requires both optical microscope observations and an analysis of the chemical composition of the ceramic mass

1 Safrai 1994: 126.
2 Safrai 1994: 129.
3 See Finkielsztejn 2006: 254, note 3, for explanation of the term "jar" commonly used to describe the Levantine types of amphorae.
4 E.g., Adan-Bayewitz 1993.
5 Berlin 1997a: 9–10; Berlin 1997b: 77–78.

of the containers. In our research, we have adopted both of these methods.

1.2. The aim of the study

The primary research question relevant to the production of the wine/oil jars in western Galilee/southern Phoenicia is the relation between the formal types of the vessels and their presumed manufacturing centres as reflected by the fabrics, and supported by tentative identification of raw material sources. The questions posed at the start of our project were the following:

– How many 'ceramic workshops' (reflected by different 'petrographic groups') could possibly take part in providing a single site with amphorae (be they destined for wine or olive oil)? How closely do the kinds of material distinguished on the basis of an on-field macroscopic observation coincide with the divisions obtained as a result of a physico-chemical examination?
– Does the material used to produce jars of the Persian and Hellenistic periods (6th–2nd centuries BC) differ from that used to produce vessels of the same function in the Roman period (1st century BC – 3rd century AD)? Can we speak of any technological evolution over the ages?
– Is it possible to indicate the source (sources?) of the material used to produce the jars found at the west Galilean sites?
– Does the physico-chemical examination of jars identical in shape and similar in date, but differing in colour, confirm their different workshop origin?

1.3. The sampled material

In order to meet the research aims, ca. 250 samples representing several forms of jars considered as local/regional (including some "control" samples of other pots in visually similar fabrics) were collected from three sites within southern Phoenicia bordering on the Lower Galilee: Sha'ar-Ha'Amakim, Tell Keisan and Tel Akko (Arabic *Tell el-Fukhar*, ancient Akko); the ancient names of two first sites remain unknown[6]. The very geographical situation of Sha'ar-Ha'Amakim on a branch of *Via Maris*, between the plain of Akko (Zevulun Valley) in southern Phoenicia, the hills of Lower Galilee to the east, and the plain of Esdrelon (Yezreel Valley) to the south, made it a perfect place for interregional trade exchange, potentially receiving ceramic products from different sources. As regards the network of roads in Galilee of the Iron Age and the Roman period,[7] it is logical to assume that the roads of the Iron Age are more relevant for the regional trade in agricultural products and domestic pottery than those of the Roman period. Tell Keisan was a rural site in the hinterland of the Phoenician Akko, and Tel Akko itself was a Phoenician maritime port town flourishing till the 3rd/2nd century BC when the settlement centre as well as the harbour shifted to the west[8]. During the Persian period, the region of the three above-mentioned settlements pertained to Transeuphratene province of the Achaemenid empire. After the conquest by Alexander the Great, the region of the three sites became successively a part of the Ptolemaic (3rd century BC) and the Seleucid realm (2nd century BC). However, with the Hasmonean conquest of the Galilee at the turn of the 2nd century BC, Sha'ar-Ha'Amakim was included into the Hasmonean (Judean) and then the Herodian state, while Tell Keisan and Akko (the latter known by then as Ptolemais and/or Antiochia) stayed in the sphere of the gentile (non-Jewish) culture.

The samples from the three sites as considered together represent the period comprised between the 7th/6th century BC and 5th/6th century AD, however, their number and chronology differ from one site to another. Thus, Sha'ar-Ha'Amakim yielded the biggest number of the samples, covering the period between the 7th/6th century BC and 3rd/4th century AD, specifically, 132 jar samples (among them a few may have pertained to other large closed forms such as *pithoi*), plus eight samples of jugs and eight samples of other clay objects. From Tell Keisan, there come 74 samples dated to between the 7th/6th century BC and the 5th/6th century AD. The slightest number of samples with the most narrow time-range come from Tel Akko: 24 samples, dated to between the 7th/6th and 3rd century BC.

Our research has been twofold. The archaeological part of it dealt with the formal classification of the jars and with their chronology as based both on the contexts of the sampled finds and on available comparisons. The archaeometry part consisted of a series of physico-chemical analyses, specifically, petrography, micropaleontology, and Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES).

As specified above, the main body of the samples come from Sha'ar-Ha'Amakim, in the exploration of which, directed by A. Segal of the Haifa University, one of the present authors (Jolanta Młynarczyk) was taking part between 1993 and 1998.[9] Her responsibility included not only a ceramic research, but also

6 On the alleged identification of Sha'ar-Ha'Amakim with Hellenistic Geba (Gaba), see Dvorjetski 2009.

7 Strange 1977: 40, fig. 1.

8 Dothan 1976; Dothan & Goldman 1993.

9 Segal et al. 2009.

the stratigraphical study, hence most of our samples retrieved from Sha'ar-Ha'Amakim can be connected to one of the chronological phases of the site's history. The samples from Tell Keisan in the hinterland of Akko come, for most part, from disturbed or mixed contexts of the hitherto unpublished excavations carried out by the Ecole Biblique et Archéologique in Jerusalem in the years 1979–1980. Therefore, the dating of the relevant vessels in the present study is largely based on comparisons with other sites in the region and with the published part of the Tell Keisan jar finds excavated by the same institution in 1971–1976 and attributed to Keisan chronological phases 3 (580–380 BC) and 2 (380–150 BC).[10] Finally, the samples from Tel Akko come from the excavations conducted from 2010 on by the joint team of the Pennsylvania University and the University of Haifa, directed by Ann Killebrew and Michal Artzy.[11] They were taken from jar fragments discovered during the field season of 2011 in the layers dated to the Persian and early Hellenistic periods.

1.4. Acknowledgements

The present research was sponsored by the Polish National Science Centre (NCN) project No NN 307 034940. An initial part of the study of the ceramics from Sha'ar-Ha'Amakim was carried out by Jolanta Młynarczyk during her stay at the Albright Institute for Archaeological Research (Jerusalem) in the framework of the A.W. Mellon Fellowship in 2004/5.

Many thanks are due to the Directors of the excavations from which our pottery samples have come, specifically: to Prof. Arthur Segal (*Emeritus*, Zinman Institute of Archaeological Research, University of Haifa), Jean-Baptiste Humbert, O.P. (Ecole Biblique et Archéologique Française, Jerusalem) and Prof. Ann Killebrew (University of Pennsylvania, USA). We would like to warmly thank Dr. Uzi Dahari, the Deputy Director of the Israel Antiquities Authority, for the permission to export the pottery samples abroad in order to carry out the analyses, and Prof. Andrzej Muszyński for his insightful review.

We are also grateful to Prof. Barbara Olszewska for the micropalaeontological analysis. Finally, we extend our thanks to Dr. Mariusz Burdajewicz (Warsaw) who made all the pottery drawings and composed the pottery figures.

10 Briend & Humbert 1980: pls 7–8 and 19.

11 Killebrew & Oleson 2014.

2. Methodology

2.1. Archaeological perspective

In order to facilitate the comparisons between the jar samples representing vessels of different (Phoenician *versus* non-Phoenician) origin, as well as their predecessors and later developments, each typo-group in our study received a numeric symbol: (1) for jar shape of Phoenician origin (with its chronological subdivisions), (2) for jar shape of non-Phoenician origin (with its chronological subdivisions), (3) for water jugs whose fabrics are visually comparable to those of the jars of non-Phoenician origin (that is, to those of group 2), (4) for vessel forms other than jars and jugs. Since the widest range of vessel shapes and a fairly long period of time is represented by the material uncovered at Sha'ar-Ha'Amakim, the finds from that site have been the basis for distinguishing the relevant shape groups.

Group 1a (**Figs. 1–2**): the Phoenician type jar, hole-mouthed (neckless), known among others as "shouldered", "waisted", "torpedo" or "carinated-shoulder" jar, its capacity amounting to 10–13 litres;[12] in Sha'ar-Ha'Amakim it occurs in the late Persian and Early Hellenistic periods, with a number of residual rim fragments of the Late Iron Age II – Iron Age III. A detailed typology of the Phoenician jars according to their shape has recently been presented by E. Bettles, based mostly on finds from Sarepta;[13] this typology, however, is virtually useless for our material in which mainly rim fragments are preserved, while the body shape can hardly be reconstructed. A more general study devoted to the Phoenician transport amphorae has been authored by D. Regev.[14]

Macroscopically, the prevailing fabric of the jars in our group 1a is the so-called Phoenician Semi-fine ware, first described by A. Berlin at Tel Anafa in the Hula Valley,[15] and said to have come from the Tyre area. Actually, the same fabric characterizes the jars said to have been manufactured at Sarepta;[16] it is common both at Tel Akko and Tell Keisan. Another recognizable fabric, less represented at Sha'ar-Ha'Amakim, but very common at Tel Akko and Tell Keisan during the Persian and Hellenistic periods, is the so-called Light White ware.[17]

Group 1b (**Fig. 3** and **4: 1–2)** is the late Phoenician type jar, hole-mouthed with a thick out-rolled rim; the body is bag-shaped and mildly wheel-ridged usually except for the shoulder; it has twisted handles and a knob base. In terms of the fabric, greatly prevailing is the so-called Phoenician Semi-fine ware, already common in group 1a.[18] Indeed, P. Gendelman describes the type as "Phoenician Amphora" (although the present authors find the term "Late Phoenician" as more proper), produced between the late 2nd – early 1st century BC and the late 1st-early 2nd century AD.[19] G. Finkielsztejn calls the form in question the "ribbed pear-shaped amphora".[20] At Tel Anafa in the Hula Valley the type (termed "Semi-Fine Baggy Jars"), whose examples were considered as having been brought from Tyre, was present by 125 BC,[21] and in Tel Dor it made its appearance in the contexts of the second half of the 2nd century BC.[22] It is also known from a Hellenistic context in Akko.[23] At Sha'ar-Ha'Amakim, however,

12 According to Zemer 1978: 24–25, nos. 18–22, pls 6–7 (date range of the 7th/6th to 4th century BC).

13 Bettles 2003a, Bettles 2003b; see also Reynolds 2005: pl. 12, figs. 84–88 ("Persian – Hellenistic Tyrian and Sidonian amphorae").

14 Regev 2004.

15 Berlin 1997a: 9–10; Berlin 1997b: 77–78; Młynarczyk 2001:247.

16 Bettles 2003a, Bettles 2003b.

17 For the macroscopic description of the ware, see Młynarczyk 2001: 240–241.

18 It seems, however, that a parallel form was known in other wares as well, see Młynarczyk 2009b: fig. 5:12 (from Sha'ar-Ha'Amakim) and notes 45–46 (from Ramat Hanadiv and Machaerus).

19 Gendelman 2012: 34*–35*, fig. 1:9. For a 1st century AD example, see Reynolds 2005: 605, pl. 18, fig. 136.

20 Finkielsztejn 2006: 255, fig. 3.

21 Berlin 1997a: 155–156, pl. 57, PW 480–483.

22 Guz-Zilberstein 1995: 312, Type JR 3, fig. 6.38:6–9.

23 Avshalom-Gorni 1999, fig. 24:9 (7).

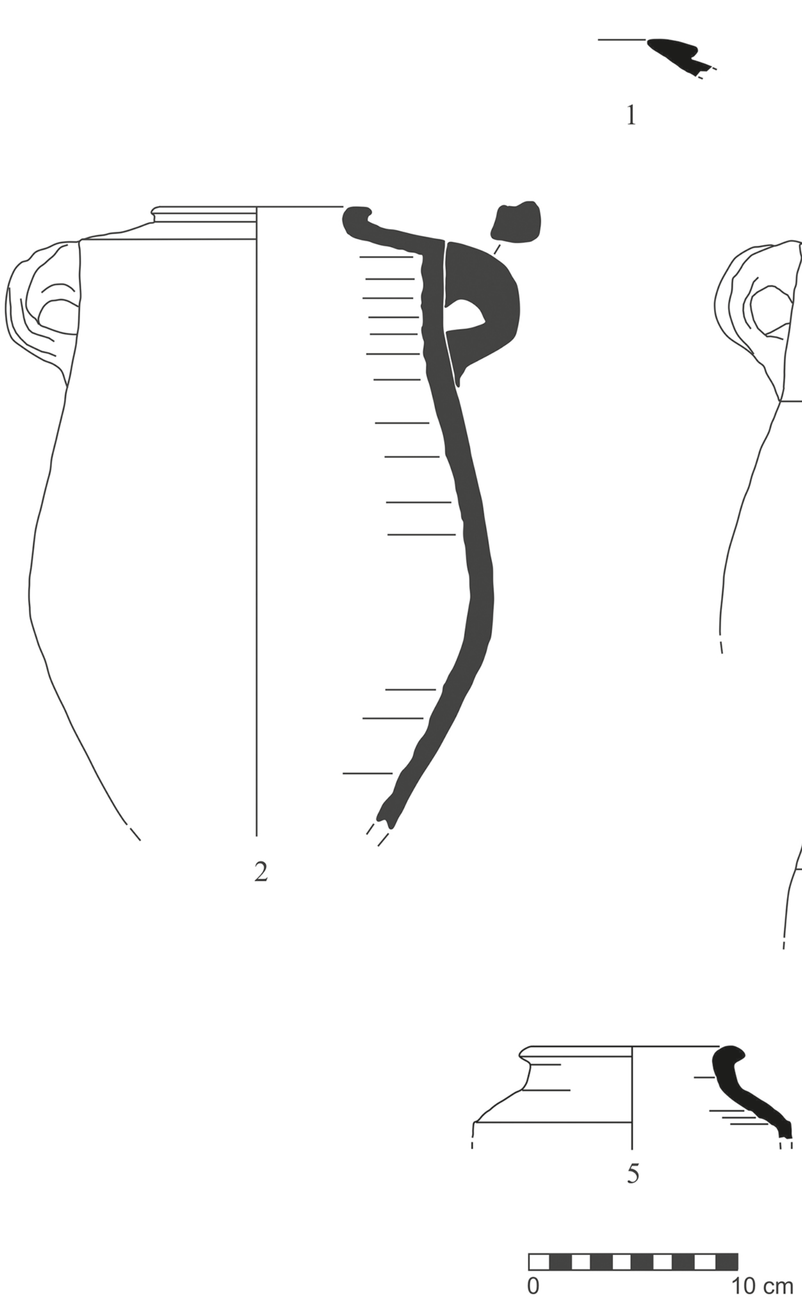


Fig. 1. Phoenician-type jars (group 1a) from Sha'ar-Ha'Amakim, Late Iron/Persian to Early Hellenistic period, with samples' numbers in bold. No. 1: inv. 943.1 (**SA-126**); No. 2: inv. 192.2 (**SA-6**); No. 3: inv. 864.1 (not sampled); No. 4: inv. 192.5 (not sampled); No. 5: inv. 195.8 (**Sx-129/Sx-135**). Drawn by Mariusz Burdajewicz

its examples, represented by just rims, handles and body sherds, have occurred in context with the Late Hellenistic and Early Roman pottery. Of the inland sites, beside Sha'ar-Ha'Amakim and Tel Anafa, the type made its appearance also in Yodefat.[24] In the Late Hellenistic stratum at Shiqmona (a destruction layer dated to between 130 and 125 BC),[25] the capacity of such jars amounted to 26 litres,[26] while Zemer illustrates a similar jar with the capacity of ca. 19 litres.[27] Occasionally, the handles of the jars were stamped. The stamps in Phoenician were confidently identified as belonging to the Tyrian producers, but Sha'ar-Ha'Amakim has yielded three stamps in Greek which remain un-deciphered and not connected to any manufacturing centre (cf. handle **Fig. 3:7**).[28]

24 Avshalom-Gorni & Getzov 2002, 79, fig. 5.2:1–2.

25 Elgavish 1976: 65–67.

26 Elgavish 1976: 74–75, fig. 6:18, pl. 15:D.

27 Zemer 1978: 32, no. 27, pl. IX vol. ca. 19 litres (misdated to the 5th–4th centuries BC).

28 Finkielsztejn 2006: 258; Finkielsztejn 2009: 140–142, does not exclude that they may have come from Tyre as well.

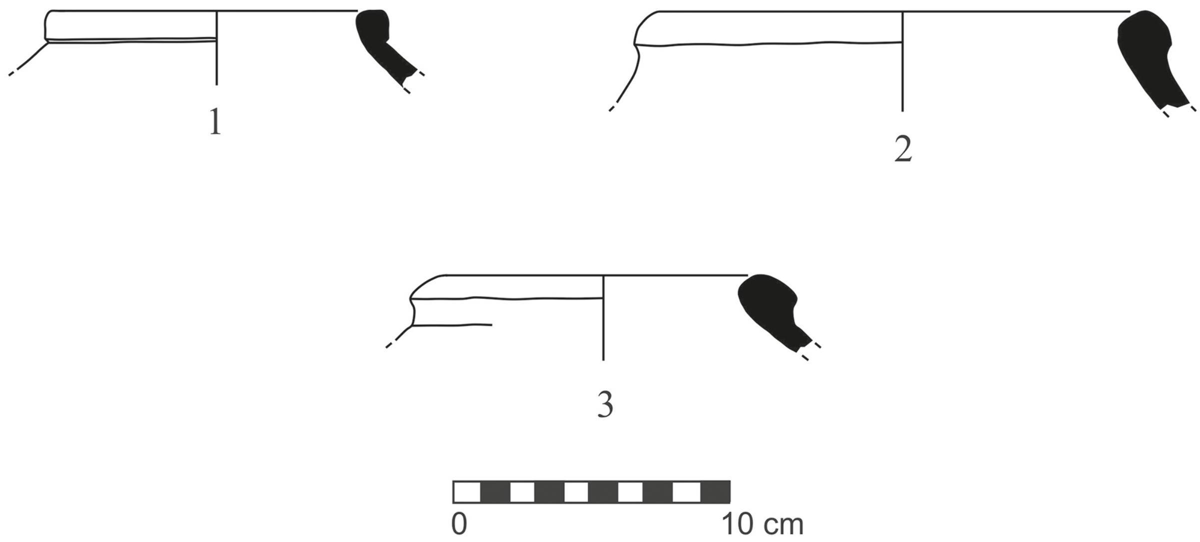


Fig. 2. Samples of jars (and/or *pithoi*?) of hole-mouthed shape from Sha'ar-Ha'Amakim, Late Iron Age(?) and Persian period. No. 1: inv. 864.8 (**SA-123**); No. 2: inv. 192 (**SA-128**); No. 3: inv. 631 (**SA-130**). Drawn by Mariusz Burdajewicz

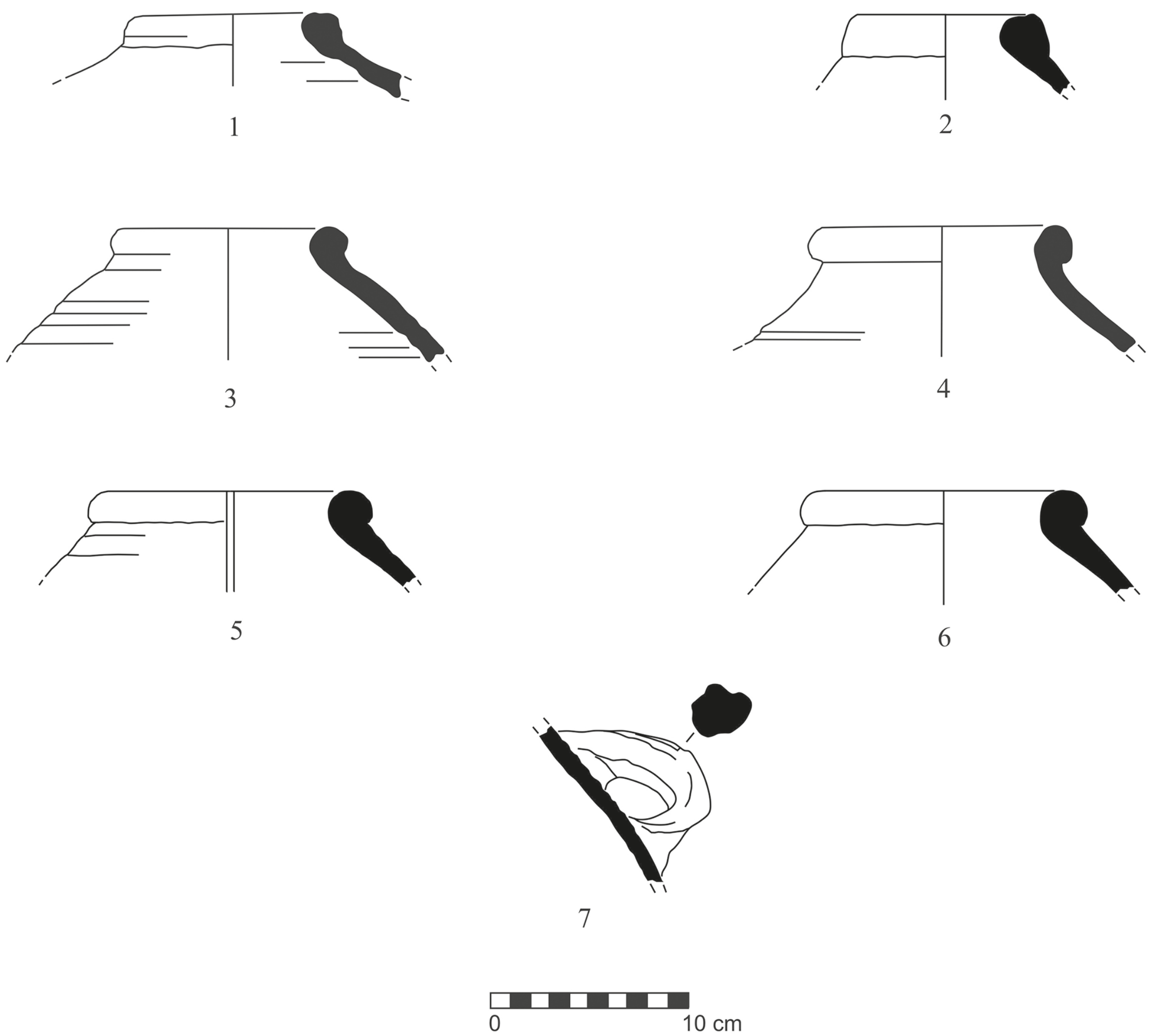


Fig. 3. Jar fragments of group 1b from Sha'ar-Ha'Amakim in Phoenician Semi-Fine ware. No. 1: inv. 818.4 (not sampled); No. 2: inv. 211.4 (**SFx-115**); No. 3: inv. 940.1 (not sampled); No. 4: inv. 200.19 (not sampled); No. 5: inv. 965.1 (**SD1-62**); No. 6: inv. 930a (**SE-86**); No. 7: inv. 652 with a stamp in Greek (not sampled). Drawn by Mariusz Burdajewicz

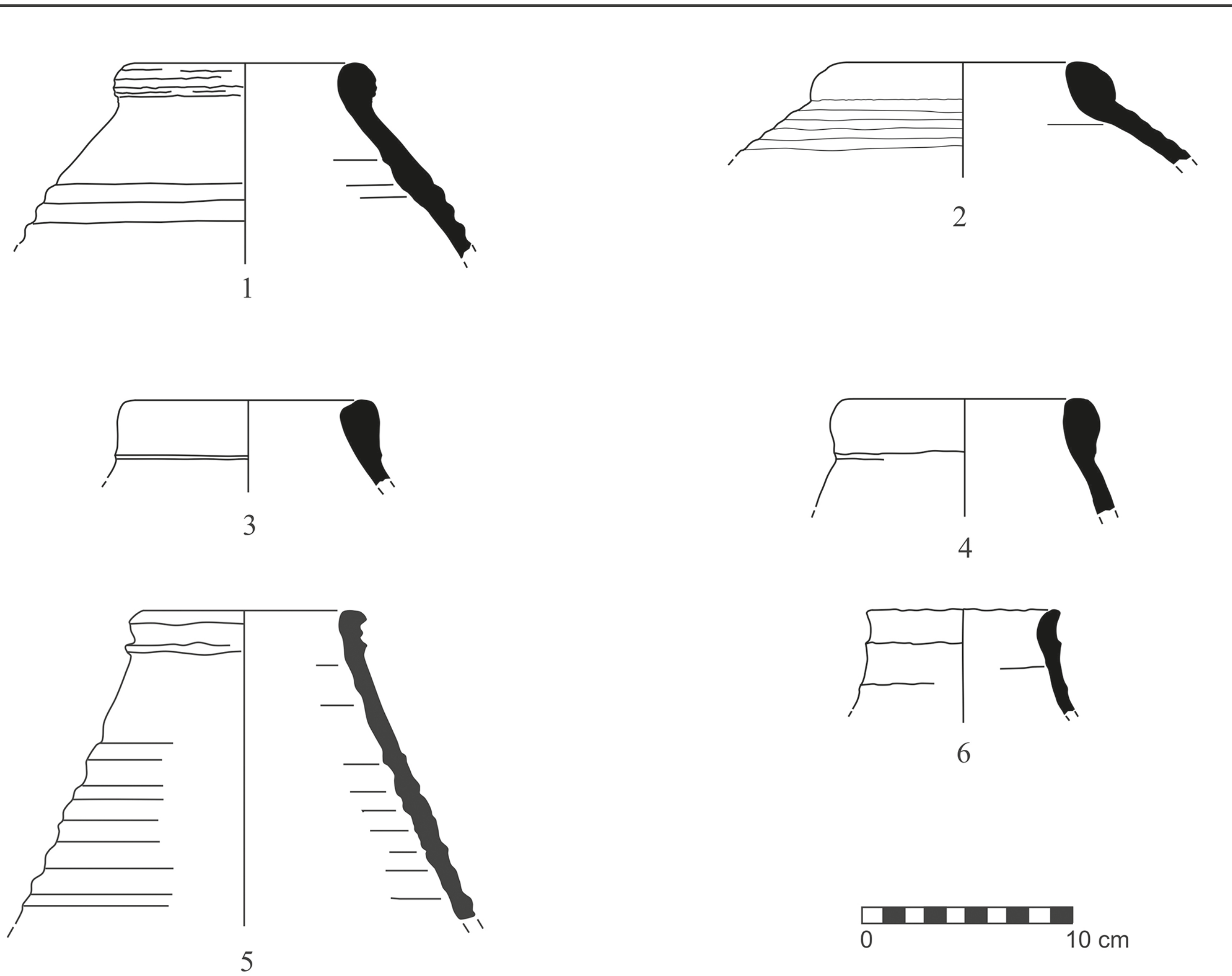


Fig. 4. Jar fragments from Sha'ar-Ha'Amakim pertaining to group 1b (Nos. 1–2, non-Phoenician fabrics) and group 1c (Nos. 3–6, non-Phoenician fabrics). No. 1: inv. 469.3 (not sampled); No. 2: inv. 204.7 (not sampled); No. 3: inv. 919a.1 (**SF-109**); No. 4: inv. 466.3 (**SFx-116**); No. 5: inv. 169.1 (**SFx-113**); No. 6: inv. 466.2 (**SFx-114**). Drawn by Mariusz Burdajewicz

Group 1c is a "post-Phoenician" type of jar, hole-mouthed with elongated body, of the Early Roman to Roman date. Its examples occur at Sha'ar-Ha'Amakim in just few fragments which represent more than one fabric (**Fig. 4:3–6**).[29] They are not stratified, but the accompanying pottery would place them in the 1st and 2nd centuries AD. Various examples of this group are known from the Lebanese coast (the latest developments dated to the 2nd/3rd century AD),[30] Akko,[31] Shiqmona,[32] Yokne'am,[33] and Ramat Hanadiv.[34]

Group 2a (**Fig. 5** and **7)** are bag-shaped jars, in the shape variant which is characteristic of the Persian and Hellenistic periods.[35] They are virtually neckless (or with short concave neck), with everted rim and oval-sectioned, usually ridged, handles set below the shoulder. The manufacturing of such jars at Tel Michal during the 5th century BC has been attested by kiln finds.[36] At Nahal Tut (near Yokne'am) jars of this form were found in a context dated to the last quarter of the 4th century BC.[37] As a matter of fact, they were common in a wide area from Judea and Sharon in the south through Samaria in the central hill country to Galilee in the north, including the whole coastal belt.[38] It is to be noted that during the later Persian and the Hellenistic periods at a number of northern sites the jars of our group 2a co-occurred with those of groups 1a and 1b. That was the case

29 Młynarczyk 2009b: fig. 5:13–14 (in the present study occurring as samples SF–109 and SFx–113, respectively).
30 Reynolds 2005: 599, pl. 12, figs. 89–91.
31 Avshalom-Gorni 1999, fig. 24:20 and 21–22.
32 Elgavish 1977: pl. XIX:142–148 and 155.
33 Avissar 1996: 74, fig. XII.7:7.
34 Calderon 2000: 92–93, pl. I:28.
35 The form described by Lapp (1962, 146–151) as "Type 11. Large Cylindrical to Bag Shaped Jars with Rounded Base"; Finkielsztejn 2006: 255, fig. 4.
36 Singer-Avitz 1989: fig. 9.4.
37 Alexandre 2006, 156 and figs. 50:1–10, 52:1–3, 8–12, 53:12–17, 60:2–18, 61:4 and 9–15.
38 For references, see Młynarczyk 2000, 226–228, notes 7–10. An example of such jar with a Phoenician inscription was found at Bat Yam near Ashdod in southern Israel, see Shapira 1966: 10, pl. 4A.

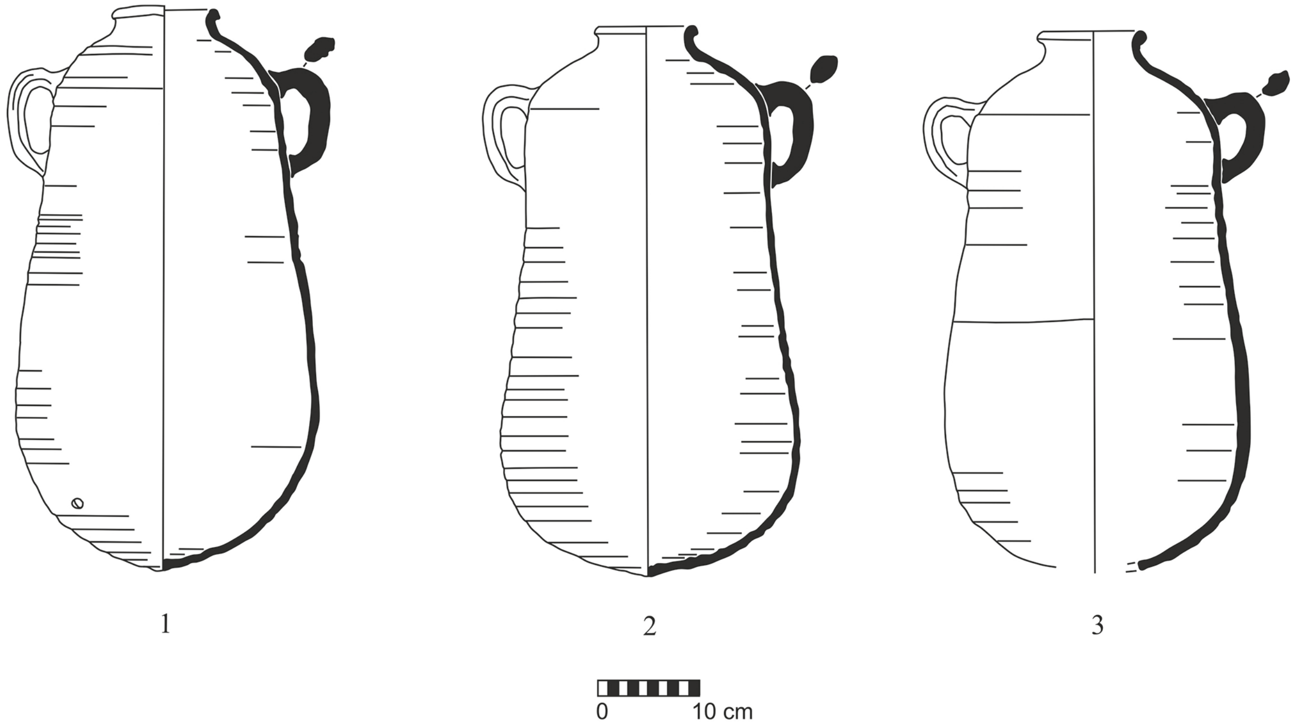


Fig. 5. Jars of group 2a (Hellenistic bag-shaped) from Sha'ar-Ha'Amakim, from the deposit in cellar G/R, not sampled. No. 1: inv. 897.7; No. 2: inv. 890.8; No. 3: inv. 889.7. Drawn by Mariusz Burdajewicz

with Yodefat,[39] Tell Keisan,[40] Tel Michal,[41] Akko,[42] and Horbat Uza stratum 10 (Hellenistic).[43]

In Sha'ar-Ha'Amakim, jar type 2a is best represented by several restorable examples found in a household wine cellar ("cistern G/R"), whose one-time fill was fairly closely dated to the end of the 3rd century and the first half of the 2nd century BC.[44] The restorable jars were destined to contain 25–26 litres of wine.

At the coastal Shiqmona (the modern Haifa, ca. 15 km to the west of Sha'ar-Ha'Amakim), similar jars continued in a Late Hellenistic layer; they had capacity of ca. 25 litres, but also of just 17 litres(!), and were said to be about half as common as the co-occurring jars of our type 1b.[45] Also at Dor, the type was still used in the second half of the 2nd century BC.[46]

Group 2b are bag-shaped jars of the Roman period,[47] present at Sha'ar-Ha'Amakim from latter 1st BC to the 3rd–4th centuries AD (**Fig. 8–10**). Those containers were thin-walled, hard-fired, usually smaller than those of our group 2a; perhaps some of them may have held olive oil rather than wine. Initially, the vessel had an elongated, near cylindrical round-bottomed body which with the time became shorter and wider ("bulbous"), typically with a ridge separating the shoulder from an upright neck, the latter associated with a variety of rim profiles.

Group 2c are the Byzantine-period jars (5th–7th century AD),[48] which developed from jars group 2b. They are absent from Sha'ar-Ha'Amakim, but very common in the Byzantine contexts of Tell Keisan, from where a couple of samples were taken for the present project (see below). This late version of the bag-shaped jar were occurring in a number of variants throughout different regions of Palestine; the one present at Tell Keisan and manufactured in the vicinity (Horvat'Uza /Tell Ayadiya) had a near-globular body with a ridged shoulder and a lin-

39 Avshalom-Gorni & Getzov 2002: 77, fig. 5.1:1–3 (our group 2a, late variant) and 80, fig. 5.2:1 (our group 1b); Aviam 2015: 111, fig. B.

40 Briend & Humbert 1980: pls. 7–8 (niveau 2: Persian/Hellenistic)

41 Singer-Avitz 1989: 139–142, fig. 9.17, nos. 1 (our 2a, described as "elongated" type) and 3 (our group 1a).

42 Regev 2010: 123–124, fig. 1–2 (our groups 1a–1b: "Phoenician amphora Forms 1–2") and fig. 3 (our group 2a: "Local amphora Form 3"); Smithline 2013:94 and fig. 11:6–8 (our group 1a) and 9 (our group 2a).

43 Smithline 2009: 146–147, fig. 4.8, nos. 1–6 (our group 2a) and nos. 7–8 (our group 1a).

44 Młynarczyk 2000; Młynarczyk 2009b, fig. 2:1–3.

45 Elgavish 1976, 74, fig. 6:19 and Pl. 15:E.

46 Guz-Silberstein 1995, 311, type JR 1, subtypes a-b, apparently of local manufacture: fig. 6.35:5 and 8–10; fig. 6.36:1, 4 and 6–9. Cf. also Lapp 1961, type 11.3, rim variant F, example from Shechem, dated to 150–100 BC.

47 The form described as "barrel-shaped" by Avshalom-Gorni & Getzov 2002.

48 Kingsley 1994–95.

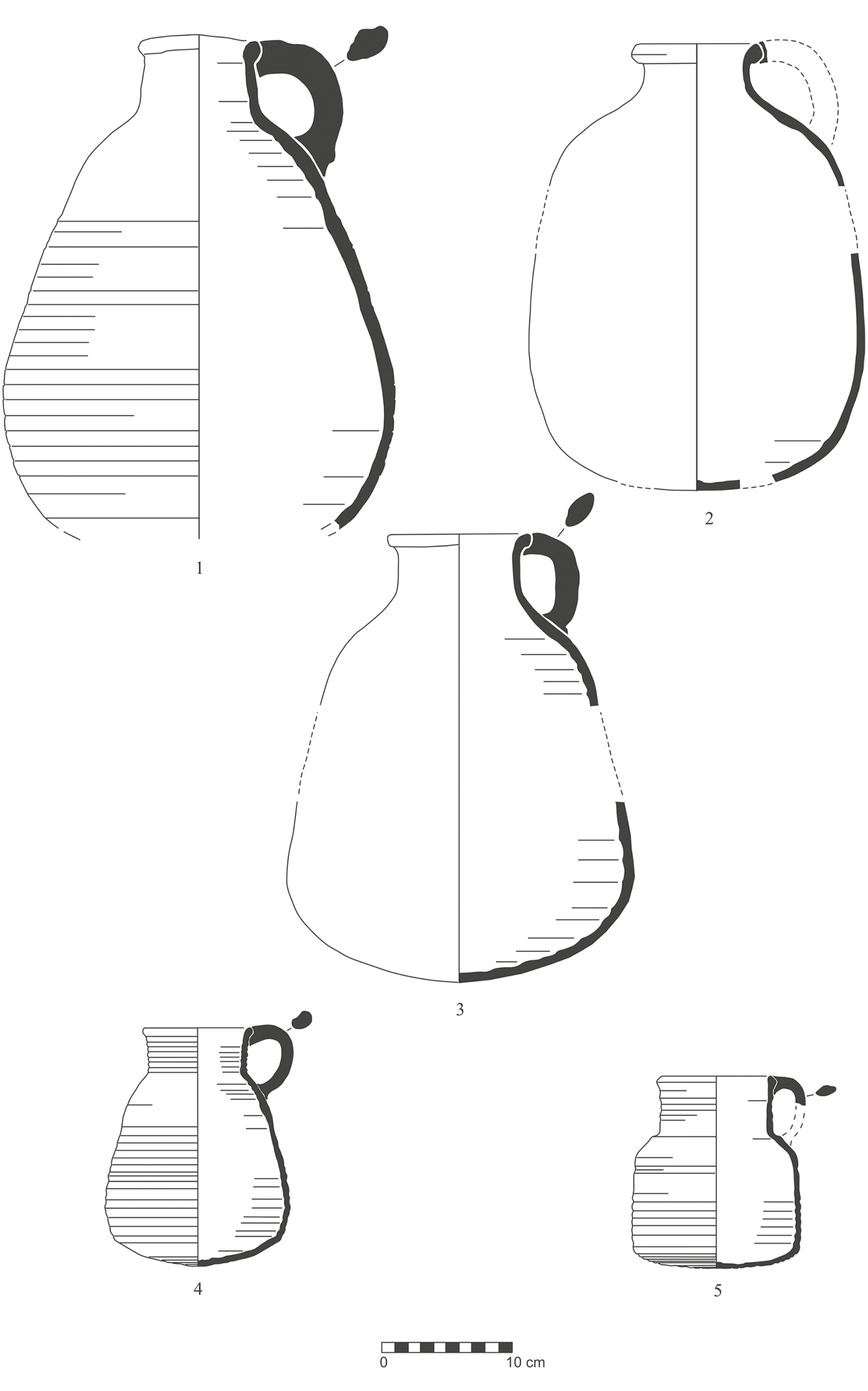


Fig. 6. Examples of bag-shaped water jugs from Sha'ar-Ha'Amakim, of the Early Hellenistic period (Nos. 1–3: our group 3a) and Roman period (Nos. 4–5: our group 3b). No. 1: inv. 889.5 (**SBc-23**); No. 2: inv. 912.7 (**SBc-19**); No. 3: inv. 889.4 (**SBc-25**); No. 4: inv. 709.4 (not sampled); No. 5: inv. 735.5 (not sampled). Drawn by Mariusz Burdajewicz

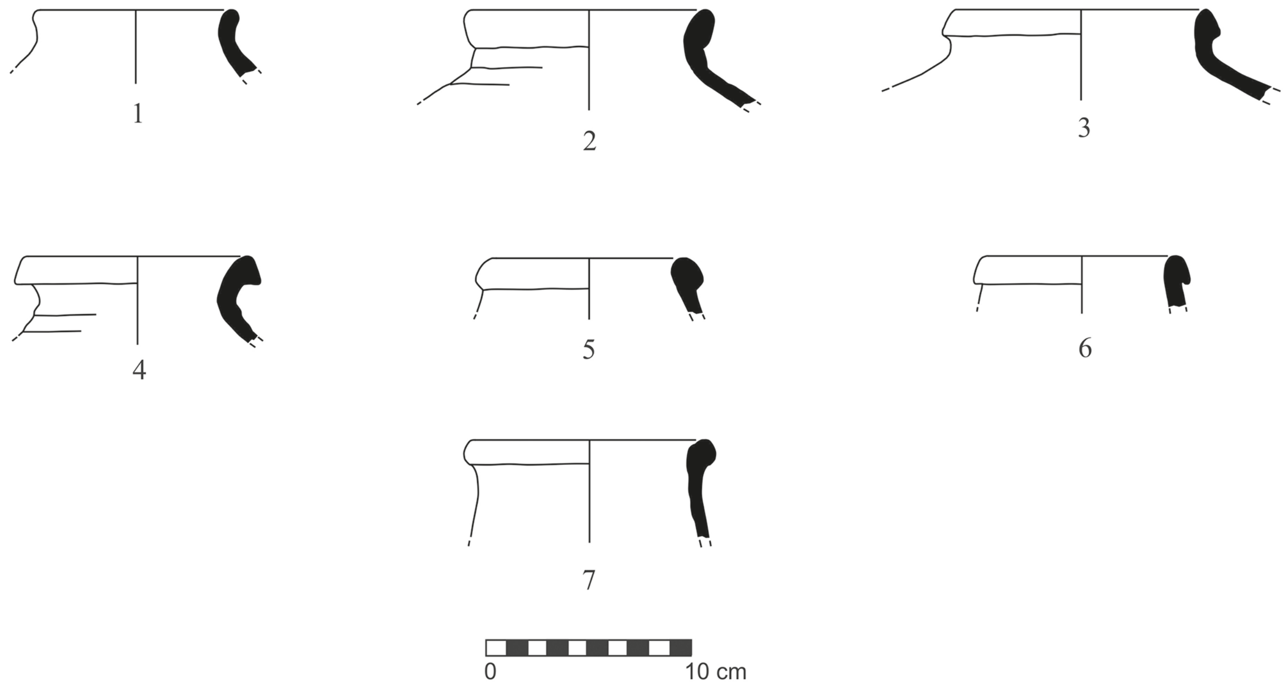


Fig. 7. Samples of the Hellenistic-type bag-shaped jars (group 2a) and water jugs (group 3a) from Sha'ar-Ha'Amakim. No. 1: inv. 864.13 (**SA-120**); No. 2: inv. 264.c (**SD1-125**); No. 3: inv. 262.a (**SD1-133**); No. 4: inv. 921.1 (**SD2-78**); No. 5: inv. 910.b (**SB-122**); No. 6: inv. 934.5 (**SA 127**); No. 7: inv. 905.4 (**SB 132**). Drawn by Mariusz Burdajewicz

ear decoration painted in white against the surface which was fired either reddish brown or dark grey.[49]

Group 3a are large bag- (or sack-) shaped jugs, apparently intended for supplying and storing water; their body sherds or small fragments of rims may sometimes be mistaken for those of jars group 2a. Unlike the jars, however, they feature a pronounced neck. Such jugs at Sha'ar-Ha'Amakim have been identified in the deposit of "cistern" G/R (**Fig. 6:1–3**).[50] Visually, they are of similar fabrics as most of the jars in group 2a. This vessel form originates in the local/regional ceramic repertoire of the Persian period, with examples attested both in the north and south.[51] In the Hellenistic period, however, the production of this form of the vessels seems to have been limited to the northern coastal area. Apart from Sha'ar-Ha'Amakim, this form of jug is still common in the Hellenistic layers of Tell Keisan[52] and Tel Dor, at the latter site occurring in a well-dated context of between 200 BC and 125 BC.[53]

Group 3b, *per analogiam*, are the Roman-period jugs, apparently destined to drew water, found in the deposit of cistern D (Phase F, **Fig. 6:4–5**). Their fabric is comparable to that of the contemporaneous wine/olive-oil jars of our group 2b. Very thin-walled (almost "egg-shell"), by their form they seem to be a distant development of storage jugs from "cistern" G/R of pre-mid 2nd century BC. However, the function of much smaller jugs 3b must have been different: they served as dipper jugs rather than storage jugs like group 3a. They are not easily datable as only a couple of parallels are known from nearby sites such as Jalame, Sumaqa and Sepphoris.[54]

Finally, also a few samples of other ceramics (marked as "group 4") were chosen for the analyses on the assumption they might be diagnostic for a local/regional source of clay. In the Sha'ar-Ha'Amakim material they are represented by fragments of domestic ovens as well as a piece of brick, while in Tell Keisan and Tel Akko by fragments of cooking and table vessels. As a general remark it should be stated that with the body sherds the vessel shape may be rather uncertain, and when a small section of the rim is preserved, any closer identification of the jar's form is not possible either. Due to usually small size of sampled fragments, in some cases it is not certain if a body sherd belonged, for example, to a jar (2a) or to a water jug (3a), or if a body sherd in Phoenician Semi-Fine ware belonged to jar form 1a or 1b. Some of the containers with a rim diameter bigger than that of average jars, may have been alternatively described as *pithoi*.

49 Landgraf 1980.
50 Młynarczyk 2000.
51 Młynarczyk 2009b:100, to which add Cimadevilla 2005, fig. IV.7:1 (Yokne'am).
52 Briend and Humbert 1980, pl. 9:3–11.
53 Guz-Silberstein 1995, 308–309, type JG 11, fig. 6.30: 1 and 4.
54 In Jalame, see Johnson 1988: 198–199, fig. 7–42:619, erroneously described as "cooking pot with ribbed neck"; in Sumaqa & Kingsley 1999: fig. 9:23; in Sepphoris & Tsuk et al. 1996: pl. IX:5.

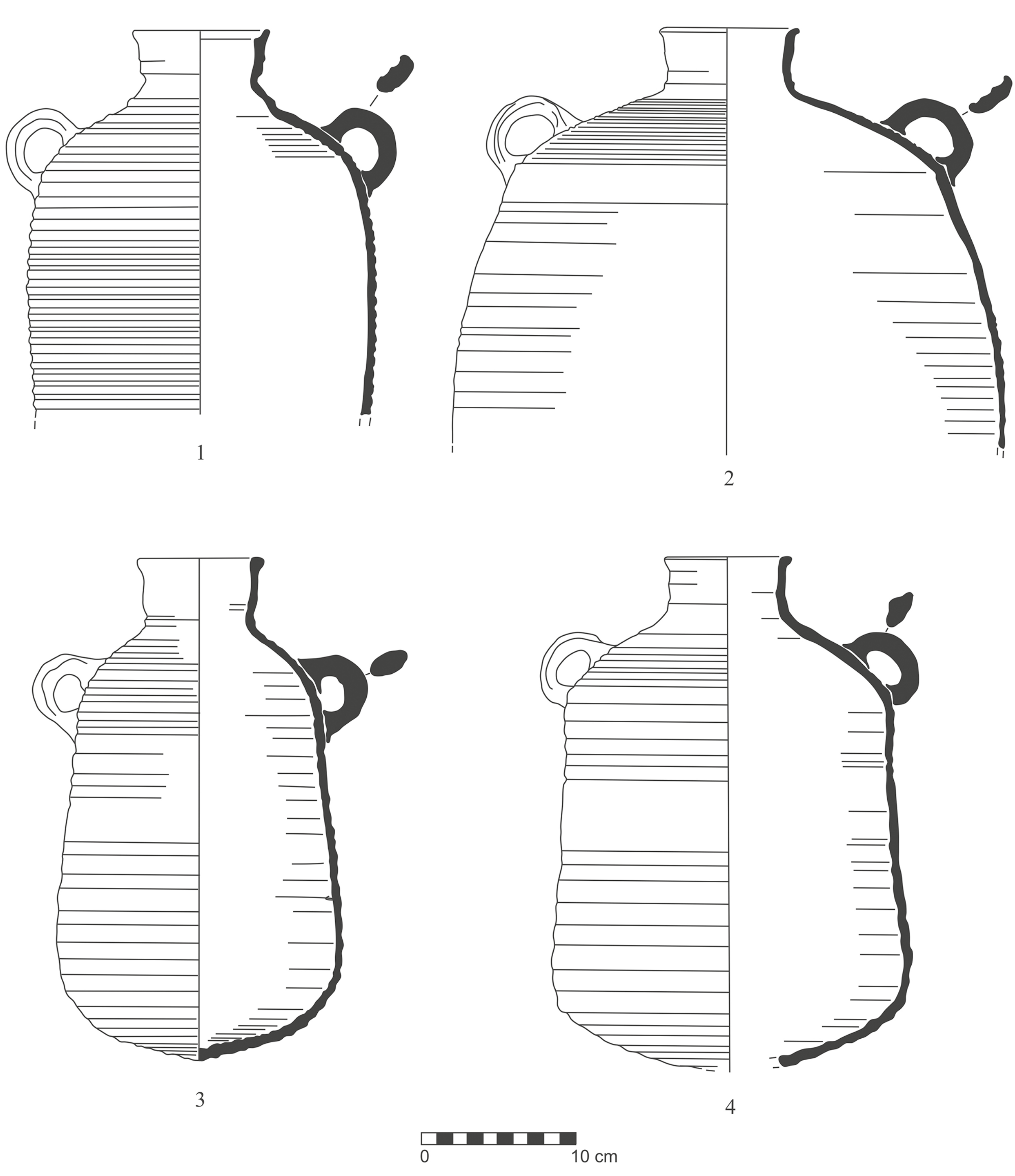


Fig. 8. Examples of bag-shaped Roman-period jars (group 2b) from Sha'ar-Ha'Amakim, not sampled. No. 1: inv. 806/809/836; No. 2: inv. 185.1; No. 3: inv. 744.1; No. 4: inv. 737.1. Drawn by Mariusz Burdajewicz

2.2. Analytical methods

Comparative petrographic and chemical analyses of 251 specimens were performed. Each sample was described macroscopically and documented photographically using an Olympus SZX-9 binocular. Polished petrographic thin sections were made of each fragment by embedding them in epoxy resin. The study was made in transmitted light complemented with observations in reflected light using an Olympus AX70 Provis petrographic microscope. Microscopic studies were conducted to establish the mineral composition and petrographic features of aplastic components and the matrix, including the temperature of its firing. Minerals hard to identify optically were examined using the Hitachi electronic microscope, their chemical composition being determined using the EDX method. To determine the age of the raw-material, each polished section was examined micro-paleontologically. This study was carried out by Barbara Olszewska from the Institute of Geological Sciences, Polish Academy of Sciences in Cracow.

Another part of each sample was cut off with steel pincers, rinsed in distilled water (secondary, pedogenic calcium-carbonate efflorescences on some samples having been removed with the help of a diamond bore), ground in an agate mortar, and sent to a chemical laboratory. The INAA and total digestion ICP/OES analyses of 50 elements were performed by the ACTLABS Activation Laboratories in Ancaster, Ontario (Canada); 251 ceramic samples were analysed. The results of the chemical analyses were interpreted mathematically using the principal components method and a spanning tree (the Wrocław dendrite). Statistical computations were performed using Statistica 10 software. The final results of the petrographic observations were checked against those of the mathematical correlation and subjected to geochemical interpretation.

3. Petrography and chemistry

3.1. Geological setting of study sites

The archaeological sites examined are situated on the borderland between two geographical units, the Zevulun Plain and the Lower Galilee foothills (Fig. 9).

Sha'ar-Ha'Amakim is situated on the north-western slopes of the Lower Galilee foothills (14 km SE of Haifa), on a synclinal Qiryat Tiv'on Eocene block constituting the south-western part of the Lower Galilee hills. In the south it is bordered by the Jezreel Valley, in the south-west, a narrow Qishon Graben pass behind which rises the Mt Carmel ridge. The western border is the Zevulun Plain, which is part of the coastal plain.

Tell Keisan is a Senonian mound located 12 km north-east of Haifa, 8 km south-east of Akko, in the north-eastern part of the Zevulun coastal plain close to the Lower Galilee foothills.

Geological evolution of the region

In order to distinguish local ceramics from imported ones and to search for potential deposits of the raw material used for their production, it is necessary to understand stages of the region's geological evolution because this implies variations in the lithology and chemistry of clayey rocks.

Generally, we can state that the present-day profile of deposits in Northern Israel and Lebanon is a record of changes of sedimentary environments, from shallow-see to open-marine ones, with lagoon, brackish and freshwater sediments intermingled, strongly influenced by magmatic episodes.[55]

The exposed rocks of the study area range in age from the Lower Cretaceous to the Recent. Sedimentation took place in the warm waters of the Neotethys Ocean, mainly on the northern edge of the African-Arabian Plate.[56]

In the lower Cretaceous until the Turonian the conditions prevailing in the Levant region were those of a shallow marine platform passing in the south and east into terrestrial environments (today Negev, Jordan and southern Sinai) and to the west, into a hemipelagic environment (over the continental shelf). The water of the marine lagoon was separated by a coral-reef barrier.[57] The mantle plume expansion influenced the depth of the sea, making it shallower or deeper, and the episodes of volcanic activity (Tayasir Volcanics) associated with this phenomenon greatly affected the mineralogy and geochemistry of the sediments.[58] This follows from the fact that the basic products of weathering of volcanic glass are expansive clays (smectites), especially efficient in absorbing trace elements.

From the Late Cretaceous (Senonian) the collision of the African-Arabian Plate with the Mesotethys Plate and the Tauride Plate led to the closure of the Neo-Tethys Ocean, its shelf undergoing compression. The result is the present S-shaped Syrian arc fold system, a mountain range extending from Sinai through Judea and Lebanon to the Palmyride belt. The upward fragments of the sea bottom have formed a belt of anticlinal elevations (Mt Carmel, the Um-el Fahm area, the Lebanese Mountains and Antilebanon) and deep, downturned synclinal depressions. With time, the deep-sea areas that formed in this way filled with chalk sediments with phosphate nodules and cherts. Today, they comprise the Ramot Menashe syncline in Galilee and the Bekaa syncline in Lebanon.

An especially widespread transgression took place in the Early Eocene, its records are chalky and limestone facies.[59]

55 Segev 2005, Bachman & Hirsch 2006: 490.
56 Bentor 1966, Beydoun 1977, Neev & Ben-Avraham 1977, Bachmann & Hirsch 2006, Walley 1997.
57 Cf. Bachman & Hirsch 2006: 488, Homberg & Bachman 2010: 3.
58 Segev & Rybakov 2010.
59 Cf. Flexeret et al. 1970; Segev & Rybakov 2011, Homberg & Bachman 2010.

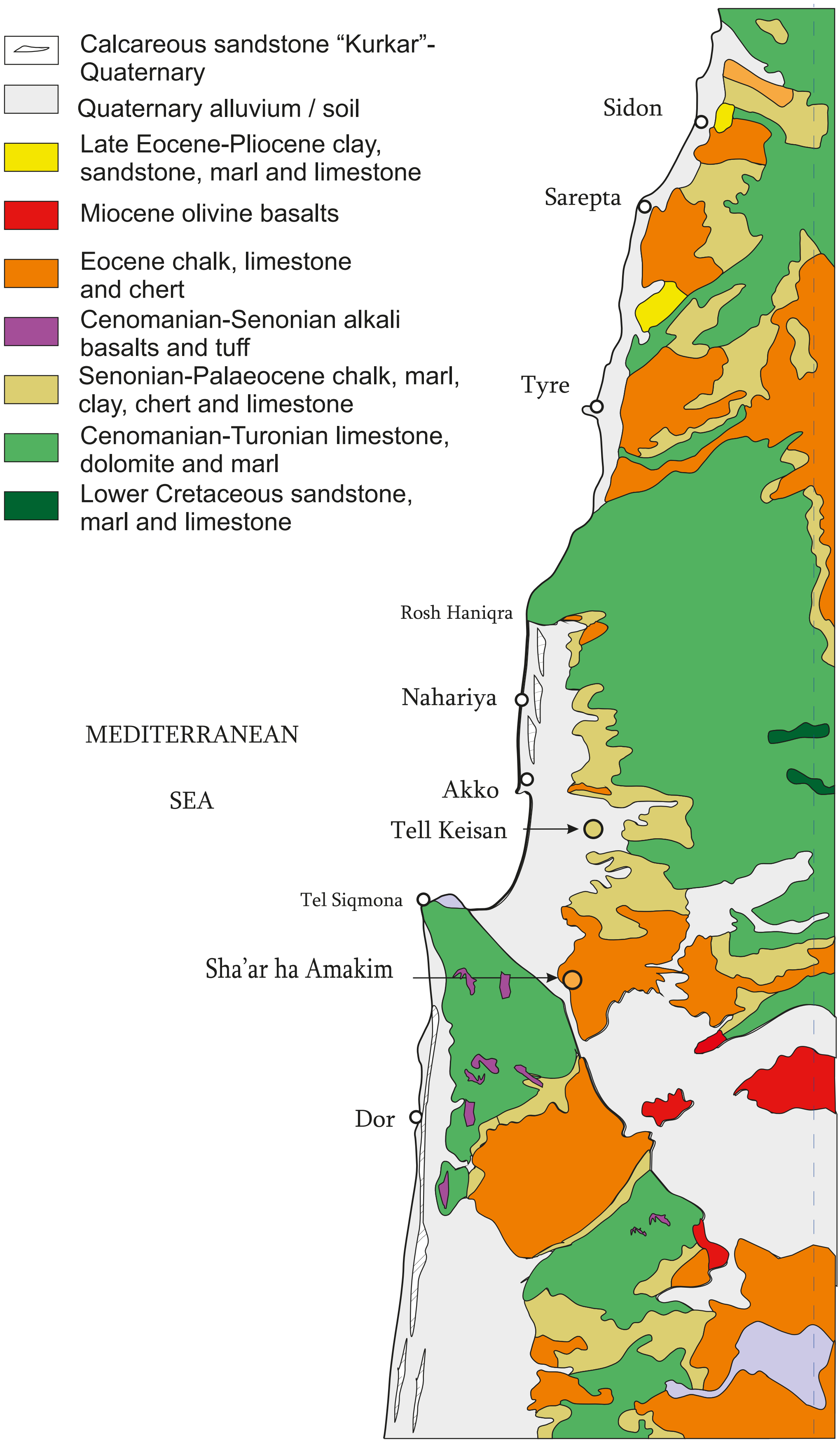


Fig. 9. Simplified geological sketch map of the study area, without fault dislocations (drawing: J. Michniewicz; based on: Sneh, Bartov, Rosensaft 1998; Walley 1998: fig. 2)

Between late Eocene to Early Miocene the northeastern Afro-Arabian plate was affected by Afar mantle plume dynamics[60], the area of Israel and neighbouring countries and continental shelf emerged.[61] That's why the Lebanon the Upper Eocene and Oligocene strata are missing, reflecting the major uplift of this time. According to Walley (1997), this corresponds to the second phase of the Syrian Arc deformation in this area. In Israel the Upper Eocene sediments form the Saqiye Group – a sedimentary prism sediments along the coastal plain and the continental shelf.[62]

In the Miocene, owing to a horizontal northward shift of Arabia relative to Sinai along the Dead Sea transform fault, the Syrian Arc fold system was cracked by numerous tectonic faults of predominantly NW-SE orientation. The Arabian and African platforms were uplifted about 1,000 metres above sea level. The uplifted platforms were alternately cut by rivers and penetrated by open-sea waters[63]. Individual fragments of the continent – tilted blocks – formed a system of horsts and grabens. In this way there appeared the Mt Carmel block and the tectonic trench of the Jezreel Valley limiting it from the north.[64]

In the late Miocene – Tortonian, 9 Ma (million years ago) after a successive subsidence of the area, the sea covered the platform leaving bioclasts and fossil coral reefs. The sea disappeared towards the end of the Miocene as a Messinian regression, 7 Ma, when nodular anhydritic and salt beds were deposited. They were then covered by fluvial clasts.

During the Pliocene (5 Ma) the Mediterranean was flooded through pre-existing erosional canyons. The resultant faulting formed most of the structures controlling the recent morphology of the area.[65] The canyons were ultimately filled with clastic terrestrial and marine deposits, partially interbedded by volcanic intrusives.

In the Late Pleistocene shales with some evaporates were deposited.[66]

The uppermost parts of the profile are alluvial deposits transported by rivers and their tributaries along the main dislocation lines: the Qishon River (70 km long, drainage 1,100 km^2) and the Hilazon River (32 km long, drainage 271 km^2)[67]. The mineral composition of sediments deposited by those rivers reflects the geochemistry of the entire drainage system. In the case of the Qishon River it extends as far as eastern Galilee.[68]

3.2. Lithology and stratigraphy

The Createaceous and Cenozoic stratigraphic units of Northern Israel and Southern Lebanon are presented in Table 1.

The Lower Cretaceous formations represent terrestrial (mostly fluvial) and shallow-marine sediments (deltaic, tidal, supra-tidal): white and brown sandstones, ferruginous shale-rich clays, shales, often ferruginous, and lignites. They crop out widely in the Lebanese Mountains ("Basal Cretaceous Sandstone" within the Chouf Formation,[69] in Israel in the Hermon massif, east of the Dead Sea (Wadi Zarga), and small areas in Samaria: Wadi Malikh and Wadi Far'ah, belonging to the Aptian Hatira and Netofa formations.[70] At Mt Carmel, Um-el Fahm and Lebanese Mountains anticlinoria outcrops shallow-sea platform dolomites belonging to the Albian Yagur Formation, covered by Cenomanian-Turonian dolomites and slightly deeper shelf-basin limestones, chalks with some cherts, and marls. These rocks comprise the Judea Group.

During the Senonian until the end of the Eocene uniform sedimentation of deep-sea chalks prevailed, locally with phosphates and some limestones. Those deposits directly overlies the Judea Group with a major regional unconformity. They fill the Ramot Menashe (Galilee) and Bekaa (Lebanon) synclinoria[71], and belong to the Senonian-Paleocene Mount Scopus Group and Eocene Avedat Group in Israel[72] and the Chekka Formation in Lebanon[73]. They are most exposed in the Lower Galilee foothills characterised by a gentle morphology.[74]

What attract special attention in a search for ceramic material are green marls, green shales and argillaceous chalks with some phosphates of the Santonian – Early Campanian Kabri Member of the Menuha Formation, the white to yellow chalk and marls of the Campanian to Maastrichtian Ghareb Formation and the Paleocene grey to green, partially bituminous marls of the Taqiye Formation.[75]

60 Segev & Rybakov 2011: 267.
61 Gvirtzman & Buchbinder 1978:1201.
62 Gvirtzman & Buchbinder 1978: 1196.
63 Gvirtzman & Buchbinder 1978: 1195; Matmon et al. 2003: 227.
64 Matmon et al. 2003.
65 Matmon et al. 2003: 227.
66 Cf. Gvirtzman et al. 2008.
67 Matmon et al. 1999.
68 Elyashiv et al. 2015.
69 Cf. Ferry et al. 2007: 39, Bellos 2011.
70 Cf. Amireh & Abed 1999, Walley 1997, Powel & Moh'd 2011.
71 Cf. Kafri 1972; Sass & Bein 1982; Lipson-Benitah et al. 1997; Buchbinder et al. 2000; Bachmann & Hirsch 2006; Bentor 1966.
72 Flexer 1968.
73 Walley 1997.
74 Levy 1983: 59.
75 Generally used in the production of ceramics, cf. Bentor 1966: 72–73, Porat 1984, Goren 1995, Gilboa et al. 2006, Gorzalczany 2008: 83.

Table 1. Cretaceous and Cenozoic stratigraphic units of Northern Israel and Southern Lebanon

Epoch				Israel, Mt Carmel & Ramot Menashe mapping units*	Israel, Shefaram, Atlit lithostratigrapic mapping units**	Israel Lithostratigraphic Group	Lebanon Mt. Lithostratigraphic formation***
QUATERNARY	Holocene			Alluvium Sand dunes	Alluvium, colluvium Soil	KURKAR	
	Pleistocene			Pleshet Fm	Terrace conglomerate		
NEOGENE	Pliocene				Basalt/Pleshet Bira		Nahr el Kalb 'Zahle Fm
	Miocene	Upper		–	Bet Nir	SAQIYE	
		Middle		–			
		Lower		–	Ziglag Fm		No strata preserved
PALEOGENE	Oligocene			–	–		
	Eocene	Upper		Maresha Fm	Bet Guvrin Fm Maresha Fm Timrat Fm Adulam Fm	AVDAT	Nummulitic limestones/ thick marls/ chalky, cherty limestones
		Middle					
		Lower		Timrat Fm Adulam Fm			
	Paleocene			Taqiye Fm	Taqiye Fm		
CRETACEOUS	Maastrichtian		Senonian	Ghareb Fm	Ghareb Fm	MT SCOPUS	Chekka Fm
	Campanian			En Zetim/Bat Shelomo Tuff int.	Mishash		
	Santonian				Menuha Fm (Kabri mbr)		
	Coniacian						
	Turonian			Bina Fm/ Sakhnin Fm/ Muhraga Fm	Bina Fm Yirka Fm	JUDEA	Maameltain Fm
	Cenomanian			Shefeya volcanics Shamir Fm Khureibe Fm Raqefet, Tavasim Tuff Isfiye Fm Maharal tuff	Yanuh/Sakhnin Fm. Me Ammi Basalt Deir Hanna Fm. (Umm el Fahm Tuff intercalation) Karkara mbr		Sanine Fm
	Albian			Yagur Fm	Yagur Fm	KURNUB	Hammana Fm
	Aptian			Rama Fm Hidra Fm Ein El Asad Fm Hatira Fm	Rama Fm Hidra Fm Ein El Asad Fm Hatira Fm		Mdairej Fm Abeih Fm
	Barremian Neocomian			Hatira Fm	Hatira Fm		Chouf Sandstone Fm.

*After Segev & Sass 2009, Karcz & Sneh 2011.
**After Sneh 2008, Sneh et al. 1996, Segev, Sass 2009 map; Segev et al. 2002.
***After Walley 1997.

The Taqiye Formation is unconformably overlain by thinly-bedded Eocene chalks of the Avedat Group: whitish-gray chalks of Adulam Fm, rich in chert limesones of Timrat Fm, chalks of Maresha Fm, greenish to grey shales and marls (Bet Guvrin Fm.),[76] Miocene-Pliocene coarse-grained, reddish, calcareous sandstones (calcarenites), sandy limestone, reddish clays, and conglomerates of well-sorted chert pebbles (Qurdani Fm.) as well as poorly sorted conglomerates (Bet Nir Fm.) of the Saqiye Group.

The Pliocene-Quaternary conglomerates, travertine, red sands, calcareous sandstone, dune sands, alluvia and soils belong to the Kurkar Group.[77] The coastal margin of the Zevulun Plain and the Galilean Coastal Plain is mostly covered by sand dunes composed of Nile-delta quartz sands.[78] They form Plio-Pleistocene and younger Pleistocene eolianite ridges, locally termed 'kurkar', which run parallel to the coastline, intercalated by red sandy loam soils

76 Gvirtzman et al. 2008: 565.

77 Levy 1983; Sneh 2004, 2008; Segev & Sass 2009; Karcz & Sneh 2011.

78 Zviely et al. 2006; Elyashiv et al. 2015.

locally termed *hamra*.[79] There are also submerged *kurkar* horizons in the nearshore zone.[80]

What should be emphasised are differences in the mineral composition of Levantine beach sands, especially in the proportions of quartz and calcareous bioclasts. While the Nile-transported quartz is a component dominating on the beaches located south of Akko, northward of Akko quartz disappears and calcareous components start to dominate.[81] The Zevulun Plain surrounding the Haifa Bay embraces a part of the Galilean seashore lowland. This area has developed as a result of an uneven subsidence of several blocks, mutually translocated to different depths, which implies the level of Cretaceous and Paleogene rocks. They occur directly under the cover of present-day alluvial deposits of rivers and soil horizons. The few outcrops of bedrocks are still exposed on the Zevulun Plain in the form of Inselbergs; one of them is Tell Keisan, built of Upper Cretaceous rocks.

3.3. Volcanism of the area

Submarine volcanism was intensive from the Jurassic to the end of the Cretaceous. Volcanic rocks are mainly tuffs and alkaline basalts.[82]

In the Lower Cretaceous Hatira Formation, weathered fragments of Tayasir volcanic rocks can be observed. In the Mt Carmel and Um el Fahm areas there are four Cretaceous magmatic/hyaloclastite outcrop horizons intercalated with carbonates:[83]

1) the Early Cenomanian Kerem Maharal tuffs containing xenolith with garnet-bearing clino-pyroxenite, rare peridotite and olivine gabbro, as well as xenocrysts of augite, garnet, kaersutite, biotite and spinel;[84]
2) the Middle Cenomanian Tavasim pyroclastics and massive Raqefet olivine basaltic flows;
3) Upper Cenomanian Makura, Me-Ammi pyroclastics and Shefeya lava flows;
4) Senonian Bat Shelomo dark pyroclastics.[85] Many of the tephra products are hyaloclastites.[86]

The Cenozoic magmatism manifests itself in the Galilean outcrops as small Miocene intrusions (olivine Lower Basalts/basanite). They are observed south and east of Qiryat Tiv'on[87] in the foothills where a few Pliocene volcanic bodies of cover basalts represent the Bashan volcanic event[88]. In Lebanon four volcanic events have been recognised: Upper Jurassic, Lower Cretaceous, Upper Cretaceous, and Cenozoic-Pleistocene. Jurassic pyroclasts and lavas occur locally in northern Lebanon (north-east of Beirut) between the limestones and clays of the Oxfordian Bahannes Formation.[89] According to Walley (1997), the Lower Cretaceous Chouf sandstone contains basaltic volcanic rocks and reddish clayey beds which appear to be weathered volcanic tuffs. In northern Lebanon and locally elsewhere basalts and pyroclasts occur in the Lower Cretaceous Abeih Formation. At least two horizons (locally over 100 m thick) of pyroclasts and volcanic rocks can occur in the Albian Hammana Formation. The large-scale youngest southern extension of Syrian Homs alkali basalts lies north of Tripoli in the Akkar area.[90]

79 The Arab word for 'red'; cf. Sivan et al. 1999; Horovitz 1979: 84–88, 100–108; Issar 1968; Bentor 1966: 1; Sneh 2008; Segev & Sass 2009; Ravikovitch 1969; Sneh et al. 1996; Gvirtzman & Buchbinder 1978;, Barzilay 2006.

80 Cf. Zviely et al. 2007.

81 Cf. Gilboa et al. 2006: 311; Cohen-Weinberger & Goren 2004; Landau & Goren 2004: 28–29, Bettles 2003b: 297, Ownby & Griffiths 2009.

82 Cf. Segev et al. 2002, Segev 2005, Segev & Rybakov 2011, Segev et al. 2011.

83 Bentor 1966: 105; Kaminchik et al. 2014: 116; Segev & Sass 2009, Segev et al. 2002.

84 According to Singer (1966: 103) the following sequence of deposits can be distinguished in the profile of maharal pyroclasts: a) at the base – black, coarse-grained, mainly glassy tuffs, b) variously coloured and altered, red, green, grey and yellow tuffs, c) yellow, very strongly altered, tuff at the top (Segev2005: 555 after Sass 1980).

85 Cf. Segev et al. 2002.

86 Bentor 1966: 105.

87 Miocene volcanic rocks extending mainly in south-eastern Lower Galilee and the Yezre'el Valley.

88 Segev 2005; Levy 1983, Sneh et al. 1998.

89 Cf. Walley 1997: 9, Lateef 2014.

90 Abdel-Rahman&Nassar 2004;, Chorowicz et al. 2004, George et al. 2011.

4. Petro-archaeological research on jar production in Galilee

The petrographic and chemical research on the ceramics discovered in the Levant is conducted primarily in order to determine places of their production and, by means of the study of distribution pattern of the specific pots types, to identify trade routes. While the distribution of ceramic workshops in the Galilean area during the Roman period is relatively well known in terms of archaeology, the Persian and Hellenistic periods are in this respect rather poorly represented.[91] The tangible evidence for the pottery production that embraces actual finds of the remains of pottery kilns or, at least, of some pottery wasters or warped amphora parts suggestive of the vicinity of a pottery making place, comes from very few sites. One of them is Tel Michal situated on the coast to the north of Jaffa, where jar kilns, producing bag-shaped jars (our group 2a), were discovered and dated to the Persian period.[92] An important kiln site of the same period, but making the Phoenician-style (carinated-shoulder) jars has been identified in Sarepta in southern Lebanon (see below).

The finds of the Persian-period carinated-shoulder jars are abundant along the Levantine coast, but also at some inland sites situated on trade routes (see map, **Fig. 38**).[93] Only in the southern Levant they have been found in at least 40 sites.[94] At the same time, however, the number of actual kilns known from that period is meagre.

According to Elizabeth Bettles' investigation, an especially important role as a centre of production of the carinated-shoulder amphorae was played by workshops located in Phoenician Sarepta, where remnants of numerous Persian-period pottery kilns were discovered.[95] During her study, Bettles examined 307 thin sections of the carinated-shoulder amphorae gathered from ceramic assemblages discovered at 21 different sites (from north to south): Sarepta, Lohamei Ha-Geta'ot, Akko, Tell Keisan, Qiryat Ata, Gil'am, Tel Abu Hawam, Shiqmona, Atlit, Dor, Jokne'am, Tel Qiri, Ma'agan Michael, Tel Mevorakh, Tel Megadim, Tel Michal, Ashdod fortress, Tel Ashdod, Ashkelon, Lachish, Tel el-Hesi. The result of this work was the distinction of two basic fabric classes, FC 1 and FC 2.

- Fabric Class 1 (with its four subclasses: 1A, 1B, 1C, 1D is characterised by a very fine, dense and highly calcareous matrix incorporating various quantities and genera of foraminifers of orange-red, red and brown colour.
- Fabric Class 2 (four subclasses: 2A, 2B, 2C, 2D), characterised by a ferruginous silty matrix, with varying levels of carbonate matter.

Predominant among those amphorae is FC 1A, which the author describes as follows: "macroscopically, this fabric is characterized by moderate to sparse amounts of transparent and translucent well-sorted fine sand-sized inclusions, moderate multi-chambered microfauna, and sparse blobs or streaks of red iron oxide of medium to coarse sand-sized, cloudy pale yellow limestone of very coarse sand. Under microscope the matrix consists of a fine, dense, foraminiferous and ferruginous marl of clear orange colour with streaks of ferric oxide, Globigerinidae of Paleogene age, including *Acarinina* sp.".[96] Moreover, Bettles notes the presence of rare white mica flakes.[97] "Aplastic inclusions make up 2–5% of the volume. They consist predominantly of quartz and carbonate grains, with accessory minerals of hornblende, epidote, feldspar, chert and schist, as well as fragments of coralline algae, *Amphiroa* sp.".[98] Bettles regards FC 1A as local to Sarepta on the basis of ~~a~~ comparison of the petrography of the amphorae discovered at that site with the local source – foraminiferous chalky Middle Eocene marls, and also on the presence of local pottery workshops dated to the Late Bronze Age and throughout the 1st millennium BC,[99] as well as on a comparison of the chemical composition of those amphorae to eleven

91 Nitschke et al. 2011; Leibner 2009: 7.

92 Singer-Avitz 1989, 132, fig. 9.12:6–10, pl. 63:1–5.

93 For the network of roads in Galilee, see Strange 1977: 40, fig. 1.

94 Cf. Bettles 2003b: 53–54.

95 Bettles 2003a: 63; Bettles 2003b: 96.

96 Bettles 2003a: 67.

97 A feature not found in the Sha'ar-Ha'Amakim amphorae of corresponding group 1a.

98 Bettles 2003a: 67.

99 Bettles 2003b: 151.

pottery sherds from Sarepta previously analysed by Gunneweg et al.[100]

The next in terms of frequency is FC 2A, "characterised by a matrix reddish-brown in colour, ferruginous, silty and moderately calcareous, with sand-sized quartz accounting for up to 25% of the volume", which in Bettles' opinion is "consistent with the *hamra* paleosol cropping out along the coastal region of Israel".[101] She also distinguished:

- Fabric Class 1B, "with a chalk-rich matrix with foraminifers of Paleogene age, distinct from FC 1A by a very pale yellow or very pale grey/green colour. In the author's opinion, the presence of coralline algae, fragments of kurkar and chalk-rich clay of Paleogene age is consistent with a source on the northern coast of Israel".
- Fabric class 1C "of a pale orange hue, with a foraminiferous chalk-rich matrix with abundant Upper Cretaceous and some Paleogene foraminifers, silty clay pellets, pale-grey chalk grains, monocrystalline quartz (10–15% of the volume), coralline algae, and phosphatic bone fragments". Provenance proposed: southern coastal Levant.
- Fabric class 1D, "highly distinctive because of its very pale, yellowish grey colour with a greenish tinge, a highly calcareous matrix fired at a high temperature, i.e. 850–1,000°C, *terra rossa* soil inclusions, kurkar clasts, volcanic and sub-volcanic inclusions"; a possible source would be the Haifa Bay.
- Fabric class 2B, "with a dense ferruginous loess matrix, low in calcareous content, manufactured in the southern Shephela/ north-western Negev (?) region".
- Fabric class 2C, "with a highly calcareous, fine, dense matrix of dull orange colour, rare dolomitic crystals, multi-chambered foraminifers and fragments of bivalve shells, poorer sorting of quartz grains, and temper containing Amphiroa sp. and basaltic tuff indicative of the Carmel Range".
- Fabric class 2D, "of calcareous silty clay with white mica, basaltic fragments and heavy minerals probably originating from the northern coastal Levant or Cyprus".

According to Bettles, "the material of most of those fabric classes is of Paleocene-Eocene age, as indicated by the foraminifers it contains. Only the ceramics of fabric class 1C were made of Late Cretaceous (Senonian) marl".

Foraminiferous marls of Paleocene-Middle Eocene age are exposed along the Lebanese and north Galilean coast, between Sidon and Akko.[102] That is why Bettles' FC 1A, described by other scholars as "Phoenician clay", need not come from the Sarepta region alone, because it was used at various times to produce all kinds of pottery since at least the Iron Age.[103] However, worth emphasizing is the distinctness of those marls from the older horizons of lithologically similar rocks, especially Paleocene Taqiye marls and Senonian marls, identifiable by the presence of foraminifers.[104]

As for the Late Persian and early Hellenistic periods, we have indirect written evidence for the existence of wineries both in the Carmel area and in the region of Upper Galilee. The first case is confirmed by a carinated-shoulder jar found at Shiqmona, dated to the late Persian period, 4th century BC, with a Phoenician inscription which gives its contents as the wine from "Gat Carmel" ("Carmel winepress")[105]. Its fabric description has not been specified, but the vessel shape corresponds to Bettles type B1–B2.[106]

As to the Upper Galilee, a wine-making locality occurring in the written sources of ca. mid-3rd century BC is Baitanata ("Beth-anath" or "Beit Anat": the "House of Anat", named after a Phoenician deity); it is mentioned in the papyri from the famous Zeno archive found in the Fayyum in Egypt, specifically, in the account of Zeno's travel to Palestine in 259–258 BC.[107] Unfortunately, despite a number of different suggestions, an exact location of this estate, apparently belonging to Apollonios, a dignitary at the court of Ptolemy II, remains unknown; it must have been situated to the east/north-east of Akko, between Kadassa (Kedesh) and Akko (the latter re-named Ptolemais by that time).[108] The wine from Baitanata, praised for its quality comparable to that of the Chian wine,[109] was being shipped to Egypt (one papyrus mentions a shipment of 57 wine jars from the estate in question)[110] which strongly suggests that it was contained in the Phoenician-style carinated-shoulder jars (our group 1a), more suitable for transportation than the bag-shaped ones ("group 2a"). In this connection, one should question the statement by Berlin and Stone that the carinated-shoulder jars "in chalky and granular versions of semi-fine ware"

100 Gunneweg et al. 1986: 14, Table 6.

101 Those conclusions are corroborated by Gorzalczany's (2006) later study of Persian-period vessels found in the kilns of Tel Michal and amphorae discovered at Horbat Malta which, according to Gorzalczany (2008), were made of a mixture of *terra rossa* and rendzina soils rich in nummulitic chalk.

102 Cf. Sneh et al. 1998; Bettles 2003b: 148–149.

103 Cf. Cohen-Weinberger & Goren 2004; Stager 2011: 58, 101; Gilboa et al. 2015: 374.

104 Cf. Sneh 1998; Beydoun 1977: 332.

105 Elgavish 1994: 90, ill. 68.

106 Bettles 2003b, 116–117, fig. 4.11–12.

107 Pestman 1981: 264 (vol. XXI A) and map II (vol. XXI B), tracing the itinerary of Zeno. Kloppenborg 2006:367–368 gives 257 BC as the date of Zeno's visit to a Galilean estate.

108 According to Pestman 1981, vol. XXI B: map II, while Kloppenborg 2006: 369 seems to prefer to situate Beit Anat to the east of Kedesh.

109 Kloppenborg 2006: 368 quoting relevant papyri.

110 Kloppenborg 2006: 371 (PSI VI 594).

which they regard as local to Akko were probably used as containers for olive oil.[111]

An interesting phenomenon is the occasional occurrence of stamps on the handles of Late Hellenistic jars of our group 1b. It is not clear if they were applied by the pottery workshops owners or by some officials responsible for the control of the vessels' contents. In both cases, however, they are indicative of the area of their production. The stamps are in Phoenician[112] or in Greek, the latter (including three examples from Sha'ar-Ha'Amakim) unfortunately not deciphered, but their find spots around the Haifa bay point to the southern Phoenicia as their manufacturing area.[113]

The fabrics of bag-shaped jars (our group 2a) made in Galilee and adjacent areas during the Hellenistic period were summarized by Y. Alexandre. In her opinion, the bag-shaped jars occurred "in two different wares: a thicker buff ware and a thinner orangey-brown or pinkish-brown ware. The first group (...) was the latest appearance of the buff-ware jar tradition predominant in the Galilee since the Late Persian[114] and Early Hellenistic periods. (...) The buff-ware jar was the standard jar in the Hellenistic period at several sites (...). The second group of storage jars is made of thinner, orange-brown or pinkish-brown ware that was probably fired at a higher temperature." Alexandre quotes the parallels to this group as known from Gamla, the Hasmonean palace at Jericho, and from the Hasmonean stratum in the Jewish Quarter in Jerusalem. She also draws attention to the time span when white marl was used: "It has become clear that, whilst the buff-ware jars represent the end of an earlier tradition that first appeared in the Late Persian period and continued into the Early and Late Hellenistic periods, the brownish ware jars represent the beginning of a tradition that started in the Late Hellenistic period and continued into the Early Roman period."[115] One should add that this change in fabrics (but also in shapes) must have been connected with the conquest of the Galilee by the Hasmoneans (either Aristoboulos I or Alexander Jannaeus) at the turn of the 2nd century BC, resulting in a Jewish "colonisation" of that land.[116] That the inspiration for both the vessel shapes and the technology was coming from Judea, is confirmed not only by the parallels from Jericho and Jerusalem, but also by those from Gamla in the Golan Heights, a Jewish settlement established within the framework of the same political changes.

Regarding the manufacturing places of the jars in the Roman-period Galilee, they are much better identified today, starting with the rabbinic sources which mention the "Carmeli" wine (the wine from the Carmel area, continuation of the tradition of the "Gat Carmel" production), as well as the wine made in Sepphoris and Tiberias.[117] As to actual find places of the pottery workshops active in Galilee during the Roman period, Z. Safrai[118] lists: Beth Shearim (unpublished), Kefar Hananya[119] and Asochis (the latter based on a Talmudic mention). Additionally, the map published by Safrai[120] adds to the pottery-making sites also Shiqmona and Tel Bira, the latter in short distance to the north of Sha'ar-Ha'Amakim. The written sources give "the names of at least seven villages and cities that were involved in the wine industry in some fashion: Sepphoris, Tiberias, Kefar Sogane, Sallamin, Acchabaron, Beth Shearim and Gennesaret".[121]

In an extensive study of common pottery sampled at 19 excavated sites of the Roman Galilee and the Golan, that was carried out in the nineties of the 20th century, D. Adan-Bayewitz and M. Wieder[122] demonstrated that in the Roman-period domestic pottery was mainly made in three manufacturing centres of Galilee: Kefar Hananya (specialising in cooking vessels), Shikhin, and a smaller production centre, Yodefat. The time-range for the activity of each of those three centers was different, with Yodefat destroyed by the Romans in AD 67,[123] while Shikhin and Kefar Hananya continued to manufacture pottery throughout the Roman period.

According to the recent state of archaeological research, excavated remains of the kilns and/or wasters make it clear that the storage jars of the Roman period were manufactured at a cluster of localities situated in the central Galilee, specifically at Yodefat, Shikhin and Karem e-Ras (Kefar Kana).[124] Of these, the kilns of Yodefat and Kefar Kana (Kafr Kanna in northern Lower Galilee, to the south-east of Yodefat) were producing jars of the type described by Aviam as "ribbed neck jars" of the 1st century AD; their production continued till AD 67 when both villages were apparently destroyed by the Romans.[125] In Yodefat, where the remains of four pottery kilns together with ceramic wasters have been uncovered, the final date for this production is confirmed by the fact that jars parallel to those manufactured in the

111 Berlin & Stone 2016: 135 (commenting on their jars fig. 9.3:2–6 and fig. 9.7:1)
112 Berlin 1997b:77.
113 Finkielsztejn 2009: 140–142 (Ph 1–Ph 3).
114 Actually, in the opinion of the present writers, at least from the end of the Iron Age IIC, i.e. 7th/6th century BC.
115 Alexandre 2013: 14–15.
116 Aviam 1993: 453–454.
117 Safrai 1994: 132–133.
118 Safrai 1994: 209.
119 For a range of cooking-ware forms manufactured there, see Adan-Bayewitz 1993.
120 Safrai 1994: 206, fig. 46.
121 Strange 1977: 41.
122 Adan-Bayewitz & Wieder 1992; Wieder & Adan-Bayewitz 1993; Wieder & Adan-Bayewitz 1999.
123 Aviam 1993: 454.
124 Aviam 2014: 141–145, note 4 and the map.
125 Aviam 2014: 140–142, 145, and figs. 4–5.

local kilns were found in one of the rooms in association with some coins, the latest of which were dated to AD 64[126]. The pottery in question is composed of local reddish-yellow carbonate rendzina soil mixed with much less calcareous clayey red soil.[127] No wine presses have been discovered at Yodefat so far, but the oilve oil production have been attested,[128] which may raise a question of the contents of this type of jars: wine, olive oil or both?

At Shikhin, which was an important supplier of storage jars, the vessels were made of one of the three soil types: colluvial-alluvial soils, brown smectite grumusols, or pale rendzinas. No tempering admixture was used, whereas in Yodefat highly calcareous rendzina was enriched with an addition of *terra rossa*.[129] As to Khirbet Qana, the bulk of identifiable potsherds of the Late Hellenistic and Early Roman periods allegedly seems to have come from Shikhin and Kefar Hananya, although Edwards mentions "more recent evidence of pottery kilns at additional sites, some using the same forms as those made at Shikhin and Kefar Hananya".[130]

Another cluster of workshops manufacturing wine (and/or olive oil) jars of the Roman period have been identified in western Galilee to the east of Akko and close to Tell Keisan, specifically, at Yavor[131], Ahihud[132] and in Horbat Uza/ Khirbet Aiyadiya.[133]

Common pottery and jars discovered at the kiln site of Ahihud were made of at least four varieties of material described as: (1) *terra rossa* and ferruginous ooliths assigned to Kefar Hananya workshops[134]; (2) *terra rossa* and sand of a yellowish-brown silty matrix and quartz sea sand, assigned as local to Ahihud workshops[135], and (3) *terra rossa* and carbonate material, composed of *terra rossa* and calcareous streambed sand. Compared with group (2), the clay paste of (3) was less levigated. In the opinion of Avshalom-Gorni & Shapiro, some of those vessels could be copies of the Shikhin technology; storage jars made of this material are characterised by a thick grey core and relatively thin edges in the cross-section. And finally (4) non-homogeneous clay and *terra rossa* pellets made of calcareous rendzina – a soil rich in reddish oval pellets of different size and distinct silty texture. Sometimes the pellets are dark grey to black, having been fired in reduced-oxygen conditions in the kiln. They match the Yodefat group of pottery as described by Wieder and Adan-Bayewitz (1999). An analysis of 1,083 sherds from Ahihud, mostly from Stratum I in which two kilns were discovered, allowed the authors to identify the pottery produced at that site. Those were four types of 'barrel jars' (to use the terminology of the authors): the Yavor type (as already known from a site 3.5 km north-east of Tell Keisan), the local Ahihud type (4.2 km north-east from Tell Keisan), and two types, 1a and 1b, known from Horvat Uza (4.5 km north from Tell Keisan).

The petrography of some samples of different types of vessels, and from different periods discovered at Tell Keisan have been studied by several authors, specifically: Jonathan Glass (1980), Liliane Courtois (1980), as well as by Elisabeth Bettles (2003b) and, finally, by Paula Waiman-Barak and Ayelet Gilboa (2016) in the framework of their study of the Iron Age transport containers.

According to Glass (1980), among the Late Roman jars found at Tell Keisan, the white painted red amphorae ("Aiyadiya" type) and the white painted black ones ("Beisan" type), accounted for 91% of the total number of analysed sherds. These two groups differ by their petrography. The fabric of the "red" storage jars contains medium-size sand, up to 0.2 mm in diameter, composed of subrounded quartz and carbonates, embedded in a silty clayey groundmass. In addition, the sand contains flint, feldspars and a few hornblende grains. According to Glass, the raw materials similar to the red amphorae are available in the vicinity of Tell Keisan, but are also common at various other places along the coastal plain.[136] This author also points to the presence of similar products discovered near the Khirbet Aiyadiya/ Horbat 'Uza kilns,[137] 4.5 km north of Tell Keisan.

The paste of the "black" amphorae is composed of highly vitrified groundmass rich in silty quartz (0.05–0.08 mm), some coarse grains are also present. Light shale fragments are common too, reaching a size of 2 mm. The shale fragments themselves are also silty. In Glass' opinion, those two amphora types were produced in separate workshops: the red ones near the sand-rich Mediterranean coast, possibly in Khirbet Aiyadiya, the black ones further to the East.

L. Courtois (1980) studied Iron Age common pottery of the Iron Age I period, dated to the beginning of the 11th century BC – material found in pit 60667 (niv. 9c) as well as basket-handled amphorae found in level 4 and dated to the late 7th century BC. What she considered to be local ceramics, were jars

126 Aviam 2015: 118.
127 Aviam 2014: 144; Wieder & Adan-Bayewitz 1999: 339.
128 Aviam 2015: 113–114.
129 Wieder & Adan-Bayewitz 1999.
130 Edwards 2002, 110 and note 28.
131 Aviam 2014: 144; Avshalom-Gorni & Shapiro 2015: 76.
132 Avshalom-Gorni & Shapiro 2015.
133 Avshalom-Gorni 2009a, 2009b.
134 The authors claim that the presence of ferruginous ooliths is evidence of the connection of the material with the Lower Cretaceous rocks near Kefar Hananya, which is difficult to accept because landforms of this type are a common effect of laterite weathering, cf. e.g. Jones 1965.
135 According to the authors, the same material was used in Horbat Uza.
136 Glass 1980: 78.
137 As to the name, see Tatcher 2009: 105.

and "Plain White" ceramics. In macroscopic terms, those are heterogeneous, white-slipped ceramics with a grey core(?), containing white oval grains of chalk and brown clay grits. In thin section the raw material is rich in calcareous silt, some carbon matter containing recrystallised foraminifers, and spherical fine granules of iron oxides liberated during the destruction of the foraminifers. According to the author, this is a natural deposit forming a colluvium or a mixture of artificial sandy marl rich in biogenic elements, pigmented with iron oxides, mixed with brown nodules of clay rich in quartz (*terra rossa*), and weakened in various proportions by quartz sands with detritic shells.

As similar, but not identical, raw material the author regarded the marl rich in well-preserved foraminifers, pigmented with iron compounds, and containing grains of flints and lithothamniums. She also described a fabric rich in basalt grains and iddingsite (suggesting the provenance at the north of Tripoli in northern Lebanon).

The group of "painted ceramics" is made of marl rich in foraminifers, pigmented with iron compounds collected around clusters of those microorganisms. Fragments of chalk are observed. A micropaleontological examination allowed determining the age of this material at the Lower Eocene. Courtois assigns a similar type of material to Phoenician containers from Tyre and Sidon[138].

The basket-handle amphorae are made of very fine paste, rich in angular quartz sand, feldspar, limestone grains, micrite, radiolarite, and rare fragments of hyaloclastite. The finest sand (200 μ) includes pyroxene, biotite, zircon, epidote, garnet, and the most characteristic one, oxyhornblende. Courtois rejects the possibility of those amphorae being of local provenance upon comparing them with containers regarded as local to Keisan, proving a different raw material and technology. The origin of basket-handle jars from Tell Keisan was investigated by Gunneweg and Perlman[139] using the NAA method. According to those authors, "the chemical fingerprint at Kalopsidha (eastern part of Cyprus) is similar to the chemical composition of the Tell Keisan".

E. Bettles (2003b) performed a petrographic study of 19 carinated-shoulder amphorae from Tell Keisan. They were chosen on the criterion of form and fabric variability, as well as of the date of their respective contexts: Late Iron Age; Persian Period; Hellenistic Period; Persian-Hellenistic Period; Late Roman-Byzantine Period. In this group, she assigned as many as 17 specimens to Fabric Class 1A (her Sarepta group). Only two specimens, KS:22 of the Persian-Hellenistic Period and KS:29 of the Late Iron Age she identified as her Fabric Class 1D (Haifa bay?).[140]

Paula Waiman-Barak and Ayelet Gilboa (2016) examined 51 vessels from Tell Keisan dated to the Early Iron Age (end of the 2nd millennium BC), which included lentoid flasks of various sizes, carinated jars (and occasionally other forms of jars), Philistine-looking wares, and, in addition, two Phoenician Bichrome jugs and two red-painted jugs of unclear morphology. In order to determine their provenance, the authors employed petrography. They identified seven petro-fabrics:

A2 – coastal alluvium and non-calcareous clays (dark brown in PPl), mixed with *terra rossa* soil and limestone inclusions – rich in calcareous components, nari, limestones, microfossil algae, and fragments of eroded basalts the authors assigned as local to Tell Keisan;[141]

A3 – young soils mixed with non-calcareous dense clays (dark brown or yellowish in PPl), eroded *terra rossa*, and limestone with or without silty quartz inclusions were assigned to the Akko area;

B – Neogene marl with silt, quartz and marine biogenic debris was assigned to the southern Lebanese coast between Tyre and Sidon;

C – calcareous clays from Pleistocene wetlands, assigned to Dor or Shiqmona;

C/D – foraminiferous silty alluvials with limestone and large coastal quartz were assigned to the Carmel Coast;

D – foraminiferous silty alluvials with limestone and large coastal quartz were assigned to the northern Philistine Coast;

D/F – alluvial sediments with coastal sands with limestone and large coastal quartz were assigned to the southern coast of Philistia and north-western Negev.

Regrettably, the authors do not give specific grounds for identifying the provenance of individual groups of ceramics, an example being the suggested connection of petro-fabric C with "Pleistocene wetlands of Carmel Coast"; this remark also applies to most of the remaining "identified" provenances, including Petro-Fabric A2, supposedly produced in Tell Keisan.

Unlike the ceramics from Tell Keisan, no type of pottery from Sha'ar-Ha'Amakim, storage jars included, has been petrographically analysed till now. The present project is the first attempt at examining the jars, jugs and a couple of other ceramic products from that interesting site.

138 The description of the petrography of those vessels corresponds to that of group I.A1 in this work.
139 Gunneweg & Perlman 1991: 591.
140 Bettles 2003b: 294, Appendix IV.
141 Following Courtois 1980 and Aznar 2005.

5. Sha'ar-Ha'Amakim

5.1. Sampled pottery from Sha'ar-Ha'Amakim: typological and chronological considerations

The ceramic assemblage retrieved during the excavations of 1984–1998 at Sha'ar-Ha'Amakim, directed by A. Segal (University of Haifa), dates from the Persian/Hellenistic and Roman periods (4th/3rd century BC to 3rd/4th century AD); however, it includes also a number of potsherds of the Iron Age IIC found as residual in the layers of later periods[142]. Despite some suggestions that this might be the site of the Hellenistic-period Geba (Gaba),[143] the ancient name and the character of the site remain unknown, the more so that the excavations unvealed only a portion of the inhabited area of undetermined size.[144]

The essential part of the ceramic research conducted at Sha'ar-Ha'Amakim by one of the present authors (Jolanta Młynarczyk)[145] focused on typological and chronological aspects of the common-ware pottery, of which a major part are the jars for the storage of liquids. The vessels in question were divided according to their form, with some preliminary division into fabrics on macroscopic examination[146].

Most of the ceramic forms have been dated on the basis of parallels combined with the stratigraphic sequence of the Sha'ar-Ha'Amakim layers whenever such evidence was available. The comparisons made between the ceramic assemblage of Sha'ar-Ha'Amakim and those from other sites in northern Israel (Dor, Shiqmona, Akko and Tell Keisan; Jalame, Bet Shearim and Sepphoris; Gush Halav, Meiron and Khirbet Shema; Tel Anafa and Hippos – Sussita) lead to better understanding of the characteristics of pottery production in the western Galilee throughout several centuries.

While examined as chronological assemblages closely connected to the successive settlement phases (Phase A through F),[147], the Sha'ar-Ha'Amakim pottery appears to reflect historical development of the site.

The beginnings of the settlement must have dated back to the Iron Age IIC period (8th/7th century BC) as attested by the presence of small pottery fragments found in secondary contexts.[148] They include some jar rims of the later 7th century and into 6th century BC date (e.g. **Fig. 1:1**). However, no architectural remains could have been connected with this early phase.

The Persian-period ceramic assemblage is rather meager and consists mainly of storage jars. In a striking contrast with Tell Keisan situated nearby in the Akko plain, not more than 18 km from Sha'ar-Ha'Amakim, it contains virtually no Greek importations of any kind. This would suggest that, before the 3rd century BC, the site of Sha'ar-Ha'Amakim was a mere agricultural village, probably producing wine and/or olive oil. In the stratigraphy of Sha'ar-Ha'Amakim the Persian-period alongside the Early Hellenistic period are represented by Phase A. Besides, many fragments of jars typologically pertaining to this Phase were found as residual in some contexts of the later period.

The storage vessels of Phase A pertain to our shape groups 1a, 2a and 3a, of which the best recognizable are examples of group 1a representing three different rim/shoulder profiles. One of them is the

142 Młynarczyk 2009b; Burdajewicz 2015.
143 Dvorjetski 2009.
144 Segal et al. 2009.
145 The research project entitled "Between Phoenicia and Galilee: a study of local and imported ceramics from a Hellenistic and Roman-period site of Sha'ar ha-Amakim, Israel" conducted within the framework of the Andrew W. Mellon Foundation Research Fellowship Program at the W.F. Albright Institute of Archaeological Research in Jerusalem, December 2004–February 2005. See Młynarczyk 2009b.
146 For the first overview of jars from Sha'ar-Ha'Amakim (an archaeological and petrographic study), see Michniewicz & Młynarczyk 2017.

147 Młynarczyk 2009a.
148 Burdajewicz 2015:14, fig. 5 (for jar rims).

flat-shouldered jar with thickened out-turned rim and concave/convex body profile,[149] illustrated by **Fig. 1.2** and **Fig. 1.3**, both of them macroscopically described as pertaining to the Phoenician Semifine ware. This shape variant is known from many sites, mostly those situated along (or close to) the coast: Apollonia-Arsuf,[150] Tel Dor,[151] Shiqmona,[152] Tell Keisan,[153] Horbat 'Uza,[154] Akko,[155] Nahariya[156] and several others, but also inside the Galilee, e.g. Capernaum,[157] occasionally also in the south of the country.[158] It continued into the Early Hellenistic period, as proved by published finds from e.g. Akko[159] and Sidon.[160]

The second shape variant of group 1a are jars with a short upright rim triangular in section and rather short sloping shoulder ending in a flange (**Fig. 1:4**, not sampled, and a sample from Tell Keisan: **Fig. 12:9**); their fabric, white to pinkish white, can be described as "Light White ware". The best parallels come from Tell Keisan level 2b containing late Persian and early Hellenistic material,[161] from nearby Khirbet Kinniyeh,[162] and from Akko.[163] This shape variant occurs at several other sites within the region of Akko/Haifa bay, such as Horbat Uza, Gil'am, Shiqmona, but also Yokne'am on the Megiddo pass; H. Smithline must be right in stating that "the provenience of this variant is in the northern coastal plain and its hinterland").[164] As the finds from Apollonia-Arsuf dated to between mid-5th and mid-4th century prove,[165] this variant was occurring also further to the south.

The third shape variant of jars in group 1a has the shoulder sloping to a slight carination, a kind of short neck and everted rim **(Fig. 1:5**). One of the examples has a slight flange below the shoulder, another has a ridge below the "neck". They seem to pertain to the same group as jar rims from stratum Persian 2 (late 6th to mid-5th century BC) at Apollonia, which continued into the late Persian period (mid-5th to mid-4th century BC).[166] However, in the area of Akko this shape variant definitely continues (or perhaps even flourishes) into the early part of the Hellenistic period, to judge by the finds from Tell Keisan,[167] Akko[168] and Horbat 'Uza.[169]

Bag-shaped jars (group 2a) and jugs (group 3a) are represented in the contexts of Phase A by some fragments of rims. Both vessel shapes, which originate in the Persian period, share the same rim diametre and rim profile, thus when only a small section of the rim is preserved, it is almost impossible to identify the vessel form with any certainty. The predecessors of the baggy jars go back to the late IA IIC and the Persian periods, as attested by finds from a number of sites.[170] E. Stern classifies such jars as his type F1, distributed during the 5th–4th centuries BC "in the north of the country, in the centre and in the Sharon plain".[171] Indeed, one of their manufacturing places has been found at Tel Michal and dated to the Persian period.[172] In Apollonia-Arsuf they appeared in the period between mid-5th and mid-4th century,[173] and at Shiqmona in the late Persian-period stratum B (4th century BC).[174] At the site of Nahal Tut near Yokne'am (not more than 8–9 km to the south – south-west from Sha'ar-Ha'Amakim), jars of this shape were found in the context of the last quarter of the 4th century BC.[175]

Chronological Phase B at Sha'ar-Ha'Amakim[176] corresponding to the first half of the Hellenistic pe-

149 For the type, see Zemer 1977: 25 pl. 7, nos. 19–22 (5th-4th century BC); Stern 1982: 108–110, type H 6.
150 Tal 1999, fig. 4.13:22–23 from stratum Persian 1 (late 6th to mid-5th century BC) and fig. 4.26:2 from stratum Persian 2 (mid-5th to mid-4th century BC).
151 Stern 1995: 58–62 ("flat-shouldered jars"), many examples on figs. 2.7 and 2.8
152 Elgavish 1968: pl. LI, no. 106, Persian-period stratum.
153 Briend & Humbert 1980, pl. 7:3 and 5 (attributed to level 2, dated 380–150 BC), and pl. 18:1–1a and 4 (from level 3, dated to 580–380 BC, apparently in the Phoenician Semi-fine ware);
154 Smithline 2013, fig. 4.4:1–2 (stratum 11: Persian period).
155 Many examples from Persian-period stratum at Tell Akko, excavated since 2011.
156 Ovadiah 1993: 24*, fig. 3:9–10.
157 Loffreda 2008: 118, Tipo ANF 1a (Persian period, with parallels from elsewhere).
158 E.g., in Gezer: Gitin 1990, pl. 28:14 and 19–20 (5th–4th centuries BC).
159 Smithline 2013: 94, fig. 11:6–8; Berlin & Stone 2016: fig. 9.3:1–2 (3rd century BC)
160 Reynolds 2000: 388, fig. 1:3 (4th/3rd century BC).
161 Briend & Humbert 1980, pl. 7:1–2, 2a–b, and variants 3–3a; their early prototypes from level 3 dated to the 6th–5th centuries are items pl. 18:2–7.
162 Briend & Humbert 1980, pl. 17:23 with variants nos. 26 and 30 in two different fabrics.
163 Dothan 1976: 28–29, fig. 27.14, stratum 4 dated to the 4th century BC.
164 Smithline 2009: 138–140, fig. 4.4:6–12, commenting on Horbat Uza finds and quoting parallels from Keisan, Shiqmona, Gil'am and Yokne'am. At Yokne'am this variant occurs alongside the previous one, in the late 5th – early 4th century contexts, see Cimadevilla 2005, figs. IV.1:2–4, IV.4:1–4, IV.8:1–5 and 7–9, IV.9:1–2, IV.16 and photos IV.1–2.
165 Tal 1999, fig. 4.26:6–7 and fig. 4.40:7–11.
166 Tal 1999, fig. 4.13:1–4, and fig. 4.39:14.
167 Briend & Humbert 1980, fig. 10:7.
168 Dothan 1976: fig. 42:1 (attributed to the 4th century BC); Regev 2010: 123–124, figs. 1–2; Berlin & Stone 2016: fig. 9.3: 3–6 (3rd century BC), fig. 9.11:9 (late 3rd – mid-2nd century BC); fig. 9.20:10 (mid-late 2nd century BC, "white ware"), fig. 9.22:1 (first half of 1st century BC, Semi-fine).
169 Smithline 2009: 147, fig. 4.8:7–8.
170 E.g. Zemer 1978: 31–32 and pl. 8, nos. 25–26 (recovered from the sea at Dor and Atlit respectively); Briend and Humbert 1980, pl. 25: 6 and 9 from level 4 (650–580 BC).
171 Stern 1982: 104–105.
172 Singer-Avitz 1989, *passim*.
173 Tal 1999: fig. 4.25:1–12 and 15–16; fig. 4.40:3–6.
174 E.g. Elgavish 1968: pl. LX:143.
175 Alexandre 2006: 156 and fig. 50:1–10, fig. 52:1–3 and 8–12, fig. 53:12–17, fig. 60:2–18, fig. 61:4 and 9–15. For nearby Yokne'am see Cimadevilla 2005, figs. IV.8:6, IV.10, IV.16:8–10.
176 Młynarczyk 2009a: 49–50.

riod yielded a rich ceramic assemblage of the 3rd to 2nd centuries BC. Apart from masses of domestic pottery, it contained transport amphorae and fine wares imported from different areas of the Mediterranean (Cyprus, Rhodes, coastal Asia Minor, southern Italy) suggesting trade contacts and rather high material status of the inhabitants of what could have been a manor house(?) to judge by the architectural plan. A rich pottery deposit found in the fill of an abandoned rock-cut wine cellar ("cistern G/R") attests to a violent destruction of the house about the mid-2nd century BC.[177] A large part of this deposit consisted of restorable baggy jars (group 2a, **Fig. 5**) and water jugs (group 3a, **Fig. 6:1–3**),[178] with some residual fragments of jars of group 1a, including those of the late IA IIC.

The Sha'ar-Ha'Amakim examples of baggy jars correspond to variants 11.2 and 11.3 of the form broadly described by P. Lapp as "Large Cylindrical to Bag Shaped Jars with Rounded Base".[179] According to him, subtype 11.3 ("rounded rim") would date to between 200 BC and 29 BC, and subtype 11.2 ("squared rim") to between 175 BC and AD 68. The restorable jars from Phase B at Sha'ar-Ha'Amakim find close parallels in Hellenistic contexts at Shiqmona,[180] Tell Keisan[181] and at a considerable number of sites, situated in the coastal zone like Akko,[182] Dor,[183] Ramat Hanadiv[184] and Apollonia-Arsuf,[185] as well as inland, e.g. in Yokne'am,[186] Samaria[187] and Capernaum.[188]

The bag-shaped jars of group 2a from Sha'ar-Ha'Amakim pertaining to Phase B (which includes well-dated finds from "cistern" G/R) display several variants of everted rim profile such as triangular or oval-sectioned one. Most of the shape variants are virtually neckless, while some of them have a kind of a short strongly concave neck; the fragments with more pronounced neck may pertain to storage jugs (group 3a). Occasionally, the jars may have one or two ridges separating the shoulder from the rim.[189]

The ceramics of chronological Phase B also include some examples of jars representing the Hellenistic variant of shape group 1a such as is known from Akko,[190] Tell Keisan[191] and Capernaum.[192]

Chronological Phase C in Sha'ar-Ha'Amakim, considered to have spanned the second half of the 2nd century BC to slightly beyond the mid-1st century BC,[193] yielded examples of jars of shape groups 2a and 1b, accompanied by a number of residual finds of shape group 1a. Jars of shape group 2a continue into the 1st century BC; however, no example of entire vessel was found to enable description of the Late Hellenistic shape variant occurring in Sha'ar-Ha'Amakim. Such examples are known from a number of other sites, such as Shiqmona (second half of the 2nd century BC),[194] Caesarea ("Late Hellenistic Smooth-Walled Bag Amphora"),[195] Capernaum[196] or Gamla.[197] The neck is usually more pronounced than it was in the Persian or early Hellenistic periods.[198] One of the jars assigned to early Phase C (no. D 241 probably of the mid- to late 2nd century BC, not illustrated) has a large hole drilled through the wall right below its shoulder which has a faint ridge separating it from the neck. Commenting on the purpose of such holes occasionally present in wine jars, J.P. Oleson states that they "could have served (...) as an outlet for carbon dioxide produced during secondary fermentation, as an inlet for oxygen to promote maturing and development of a bouquet, or as a spout for pouring wine after the stopper had been removed".[199]

The jars of group 2a present in Sha'ar-Ha'Amakim in the contexts of Chronological Phases A, B and C, and also found (as residual?) in phase D1 (see below), were made of more granular fabrics than those of groups 1a–1b; sometimes they were fired with a core of a different colour, and normally had a pale-coloured surface. Visually, their fabrics can be described as gritty orange, pale brown, pale pink, light greyish brown etc, often with a range of mineral inclusions (white, light grey, dark grey, brown). However, a few examples of jars of group 2a from Sha'ar-Ha'Amakim can be identified as the Light White ware, the same as the one common in group 1a examples at Tell Keisan and Tel Akko.

Fragments of jars pertaining to shape group 1b (**Fig. 3 and 4:1–2**) made their appearance in chronological Phase C of Sha'ar-Ha'Amakim; it is to be noted that not a single piece of this shape was found in the "cistern" G/R sealed at ca. 150 BC, while a

177 Młynarczyk 2000; Młynarczyk 2009b: figs. 2–4 and fig. 5:1–8.
178 Młynarczyk 2009b: fig. 2:1–3 (jars) and fig. 2:4–7 (jugs).
179 Lapp 1961: 146–151.
180 Elgavish 1968: pl. LX:143.
181 Briend and Humbert 1980: pl. 8 (jars) and 9 (jugs), Late Persian to mid-Hellenistic.
182 Smithline 2013: fig. 4.8:1–6; Berlin & Stone 2016: fig. 9.7:2 (3rd century BC), fig. 9.13:2 and fig. 9.19:2 (mid – late 2nd century BC), fig. 9.22:4 (first half of 1st century BC).
183 Guz-Silberstein 1995: 312, figs. 6.35, 6.37, type Jr 1.
184 Silberstein 2000: pl. I:1–4, 6–7, 9.
185 Fischer and Tal 1999: fig. 5.8:4 and fig. 5.15:2–5, 8, 10–11 from early Hellenistic contexts.
186 Avissar 1996: fig. X.5:1–2 and X.6:1–4.
187 Zayadine 1966: pl. XXVI and XXVII:1–7, 10.
188 Loffreda 2008: 119, tipo ANF 2.
189 Cf. Briend & Humbert 1980: pl. 8:1, 1e–f (level 2, F 2003).
190 Regev 2010: fig. 1:5–6 (Form 1b); Smithline 2013: fig. 11:6–8.
191 Briend and Humbert 1980: pl. 7:8.
192 Loffreda 2008: 118–119, tipo ANF 1b.
193 Młynarczyk 2009a: 50.
194 Elgavish 1976: 74–75, fig. 6:19 and pl. 15E.
195 Oleson et al. 1994: 145, fig. 54 C 52 (Deposit 7).
196 Loffreda 2008: 119–120, Tipo ANF 3 and Tipo ANF 4.
197 Berlin 2006:48, figs. 2.22, 2.23.
198 Gitin 1990: pl. 39: 6–7 from Gezer.
199 Oleson et al. 1994: 20.

number of fragments came from chronological Phases D and E (in the latter phase apparently present as residual). All the fragments classified as pertaining to shape group 1b have been macroscopically identified as representing Phoenician Semi-fine ware, with one possible exception. This means that the jars in question were coming from the same manufacturing region(s) as the majority of jars shape group 1a found in the Galilee. Sha'ar-Ha'Amakim yielded three examples of rectangular stamps impressed on the twisted handles (e.g. **Fig. 3:7**) which, unfortunately, were detached from jars of this shape group.[200] The stamps are inscribed with Greek letters including a monogram followed by an abbreviation(?); however, they haven't been deciphered yet. Single examples of the same stamp (each from a different die) come from two other places in the Haifa Bay: Kfar Samir/Castra (a part of the present-day Haifa) and the neighbourhood of Akko, while a third one is kept in the Graeco-Roman Museum in Alexandria.[201]

The parallels from other sites, where dated, are said to have first occurred in the second half of the 2nd century BC. Among them is the "Semi Fine Baggy Jar" type at Tel Anafa in Hula Valley, present there by ca. 125 BC.[202] At Shiqmona such jars come from a destruction layer dated to between 130 and 125 BC.[203] They have pear-shaped bodies of varying sizes, which are otherwise identical: knob base, twisted handles, thick outward folded rim and shoulder which can be either slightly convex or sloping towards a slight carination. The latter are direct descendants of our shape group 1a, and are stylistically earlier than those of group 1b which have convex shoulder devoid of carination, like the jars from Tel Anafa. Also at Dor the jars comparable to those from Shiqmona and classified by Guz-Zilberstein as Type JR 3 (even if they embrace two different shoulder profiles) occur in contexts dated to the second half of the 2nd century BC.[204] They are present at Ramat Hanadiv,[205] Yokne'am ("neckless ribbed storage jar with thickened outward folded rim")[206] and, of course, in Akko in the contexts dated to between the mid-2nd century and second half of the 1st century BC.[207]

Worthy of note is the fact that in the above-mentioned destruction layer at Shiqmona (ca. 130–125 BC) the jars of our shape group 1b occur alongside those of shape group 2a; the ratio of examples of group 1b to those of 2a has been estimated as ca. 2:1.[208]

In the chronological Phase D1, that is, after the mid-1st century BC and during the reign of Herod the Great, the Roman-period type of baggy jars (shape group 2b) made its appearance at Sha'ar-Ha'Amakim.[209] The presence of several variants of this shape group covers Phases D1-D2, E and F.[210] Among the sampled material stratigraphically attributed to Phase D1 ("Herodian"), there are nine examples of baggy jars of the Hellenistic type (group 2a) *versus* two examples of the late Phoenician type (group 1b) and only three examples of the Roman-type baggy jar (group 2b); additionally, one jar rim is a transition between a late form of group 2a and 2b (**Fig. 10:6**). The jars of shape group 2b become definitely dominant in Phase D2 dated to the first half of the 1st century AD,[211] followed by Phase E dated to the second half of the 1st century AD and into the 2nd century AD;[212] Phase E would also cover the years of the Jewish Revolt in the Galilee and the following decades. That Sha'ar-Ha'Amakim was a Jewish settlement by that time is evidenced by finds of the fragments of chalk vessels notably including fragments of characteristic *kallal* vessels for ritual purification.[213]

The final period of habitation at Sha'ar-Ha'Amakim (Phase F) has been dated to between the 2nd and the 3rd/4th centuries AD by the material found in unsealed Stratum I and in the fill of a water cistern ("Cistern D"). The latter, apparently in use down to the first half of the 4th century AD, contained a rich deposit of common-ware forms, mainly jars, jugs and cooking pots. Most ceramics pertained to Phase F,[214] with some residual objects of Phase E (1st/2nd centuries AD),[215] perhaps also of Phase D2.

The standard fabric of the jars of the later 1st century BC[216] and those of the 1st–2nd centuries AD[217] is macroscopically very dense, thin-walled and of extremely "metallic" feel, with full or partial ash-grey core and white mineral inclusions seen mostly as

200 Finkielsztejn 2009: 140–142.
201 Finkielsztejn 2009: 141–142.
202 Berlin 1997a:155, PW 480–483, with references indicating the distribution of the type.
203 Elgavish 1974: pls VI, XIV, XVII, XIX and XXIII; Elgavish 1976: 65–67, 74, pl. 15:D.
204 Guz-Zilberstein 1995: 312, Type JR 3, fig. 6.38:7–9.
205 Silberstein 2000, 421–425, pl. II:1–11.
206 Avissar 1996, 54, fig. X.5:5.
207 Avshalom-Gorni 1999: fig. 24:9 (7); Regev 2010: 122 and fig. 1:1–4, Form 1a; Berlin & Stone 2016: fig. 9.13:1 and fig. 9.19:1 (mid- to late 2nd century BC), fig. 9.22:2–3 (first half of 1st century BC), fig. 9.24:1 (second half of 1st century BC, "probably residual").
208 Elgavish 1976: 74, fig. 6:19; Elgavish 1994: 101, fig. 77.
209 Fernandez 1983: T 1:3 (50 BC–150 AD).
210 For the stratigraphy of Phases D through F, see Młynarczyk 2009a: 50–54.
211 With jars Fernandez 1983: T 1.3 (ca. 50 BC–AD 150).
212 With jars Fernandez 1983: T 1.3 (ca. 50 BC–AD 150) and T 1.2 (AD 50–150).
213 Burdajewicz 2009:203–206, fig. 1:1–4.
214 Młynarczyk 2009b: fig. 7:7, possibly to be identified with Diez Fernandez 1983: type T 1.8 (1st/2nd to 2nd/3rd century AD) or/and T 1.9 (late 2nd to early 4th century AD); close to Johnson 1988: fig. 7–53, no. 809 of the same fabric.
215 Młynarczyk 2009b: fig. 7:6, corresponding to Diez Fernandez 1983, type T 1.2, dated to ca. 50–150 AD.
216 Diez Fernandez 1983: 181–182 and 229, T 1.3, with *floruit* between 50 BC and AD 50; see Młynarczyk 2009b: fig. 7:1.
217 Diez Fernandez 1983: T 1.8 and T 1.7 respectively; see Młynarczyk 2009b: fig. 7:2 and 3.

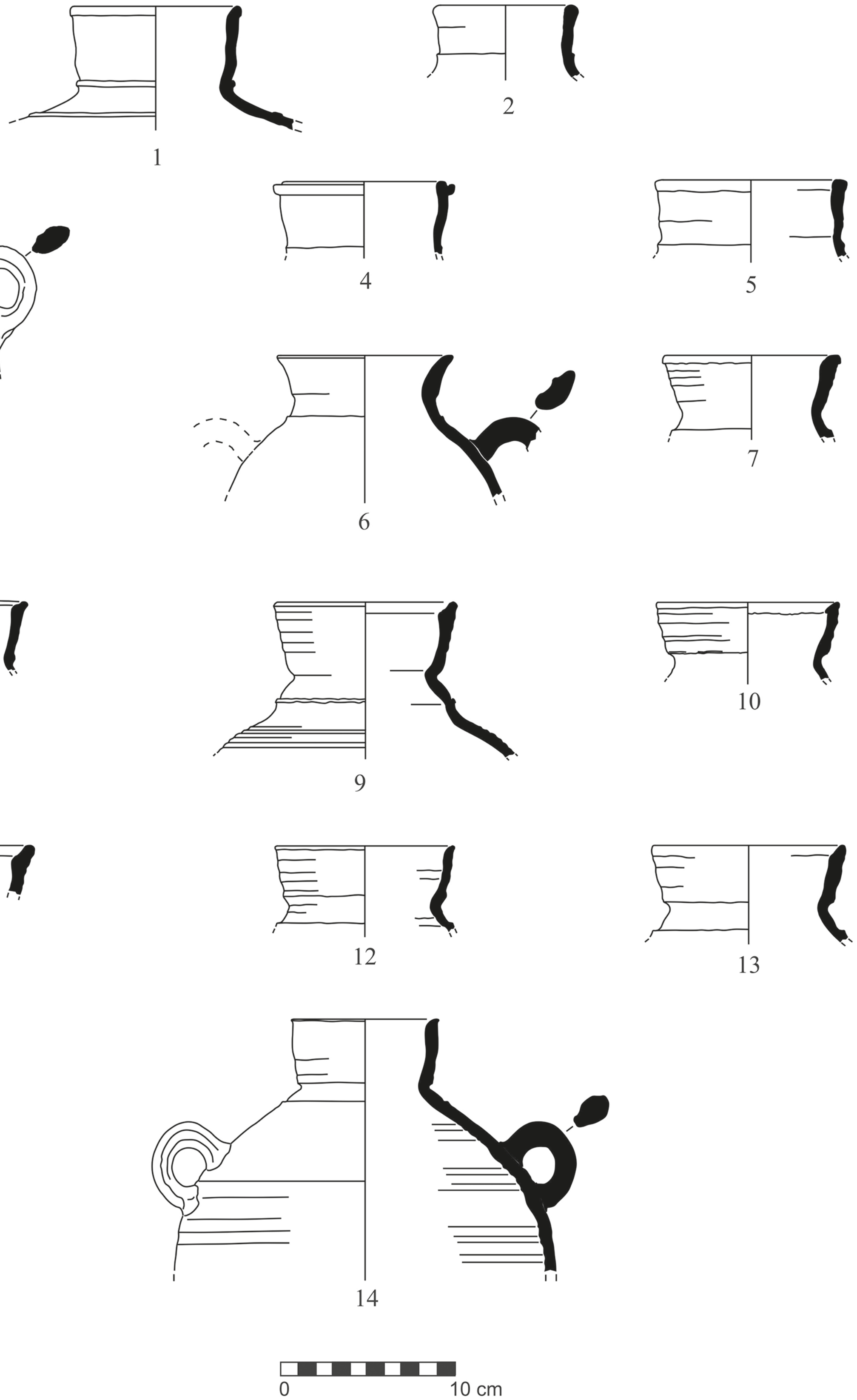


Fig. 10. Examples of Early Roman jars from Sha'ar-Ha'Amakim. No. 1: inv. 518.1 (not sampled); No. 2: inv. 854.2 (**SE-134**); No. 3: inv. 856.1 (**SE-90**); No. 4: inv. 919.7 (**SF-108**); No. 5: inv. 800.3 (**SF-110**); No. 6: inv. 939.8 (**SD1-70**); No. 7: inv. 934.4 (**SE-101**); No. 8: inv. 936.10 (**SD2-74**); No. 9: inv. 923.1 (**SC-36**); No. 10: inv. 936.9 (**SD2-73**); No. 11: inv. 937.8 (**SD2-85**); No. 12: inv. 947.1(not sampled); No. 13: inv. 921.2 (not sampled); No. 14: inv. 875.11 (not sampled). Drawn by Mariusz Burdajewicz

eruptions to the surface which is beige, pale pink, light greyish brown or reddish brown. Some jars preserve remains of a thin and flaky beige slip or surface wash. Two notable exceptions should be mentioned, though. One of them is rim **Fig. 10:6** of Phase C/D1 made of rather soft and gritty dark reddish brown fabric; its form is transitional between our shape group 2a and the earliest variant of group 2b. Another interesting case is rim fragment **Fig. 10:8** which represents an early variant of shape group 2b (Fernandez T 1.3) found in a context of Phase D2. Unlike the other examples of this particular type with their characteristic "metallic" firing, this one is of a "white fabric", macroscopically corresponding to the "Light White ware" of a number of jars of the Persian and Hellenistic periods (shape groups 1a and 2a). Thus, these two jar fragments are important testimony to the transition from the Hellenistic to Roman-period shape of the baggy jar (**Fig. 10:6**), as well as to a survival of the Hellenistic technology in production of a Roman-period shape of jar (**Fig. 10:8**).

Subsequently, in the 2nd/3rd century AD and later, the jars present at Sha'ar-Ha'Amakim have no grey core anymore, their break assuming the hues of red with abundant white grits, the surface fired to dark pink, orange-red or reddish brown.[218]

For the Early Roman period, the best parallels to our jars are provided by the products of Yodefat, a Jewish settlement destroyed by the Romans in AD 67 and never rebuilt, where pottery kilns were found.[219] The "Yodefat type" is common at Sha'ar-Ha'Amakim during chronological Phases D1 to E (see **Fig. 8:1** and **Fig. 10:1, 7–14** and probably **Fig. 11:7**). In Sepphoris this type appears in ceramic assemblages dated to before AD 70,[220] while it is entirely absent from Jalame, where the earliest ceramic finds may have been of the 2nd century AD.[221] Allegedly, the same type of jars was being fired in two kilns discovered at Karm er-Ras site of Kafr Kanna (to the south-east of Yodefat and east of Sepphoris).[222] It is fairly certain that the same type was manufactured in Shikhin just about 2 kilometres from Sepphoris. The distance between Sha'ar-Ha'Amakim and Yodefat (ca. 19 km) is comparable to that between Sha'ar-Ha'Amakim and Sepphoris (ca. 17 km), so it is difficult to tell which of the two sites, if any, may have been supplying Sha'ar-Ha'Amakim in jars. However, given these distances, it is more probable that the jars found in Sha'ar-Ha'Amakim were manufactured at a place situated much closer to the site, e.g. in Beth Shearim just 2–3 km from Sha'ar-Ha'Amakim, where the existence of a pottery workshop of an unspecified period was mentioned.[223]

The parallels to the examples of shape group 2b assigned to our chronological Phase E (second half of the 1st century AD and later, such as **Fig. 11:1–4**) come from Shikhin[224] and from its neighbour Sepphoris[225] as well as from the pottery workshops of Yavor and Ahihud, both in the vicinity of Akko.[226] As regards the forms of jars attributed to chronological Phase F of Sha'ar-Ha'Amakim (**Fig. 11:8–13**), their close parallels are found in Ahihud and in Stratum 9 (AD 310–330) at Horbat 'Uza.[227] Actually, the kiln site of Ahihud pertained to the cluster of sites situated less than 10 km to the east of Akko, embracing also Yavor and Horbat Uza; all the three sites apparently began their activity as jar manufacturing centres in the middle Roman rather than the Early Roman period, that is, from the mid-2nd century AD on.[228] The presence of these parallels does not suggest any import of jars to Sha'ar-Ha'Amakim from the sites in question; it just illustrates standardisation of the jar shapes and perhaps also of their fabrics. Comparable finds from Sepphoris have been dated to the 2nd–3rd centuries.[229] Some parallels to the jars of our chronological Phase F come also from Jalame which is basically a Late Roman site, situated at a distance of ca. 3 km to the west of Sha'ar-Ha'Amakim.[230] The end of Phase F should be set within the first half of the 4th century AD, as the latest variants of jars' shape group 2b from the site seem to slightly precede (or overlap?) the jar form occurring in the destruction layer of the Villa of Dionysos in Sepphoris, the latter dated to ca. mid-4th century AD.[231]

There are a few examples of jars (e.g. **Fig. 8:3, Fig. 11:5**) which do not exactly fit the existing typologies of wine jars. They appear to be smaller than the average and at least some of them, specifically those found in Cistern D (**Fig. 8:3**) corresponding to chronological Phase F, have a horizontal white band (or two bands) painted at ca. mid-height of the body

218 Diez Fernandez 1983: T 1.8 and T 1.9.

219 For the Yodefat type of jar, see Avshalom-Gorni & Getzov 2002: 77, fig. 5.1: 4–7; Aviam 2014: 142, fig. 5; Aviam 2015: 114 and 118; Avshalom-Gorni & Shapiro 2015: fig. 10, no. 1.

220 Balouka 2004:37, pl. 2:1–2.

221 Johnson 1988:214, no. 762.

222 Aviam 2015: 118.

223 Safrai 1994: 209.

224 Ceramic vessels made in Shikhin were praised in the Talmud, cf. Neubauer 1868:202.

225 Balouka 2004:pl. 2:3, allegedly continued in Sepphoris until 3rd/4th century.

226 For the Shikhin type of jar, see Avshalom-Gorni & Getzov 2002: 77, fig. 5.1:8–12, tentatively dated to AD 63–135; recently also Avshalom-Gorni & Shapiro 2015: fig. 10, nos. 3–3a.

227 Avshalom-Gorni & Shapiro 2015: fig. 10, no. 6 (type "Ahihud jar"), nos. 7 and 9 (type "Uza 1a jar"), and 10 (type "Uza 1c").

228 See Avshalom-Gorni & Shapiro 2015: 76–78 (the typology of the jars, fig. 10:6 and 7, 9) and 80 (discussion of the chronology).

229 Balouka 2004: 37, pl. 2:5.

230 Cf. Johnson 1988: fig. 7–52, nos. 785 and 787–788; fig. 7–53, no. 811 (Late Roman development of our fig. 10:10–12).

231 Balouka 2004: 39, pl. 4:2–4, seemingly developments/descendants of Sha'ar-Ha'Amakim jars Fig. 10:9–12.

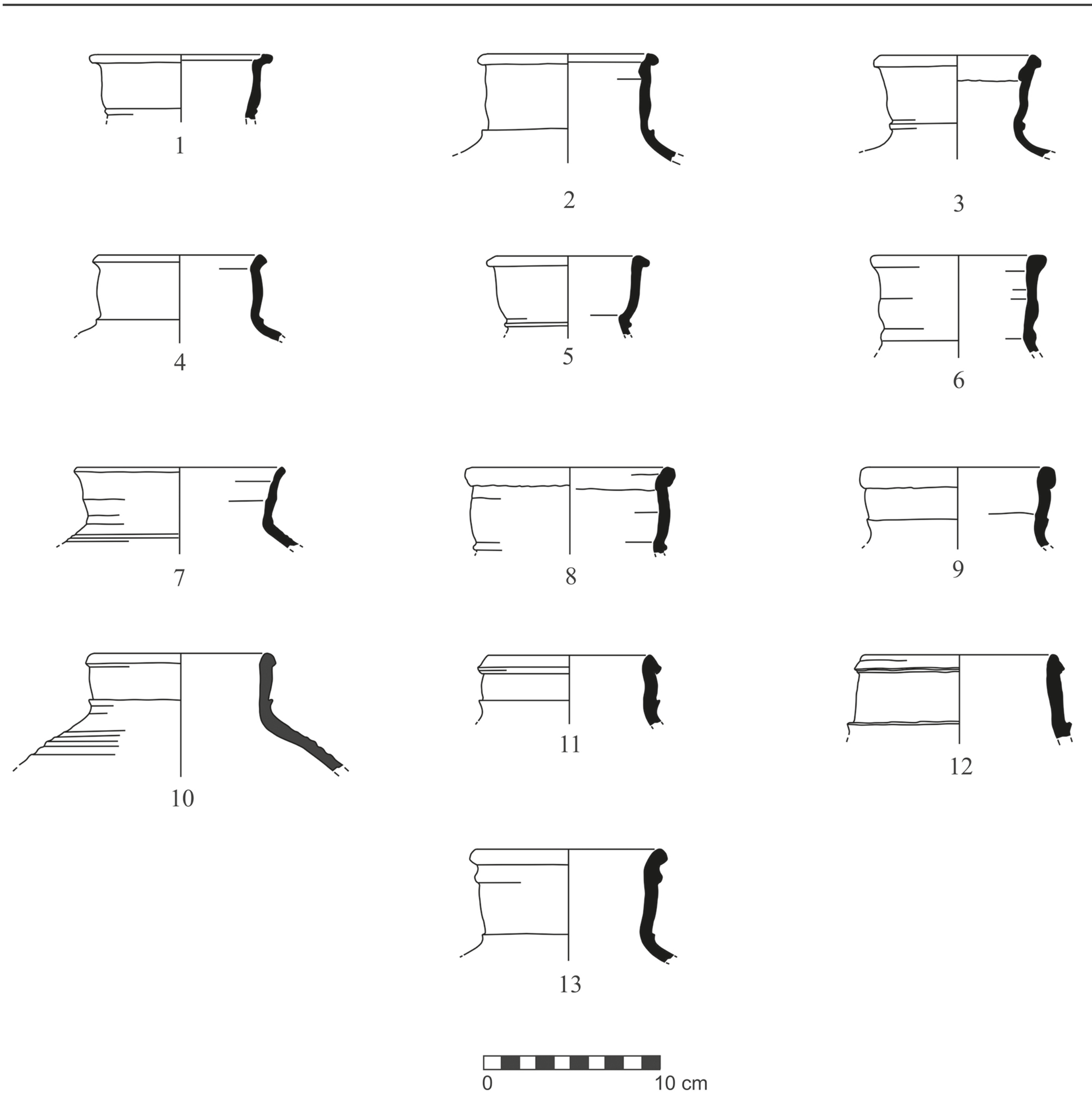


Fig. 11. Examples of Roman jar fragments from Sha'ar-Ha'Amakim. No. 1: inv. 896.6 (**SX-141**); No. 2: inv. 932.10 (**SFx-118**); No. 3: inv. 861.1 (not sampled); No. 4: inv. 801.4 (**SE-99**); No. 5: inv. 950.2 (**SF-107**); No. 6: inv. 626 (**SDc-131**); No. 7: inv. 954.1 (**SD1-121**); No. 8: inv. 919.4 (**SF-104**); No. 9: inv. 919.6 (**SF-124**); No. 10: inv. 871.11 (**SFx-149**); No. 11: inv. 932.11 (**SFx-117**); No. 12: inv. 919.5 (**SF-105**); No. 13: inv. 210.1 (not sampled). Drawn by Mariusz Burdajewicz

(three such body sherds have been sampled for physico-chemical analysis: SDc-44, SDc-47 and SDc-50). It is probable that these jars were containers for olive oil which would be destined not for domestic use but perhaps for a tithe. A 5th(?) century AD mosaic floor of the synagogue in Sepphoris depicts such jar as a part of the daily offering alongside flour and a lamb. The jar's surface is black with a white horizontal band at its mid-height and it is described in Hebrew as "shemen" (oil).[232] One should note that, as we mentioned above, Sha'ar-Ha'Amakim in the Herodian and Roman periods, unlike in the Persian and Hellenistic periods, must have had a Jewish population. Besides, according to the Mishna (*Kelim*, 11, 2), the Galilean potters were making a special kind of containers destined for the olive oil.[233]

Examples of shape group 3b at Sha'ar-Ha'Amakim come from the contexts of chronological Phases E and F, the latter represented mainly by finds from the water cistern in area D (**Fig. 6:4–5**) which points

[232] Weiss & Netzer 1996, 1998:20–21.

[233] Neubauer 1868: 180.

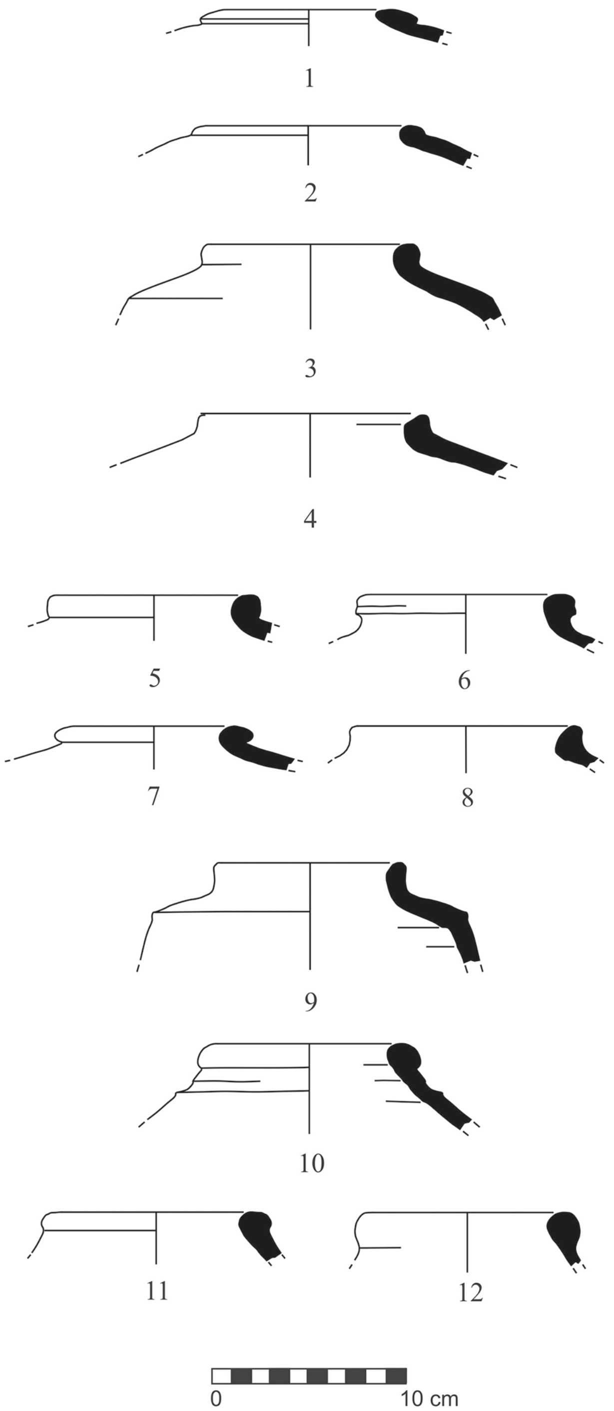


Fig. 12. Select samples from Tell Keisan. No. 1: TK-191; No. 2: TK-173; No. 3: TK-172; No. 4: TK-185; No. 5: TK-175; No. 6: TK-186; No. 7: TK-169; No. 8: TK-183; No. 9: TK-182; No. 10: TK-190; No. 11: TK:176; No. 12: TK-218. Drawn by Mariusz Burdajewicz

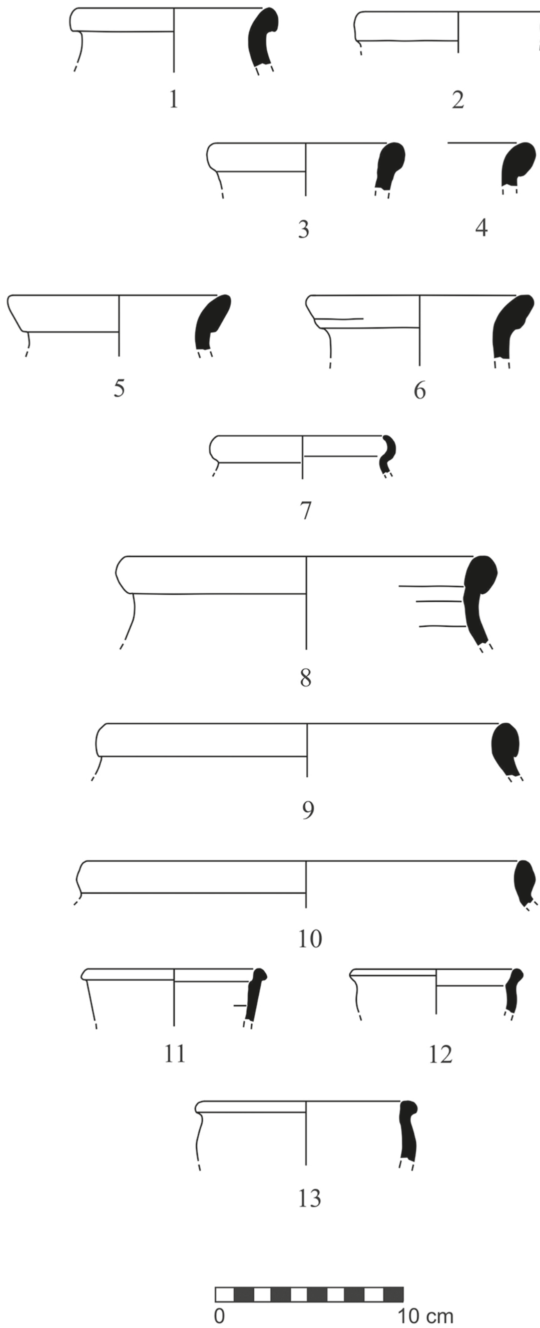


Fig. 13. Select samples from Tell Keisan (continued). No. 1: TK-177; No. 2: TK-192; No. 3: TK-180; No. 4: TK-184; No. 5: TK-171; No. 6: TK-170; No. 7: TK-193; No. 8: TK-187; No. 9: TK-178; No. 10: TK-179; No. 11: TK-174; No. 12: TK-189; No. 13: TK 188. Drawn by Mariusz Burdajewicz

to their use as dipper jugs. With slightly convex bottoms and wide necks, they are very thin-walled, macroscopically resembling the fabrics of jars of shape group 2b.

Finally, a relatively small group of fragments pertain to jars of shape group 1c (e.g. **Fig. 4:3–6**); none of them comes from any stratified context, but according to the accompanying material and the overall chronological phasing of the site, they probably date from the 1st and 2nd centuries AD (that is, to chronological Phases D2, E, and early Phase F). Several regional parallels to that shape variant can be referred to, none of them dated with any precision, among them finds from the Roman-period Shiqmona,[234] Yokne'am,[235] Ramat Hanadiv.[236] The fragments of jars **Fig. 4:5–6** resemble by their form the Tyrian holemouth amphora of the late 2nd century AD[237] or early 3rd century AD,[238] the examples of which have been known also from the coastal sites of Shiqmona[239] and Akko.[240]

The symbols for the samples from Sha'ar-Ha'Amakim listed below have been composed of the following elements:

"S" as an initial for Sha'ar-Ha'Amakim is followed by the letter marking the chronological phase, specifically: A, B, C, D1, D2, E, F; thus for instance: SA, SC etc. An exception are the samples of vessels from the cistern in area D which are marked as SDc, where the letter "D" refers to the excavation area and not to the chronological phase, with the letter "c" for "cistern". Similarly, the samples from the fill of the rock-cut underground cellar attributed to Phase B are marked as SBc with "c" for cistern/cellar. The un-stratified finds receive the letter "x": thus, e.g. SFx mean the potsherds attributed to the chronological phase F, but found in un-sealed contexts, and SX are the ceramics found without any contextual indication as to their chronology, and dated merely on the basis of *comparanda*. Finally, the numbers indicate the running number of samples as registered for the physico-chemical analyses.

234 Elgavish 1977: 70, fig. XIX:142–144 and 155.

235 Avissar 1996: 74, fig. XII.7:7.

236 Calderon 2000: 92–93, pl. I:28.

237 Reynolds 1997–1998: 81, fig. 200. A fragment of a comparable amphora from the nearby Jalame (Johnson 1988: fig. 7–50, no. 747, undated) is made of a "fine red clay with pale yellow slip". See also Reynolds 2005: pl. 12, figs. 89–91 ("Tyrian amphorae of the Roman period"); Avshalom-Gorni & Getzov 2002: 79, fig. 5.2:4 (from Yodefat).

238 Reynolds 2000: 390, fig. 8:44.

239 Elgavish 1977: fig. XIX:145–148.

240 Avshalom-Gorni 1999, fig. 24:21–22.

5.2. List of samples from Sha'ar-Ha 'Amakim

The list is arranged by: (a) chronological phase, (b) sample number (followed by excavation number).

Sha'ar-Ha'Amakim Chronological Phase A (Late IA IIC and Persian to Early Hellenistic periods)

SA-1 (C 924.1)**:** body sherd with handle root (group 2a), incorporated in the construction of a domestic oven). Fabric described as close to "Light White Ware": pale pink, spongy, white and black grits; surface white. Early Hellenistic. **SG: IV.A.**

SA-2 (F/G 864.7): short out-turned rim of jar (group 1a). Fabric described as Phoenician Semi-Fine ware; Persian period? S**G: I.A1.**

SA-3 (O 636) rim of storage jug (group 3a). Fabric pale pink, with tiny voids and tiny white (and red?) inclusions, surface white. Early Hellenistic. **SG: IV.A.**

SA-4 (F/G 864.a): handle of jar (group?). Fabric very gritty light red with many small voids and some white grits (up to some large); very pale yellow ("buff") slip. Late IA IIC? **PG: V.**

SA-6 (F 192.2, **Fig. 1:2**): body sherd of jar (group 1a). Fabric "buff", with red grits. Early(?) Persian period. Cf. Młynarczyk 2009b, fig. 1:1. **SG: I.A1.**

SA-7 (H 943.2): jar rim of form comparable to **Fig. 1:1** (group 1a). Fabric pale beige, spongy (some tiny white grits and occasional red ones), surface very smooth, almost white, with faint traces of pale red "paint". Late IA IIC period. **SG: IV.H.**

SA-10 (H 943.4): out-turned rim and neck of jar (group 2a). Fabric light brown with white, black and rare red grits; surface wet-smoothed, very pale brown, almost white. Persian period. **SG: IV.C.**

SA-12 (O 617.a): rim fragment of jar (group 2a). Fabric light brown, rather dense, with tiny white (and black?) grits, surface pale grey. Hellenistic period (in this context, Early Roman intrusion). **PG: V.**

SA-120 (F/G 864.13, **Fig. 7:1**): rim of jar, upright, just slightly out-turned (group 2a). Fabric very pale brown with voids, some dark grey grits and fewer small white ones, surface as the break, rough. Persian(?) period. **SG: IV.D.**

SA-123 (F/G 864.8, **Fig. 2:1):** rim of jar (group 1a). Fabric brick red with many voids and small white grits, occasionally up to large and very large lumps; surface coarse, fired from very pale brown (almost white) to pale red. Late IA IIC period(?). **PG: VI**.

SA-126 (H 943.1, **Fig. 1:1):** rim of jar (group 1a). Fabric light red with many small to medium-sized white grits and some red "dust"; surface wet-smoothed, pale pink. IA IIC/III period. **SG: I.A1.**

SA-127 (H 943.5, **Fig. 7:6):** out-folded (flanged) rim and neck of jar (group 2a). Fabric gritty pale reddish brown with some small light grey and white grits; surface pink, gritty in feel. Persian period. **SG: I.A2.Eo ("Eocene").**

SA-128 (F 192, **Fig. 2:2**): rim of *pithos* (rather than jar) (group 2a/4). Fabric with sandwich firing: light red outside, dark brownish grey inside, with many large and small pale grey rounded grains; surface pale orange-pink. Late IA IIC(?) period. **SG: I.A2.Cr ("Cretaceous").**

SA-130 (O 631, **Fig. 2:3**): jar rim (group 2a?). Fabric pale yellowish pink with some rectangular white and grey grits and some voids; surface wet-smoothed, light yellowish pink. Persian/Hellenistic period. **SG: I.A2.Cr ("Cretaceous").**

Pertaining to Chronological Phase A, but found as residual in "cistern" G/R (in a mid-Hellenistic context):

SA-5 (G/R 897.4): rim of jar (group 1a). Fabric pale beige, with some tiny white grits and occasional red ones; surface smooth, almost white. Persian period or earlier(?). **SG: IV.H.**

SA-8 (G/R 910.13): rim of jar (group 1a). Fabric described as Phoenician Semi-Fine ware. Persian or Early Hellenistic period. **SG: I.A1.**

SA-9 (G/R 905.2a): rim of jar (group 1a). Fabric very pale brown with voids, some dark grey grits and fewer small white ones, surface colour as the break. Persian or Early Hellenistic period. **SG: IV.D.**

SA-11 (G/R 908): jar handle fragment, group 1a. Fabric described as Phoenician Semi-Fine ware. Persian or Early Hellenistic period. **SG: I.A1.**

SA-13 (G/R 908.17): rim of jar (group 1a). Fabric very granular yellowish pink with some small white grits and voids, surface rather smooth, of the same colour. Persian or Early Hellenistic period. **SG: I.A1.**

Sha'ar-Ha'Amakim Chronological Phase B (Hellenistic, to ca. mid-2nd century BC)

All the samples in this group come from the fill of "cistern" G/R (hence "c" in the symbol for every sample).

SBc-14 (G/R 887): handle fragment of jar (group 2a). Fabric very pale brown with large white grits and smaller black ones. Hellenistic period. **PG: V.**

SBc-15 (G/R 887.13): body sherd of jar (group 2a). Fabric gritty pale reddish brown with some small light grey and white grits; surface pink, gritty in feel. Persian period. **SG: I.A2.Eo.**

SBc-16 (G/R 891.a): body sherd of jar, misfired, with iron residue on the wall (group 2a). Fabric light grayish brown with voids, black and white grits, surface very pale brown, gently ribbed, "pitted", with occasional white eruptions; macroscopically, the same fabric as SBc-24. Hellenistic period. **SG: IV.C.**

SBc-17 (G/R 905.14): rim fragment of jar (group 2a). Fabric pale greenish grey with lime eruptions. Hellenistic period. **PG: V.**

SBc-18 (G/R 883.32): rim fragment of jar (storage jug?) (group 2a or 3a). Fabric very pale brown, close in appearance to "Light White Ware". Hellenistic period. **PG: V.**

SBc-19 (G/R 912.7, **Fig. 6:2**): body sherd of storage jug (group 2a or 3a). Fabric rather soft dark brown with large pale grey mineral eruptions, pale reddish brown at surface, eroded. Cf. Młynarczyk 2009b, fig. 2:5. Hellenistic period. **PG: VIII.**

SBc-20 (G/R 886.4): rim fragment of jar (group 2a). Fabric powdery ("chalky"), pale pink. Hellenistic period. **SG: ?**

SBc-21 (G/R 906.12): rim fragment of jar (group 2a). Fabric powdery ("chalky"), very pale brown with white (from small to big), black and red-brown grits; surface "white" (visually, the same as body sherd of jug SBc-23 of SG IV.B). Hellenistic period. **SG: IV.A.**

SBc-22 (G/R 898.18): jar rim (group 2b) in "cook ware". Early Roman Period (intrusive). **SG: II.A.**

SBc-23 (G/R 889.5, **Fig. 6:1):** body sherd of storage jug (group 3a). Fabric pink with pale yellow slip. Cf. Młynarczyk 2009b, fig. 2:4. Hellenistic period. **SG: IV.B.**

SBc-24 (G/R 910.a): body sherd of jar (group 2a). Fabric very pale brown with many black and brown medium-sized and large grits, fewer white ones; surface "white"; macroscopically, the same fabric as SBc-16). Hellenistic period. **SG: IV.E.**

SBc-25 (G/R 889.4 (890), **Fig. 6:3):** body sherd of storage jug (group 3a). Fabric beige-pink. Cf. Młynarczyk 2009b, fig. 2:7. Hellenistic period. **SG: IV.B.**

SBc-26 (G/R 907): handle fragment (group1a or 2a). Fabric ("Light White Ware") very pale brown with occasional large voids, many "black" grits and some large white ones; surface "white". Early Hellenistic period. **SG: IV.D.**

SBc-27 (G/R 892.19): rim fragment of jar (group 2a). Fabric hard-baked, pink with pale yellow (very pale brown) surface. Hellenistic period. **PG: V.**

SBc-28 (G/R 906.13): rim fragment of jar (group 2a). Fabric greenish grey with lime eruptions and black grits. Possibly earlier than the Hellenistic period. Hellenistic period. **SG: IV.E.**

SBc-29 (G/R 901.16): rim fragment of jar (group 2a) or jug (3a); the same profile as SBc-34 and SBc-132. Fabric gritty orange. Hellenistic period. **PG: V.**

SBc-30 (G/R 891): fragment of shoulder of jug field register no. 890.5 (group 3a). Fabric pink with very pale brown surface, its inner surface partly vitrified. Hellenistic period. **PG: V.**

SBc-31 (G/R 892.20): rim fragment of jar (group 2a). Fabric hard-baked, pink with pale greenish yellow exterior and large lime eruptions, coarse in feel; macroscopically (and petrographically), the same fabric as SBc-17. Hellenistic period. **PG: V**.

SBc-32 (G/R 887.14): rim fragment of jar (group 2a). Fabric gritty orange, surface eroded. Hellenistic period. **PG: V.**

SBc-33 (G/R 893.22): rim fragment of jar (group 2a). Macroscopically and petrographically the same fabric as SBc-28. Hellenistic period. **SG: IV.E.**

SBc-34 (G/R 908.40): rim fragment of jar (group 2a). Fabric very pale brown with some voids, many "black" grits and some large white ones; surface "white". Hellenistic period. **SG: IV.D.**

SBc-35 (G/R 891.14): rim fragment of jar (group 2a). Fabric coarse yellow. Hellenistic period. **SG: I.A3.**

SBc-122 (G/R 910.b, **Fig. 7:5**): rim of jar (group 2a). Fabric hard reddish brown with partial grey core at rim; some black grits and many small white ones, with many larger eruptions on surface, the latter fired to smooth light reddish brown. Hellenistic period. **PG: ?**

SBc-132 (G/R 905.4, **Fig. 7:7**): rim of storage jug (group 3a). Fabric "sandy" (gritty), light yellowish brown banded pale red, with pale grey core at rim; contents: sizeable light grey oval grains, some small white (and dark grey?); surface fired from pale yellowish beige to pink/pale red, with many tiny white eruptions? (coarse feel). Hellenistic period. **PG: ?**

Sha'ar-Ha'Amakim Chronological Phase C (Late Hellenistic/Hasmonean, ca. 150 till ca. 40/25 BC)

SC-36 (F/G 860.e): rim of jar (group 2b), comparable to **Fig. 10:9** (Fernandez T 1.3). Fabric brownish red with grey core, surface uniform light brownish red with fine rare lime eruptions. Early Roman period. **SG: II.B.**

SC-37 (F/G 860.b): handle of jar (group 2a), "Light White Ware". Hellenistic period. **PG: IV.D.**

SC-38 (F/G 860.c): rim of jar (group 2a). Fabric very pale brown, almost white, similar to "Light White Ware". Hellenistic period**. PG: V.**

SC-39 (F/G 860.d): rim of jar (group 1a) of a shape paralleled by **Fig. 1:2**. Fabric (many voids, some white grits, some minute red ones, occasional glistening particles) described as Phoenician Semi-Fine ware**.** Persian/Hellenistic period, residual. **SG: I.A1.**

SC-40 (F/G 860.a): handle of jar (group 1a or 1b). Fabric pink with pale yellow slip. Hellenistic period. **SG: IV.B.**

SC-41 (F/G 850.a): handle of jar (group 1b), Fabric described as Phoenician Semi-fine ware. Late Hellenistic period. **SG: I.A1.**

Sha'ar-Ha'Amakim Chronological Phase D1 ("Herodian": late 1st century BC)

SD1-58 (B 262.e): handle fragment of jar (group 2a). Fabric pale pinkish beige, very granular (voids, some white grits, fewer black ones); surface almost white; found in association with unbaked clay. Late? Hellenistic period. **PG: V.**

SD1-59 (B 262.d): rim fragment of jar (group 2a). Fabric "spongy" in appearance, very pale brown, with rare black grits; found in association with unbaked clay. Late? Hellenistic period. **SG: IV.A.**

SD1-60 (B 264.b): rim fragment of jar (group 2a). Fabric granular pale pinkish beige, surface almost white, lightly wet-smoothed. Late? Hellenistic period. **PG: V.**

SD1-61 (B 262.b): rim fragment of jar (group 2a). Shape and fabric the same as SD1-59**. SG: IV.A.**

SD1-62 (C 965.1, **Fig. 3:5**): body sherd of jar (group 1b), with shallow external ribbing. Fabric macroscopically described as Phoenician Semi-fine ware. Late Hellenistic period. **SG: I.A1.**

SD1-63 (H 953): handle of jar (group 2b). Fabric granular red, with some voids, many white grits (up to very large) and occasional black grits. Early Roman period. **PG: VII.**

SD1-64 (D 920.a): body sherd of jar (group 2a). Fabric very granular light grey banded pink outside, with shallow voids, many small white grits and fewer black; exterior surface fired to pink. Hellenistic period. **SG: II.B.**

SD1-65 (H 939.10): rim of jar (group 2a). Fabric hard-baked, brown with voids, many small white grits and fewer larger black ones; surface fired to pale beige, wet-smoothed. Hellenistic period. **SG: IV.C.**

SD1-66 (B 262.c): rim fragment of jar (group 2a). Fabric very granular, light red, with rare white eruptions (some small red grits?); surface yellowish pink, cracked. Hellenistic period. **SG: I.A3.**

SD1-67 (B 264.a): rim fragment of jar (group 1b). Fabric described as Phoenician Semi-Fine ware, clay accretion inside the rim. Late Hellenistic period. **SG: I.A1.**

SD1-68 (H 939): handle root of jar (group 2b) of the same form and fabric as SD1-63: granular red, with some voids, many white and fewer black grits. Early Roman period. **PG: VII.**

SD1-69 (F 822): rim of jar (group 2b), similar to **Fig. 10:13** (Fernandez T 1.3; Avshalom-Gorni & Shapiro 2015, fig. 10: "Yodefat jar"). Fabric "metallic" hard fired, ash-grey; surface light reddish brown outside, brown inside. Early Roman period. **SG: II.B.**

SD1-70 (H 954): body sherd from jar **Fig. 10:6** of a form transitional between group 2a and 2b. Fabric rather soft, dark reddish brown with some grey mineral inclusions, reddish brown at surface. Early Roman period. **PG: VIII.**

SD1-121 (H 954.1, **Fig. 11:7**): rim of jar group 2b (or cooking pot? group 4). Fabric brown banded light red, with small white grits and some rounded black grains, surface uneven in colour, brick-red to dark reddish brown. Early Roman period. **SG: II.D2.**

SD1-125 (B 264.c, **Fig. 7:2**): rim fragment of jar (group 2a). Fabric macroscopically described as "hard orange ware": reddish yellow, with some tiny to medium-sized white grits and some reddish brown; some minute glistening particles (quartz?); surface pale reddish yellow. Late? Hellenistic period. **SG: I.A3.**

SD1-133 (B 262.a, **Fig. 7:3**): rim fragment of jar (group 2a) with traces of burning/ashes? on surface. Fabric gritty orange with some small white, angular pale grey (glistening: quartz?) particles, occasional dark grey grits; surface pinkish beige (where not burnt). Hellenistic period. **PG: V.**

Sha'ar-Ha'Amakim Chronological Phase D2 (first half of 1st century AD)

SD2-71 (P(n) 959.3): rim of jar (group 1b), its profile comparable to **Fig. 3:1**, with clay accretions inside and out. Fabric macroscopically described as Phoenician Semi-Fine ware. Late Hellenistic period. Cf. Młynarczyk 2009b, fig. 5:9. **SG: I.A1.**

SD2-72 (B/D 957.1): – rim of jar (group 2b); "red fabric". Early Roman period. **SG: I.A3.**

SD2-73 (H 936.9, **Fig. 10:10**): rim of jar group 2b (Fernandez T 1.3). Early Roman period. **SG: II.C.**

SD2-74 (H 936.10, **Fig. 10:8**): rim of jar group 2b (Fernandez T 1.3). Fabric, macroscopically described as "white ware", is very hard fired, pale brown with some black grits and occasional white ones; surface wet-smoothed, very pale brown. Early Roman period. **SG: IV.D.**

SD2-75 (F/G 858.b): rim of jar group 2b (Fernandez T 1.3). Fabric very hard and dense, reddish brown with occasional small white grits; surface brown with reddish hue. Early Roman period. **SG: II.C.**

SD2-76 (H 937.7a): rim of jar group 2b of profile comparable to **Fig. 10:10** (Fernandez T 1.3). Fabric very hard and dense, "metallic" grey; surface light brown inside, pink to beige outside, with some small white eruptions. Early Roman period. **SG: II.B.**

SD2-77 (C 955.a): rim of jar (group 2b). Fabric hard-fired, dense grey, with very pale brown surface and just occasional small white eruptions. Early Roman period. **SG: II.B.**

SD2-78 (C 921.1, **Fig. 7:4**): rim of jar (group 2a). Fabric dense, with dark grey section, with many small white grits and some black ones; surface pale brown. Hellenistic, residual. **SG: VIII.**

SD2-79 (H 937.a): body sherd of jar (group 2b), misfired. Fabric grey, with occasional deep voids, some small white grits plus large eruptions; surface pale reddish brown inside, pale brown outside. Early Roman period. **SG: II.B.**

SD2-80 (C 955.b): rim of jar group 2b (Fernandez T 1.3), paralleled by profile **Fig. 10:10.** Early Roman period. **SG: II.B.**

SD2-81 (C 947): rim of jar group 2b (Fernandez T 1.3), paralleled by profile **Fig. 10:10.** Early Roman period. **SG: II.C.**

SD2-82 (H 937.b): body sherd of *pithos*? (group 4). Date uncertain. **PG?**

SD2-83 (C 921): rim of jar group 2b (Fernandez T 1.3). Fabric very hard and dense, reddish brown with ash grey core; surface brown with reddish hue. Early Roman period. **SG: II.C.**

SD2-84 (F/G 858.a): rim of jar group 2b, of profile comparable to **Fig. 10:13** (Fernandez T 1.3; Avshalom-Gorni & Shapiro 2015, fig. 10: "Yodefat jar"). Fabric very hard and dense grayish brown, with occasional small white and dark grits; surface pale brown outside (some rather small white eruptions), very pale brown inside. Early Roman period. **SG: II.D3.**

SD2-85 (H 937.8, **Fig. 10:11**): rim of jar group 2b (Fernandez T 1.3). Early Roman period. **SG: II.D2.**

Sha'ar-Ha'Amakim Chronological Phase E (second half of 1st century AD)

SE-86 (H 930a.2, **Fig. 3:6**): rim of jar (group 1b). Fabric orange fabric with occasional small white grits and some tiny dark grey/black and red ones; surface pale orange, rather rough in feel, with clay accretions. Late Hellenistic/Early Roman period, residual. **SG: I.A1.**

SE-87 (H 926): handle of jar (group 2b). Fabric hard and dense, dark grey at break; surface light red (some small white eruptions), the exterior covered with very pale brown slip. Early Roman period. **SG: II.B.**

SE-88 (F 816.b): fragment of shoulder of jar with a ridge below the neck (group 2b). Fabric light brownish grey banded light brick-red, with some large white grits and rather many small black ones; surface wet-smoothed, light brick-red, with some medium-size white eruptions. Roman period. **PG: ?**

SE-89 (G 808.a): rim of jar (group 2b) of the same profile as **Fig. 11:4** (Fernandez T 1.5/6). Fabric hard-baked, dense light brick red, with many small white (rounded and fewer oblong) white grits (and few black ones?); surface evenly light reddish brown (pale brick red). Roman period. **SG: II.D2.**

SE-90 (F/G 856.1, **Fig. 10:3**): handle of jar (group 2b). Fabric granular light brown (pinkish beige) with some large white and pale grey grits and smaller black ones; surface thickly wet-smoothed, "white". Early? Roman period. **SG: IV.D.**

SE-91 (H 930b): body sherd of jar (group 2b), ribbed. Fabric very hard and dense grey with only rare white eruptions; surface light brown with poor remains of pale beige slip(?). Roman period. **SG: II.D1.**

SE-92 (F/G 854): neck/shoulder of jar with a ridge below neck (group 2b). Fabric very hard and dense, with "sandwich section": light brick red outside, brownish grey inside; many small white grits; surface (with occasional large white eruptions) pale pink-beige inside, very pale brown outside. Roman period. **SG: II.B.**

SE-93 (H 934): body sherd of jar (group 2b), misfired(?). Fabric very hard and dense, with grey core; surface pinkish brown inside, very pale brown outside with rare white eruptions. Roman period. **SG: II.D4.**

SE-94 (H 931): fragment of ring handle of jar (group 2b). Fabric light grey banded light red; rather many white grits, tiny to small, rounded and oblong; several rounded small red-brown grits; surface pale red. Early? Roman period. **PG: III.**

SE-95 (G 808.b): rim of jar (group 2b) of the same profile as **Fig. 11:4** (Fernandez T 1.5/6). Fabric very hard and dense, ash-grey; surface smooth light brick-red, occasionally "pitted"; Roman period. **PG:?**

SE-96 (F 816.a): body sherd of jar (group 2b). Fabric dense and hard, ash grey with many small and larger white grits (plus eruptions, up to very large); surface pinkish brown inside, light yellowish brown outside. Roman period. **SG: II.C.**

SE-97 (B/D 940.7): rim of jar (group 2b). Fabric evenly fired to pale red/yellowish red, with voids and some red grits (also as eruptions to the surface). Roman period. **PG: III**.

SE-98 (O 825/2.5): rim of jar (group 2b), similar to profile **Fig. 11:4** (Fernandez T 1.5/6). Fabric with dark grey core banded light brick-red; light brick red surface with few small white eruptions. Roman period. **SG: II.B.**

SE-99 (A/G 801.4, **Fig. 11:4**): rim of jar group 2b (Fernandez T 1.5/6). Fabric with dark grey core banded light brick-red; light brick red surface with few small white eruptions. Roman period. **SG: II.B.**

SE-100 (F/G 856.10): "cupped" rim of jug (group 3b). Fabric dense and clean, very pale brown, surface fired to white. Early Roman period. **SG: IV.F.**

SE-101 (H 934.4, **Fig. 10:7**): rim of jar group 2b (a late variant of Fernandez T 1.3?). Fabric light brown with grey core; surface very pale brown. Roman period. **SG: I.A3.**

SE-134 (F/G 854.2, **Fig. 10:2**): rim of jar group 2b. Fabric with "sandwich" section: light brown banded brownish grey outside; some small voids, small black grits, rare white ones; surface light brown. Roman period. **SG: I.A3.**

Sha'ar-Ha'Amakim Chronological Phase F (2nd–3rd/4th century AD)

SF-102 (H 919): ribbed body sherd of jug (group 3b) or jar (group 2b). Fabric deep pink (light red), finely granular with some voids, some small white grits and some red ones(?); surface of the same colour as the break. Roman period. **PG: III.**

SF-103 (P/H 950.a): rim of jar (group 2b). Fabric hard and dense, light red with many small to medium-sized white grits; surface light red inside (some large white eruptions) to "pink" on rim, with pinkish beige exterior. Roman period. **SG: II.D2.**

SF-104 (H 919.4, **Fig. 11:8**): rim of jar group 2b (Fernandez T 1.8). Fabric light brown with many white grits of all sizes; surface pale brown/beige. Roman period. **SG: II.D2.**

SF-105 (H 919.5, **Fig. 11:12**): rim of jar group 2b (Fernandez T 1.8). Fabric pink/light red at break and surface. Roman period. **PG: III.**

SF-106 (P/H 950.b): rim of jar (group 2b). Fabric very hard and dense, with dark grey core banded red; interior surface dark red, exterior pale beige. Roman period. **SG: II.B.**

SF-107 (P/H 950.2, **Fig. 11:5**): rim of jar (group 2b). Fabric light brick-red with thin light brown-grey core; some small white and black (small deep voids?) grits. Roman period. **SG: II.B.**

SF-108 (H 919.7, **Fig. 10:4**): rim of jar group 2b (Fernandez T 1.2). Fabric deep pink (light red), with some voids, some small white grits; surface of the same colour as the break. Early? Roman period. **PG: III.**

SF-109 (H 919a.1, **Fig. 4:3**): rim of jar (group1c). Fabric pale reddish brown with some voids, some white and dark red(?) grits; surface fired to very pale brown. See Młynarczyk 2009b, fig. 5:13. Early? Roman period. **PG: VI?**

SF-110 (F 800.3, **Fig. 10:5**): rim of jar (group 2b). Fabric very hard and dense, light red with some dark red and white grits; surface just paler than the break, with occasional sizeable white eruptions and clay accretions. Roman period. **SG: II.C.**

SF-124 (H 919.6, **Fig. 11:9**): rim of jar group 2b (Fernandez T 1.9). Fabric light pink with voids, some black (and tiny red?) grits, surface just slightly paler than the break, with occasional white eruptions. Roman period. **SG: I.A3.**

Unstratified (most of them apparently pertaining to Chronological Phase F)

SFx-111 (P(n) 932): piece of a *taboun*: **PG?**

SFx-112 (B/D 923): body sherd, ribbed inside and out, of a tubular-shaped jar (group 1c). Fabric very hard, pink, with tiny voids and occasional white grits; surface colour as the break. Roman period. **SG: I.A3.**

SFx-113 (C 169.1, **Fig. 4:5**): body sherd of jar (group 1c), with clay accretions inside. Fabric very hard and dense, light red/pink, surface just slightly paler. Roman period. **PG: III.**

SFx-114 (R 466.2, **Fig. 4:6**): rim of jar (group 1c). Fabric the same as that of SFx-113. Roman period. **PG: III**.

SFx-115 (C 211.4, **Fig. 3:2**): rim of jar (group 1b), residual in the Roman-period context. Fabric macroscopically described as Phoenician Semi-Fine ware. Late Hellenistic period. **SG: I.A1**.

SFx-116 (R 466.3, **Fig. 4:4**): rim of jar (group 1c). Fabric very hard, very granular (voids?) pale reddish brown, with white grits from small to big ones; surface very pale greenish brown. Roman period. **PG: ?**

SFx-117 (P(n) 932.11): rim of jar (group 2b), cf. **Fig. 11:10** (Fernandez T 1.8). Fabric hard and dense, light red/pink, with the surface just slightly paler, macroscopically the same as SFx-113. Roman period. **PG: III.**

SFx-118 (P(n) 932.10): rim of jar (group 2b), cf. **Fig. 11:3** (Fernandez T. 1.7). Fabric red fabric with thin grey core and some medium-size white grits; surface light red inside (beige on the lip), pale pink/beige outside. Roman period. **SG: II.C.**

SFx-149 (P/D 871.11, **Fig. 11:10**): rim and shoulder of jar group 2b (Fernandez T 1.8). Fabric: dense, light red/pink, with surface slightly paler pink. Roman period. **PG: III.**

Pottery deposit from Cistern in Area D

SDc-42 (737.b): handle of jar (group 2b). Fabric light red with many small white grits, some red (and black?) ones; surface with thin very pale brown slip (wash?); many white eruptions up to big large. Roman period. **SG: II.D2.**

SDc-43 (737.c): handle of jar (group 2b). Fabric dense, "metallic" grey, with occasional medium-size white eruptions; surface light reddish brown inside, pale brown outside. Roman period. **SG: II.D4.**

SDc-44 (748.b): body sherd of jar (group 2b) with two(?) parallel horizontal bands painted white. Fabric very hard, light brownish grey section banded pale red, with sizeable white lumps; interior fired to pale red, exterior to pale reddish brown with beige spots(?). Roman period. **SG: II.B.**

SDc-45 (728.6): rim of jar (group 2b), misshapen. Roman period. **SG: II.D3.**

SDc-46 (737.a): handle of jar (group 2b). Fabric light red with many small white grits, some red (and black?) ones; surface reddish yellow with many small white eruptions. Roman period. **SG: II.C.**

SDc-47 (748.a): body sherd of jar (group 2b) with two(?) parallel horizontal bands painted in white. Fabric very hard baked, light red with many small white grits and larger eruptions onto surface; interior fired to pale red, exterior to pale brown (beige). Roman period. **SG: II.C.**

SDc-48 (742.4): rim of jar (group 2b). Fabric orange-red with voids and white grits; surface fired from very pale brown (almost white) to pale red. Roman period. **PG: VI.**

SDc-49 (745): body sherd of thin-walled dipper jug (group 3b). Fabric deep brick-red with many voids and occasional small white grits; surface light brick-red, with few small white eruptions, slightly gritty in feel. Roman period. **SG: II.D2.**

SDc-50 (748.c): body sherd of jar (group 2b) with a horizontal band painted in white. Fabric very hard light red (with light brown core?) with some small white (and red?) grits; surface fired to pale reddish brown, inside and out. Roman period. **SG: II.A.**

SDc-51 (744.29): rim of jar group 2b (Fernandez T 1.3). Fabric hard baked, orange with medium-to-large white grits and some small rounded black ones; some small voids; surface uniform pink with small white and some tiny red grits; horizontal wheel marks and accretions on rim top. Early Roman period. **SG: I.A2.Eo.**

SDc-52 (737.40): body sherd of dipper jug (group 3b). Fabric very dark brown, with many white grits, from small to large (and many eruptions of all sizes); surface grayish brown inside, brownish grey outside, delicately ribbed. Roman period. **SG: II.D1.**

SDc-53 (744.36): rim of jar (group 2b), its profile paralleled by **Fig. 11:13** (Fernandez T 1.10). Fabric light red, very hard, with small white grits unevenly distributed, some small rounded red-brown grits and few black ones, and with irregular rare deep voids; surface fired unevenly, pink to beige, with small and large white eruptions. Roman period. **SG: II.D2.**

SDc-54 (747.3): rim of jar (group 2b), profile comparable to **Fig. 11:6** (Fernandez T 1.9) Fabric with "sandwich" firing corresponding to colours of the surface: pale brown inside, outside, pale red with small white grits unevenly distributed, some small rounded red-brown grits and few black ones; occasional deep voids; many small white eruptions to the surface. Roman period. **SG: II.A.**

SDc-55 (735.d): body sherd of dipper jug (group 3b). Fabric thin-walled, brown, with some tiny white grits and some oblong voids; surface brown inside and smooth pale brown (beige) outside (delicately ribbed), with rare small white eruptions. Roman period. **SG: II.D4.**

SDc-56 (744.37): rim of jar (group 2b). Fabric pale bodied, rather dense pinkish brown with many tiny white and some minute brown grits; surface wet-smoothed, very pale brown with just few small white eruptions. Roman period. **SG: II.D2.**

SDc-57 (742.3): rim of jar (group 2b). Fabric pale red with small white grits unevenly distributed, some small rounded red-brown grits and few black ones; occasional deep voids; many small white eruptions to the surface. Roman period. **SG: II.A.**

SDc-131 (626, **Fig. 11:6**): rim of jar group 2b (Fernandez T 1.9). Fabric light pinkish brown with rather many tiny white grits (some larger eruptions) and many minute dark brown(?) ones; surface thickly wet-smoothed, pale brown. Roman period. **PG: ?**

Other samples (not stratified: symbol X)

SX-119 (G 195.7b): handle of jar (group 1b), comparable to **Fig. 3:7.** Fabric pale pinkish brown with minute circular voids(?), occasional tiny white grits, occasional red ones; surface pale pinkish beige. Late Helenistic period. **SG: I.A1.**

SX-129; SX-135: double number of the sample! (G 195.8, **Fig. 1:5**): rim of jar with short neck and carinated shoulder (group 1a). Fabric light red, with some tiny white grits, occasional small red ones, surface pink. Persian(?) period. **SG: I.A1.**

SX-141 (E 896.6, **Fig. 11:1**): rim of jar group 2b (Fernandez T 1.5). Fabric brownish red (2.5 YR 5/4 reddish brown) with dark blue-grey core; remains of beige wash (slip?), 7.5 YR 8/2 (pinkish white). Roman period. **SG: II.D2.**

SX-142 (460.c): rim of jar (group 2b). Fabric dense, ash grey; pale brown surface with white eruptions. Early Roman period. **SG: II.B.**

SX-143 (G 180.29): rim of jar (group 1b). Fabric macroscopically identified as Phoenician Semi-Fine ware: pink, with small white and red grits; pale beige surface. Late Hellenistic period. **SG: I.A1.**

SX-144 (E 896.a): body sherd of jar (group 2b), misfired (air pockets in the section). Fabric with grey section and lime eruptions; surface fired to light brown outside, to dark reddish brown inside. Early? Roman period. **SG: IIC.**

SX-145 (460.d): rim of jar (group 2b). Fabric hard baked, grey in section. Early Roman period. **SG: II.D3.**

SX-146 (460.e): rim of jar (group 1b). Fabric very dense, pale orange with small red (and black?) grits, paler surface. Late Hellenistic period. **SG: I.A1.**

SX-147 (460.b): rim of jar group 2b (Fernandez T 1.7). Fabric very hard and dense, ash-grey; pale brown surface with white eruptions. Roman period. **SG: II.C.**

SX-148 (460.a): rim of jar (group 2b). Fabric fired very hard, dense light red, with occasional tiny white and black grits, surface pale red. Roman period. **SG: II.B.**

SX-150 (M 305): shoulder sherd of a jar (group 2b). Fabric fired very hard, yellowish pink with many small white grits, paler surface; densely ribbed (context: 1st century AD?). **PG: III.**

SX-151 (E 896.b): body sherd (shoulder) of jar (group 2b). Fabric brick-red with dark grey core and lots of lime (up to large particles). Roman period. **SG: II.B.**

SOV-111: *taboun* sherd, Roman period. **PG: ?**

SOV-136 (K 208): piece of a brick, Roman. **PG: ?**

SOV-137 (M 305): *taboun* sherd (context: 1st century AD?). **SG: II.A.**

SOV-139 (C): three pieces of baked clay (construction of a *taboun*?), most probably Early Hellenistic (Phase B). **SG: IV.E.**

SOV-249: body sherd of jar (group 2a) re-used in the construction of a domestic oven. Hellenistic period. **PG: V.**

SOV-250: body sherd of jar (group 2b) re-used in the construction of a domestic oven. Roman period. **SG: II.B.**

5.3. Sha'ar-Ha'Amakim petrographic database[241]

The study material from Sha'ar-Ha'Amakim comprised 152 items, including 135 fragments of jars (Levantine amphorae, among them a few may have pertained to other large closed forms such as *pithoi* or jugs), plus 9 samples of jugs and eight samples of other ceramic objects.

[241] The petrography of Sha'ar-Ha'Amakim ceramics was previously presented at Études et Travaux (Michniewicz & Młynarczyk 2017).

Table 2. Descriptive information and petrographic group assignment of the analysed ceramics from Sha'ar-Ha'Amakim

Sample symbol	Excava-tion no.	Fragment description	Archaeological context	Dating	Vessel form (group)	PETRO GROUP
SA-1	924.1	body sherd with handle root (construction of an oven)	Phase A (Late IA II and Persian/ Hellenistic periods)	Early Hellenistic	2a	IV.A
SA-2	864.7	rim of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Persian?	1a	I.A1
SA-3	636	rim of storage jug	Phase A (Late IA II and Persian/ Hellenistic periods)	Early Hellenistic	3a	IV.A
SA-4	864.a	handle of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	late IA IIC?	?	V
SA-5	897.4	rim of jar	Found as residual in cistern G/R Hellenistic context	Persian	1a	IV.H
SA-6	192.2	body sherd of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Late IA II to Early Hellenistic	1a	I.A1
SA-7	943.2	rim of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	late IA II	1a	IV.H
SA-8	910.13	rim of jar	residual in cistern G/R Hellenistic context	Persian or Early Hellenistic	1a	I.A1
SA-9	905.2a	rim of jar	residual in cistern G/R Hellenistic context	Persian or Early Hellenistic	1a	IV.D
SA-10	943.4	rim and neck of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Persian	2a	IV.C
SA-11	908	fragment of jar handle	residual in cistern G/R Hellenistic context	Persian or Early Hellenistic	1a	I.A1
SA-12	617.a	rim fragment of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Persian or Early Hellenistic (?)	2a	V
SA-13	908.17	rim of jar	residual in cistern G/R Hellenistic context	Persian or Early Hellenistic	1a	I.A1
SBc-14	887	handle fragment of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	V
SBc-15	887.13	body sherd of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	I.A2.Eo
SBc-16	891.a	body sherd of jar, misfired	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	IV.C
SBc-17	905.14	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	V
SBc-18	883.32	rim of jar or storage jug	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a or 3a	V
SBc-19	912.7	body sherd of jar or storage jug	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a or 3a	VIII
SBc-20	886.4	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	?
SBc-21	906.12	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	IV.A
SBc-22	898.18	jar rim in "cook ware"	intrusive in Hellenistic context of Phase B	Early Roman	2b	II.A
SBc-23	889.5	body sherd of storage jug	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	3a	IV.B
SBc-24	910.a	body sherd of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	IV.E
SBc-25	889.4	body sherd of storage jug	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	3a	IV.B
SBc-26	907	fragment of handle	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic?	1a or 2a	IV.D
SBc-27	892.19	rim fragment of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	V
SBc-28	906.13	fragment of jar(?) rim	Phase B (Hellenistic, to ca. 150 BC)	Persian? (residual)	2a	IV.E
SBc-29	901.16	rim fragment of jar or jug	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a or 3a	V
SBc-30	891	shoulder of storage jug	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	3a	V

Sample symbol	Excava-tion no.	Fragment description	Archaeological context	Dating	Vessel form (group)	PETRO GROUP
SBc-31	892.20	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	V
SBc-32	887.14	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	V
SBc-33	893.22	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	IV.E
SBc-34	908.40	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	IV.D
SBc-35	891.14	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	2a	I.A3
SC-36	860.e	rim of jar	Phase C (Late Hellenistic/Hasmonean ca. 150 till ca. 40/25 BC	Early Roman (Herodian?)	2b	II.B
SC-37	860.b	handle of jar	Phase C (Late Hellenistic/Hasmonean ca. 150 till ca. 40/25 BC	Hellenistic	2a	IV.D
SC-38	860.c	rim of jar	Phase C (Late Hellenistic/Hasmonean ca. 150 till ca. 40/25 BC	Hellenistic	2a	V
SC-39	860.d	rim of jar	Phase C (Late Hellenistic/Hasmonean ca. 150 till ca. 40/25 BC	Late Persian, residual	1a	I.A1
SC-40	860.a	handle of jar	Phase C (Late Hellenistic/Hasmonean ca. 150 till ca. 40/25 BC	Hellenistic	1a or 1b	IV.B
SC-41	850.a	handle of jar	Phase C (Late Hellenistic/Hasmonean ca. 150 till ca. 40/25 BC	Late Hellenistic	1b	I.A1
SDc-42	737.b	handle of jar	Cistern D	Roman	2b	II.D2
SDc-43	737.c	handle of jar	Cistern D	Roman	2b	II.D4
SDc-44	748.b	body sherd of jar	Cistern D	Roman	2b	II.B
SDc-45	728.6	rim of jar	Cistern D	Roman	2b	II.D3
SDc-46	737.a	handle of jar	Cistern D	Roman	2b	II.C
SDc-47	748.a	body sherd of jar	Cistern D	Roman	2b	II.C
SDc-48	742.4	rim of jar	Cistern D	Roman	2b	VI
SDc-49	745	body sherd of thin-walled dipper jug	Cistern D	Roman	3b	II.D2
SDc-50	748.c	body sherd of jar	Cistern D	Roman	2b	II.A
SDc-51	744.29	rim of jar	Cistern D	Roman	2b	I.A2Eo
SDc-52	737.40	body sherd of dipper jug	Cistern D	Roman	3b	II.D1
SDc-53	744.36	rim of jar	Cistern D	Roman	2b	II.D2
SDc-54	747.3	rim of jar	Cistern D	Roman	2b	II.A
SDc-55	735.d	body sherd of dipper jug (thin-walled)	Cistern D	Roman	3b	II.D4
SDc-56	744.37	rim of jar	Cistern D	Roman	2b	II.D2
SDc-57	742.3	rim of jar	Cistern D	Roman	2b	II.A
SD1-58	262.e	handle of jar	Phase D1 (Herodian: late 1st century BC)	Late Hellenistic(?)	2a	V
SD1-59	262.d	rim of jar, LWW(?)	Phase D1 (Herodian: late 1st century BC)	Hellenistic (residual?)	2a	IV.A
SD1-60	264.b	rim of jar	Phase D1 (Herodian: late 1st century BC)	Late Hellenistic	2a	V
SD1-61	262.b	rim of jar, LWW	Phase D1 (Herodian: late 1st century BC)	Hellenistic (residual?)	2a	IV.A
SD1-62	965.1	body sherd of jar	Phase D1 (Herodian: late 1st century BC)	Late Hellenistic	1b	I.A1
SD1-63	953	handle of jar	Phase D1 (Herodian: late 1st century BC)	Early Roman	2b	VII
SD1-64	920.a	body sherd of jar	Phase D1 (Herodian: late 1st century BC)	Hellenistic, residual	2a	II.B
SD1-65	939.10	rim of jar	Phase D1 (Herodian: late 1st century BC)	Hellenistic (residual)	2a	IV.C
SD1-66	262.c	rim of jar	Phase D1 (Herodian: late 1st century BC)	Hellenistic residual(?)	2a	I.A3
SD1-67	264.a	rim of jar	Phase D1 (Herodian: late 1st century BC)	Late? Hellenistic, residual	1b	I.A1
SD1-68	939	handle root of jar	Phase D1 (Herodian: late 1st century BC)	Early Roman	2b	VII
SD1-69	822	rim of jar	Phase D1 (Herodian: late 1st century BC)	Early Roman	2b	II.B
SD1-70	954	body sherd of jar	Phase D1 (Herodian: late 1st century BC)	Early Roman	2b	VIII? CR!
SD2-71	959.3	rim of jar	Phase D2 (1st half of 1st century AD)	Late Hellenistic (residual) or Early Roman	1b	I.A1

Sample symbol	Excava-tion no.	Fragment description	Archaeological context	Dating	Vessel form (group)	PETRO GROUP
SD2-72	957.1	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	I.A3
SD2-73	936.9	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.C
SD2-74	936.10	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	IV.D
SD2-75	858.b	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.C
SD2-76	937.7a	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.B
SD2-77	955.a	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.B
SD2-78	921.1	rim of jar	Phase D2 (1st half of 1st century AD)	Hellenistic (residual)	2a	VIII
SD2-79	937.a	body sherd of jar, misfired	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.B
SD2-80	955.b	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.B
SD2-81	947	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.C
SD2-82	937.b	body sherd of pithos?	Phase D2 (1st half of 1st century AD)	Early Roman?	4	?
SD2-83	921	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.C
SD2-84	858.a	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.D3
SD2-85	937.8	rim of jar	Phase D2 (1st half of 1st century AD)	Early Roman	2b	II.D2
SE-86	930.a.2	rim of jar	Phase E (2nd half of 1st century AD)	Early Roman	1b	I.A1
SE-87	926	handle of jar	Phase E (2nd half of 1st century AD)	Roman	2b	II.B
SE-88	816.b	shoulder of jar	Phase E (2nd half of 1st century AD)	Roman	2b	?
SE-89	808.a	rim of jar	Phase E (2nd half of 1st century AD)	Roman	2b	II.D2
SE-90	856.1	handle of jar	Phase E (2nd half of 1st century AD)	Roman	2b	IV.D
SE-91	930.b	body sherd of jar	Phase E (2nd half of 1st century AD)	Roman	2b	II.D1
SE-92	854	neck/shoulder of jar	Phase E (2nd half of 1st century AD)	Roman	2b	II.B
SE-93	934	body sherd of jar, misfired	Phase E (2nd half of 1st century AD)	Early Roman	2b	II.D4
SE-94	931	handle of jar	Phase E (2nd half of 1st century AD)	Early Roman	2b	III
SE-95	808.b	rim of jar	Phase E (2nd half of 1st century AD)	Early Roman	2b	?
SE-96	816.a	body sherd of jar	Phase E (2nd half of 1st century AD)	Roman	2b	II.C
SE-97	940.7	rim of jar	Phase E (2nd half of 1st century AD)	Roman	2b	III
SE-98	825/2.5	rim of jar	Phase E (2nd half of 1st century AD)	Roman	2b	II.B
SE-99	801.4	rim of jar	Phase E (2nd half of 1st century AD)	Early(?) Roman	2b	II.B
SE-100	856.10	"cupped" rim of jar/ large jug	Phase E (2nd half of 1st century AD)	Roman	3b	IV.F
SE-101	934.4	rim of jar	Phase E (2nd half of 1st century AD)	Early Roman, residual	2b	I.A3
SF-102	919	body sherd of dipper jug(?) or jar?	Phase F (2nd-3rd/4th century AD)	Roman	3b? (2b?)	III
SF-103	950.a	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	II.D2
SF-104	919.4	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	II.D2
SF-105	919.5	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	III
SF-106	950.b	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	II.B
SF-107	950.2	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	II.B
SF-108	919.7	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	III
SF-109	919.a.1	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	1c	VI?
SF-110	800.3	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	II.C
SFx-111	932	piece of oven (taboun)?	not stratified (apparently pertaining to Phase F)	Roman	4	?
SFx-112	923	body sherd of jar	unstratified (apparently pertaining to Phase F)	Roman	1c	I.A3
SFx-113	169.1	body sherd of jar	not stratified (apparently pertaining to Phase F)	Roman	1c	III
SFx-114	466.2	rim of jar	not stratified (apparently pertaining to Phase F)	Roman	1c	III
SFx-115	211.4	rim of jar	not stratified (apparently pertaining to Phase F)	Roman	1b	I.A1

Sample symbol	Excava-tion no.	Fragment description	Archaeological context	Dating	Vessel form (group)	PETRO GROUP
SFx-116	466.3	rim of jar	unstratified (apparently pertaining to Phase F)	Roman	1c	?
SFx-117	932.11	rim of jar,	not stratified (apparently pertaining to Phase F)	Roman	2b	III
SFx-118	932.10	rim of jar	not stratified (apparently pertaining to Phase F)	Roman	2b	II.C
SX-119	195.7b	handle of jar	not stratified	Late Hellenistic or Early Roman	1b	I.A1
SA-120	864.13	rim of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Persian?	2a	IV.D
SD1-121	954.1	rim of jar or cooking pot(?)	Phase D1 (Herodian: late 1st century BC)	Early Roman	2b or 4	II.D2
SBc-122	910.b	rim of jar	Phase B (Hellenistic, to ca. 150 BC)	Persian or Hellenistic	2a	?
SA-123	864.8	rim of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Late IA II?	1a	VI
SF-124	919.6	rim of jar	Phase F (2nd-3rd/4th century AD)	Roman	2b	I.A3
SD1-125	264.c	rim of jar	Phase D1 (Herodian: late 1st century BC)	Hellenistic, residual	2a	I.A3
SA-126	943.1	rim of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Late IA II	1a	I.A1
SA-127	943.5	rim and neck of jar	Phase A (Late IA II and Persian/ Hellenistic periods)	Persian	2a	I.A2.Eo
SA-128	192	rim of pithos rather than jar(?)	Phase A (Late IA II and Persia/ Hellenistic periods)	late IA II (?)	2a? 4?	I.A2.Cr
SX-129	195.8	rim of jar	not stratified	Persian	1a	I.A1
SA-130	631	rim of jar (or pithos?)	Phase A (Late IA II and Persian/ Hellenistic periods)	Persian/Hellenistic?	2a?	I.A2.Cr
SDc-131	626	rim of jar	Cistern D	Roman	2b	?
SBc-132	905.4	rim of storage jug	Phase B (Hellenistic, to ca. 150 BC)	Hellenistic	3a	?
SD1-133	262.a	rim of jar	Phase D1 (Herodian: late 1st century BC)	Late Hellenistic	2a	V
SE-134	854.2	rim of jar	Phase E (2nd half of 1st century AD)	Roman	2b	I.A3
SX-135	195.8	rim of jar	not stratified	Persian	1a	I.A1
SOV-136	208	piece of brick	not stratified	Roman	4	?
SOV-137	M 305	oven (taboun) sherd	not stratified	Early Roman (1st century AD?)	4	II.A
SOV-137'	none	oven (taboun) sherd	not stratified	Early Roman?	4	II.A
SOV-139	C	taboun(?) clay, from the construction of oven(?)	probably Phase B	Early Hellenistic?	4	IV.E
SX-141	896.6	rim of jar	not stratified	Roman	2b	II.D2
SX-142	460.c	rim of jar	not stratified	Roman	2b	II.B
SX-143	180.29	rim of jar	not stratified	Late Hellenistic or Early Roman	1b	I.A1
SX-144	896.a	body sherd of jar, misfired	not stratified	Early Roman	2b	II.C
SX-145	460.d	rim of jar	not stratified	Roman	2b	II.D3
SX-146	460.e	rim of jar	not stratified	Late Hellenistic	1b	I.A1
SX-147	460.b	rim of jar	not stratified	Roman	2b	II.C

Sample symbol	Excava-tion no.	Fragment description	Archaeological context	Dating	Vessel form (group)	PETRO GROUP
SX-148	460.a	rim of jar	not stratified	Roman	2b	II.B
SFx-149	871.11	rim and shoulder of jar	not stratified (apparently pertaining to Phase F)	Roman	2b	III
SX-150	305	shoulder of jar	not stratified	Early(?) Roman	2b	III
SX-151	896.b	body sherd of jar	not stratified	Roman	2b	II.B
SOV-249	none	body sherd of jar re-used in domestic oven (taboun)	not stratified	Hellenistic	2a	V
SOV-250	none	body sherd of jar re-used in domestic oven (taboun)	not stratified	Roman	2b	II.B

The conducted examination has lead to the distinguishing of at least nine petrographic groups and 15 subgroups (henceforth: PG; SG) of ceramics. They can be characterised as follows:

Petrographic group IA – "Algae"

Subgroup I.A1 (Figs. 14–17)

Eocene foraminiferous 'light' marl with sparse algae, chalk rich in ferruginous-globigerina ooze, 5–8% quartz sand +/– minute red soil balls.

Specimens[242]**:** SA-2, SA-6, SA-8, SA-11, SA-13[243], SC-39, SC-41[244], SD1-62, SD1-67, SD2-71, SE-86, SFx-115, SX-119, SA-126, SX-129, SX-135, SX-143, SX-146.

A group of ceramics light red in colour (5 YR 7/6), mostly fired more lightly, slightly silty on the surface. They were made of foraminiferous marl locally coloured by iron oxides, tempered with a 5–8 vol. % of sand.

On optical examination, the groundmass is pale yellow-brown or light-orange, in places of concentration of iron and manganese oxides red or opaque. In most samples the matrix is optically active, which is indicative of a low temperature of firing, 650–700°C. Only samples SA-2, SA-126, SX-129, and SX-135 were fired at a higher temperature, the result being the anisotropy of their groundmass.

A diagnostic feature of the groundmass is the presence of well-preserved, abundant Middle-Late Eocene microfauna. Those are mostly foraminifers of the *Chilogumbelina* sp. and *Globigerina* ex gr. *praebulloides-officinalis*, less commonly *Tenuitella* sp. and *Uvigerina* sp., and also numerous, though of no major stratigraphic significance, *Globigerina* sp. and *Brizalina* sp., as well as radiolarians of the genus *Spumellaria*. Their shells are either scattered throughout the matrix or form local clusters (this especially holds for *Globigerina*), which is usually accompanied by a concentration of iron and manganese oxides[245]. The clasts embedded in the groundmass, often of ferruginous chalk, vary in size and shape. They are usually more or less oval, and their boundaries are fuzzy; less frequent are clasts a few millimetres in size with sharp, irregular contours.

The content of silt-sized quartz particles is low (under 5% of the volume), some of the specimens are almost completely devoid of them.

The temper consists of irregularly scattered grains of fine sand-sized quartz (0.1–0.25 mm) accounting for 5–8% of the volume. It is well sorted, only a few grains are larger, 0.3–0.4 mm in diameter. In sample SA-126 the admixture has a different composition. The sand-sized grains are quartz-carbonates in the 50:50% proportion. Carbonate-rock fragments are coarser and partly decomposed as a result of firing.

Quartz is mostly monocrystalline, moderately rounded, less frequently subangular-subrounded. Its crystals show uniform light extinction (volcanic grains) and undulose light extinction (metamorphic grains). A few grains of polycrystalline quartz are certainly of metamorphic origin. Feldspars appear sporadically; they are both, polysynthetically twinned plagioclases and potassium feldspars distinguishable optically, especially when the twinning is cross-hatched. There are also single grains of chert with a characteristic mosaic texture, and heavy minerals, mostly rutile, apatite and green pleochroic amphibole. Titanomagnetite predominates among the numerous opaque minerals.

The presence of *Amphiroa* sp.

242 Individual symbols (A, B, ...) refer to the successive levels of stratigraphy in Sha'ar-Ha'Amakim (S) while numbers indicate the number of samples.

243 What distinguishes sample SA-13 from the other ones in this group is a higher, 15% content of the sandy admixture.

244 Samples fired in reduced-oxygen conditions.

245 It is a debatable question whether the chalk clasts rich in iron and *Globigerina* are an integral part of the material used or are an admixture intentionally added by the potter.

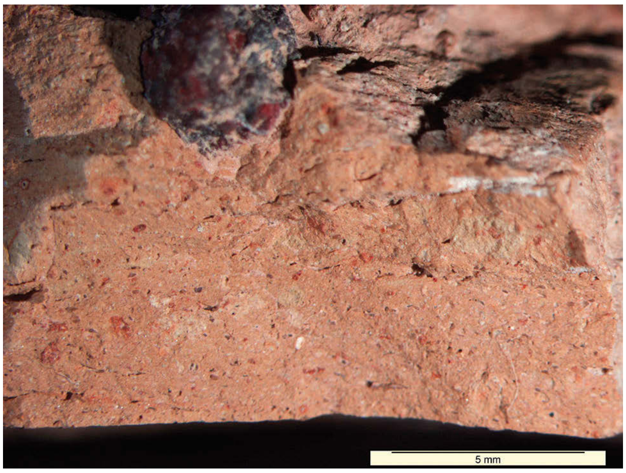


Fig. 14. SG I.A1. Fragment of specimen SA-6

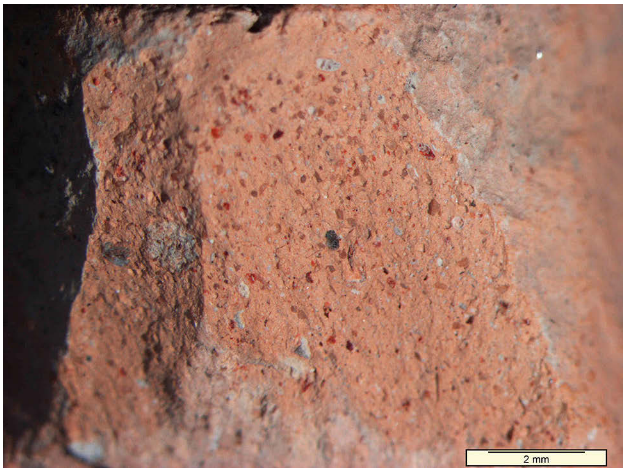


Fig. 15. SG I.A1. Fragment of specimen SC-39

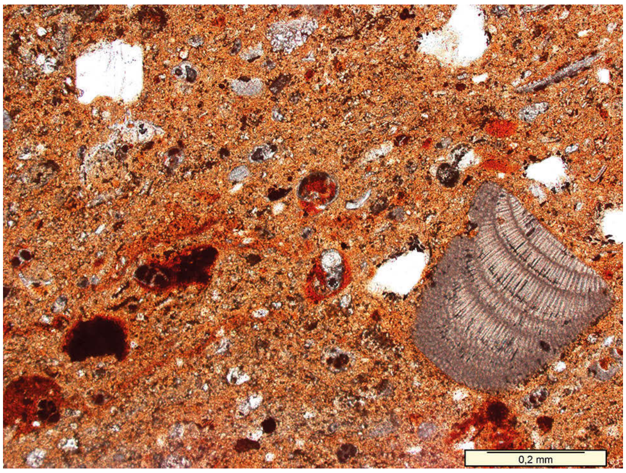


Fig. 16. SG I.A1. Specimen SA-6, photomicrograph of a thin section – Coralline red algae (*Amphiroa* sp.) embedded in clayey marl. Plane polarized light (PPL)

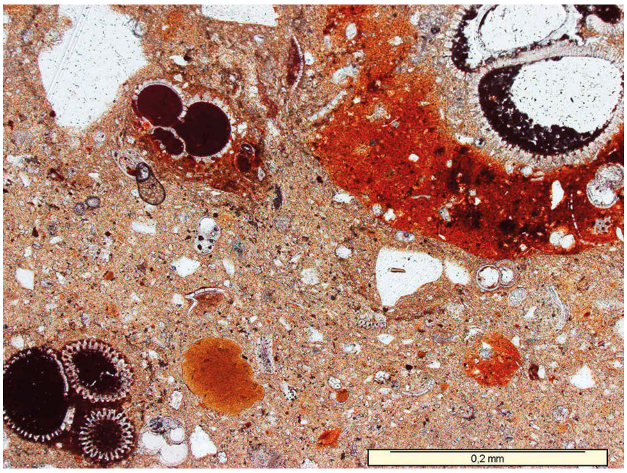


Fig. 17. SG I.A1. Specimen SC-39, photomicrograph of a thin section – *Globigerina* sp. accompanied by a concentration of iron and manganese oxides. Plane polarized light (PPL)

A characteristic feature of this group is the presence of single fragments of red algae of the family Corallinaceae especially *Amphiroa* sp. They can be identified on the basis of their texture: an alternate arrangement of layers composed of long and short cells. The alga fragments are of a fine- and a medium-sand-sized, often angular in shape. They appear regularly though in small numbers, apart from sample SA-126, Their presence among the remaining numerous microorganisms gives the impression that they are a natural component of the marl employed. However, *Amphiroa* of distinctive alternating layers of long and short cells start to be common only in the Pleistocene until the Recent forms[246]. They can be found in bioclastic sediments distributed along the Coastal Plain and in the foothill areas in Neogene formations. Today their remnants are common in the beach sand north of Haifa along the Israeli and Lebanese coast. Considering the Eocene age of the material established micro-paleontologically, the *Amphiroa* fragments it contains seem to be a component added with quartz sand.[247]

Similarities: Sidon, Sarepta, Tyre,[248] Tel Dor,[249] Horbat Malta,[250] Tel Shunem,[251] Ashdod,[252] Gamla,[253] Kommos in Crete[254].

Subgroup I.A2.Eo – "Eocene" (Figs. 18–19)

Eocene foraminiferous 'light' marl + red-soil balls + quartz sand (devoid of ferruginous globigerina ooze).

[246] Cf. Buchbinder 1975: 45.

[247] Cf. Eliyahu-Behar et al. 2008: 2899; Gorzalczany 2006: 59; Gorzalczany 2008: 83; Bettles 2003b; Landau & Goren 2004: 28.

[248] Cf. Bettles 2003a,b – Fabric Class 1A; Griffiths 2003: 18–19.

[249] Gilboa et al. 2006: 310–311; Eliyahu-Behar et al. 2008: 2899.

[250] Gorzalczany 2008.

[251] Shapiro 2016: 67–68.

[252] Cohen-Weinberger 2013: 123–124.

[253] Berlin 2006: 16.

[254] Gilboa et al. 2015: 82, fig. 3.

Fig. 18. SG I.A2.Eo. Fragment of specimen SB-15

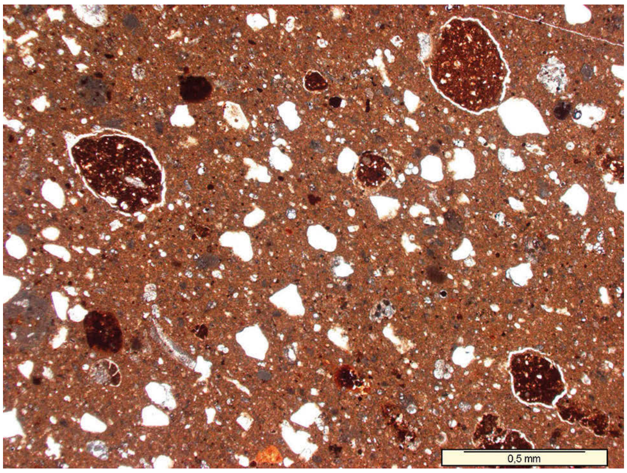


Fig. 19. SG I.A2.Eo. Specimen SB-39, photomicrograph of a thin section – *terra rossa* balls accompanied by quartz sand-sized temper. Plane polarized light (PPL) photomicrograph of a thin section – *terra rossa* balls accompanied by quartz sand-sized temper. Plane polarized light (PPL)

Specimens: SBc-15, SDc-51, and SA-127[255].

The fabric of I.A2 is macroscopically similar to that of the ceramics of group I.A1, light-orange (7.5 YR 8/6) and light-red in colour (2.5 YR 7/6-8), with similar petrographic features and micro-paleontological composition. What makes it fundamentally different from the ceramics of group I.A1 is the absence of globigerina-rich iron oxides, replaced here by a more abundant (compared with I.A1) admixture of ferruginous red soil (*terra rossa*).

Similarities: Tel Michal[256], IA Phoenician ceramics from Kommos in Crete.[257]

Subgroup I.A2.Cr – "Cretaceous" (Figs. 20–21)

Cretaceous foraminiferous 'light' marl + foraminiferous chalk + red soil balls.

Specimens: SA-128, SA-130.

Sample SA-128 – a massive vessel light-red on the surface (2.5 YR 6/6), dark-brown inside (2.5 YR 5/2). On optical examination its groundmass is light-brown, optically active. It is rich in foraminifers, with large clasts of foraminiferous chalk and a great number of dark-red *terra rossa* pellets containing fairly numerous grains of quartz silt. Silt in the matrix is mostly composed of carbonates; quartz grains are few, uniformly scattered, sometimes accompanied by feldspars. The vessel does not contain sand-sized temper. The age – Late Cretaceous, which makes it similar to SA-130. However, SA-130 contains *Amphiroa*, absent from SA-128.

Sample SA-130 – a fragment of a thin-walled vessel fired to a light-red colour (5 YR 7/6). Its groundmass is foraminiferous, light brown marl, pigmented red by fired fragments of chalk and *terra rossa* balls. The sand-sized admixture is mostly composed of monocrystalline quartz making up a few percent of the volume. Those are monocrystalline grains, usu-

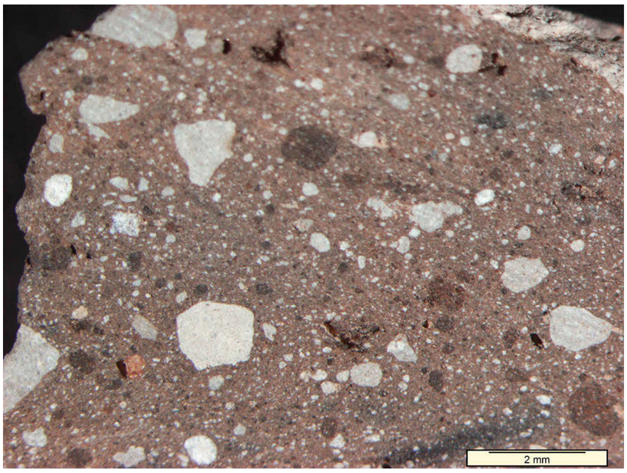


Fig. 20. SG I.A2.Cr. Fragment of specimen SA-128

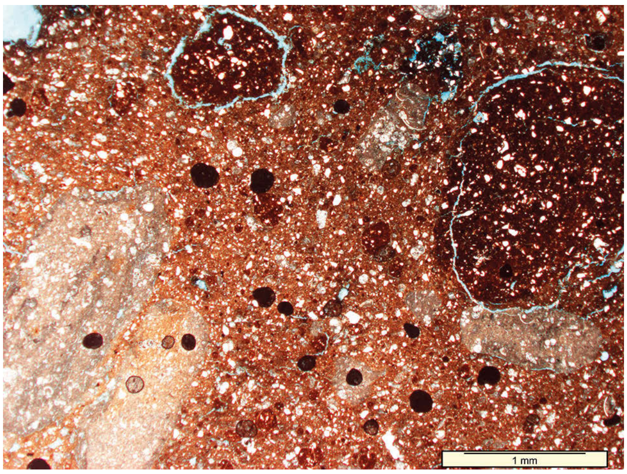


Fig. 21. SG I.A2.Cr. Specimen SA-128, photomicrograph of a thin section – whitish foraminiferous chalk clasts and dark-red *terra rossa* pellets embedded in clayey marl viewed under plane polarized light (PPL)

255 Sample SA-127 contains a high amount of quartz sand.
256 Gorzalczany 2006: 59.
257 Gilboa et al. 2015: 80–81.

ally poorly rounded, showing uniform, more rarely undulose, light extinction. Embedded in the groundmass are also large irregular fragments of carbonate rock built of fine, almost isotropic micrite, and small but well-preserved fragments of *Amphiroa* sp. algae.

The set of the recognised species determines the age of the material at the Upper Cretaceous. In this context the presence of algae should be treated as a sand-sized temper.

Subgroup I.A3 (Figs. 22–24)

Eocene foraminiferous 'light' marl plus red-soil balls plus quartz sand plus hyaloclastite fragments.
Specimens: SBc-35 (?), SD1-66, SD2-72*, SE-101[258], SFx-112, SF-124*, SD1-125, SE-134.

A group of pottery petrographically similar to I.A1, and especially to I.A2. It is light-red in colour (5 YR 7/6), made of calcareous marl enriched

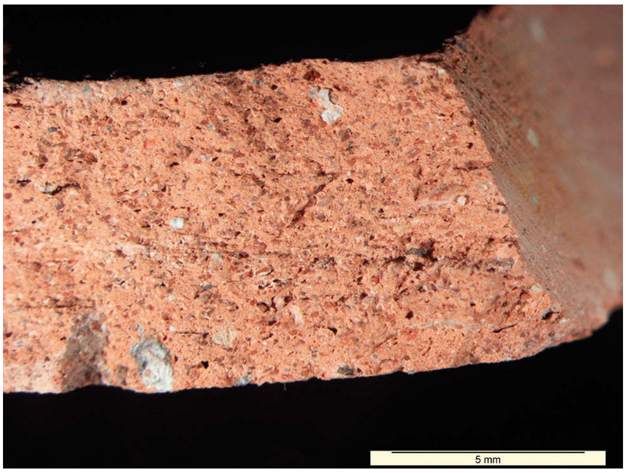


Fig. 22. SG I.A3. Fragment of specimen SX-125

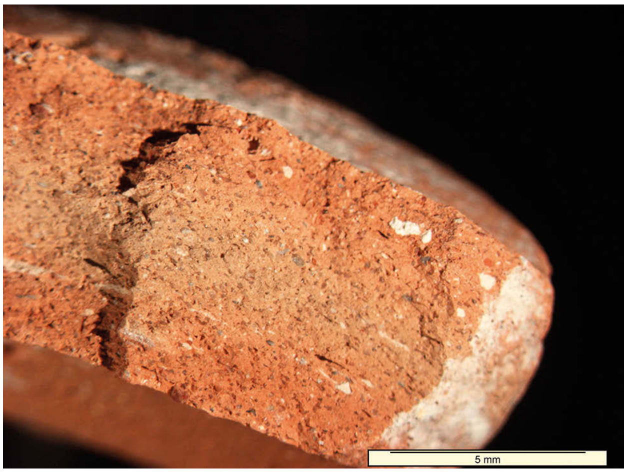


Fig. 23. SG.I.A3. Fragment of specimen SFx-112

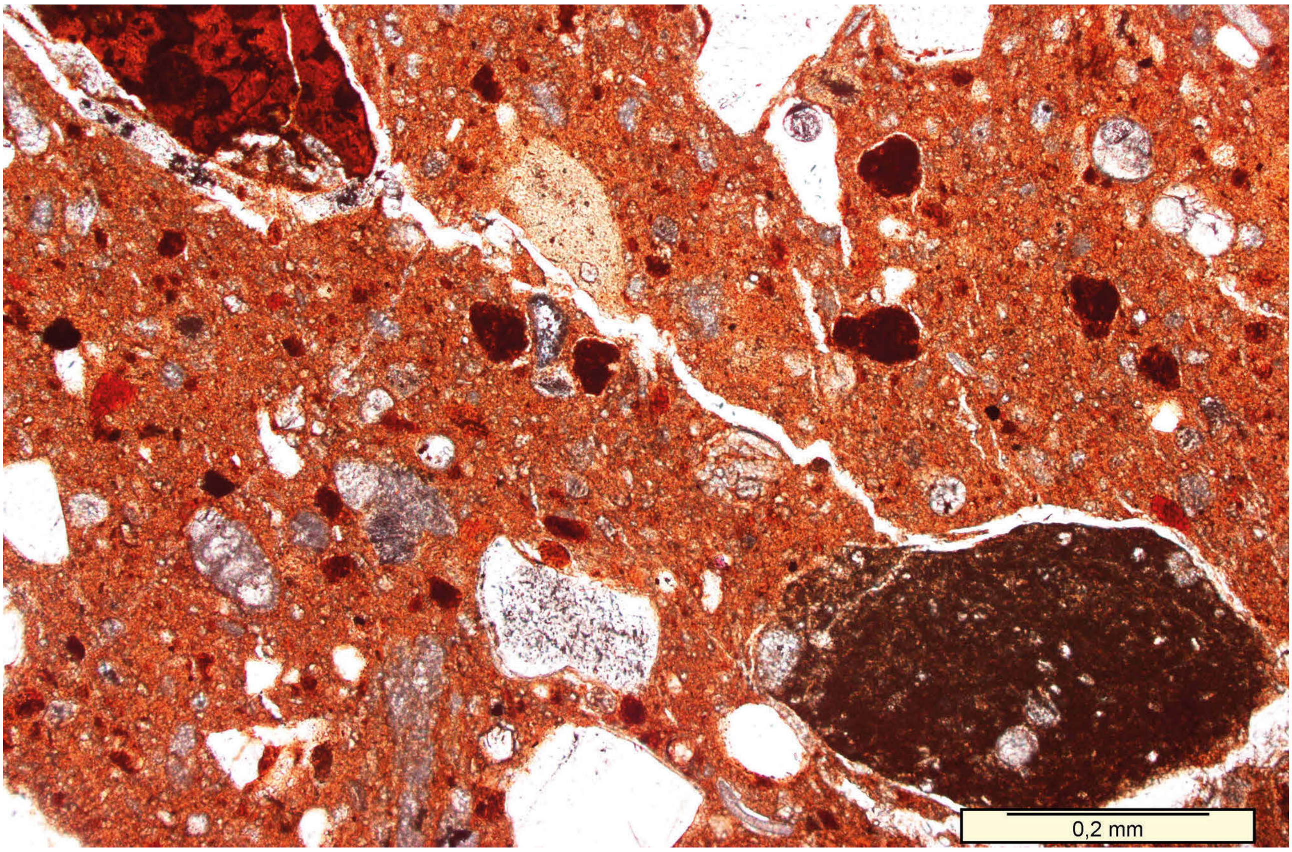
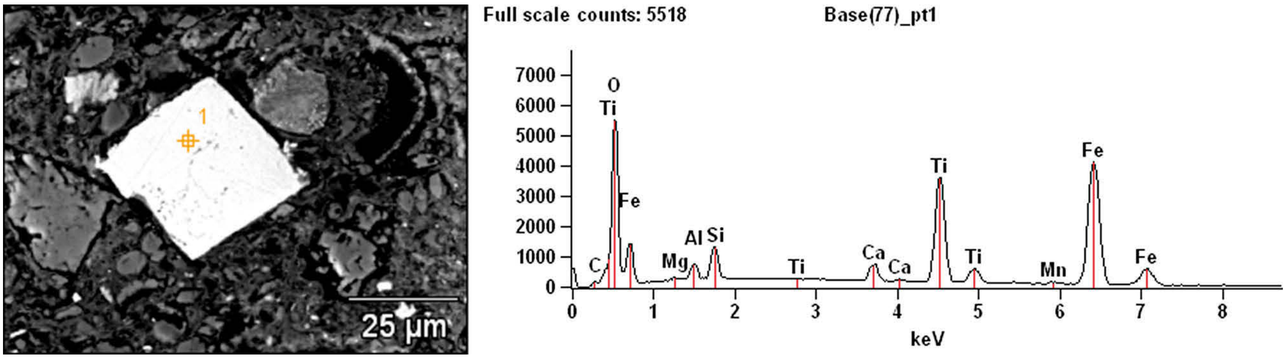


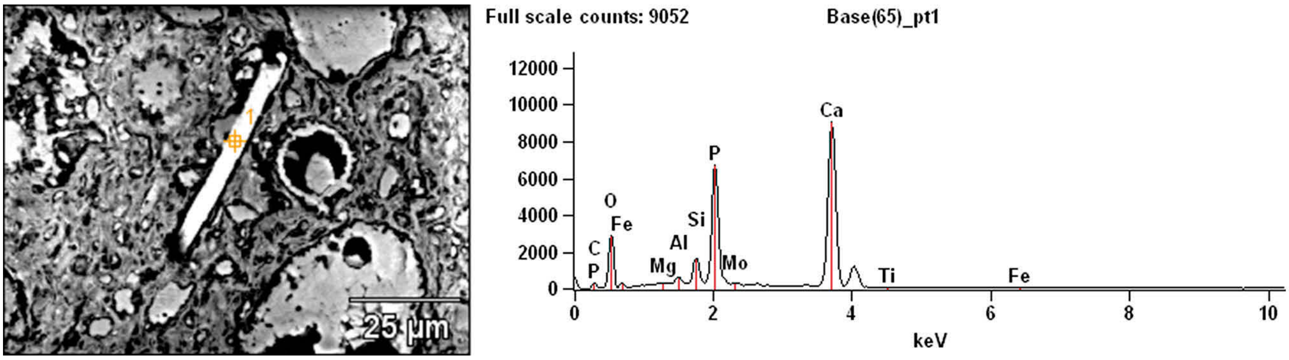
Fig. 24. SG I.A3. Specimen SD-66 10II, photomicrograph of a thin section – reddish hyaloclastite fragment, dark oval chalk clast, white quartz and feldspars Plane polarized light (PPL)

258 Containing no quartz, fired in reduced-oxygen conditions?



	MgO	Al_2O_3	SiO_2	CaO	TiO_2	MnO	Fe_2O_3
Base(77)_pt1	0.41	2.81	5.88	2.46	28.00	0.60	59.85

Fig. 25. SG I.A3. Specimen SD-72. SEM-BSE image of a rhomboidal crystal of titanomagnetite, its EDS spectrum and basic chemical composition



	MgO	Al_2O_3	SiO_2	P_2O_5	CaO	TiO_2	Fe_2O_3	MoO_3
Base(65)_pt1	0.39	1.42	6.44	36.24	53.46	0.31	0.74	1.00

Fig. 26. SG I.A3. Specimen SD1-66. SEM-BSE image of an elongated crystal of apatite, EDS spectrum together with a point analysis of its chemical composition

with an admixture of red clayey soil. The soil balls are dark-red and brown, differing in the content of quartz silt, from 2–5% (SX-125) to 10% (SF-124).

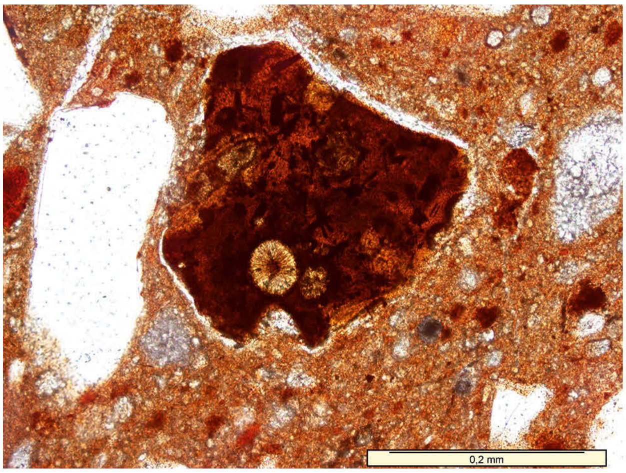
In transmitted light the matrix of individual samples is light, yellow-orange, locally grey, optically active. The slight sintering of the groundmass is corroborated by SEM observations.

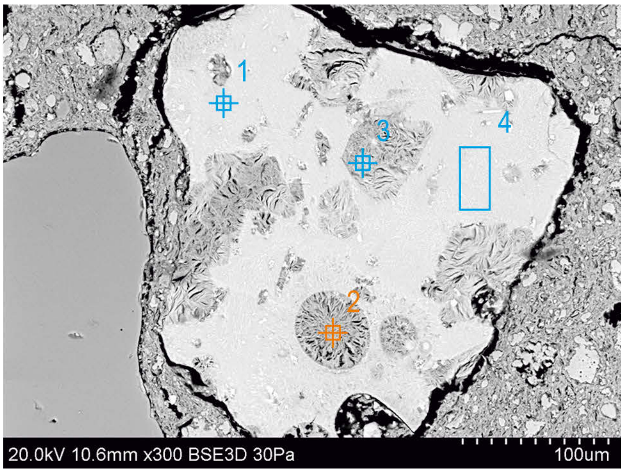
Associations of well-preserved foraminifers of the *Chiloguembelina* sp., *Chiloguembelina Cubensis* Howe and *Globigerina* ex gr. *praebulloides-officinalis* allow the age of the material to be determined as the Upper Eocene. In samples SFx-112, SD1-125, and SD1-66 also present are single fragments of *Corallinaceae*.

The material was tempered with a sand fraction of 0.15–0.25 mm. Its proportion varies: in samples SBc-35, SD1-66, SFx-112, SD1-125, SA1-127, and SE-134 it amounts to 10–20%, and in the other three samples SD2-72, SE-101 and SF-124 it does not exceed 5% of the volume. This is mostly monocrystalline quartz, showing both uniform and undulose light extinction. Most quartz grains have a moderate degree of roundness. Also present are small amounts of mainly micritic limestone, a few 'clear' plagioclases, potassium feldspars, single colourless pyroxenes, fine dark-yellow amphiboles, and opaque minerals, especially titanomagnetite (Fig. 25) Also present are single apatite crystals with characteristic low birefringence colours (cf. Fig. 26).

The presence of rare honey-yellow hyaloclasts is a characteristic feature. Sand-sized glassy 'yellow fragments' are irregularly translucent, fragmentarily argillitised, honey-brown in colour, usually characterised by sharp boundaries and fragmentary anisotropy showing undulose light extinction. Some fragments have the contours of a hexagonal habit. It cannot be excluded that some of them are pseudomorphs of garnet (?), pyroxene (?), amphibole, or olivine. What we can observe in them is a secondary mineralisation of iron, magnesium and calcium aluminosilicates, probably hydrated.

The identification of the above phases was also made using the XRD method. This study ruled out the presence of iddingsite and did not confirm the presence of minerals from the group of pyroxenes, amphiboles, olivines and garnets. A slight elevation





	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3
Base(61)_pt1	0.29	9.70	11.61	47.94	3.14	1.68	7.44	1.44	16.76
Base(61)_pt2	0.40	16.27	10.66	56.55	0.40	0.55	4.21	0.27	10.70
Base(61)_pt3	0.47	14.14	10.13	55.82	1.06	0.53	4.21	0.49	13.14
Base(61)_pt4	0.47	9.12	10.91	46.69	3.56	1.16	8.65	2.45	16.99

Fig. 27. SD1-66. Yellow fragment of hyaloclastite(?): the image obtained in transmitted light with parallel Nicol prisms (PPL) – left, a BSE image with marked points of analysis (right) and the chemical composition checked at marked points (bottom)

of the background signalcorroborates the presence of the glassy phase.

What attests to the volcanic origin of those particles is also the presence of scattered fine crystals of unaltered pyroxene, amphiboles and 'fresh' feldspars. Automorphism and no signs of any weathering or metamorphic changes of those minerals suggest their volcanic origin.[259]

Similarities: Iron Age Phoenician ceramics from Kommos in Crete[260], Tel Dor, [261] Yokneam – Amarna tablets[262], Megiddo.[263]

Petrographic group II

Red soil, silty clay, almost devoid of a sand-sized admixture.

This fabric is iron-rich; it contains an abundant amount of fine, silt-sized quartz or carbonates and taxonomically different foraminifer groups. Their age and the macroscopic similarity of shells served to distinguish its following subgroups.

Subgroup II.A (Figs. 28–33)

Paleogene foraminifers: silty rendzina soil.
Specimens: SBc-22, SDc-50, SDc-54, SDc-57, SOV-137.

[259] Cf. Cohen-Weinberger and Goren 2004: 77–78.
[260] Gilboa et al. 2015: 85, fig. 6.
[261] Cf. Eliyahu-Behar et al. 2008; "Group 5": 2901.
[262] Cf. Goren et al. 2004: 252–254, fig. EA259, Goren et al. 2002: 202.
[263] Cf. Arie et al. 2006: 560.

Fig. 28. SG II.A. Fragment of specimen SD-54

This is the most distinct subgroup. It contains a set of five thin-walled sherds fired to a light-red colour (2.5 YR 6/8-7/8) and a fragment of the wall of an oven, SOV-137.

On optical examination the matrix of the vessels is light red or light brown, depending on the level of oxidation, inactive in samples SDc-50, SDc-57 and SDc-54, active in sample SBc-22. The presence of numerous dark-red oval infillings is probably an effect of clay mixing (but the activity of earthworms cannot be ruled out.[264]

The raw material is extremely lean, rich in quartz silt, which accounts for 30–40% of the volume. It

[264] Cf. Koistra & Pulleman 2010: 410.

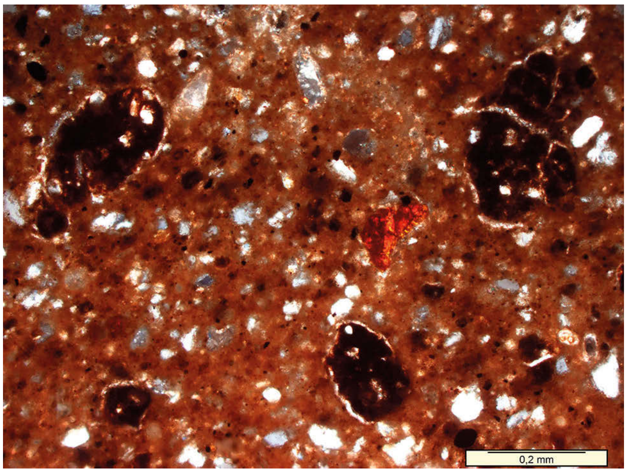


Fig. 29. SG II.A. Specimen SD-54, photomicrograph of a thin section – dark oval *terra rossa* balls and a fine "red fragment" embedded in a matrix rich in quartz-silt. Cross polarized light (CPL)

Fig. 30. SG II.A. Fragment of specimen SB22

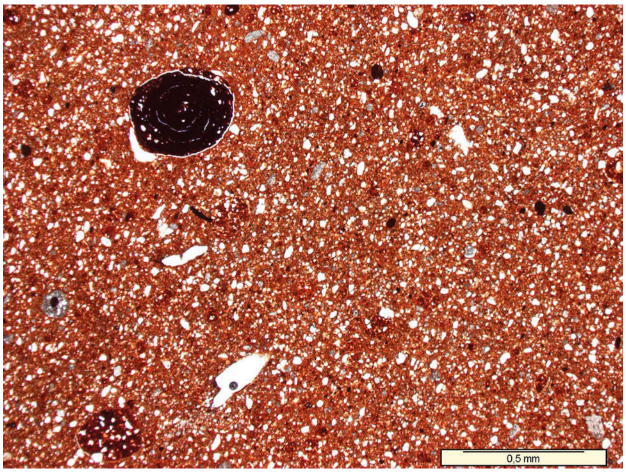


Fig. 31. SG II.A. Specimen SB22, photomicrograph of a thin section – dark-red oval infillings embedded in an extremely lean matrix, rich in quartz silt (PPL)

Fig. 32. SG IIA. Fragment of specimen SOV-137

is made up almost exclusively of particles of eolian quartz, there are also accessory grains of feldspar, oxidised amphibole and fine pedogenic (?)/ pyroclastic (?) 'red fragments'.

The sand-sized admixture consists of single oval grains of micritic limestone (especially in SDc-50), sporadically one can also find sand-sized quartz, feldspars and pyroxenes. Notable is the presence of single ferruginous (ferro-manganese) ooliths.

In spite of the sintering of the groundmass, some foraminifer associations have remained in the samples: *Acarinina* cf. *alticonica* Fleisher, *Acarinina* sp., *Chiloguembelina* sp., *Globigerina* sp., and *Paragloborotali* aff. *nana* (Bolli), dating the association to the Paleogene, most probably the Eocene. Since the rendzina soil found in the Sha'ar-Ha'Amakim region has developed on Eocene chalk, this can be a group of vessels produced locally.

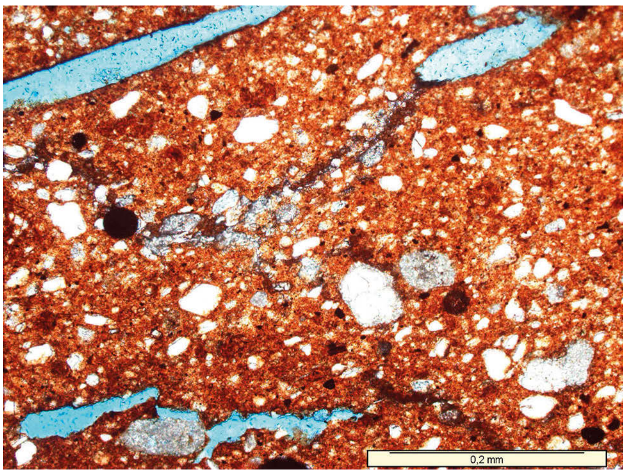


Fig. 33. SG II.A. Specimen SOV-137, photomicrograph of a thin section – numerous elongated pores left by organic matter (PPL)

The Eocene is also the age of the sample of the wall of kiln SOV-137, petrographically similar to the other samples in this subgroup (the same content of quartz silt, the presence of just a few sand-sized grains of limestone, and opaque ferruginous ooliths). Unlike the vessels of group II.1, perhaps because of a different function, this kiln fragment contains numerous straw remnants; it also shows a much lower degree of sintering.

Subgroup II.B (Figs. 34–39)

Cretaceous foraminifers: silty soil + chalk rich in *Globigerinelloides*.
Specimens: SC-36, SDc-44, SD1-69, SD2-76, SD2-77, SD2-79, SD2-80, SE-87, SE-92, SE-98, SE-99, SF-106, SF-107, SX-142, SX-148, SX-151, SOV-250.

Ceramics made of clay rich in calcite-quartz silt, with some clasts of chalk rich in *Globigerinelloides* and additions of *terra rossa* balls.

Most samples in this group: SC-36, SDc-44, SDc-49, SD1-69, SD2-79, SD2-80, SE-87, SE-98, SE-99, SF-107, SX-148, SX-151, and SOV-250, are light red on the surface and dark steel-grey on the fracture. Samples that differ in colour are SDc-46 (uniformly red) as well as SD2-76, SD2-77, SE-92, SF106, and SX142 – with a pale brown outer surface (10 YR 8/3), a grey core, and a brown inside (5 YR 6/4–5 YR 6/3).

The colour of the matrix in transmitted light varies depending on the level of reduction: red, dark red, brown, greyish black, reddish brown (cf. Appendix 1).

The groundmass is rich in quartz-calcite silt making up 30–50% of the volume. The proportions of quartz and carbonates vary, the dominant component usually being calcite, while the contribution of quartz does not exceed 15% of the volume. The actual content of carbonates is hard to determine because some of their particles have reacted with argillaceous minerals to form white points, or have left voids on decomposition, only partly filled by secondary micrite. Some carbonates, including foraminifers, have kept their crystallinity.

Fig. 34. SG II.B. Fragment of specimen SD2-80

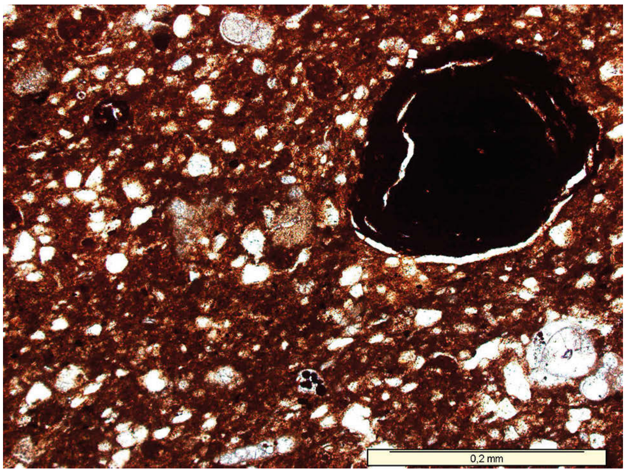
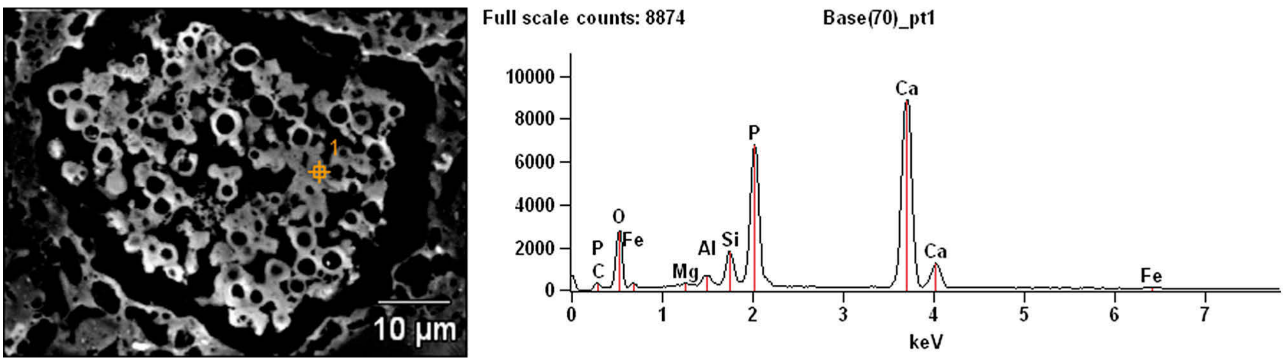
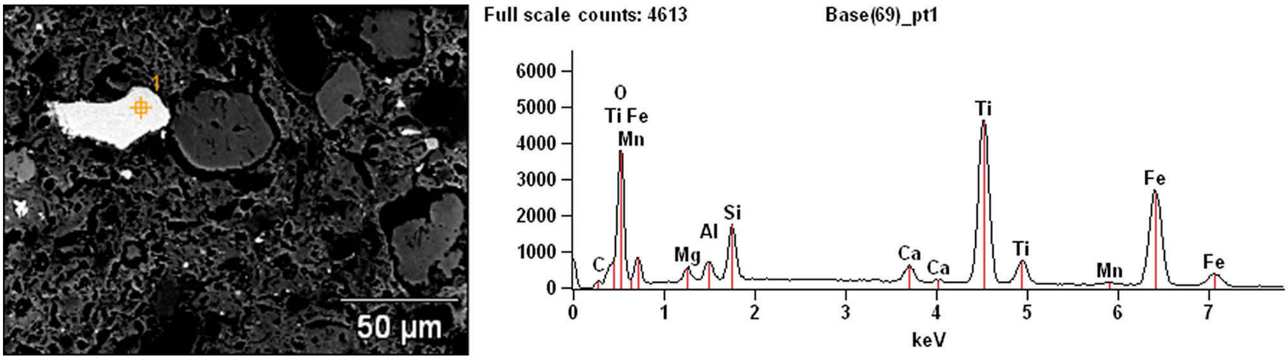


Fig. 35. SG II.B. Specimen SD2-80, photomicrograph of a thin section – pedogenic ferruginous oolith in a matrix rich in calcite-quartz silt (PPL)



	MgO	Al_2O_3	SiO_2	P_2O_5	CaO	Fe_2O_3
Base(70)_pt1	0.43	1.88	6.92	37.00	52.52	1.26

Fig. 36. SG II.B. Specimen SF-107 – electron micrograph, a cellular texture (bone fragment?) with a calcium phosphate composition



	MgO	Al_2O_3	SiO_2	CaO	TiO_2	MnO	Fe_2O_3
Base(69)_pt1	2.34	2.90	8.10	2.30	41.34	0.77	42.26

Fig. 37. SG.II.B. Specimen SF-107 – SEM-BSE image of an ilmenite crystal together with its chemical composition

Fig. 38. SG II.B. Fragment of specimen SOV-250

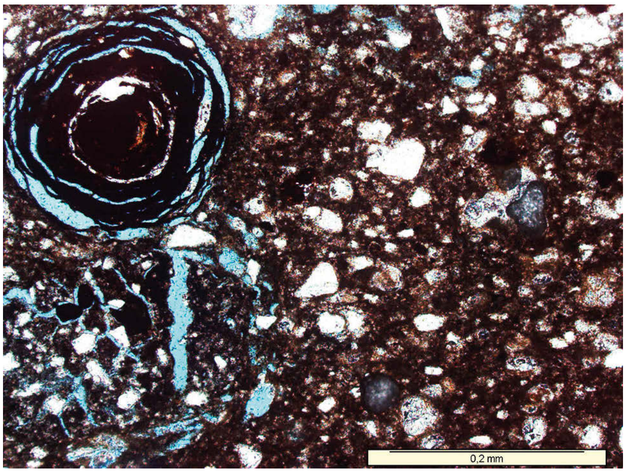


Fig. 39. SG II.B. Specimen SOV-250, photomicrograph of a thin section – ferruginous oolith diagnostic for pedogenic processes (PPL)

Accessory minerals are silt-sized potassium feldspars and plagioclases as well as single crystals of yellow-orange amphibole.

A SEM-EDS study revealed the presence of apatite, iron oxide and titanium (ilmenite?).

The material contains oval infillings and pedogenic concentration features, differing in the degree of impregnation with iron and manganese compounds. Those structures differ in colour, being cherry-red in oxidised parts of a vessel and brown or amorphous – black in reduction zones; they also vary in the content of quartz silt. Especially significant is the presence of irregular clasts of light-grey chalk rich in *Globigerinelloides* sp. It is possible that they are fragments of the parent rock on which the examined soil has developed. A characteristic feature of the entire association is the presence of opaque ferruginous ooliths. The composition of the foraminifer associations preserved in the ceramics: *Globigerinelloides* sp., *Hedbergella* sp. and *Heterohelix* sp., puts the age of the material at Upper Cretaceous.

Sand-sized aplastic inclusions (their share not exceeding 5% of the volume) are mostly variously shaped micritic, less often sparite limestones, sometimes rhomboid in contours. There also appear well preserved Echinoid spines and oval cross-sections of indeterminate organic textures, perhaps algae. A characteristic feature of the entire association is the presence of opaque ferruginous ooliths.

The SOV-250 sample coming from a domestic oven is light-brown on the surface (2.5 YR 7/3) and light-red on the fracture, with a brown core. The remainder of petrographic features are similar to those of the other vessels of this group.

Subgroup II.C (Figs. 40–44)

Cretaceous foraminifers: soil rich in carbonate silt (no chalk).

Specimens: SDc-46, SDc-47, SD2-73, SD2-75, SD2-81, SD2-83, SE-96, SF-110, SFx-118, SX-144, SX-147.

The colour of the vessels in this group varies: SDc-46, SDc-47, SF-110 and SFx-118 have been fired to a

Fig. 40. SG II.C Fragment of specimen SE-96

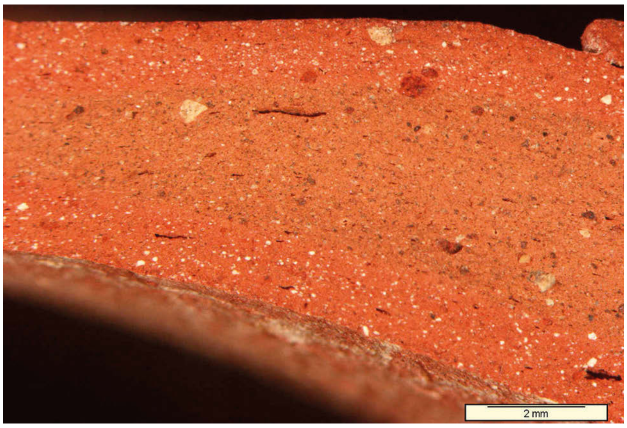


Fig. 41. SG II.C. Fragment of specimen SF-110

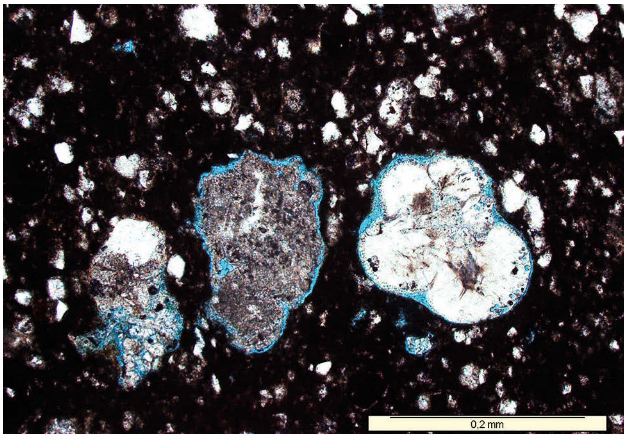


Fig. 42. SG II.C. Specimen SE-96 10II, photomicrograph of a thin section (PPL)

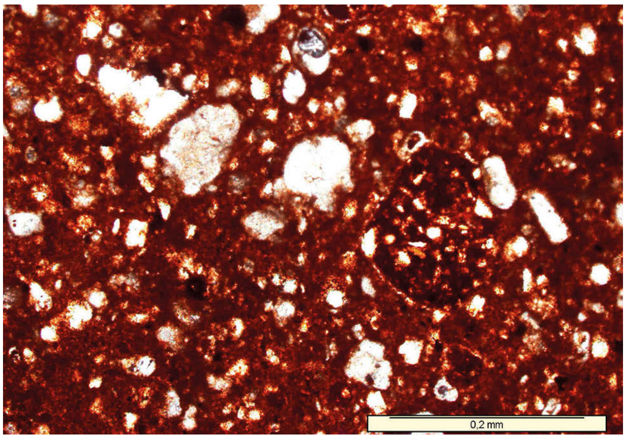


Fig. 43. SG II.C. Specimen SF-110, photomicrograph of a thin section (PPL)

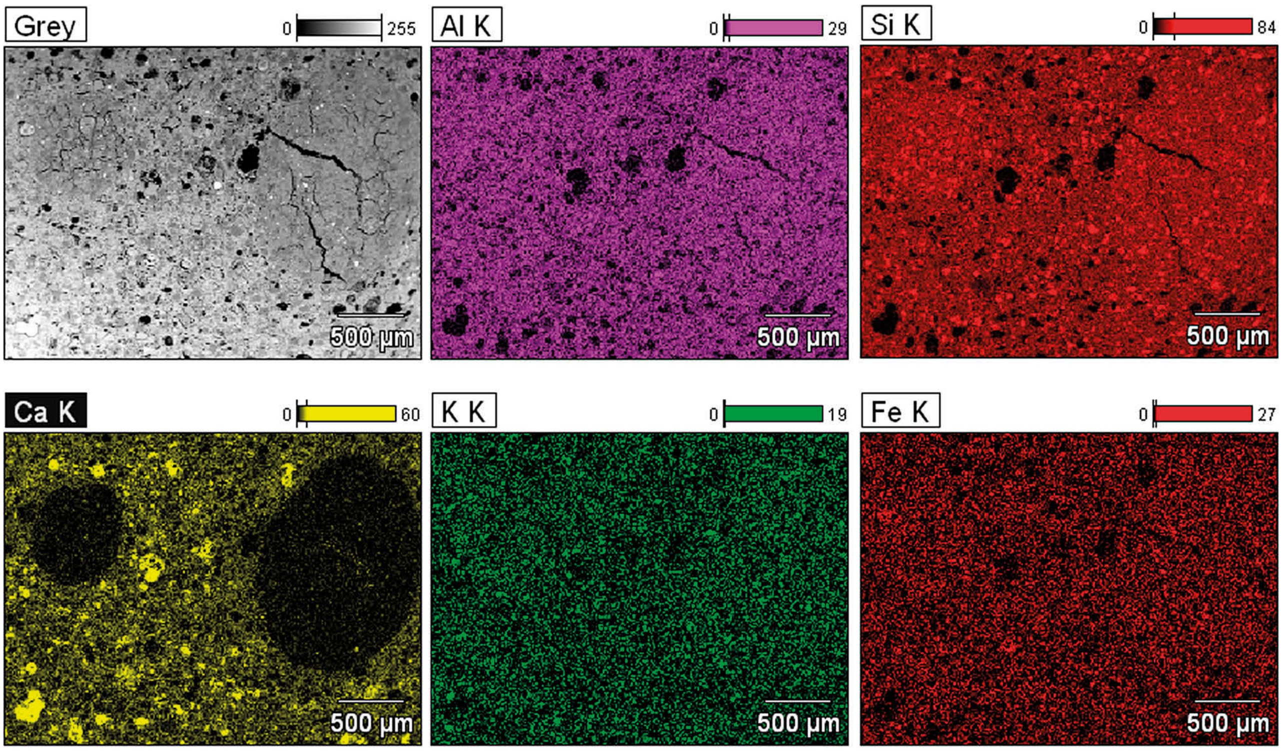


Fig. 44. SG II.C. Specimen SFx-118, electron micrograph and EDS individual element mapping of oval dark-red soil balls. Note the lack of calcium

uniform red (10R 6/8), specimens SD2-73, SD2-75, SD2-81, and SE-96 are red on the outer surface (10R 7/6), but steel-grey on the fracture, while SX-144 and SX-147 are light-brown on the outer surface (5 YR 7/4), steel-grey on the fracture, and reddish-grey (5 YR 5/2) inside.

Those are ceramics similar to group II.B, but with no chalk clasts. Besides, the chief aplastic component is carbonate silt (prevailing over quartz silt in terms of quantity). The matrix is rich in carbonate silt, hence it has been artificially enriched with an admixture of red soil devoid of carbonates.

The microfauna found in samples SDc-46, SDc-47, SD2-73 and SD2-75: *Globigerinelloides* sp., *Globigerinelloides* aff. *bolli* Pessagno, *Hedbergella* sp., and *Heterohelix* sp., show the age of the material to be Late Cretaceous.

Subgroup II.D (Figs. 45–53)

Soil rich in calcareous silt (unknown age of parent rock).

Specimens: SDc-42, SDc-43, SDc-45, SDc-52, SDc-53, SDc-55,SDc-56, SD2-84, SD2-85, SE-89, SE-91, SE-93, SF-103, SF-104, SD1-121, SX-141, SX-145.

A set of vessels produced from the material with an elevated content of calcareous silt and a small proportion, or even absence, of sand admixture, with signs of pedogenic changes. The state of preservation of the microorganisms makes it impossible to determine the geological age of the material.

This is a diversified set in which the highest similarity is mostly observed among following subsets:

II.D1. Specimens: SE-91, SDc-52.

Those are two fragments of thin-walled vessels of dark-grey colour (5 YR 5/1).

In coincident light with parallel Nicol prisms, the matrix is brown-black, with a very high degree of sintering. Quartz silt makes up ca. 10% of the volume, the next 20% are voids left by calcite silt. The silt fraction also includes single feldspars and heavy minerals, with rutile as predominant among them. There are local oval or elongated white spots left by decomposed chalk. The sand admixture is negligible – there are single grains of monocrystalline quartz and flints. Both samples are similar to the Cretaceous-clay vessels of group Sh.II.B. Notable in sample SD2-52 is a presence of dark honey-yellow hyaloclastite fragments.

II.D2. Specimens: SDc-42, SDc-49, SDc-53, SDc-56, SD2-85, SE-89, SF-103, SF-104, SD1-121,SX-141. Macroscopically, most specimens are red (10R 6/8), while SDc-56 and SF-104 are beige in colour (2.5 YR 8/3–4).

The matrix in PPl stays red and inactive (with the exception of lightly fired SD2-85), and contains ca. 15 vol.% of silt, mostly carbonate, and single silt-sized yellow amphiboles. Notable are numerous ferric ooliths. The sand admixture is mostly decomposed grains of carbonate rocks of fine and medium sand fractions, quartz silt comprising 10% of the volume.

What distinguishes this sample is the presence of many quartz grains of the sand fraction. Predominant among them is monocrystalline quartz, usually subangular, showing both uniform and undulose extinction. It is accompanied by some feldspars, always clear, and pyroxene as an accessory mineral. Also present are opaque Fe oxides.

II.D3. Specimens: SDc-45, SD2-84, SX-145.

The collection of vessels light-creamy on the surface (5 YR 8/4), grey on the fracture (5 YR 6/1).

The matrix is red or light-brown, in parts of reduction dark-brown, inactive, relatively rich in quartz silt (15% of the volume). The share of calcite silt is also considerable, but hard to assess because of the high temperature of firing. Accessory components are orange grains of oxidised amphiboles and

Fig. 45. SG II.D1. Fragment of specimen SD-52

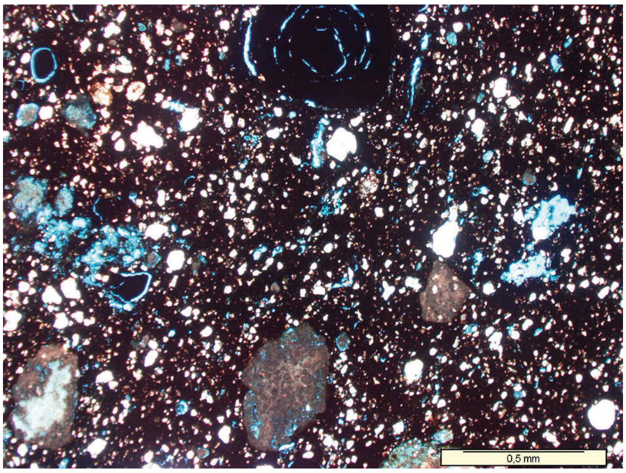


Fig. 46. SG II.D1. Specimen SD-52, visible a ferruginous oolith and yellowish spots left by decomposed chalk (PPL)

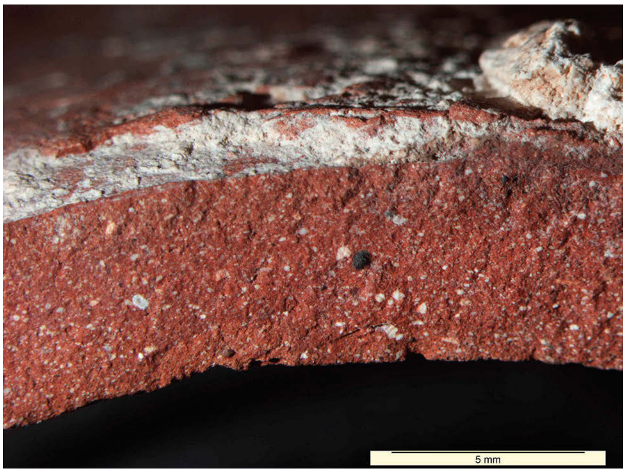


Fig. 47. SG II.D2. Fragment of specimen SE-89

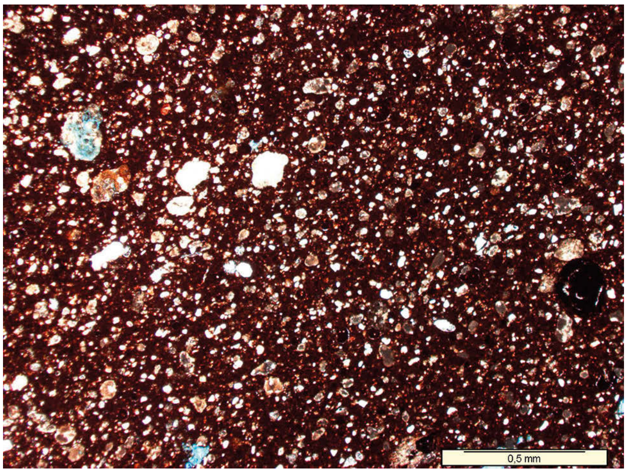
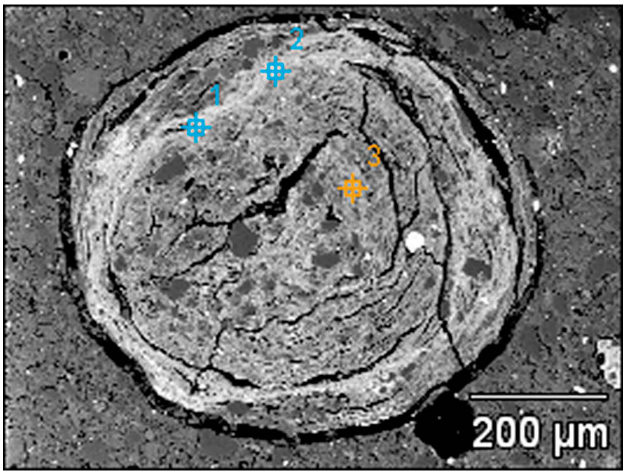


Fig. 48. SG II.D2. Specimen SE-89, photomicrograph of a thin section (CPL)



	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3
Base(88)_pt1	0.43	1.51	15.95	37.50	0.44	0.99	1.91	1.79	4.65	34.85
Base(88)_pt2	0.00	1.35	16.16	37.80	0.42	1.32	1.95	0.97	6.89	33.15
Base(88)_pt3	0.51	1.65	16.13	37.00	0.00	0.92	2.23	1.37	8.28	31.91

Fig. 49. SG II.D2. Specimen SD2-85, electron micrograph of a ferric oolith and the chemical composition checked at marked points

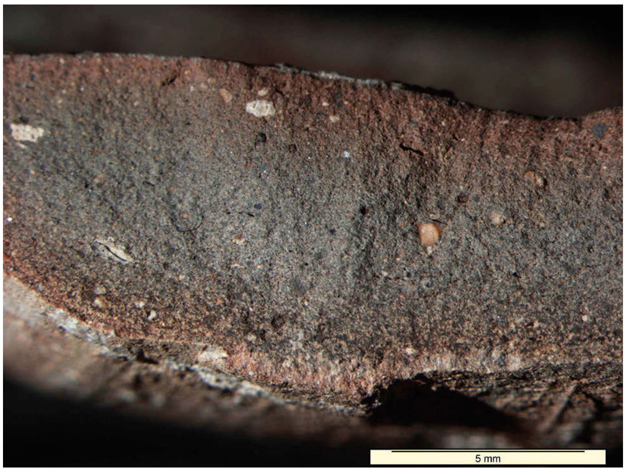


Fig. 50. SG II.D3. Fragment of specimen SX-145

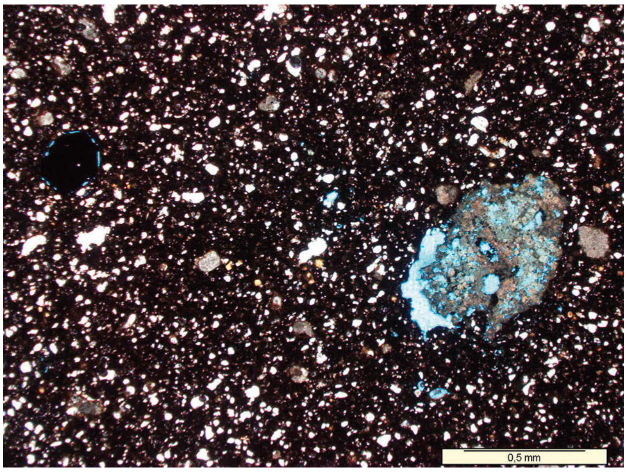


Fig. 51. SG II.D3. Specimen SX-145, photomicrograph of a thin section (PPL)

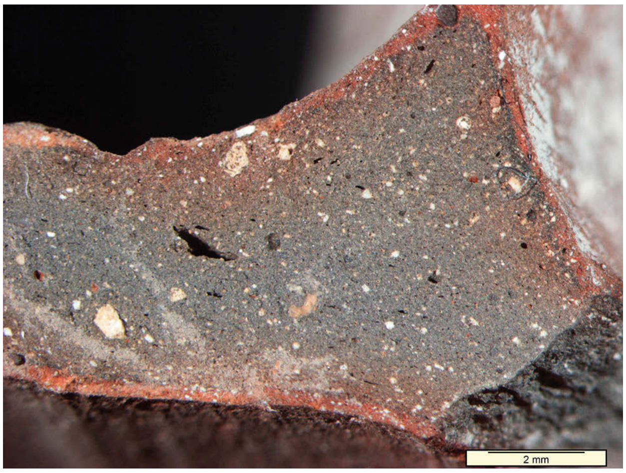


Fig. 52. SG II.D4. Fragment of specimen SD-43

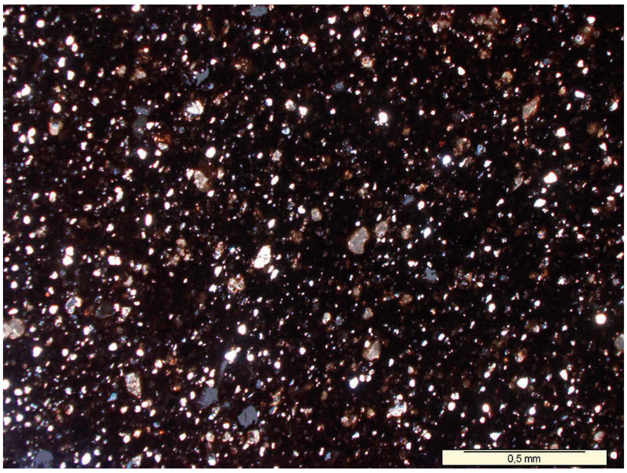


Fig. 53. SG II.D4. Specimen SD-43, photomicrograph of a thin section, cross-polarized light (CPL)

pyroxenes. A characteristic feature is the presence of chalk fragments, decomposed during firing, the remnants of which are irregular, sometimes elongated clusters of porous micrite. Sand-sized aplastic fragments are absent, in all the samples there are single ferric ooliths.

II.D4. Specimens: SDc-43, SDc-55, SE-93.

The collection of vessels light-brown on the outside (2.5 YR 7/4), grey inside (2.5 YR 5/1), heavily sintered.

The matrix is dark-grey, inactive, rich in decomposed calcareous silt.

The sand-sized admixture is less than 2% of the volume. Those are single grains of monocrystalline quartz as well as polycrystalline feldspars. What distinguishes this group from that of II.D3 is the absence of chalk clasts.

Similarities (for whole Petrographic Group II): Shikhin,[265] Horbat Uza, Ahihud,[266] Tel Michal,[267] Persian-period Horbat Malta.[268]

Petrographic Group III (Figs. 54–55)

Cretaceous dolomitic marl.

Specimens: SE-94, SE-97, SF-102, SF-105, SF-108, SFx-113, SFx-114, SFx-117, SFx-149, SX-150.

The ceramics of characteristic light-red colour (2.5 YR 7/8).

This is a group the fabric of which stands out for its very high content of fine rhombohedral crystals of dolomite. Those are amphorae with a light-red shard (2.5 YR 6/8), massive, only sample SX-150 is light brown (5 YR 6/6), as well as more lightly fired and slightly weathered. Their matrix is composed of dolomitic marl, light red and yellow in PPL, light brown in partly reduced fragments.

The argillaceous minerals of the groundmass have remained optically active in samples SE-97, SF-102, SF-105, SF-108, and SFx-117, and residually active in samples SE-94, SFx-113, SFx-114, SFx-149, and SX-150, thus reflecting the different temperatures of firing.

Dolomite crystals are silt-sized or fine-grained sand, 0.01–0.13 mm, usually automorphic, accounting for 40–60% of the volume.

The raw-material of samples SE-97 and SF-108 is enriched with an admixture of *terra rossa* containing some quartz silt. The red silty soil of *terra rossa* is distributed in the form of stains and fine pellets. The other vessels of this group contain just a few fragments of ferruginous argillaceous shales devoid of quartz silt.

Aplastic inclusions can be observed in the form of single bits of dolomitic rock; their content is higher in samples SF-102, SF-105 and SFx-114.

Most species found in the polished sections of this group are indicative of the Late Cretaceous, i.e. younger than the Albian: *Hedbergella* sp.; *Heterohelix* sp., single *Globigerinoides*. In the case of sample SF-102, the presence of *Guembelitria* aff. *cretacea* Cushman gives the age of the material as not older than the Santonian.

Similarities: different ceramic assemblages dated to several periods, usually assigned to Judean-Samarian mountain ridge,[269] Amarna tablets,[270] LBA Ashdod,[271] Bet-She'an,[272] Persian-period Tel Michal.[273]

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265 Cf. Adan-Bayewitz & Wieder 1992: 198–199; Wieder & Adan-Bayewitz 1999: 335–338.

266 Avshalom-Gorni & Shapiro 2015: 80–83.

267 Gorzalczany 2006: 60–61.

268 Gorzalczany 2008: 82–83.

269 Cf. Goren 1995: 291, Gorzalczany 2006: 61, Michniewicz & Krzyśko 2003; Michniewicz 2009.

270 Cf. Goren, et al. 2004: 262–63.

271 Cf. Cohen-Weinberger 2013: 124.

272 Cf. Cohen-Weinberger & Goren 2011: 218–219.

273 Cf. Gorzalczany 2006: 61.

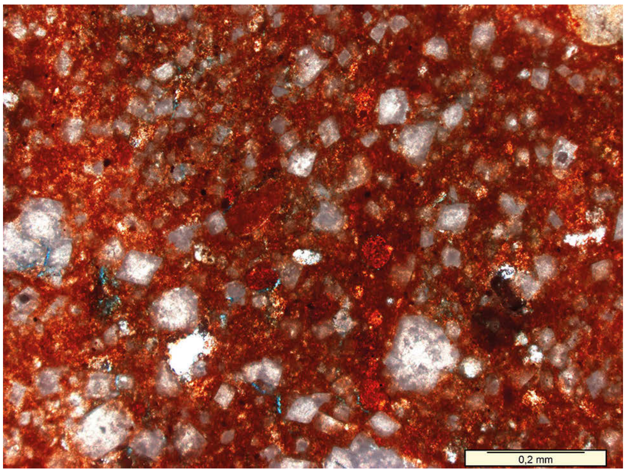


Fig. 54. PG III. Specimen SE-94, photomicrograph of a thin section. Note white stains left by decomposed dolomite (CPL)

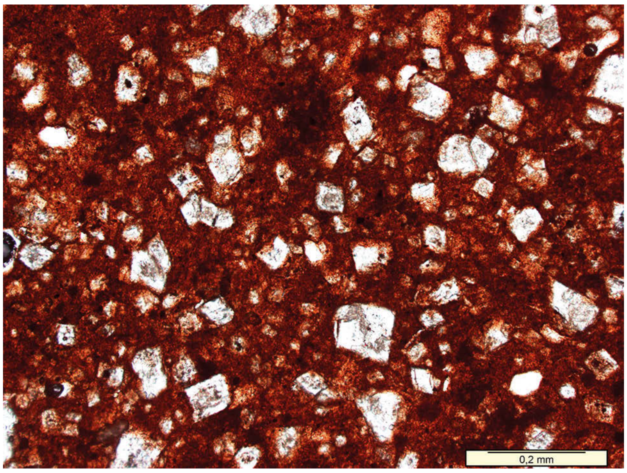


Fig. 55. PG III. Specimen SE-97, photomicrograph of a thin section – note numerous rhomb-shaped dolomite crystals (PPL)

Petrographic Group IV

'Creamy pottery': Chalky marl of different age plus *terra rossa* balls or ferruginous argillaceous shale.

Specimens: SA-1, SA-3, SA-7, SBc-21, SBc-23, SBc-24[274], SBc-25, SBc-28, SBc-33[274], SC-40, SD1-65, SA-9, SA-10, SBc-16, SBc-34, SD1-61, SE-90, SA-120, SBc-26, SC-37, SD2-74, SOV-139[274].

A group of fragments of vessels with creamy-white sherds (10 YR 8/3-5 YR 8/4), slightly darker on the fracture, sometimes light-beige (10 YR 7/3 – 6/3). They are made of highly calcareous marl containing abundant foraminifers, some *terra rossa* balls, or ferruginous argillaceous shale fragments.

Predominant among the microorganisms are foraminifers, indicating the age of the material to be Cretaceous and Paleogene. Their state of preservation differs, what has been left of them is often only fine, grey-golden clusters of micrite and voids.

The colour of the matrix in transmitted light depends on the content of *terra rossa* and the reduction level of a shard. Usually it is grey-olive with a hint of red pigmentation. Differences in the temperature of firing are reflected in the variously preserved optical activity of argillaceous minerals. *Terra rossa* occurs as an admixture in the form of dark-red points or irregular streaks and spots. In some samples there are grey, isotropic oval balls of high micro-porosity. Those are fragments of a red soil in which iron has undergone reduction. What indicates such an origin of those clasts is the locally preserved red colour, the presence of silt-sized quartz, and micro-oolithic pedogenic textures (the reduction process has not been completed). It cannot be ruled out that some of those grains are fragments of tephra.

Both the percentages of the above-mentioned components and the petrographic composition of the aplastic admixture vary. In this context we observe especially great similarities among the following subgroups of vessels:

Subgroup IV.A (Figs. 56–61)

Late Paleocene – Eocene chalky marl, red soil admixture.

Specimens: SA-1*, SA-3, SBc-21*[275], SD1-59, SD1-61.

The material devoid, or almost devoid, of a sand-sized admixture (in SA-3 and SD1-61 the sand-sized quartz accounts for less than 3% of the volume). These are ceramics light beige in colour (10 YR 8/2, 10 YR 7/2), massive, made of almost pure marl.

On optical examination, they have a granular texture as an effect of the scatter of golden micrite pellets formed by the decomposition of skeletons of microorganisms.

Fig. 56. SG IV.A. Fragment of specimen SA-1

[274] Marl of Cretaceous age.

[275] Samples containing a few reduced *terra rossa* pellets.

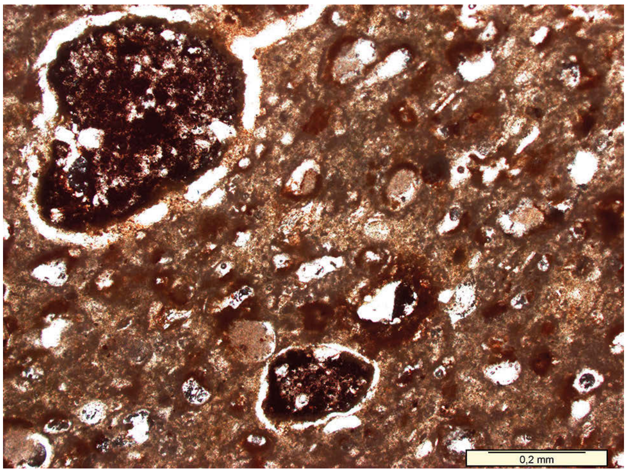


Fig. 57. SG IV.A. Specimen SA-1, photomicrograph of a thin section – isotropic oval balls embedded in a highly calcareous matrix (PPL)

The ceramics have a small admixture of ferric soil visible in the form of red pellets, often pigmented black after reduction.

The age of the material is possible to determine only in samples SBc-21 and SC-40 – the Paleogene (cf. **Appen**dix 2).

Note the grey grains of quartz silt.

Subgroup IV.B (Figs. 62–63)

Eocene Chalky marl + large clasts of isotropic levigated red soil.
Specimens: SBc-23, SBc-25, SC-40.

The matrix is grey or pale orange, with numerous clasts of red soil (0.2–2.0 mm in diameter) and clasts of grey foraminiferous chalk. Together those components make up ca. 15% of the volume. Occasionally one can find transparent, colourless sand-sized particles of the glass as well as single automorphic feldspars. What characterises this subgroup is the absence of quartz in the silt or sand-sized form.

Subgroup IV.C (Figs. 64–65)

Chalky marl of unknown age plus amorphic red clayey shales plus 5–8% of fine quartz sand.
Specimens: SA-10, SBc-16, SD1-65.

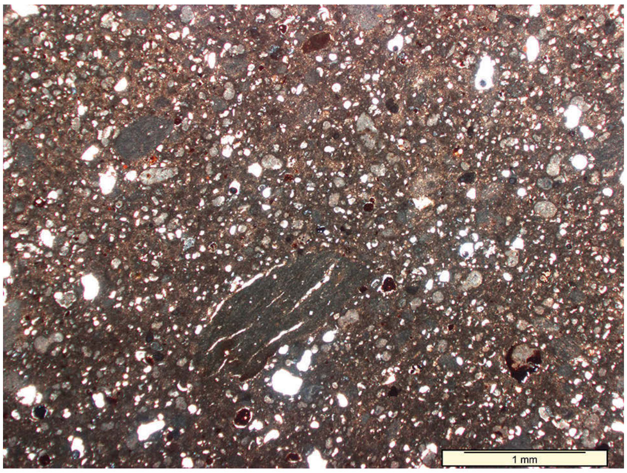


Fig. 58. SG IV.A. Specimen SA-3, photomicrograph of a thin section (PPL)

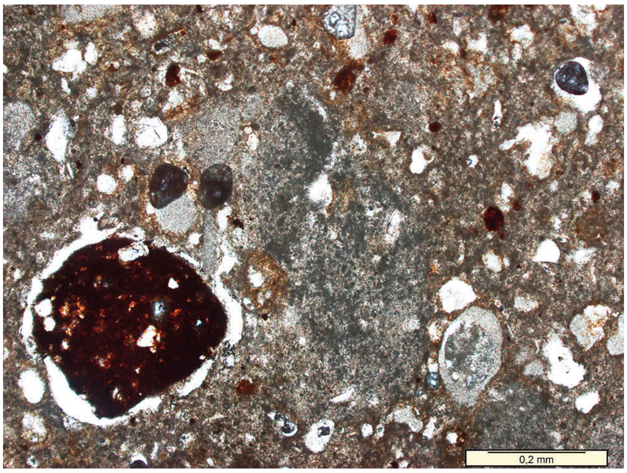
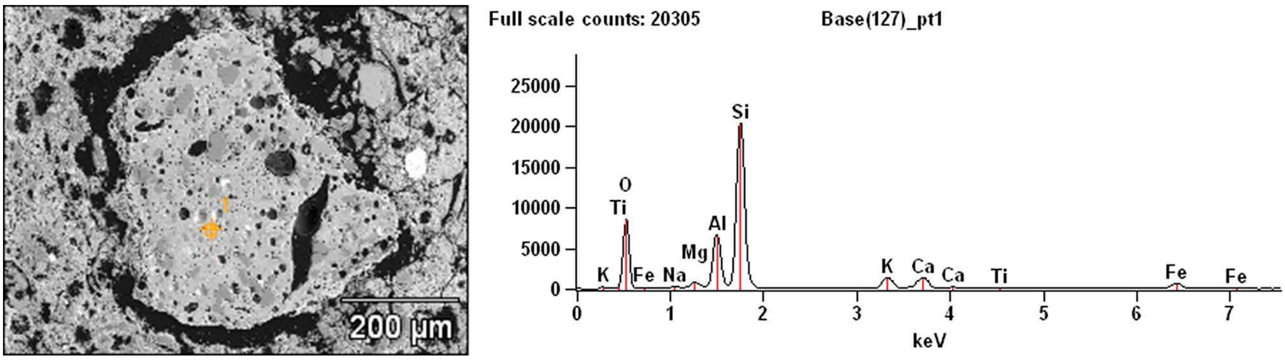


Fig. 59. SG IV.A. Specimen SA-3 (higher magnification) – a ferric soil pellet within a chalky matrix (PPL)



	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3
Base(127)_pt1	0.69	1.59	16.38	65.04	3.70	5.00	0.84	6.77

Fig. 60. SG IV.A. Specimen SA-1 – electron micrograph, the EDS spectrum and chemical composition of a pigmented black *terra rossa* pellet. The spot of analysis is marked

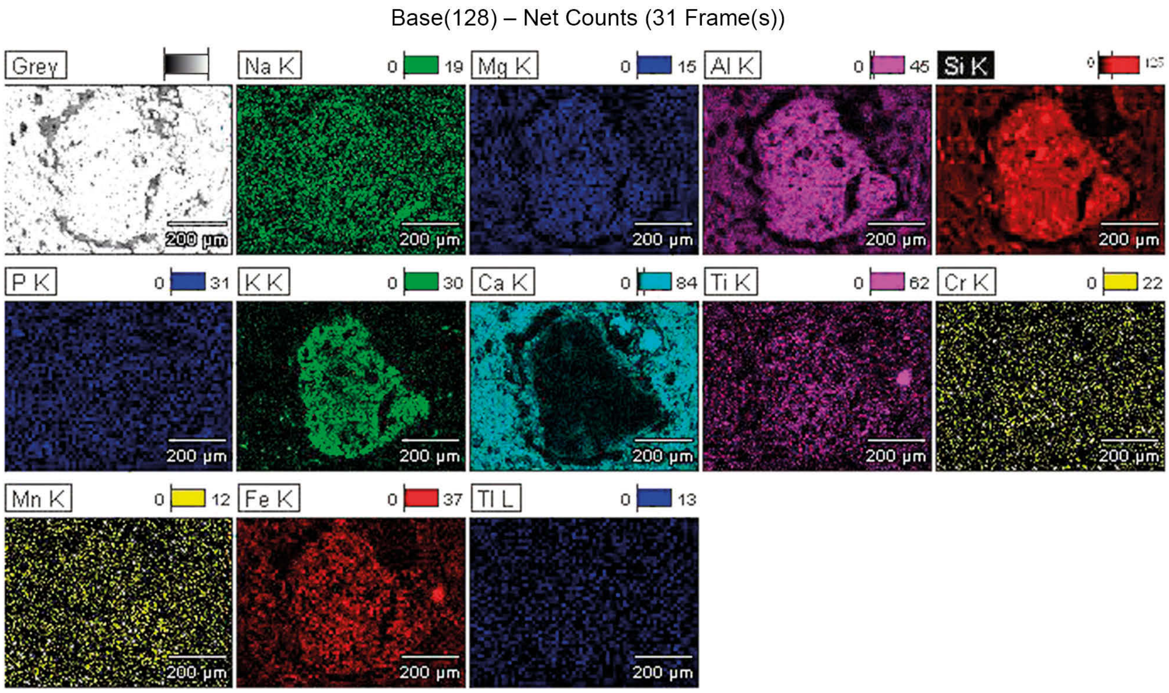


Fig. 61. SG IV.A. Specimen SA-1 – electron micrograph and EDS individual element mapping of a black *terra rossa* pellet; note the elevated level of potassium

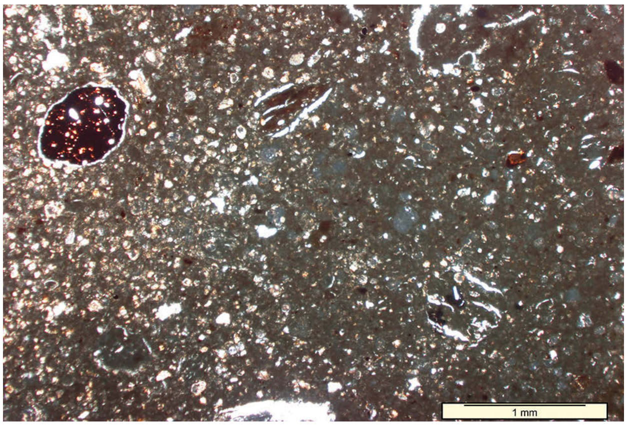


Fig. 62. SG IV.B. Specimen SBc-23, photomicrograph of a thin section (PPL)

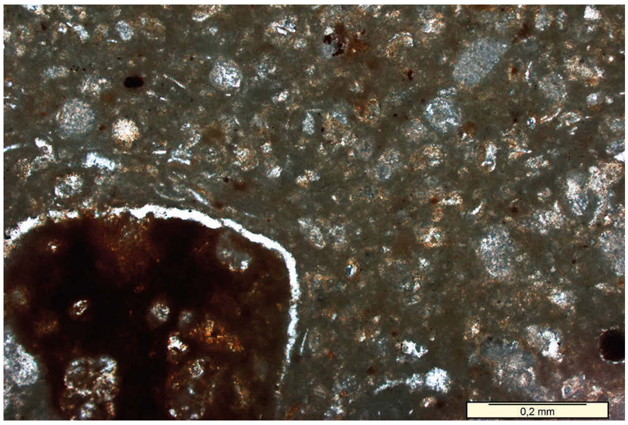


Fig. 63. SG IV.B. Specimen SBc-23, photomicrograph of a thin section (higher magnification) – red soil balls (PPL)

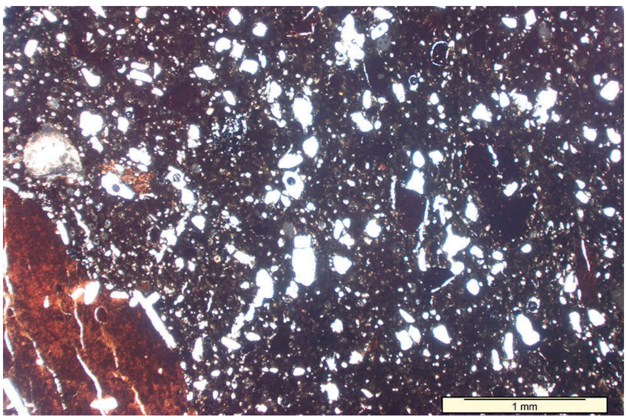


Fig. 64. SG IV.C. Specimen SD1-65, photomicrograph of a thin section (PPL), note diagnostic presence of of red shale fragment

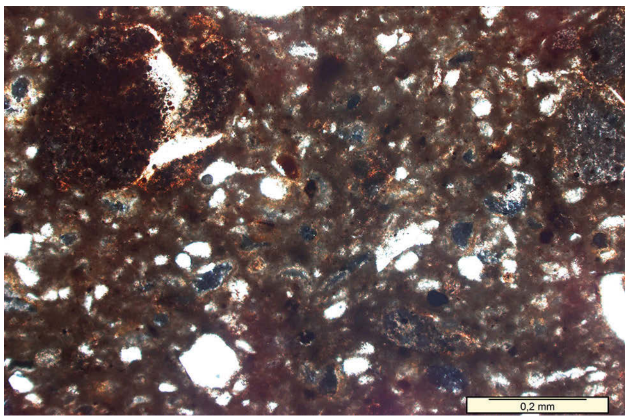


Fig. 65. SG IV.C. Specimen SD1-65, photomicrograph of a thin section at higher magnification (PPL), note the presence of an amorphic black ball

The ceramics are similar to subgroup IV.B, but with 5–10% of quartz silt and an admixture of quartz sand making up 5–7% of the volume.

Their characteristic feature is also the presence of numerous argillaceous red shales, amorphic black soil (?) balls and a small admixture of quartz silt (2–5% of the volume). Sample SA-10 contains a glass clast. The absence of preserved foraminifers makes it impossible to determine the age of the material.

Subgroup IV.D (Figs. 66–67)

Paleogene marl + 5–8% quartz sand.
Specimens: SA-5, SA-9, SBc-26, SBc-34, SC-37, SD2-74, SE-90, SA-120.

Those ceramics are similar to IV.A, but they contain 5–8% of fine-grained quartz sand. On optical examination the matrix is grey with a green hue, or yellowish-grey, mottled red with diffused iron compounds, isotropic with crossed Nicol prisms, with locally preserved original lamination.

Predominant in the aplastic admixture (5–8% of the volume) is monomineral quartz of the 0.1–0.25 mm fraction (ca. 95%), angular to subrounded, usually showing uniform light extinction. The remaining 5% of the admixture includes 'clear' feldspars and flints. Present in sample SA120 are sandstone clasts with a carbonate cement (*kurkar*).

In most samples there are relatively few variously shaped 'black components' which are pellets of red soil darkened in reduced-oxygen conditions, characterised by an elevated content of iron and magnesium. The presence of single specimens of foraminifers *Pseudohastigerina* sp. and *Chiloguembelina* sp., and of relatively numerous *Globigerina* sp. is indicative of the Paleogene (Eocene?).

Similarities: e.g. Akko, FC 1D.[276]

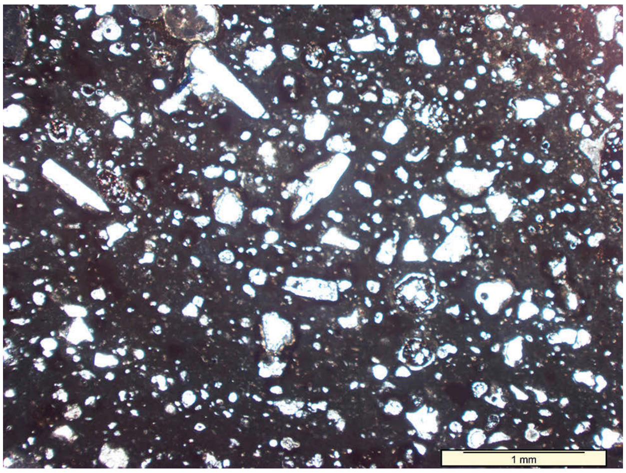


Fig. 66. SG IV.D. Specimen SX-120, photomicrograph of a thin section (PPL)

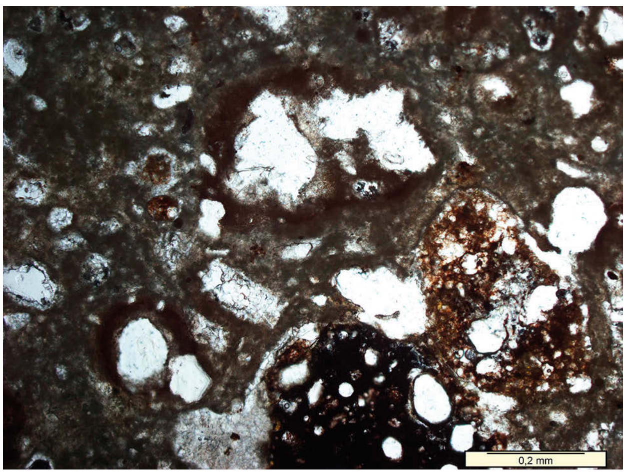


Fig. 67. SG IV.D. Specimen SX-120, photomicrograph of a thin section at higher magnification (PPL). Note the black circular component on the bottom right of the photo (PPL)

Subgroup IV.E (Figs. 66–73)

Cretaceous marl plus amorphic clayey soil or slag plus 5–8% fine quartz sand.
Specimens: SBc-24, SBc-28[277], SBc-33, SOV-139.

Macroscopically, ceramics of a creamy colour (7.5 YR 8/4) with numerous black pellets of reduced red soil, sometimes containing pedogenic ferruginous ooliths. Under the microscope, the matrix is light-grey with an orange-green hue, probably highly foraminiferous. The shells of microorganisms have undergone decomposition; what have remained of them are micrite pellets giving the groundmass a (micro-granular?) texture. The matrix does not contain quartz silt; apart from its carbonates it is optically inactive.

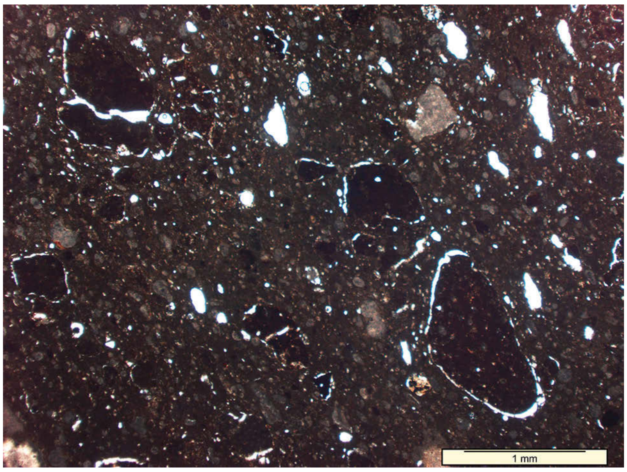


Fig. 68. SG IV.E. SBc-33, photomicrograph of a thin section (PPL)

[276] Bettles 2003b: 164–169.

[277] Because of the absence of microorganisms preserved in the material, it can be of Eocene age and belong to the technologically similar subgroup IV.B.

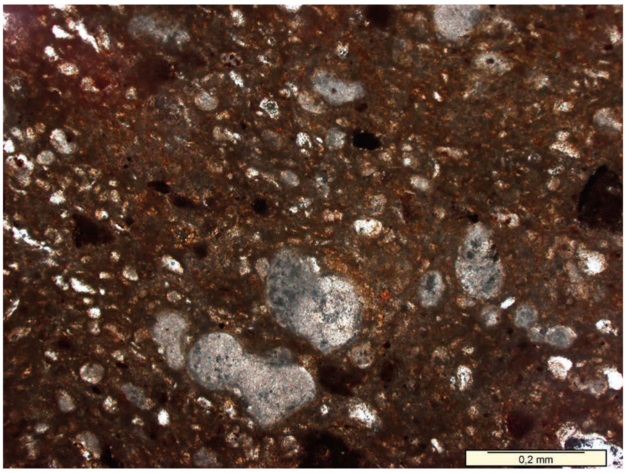


Fig. 69. SG IV.E. Specimen SBc-33, photomicrograph of a thin section (higer magnification– numerous white carbonates left by decomposed microfossils (CPL)

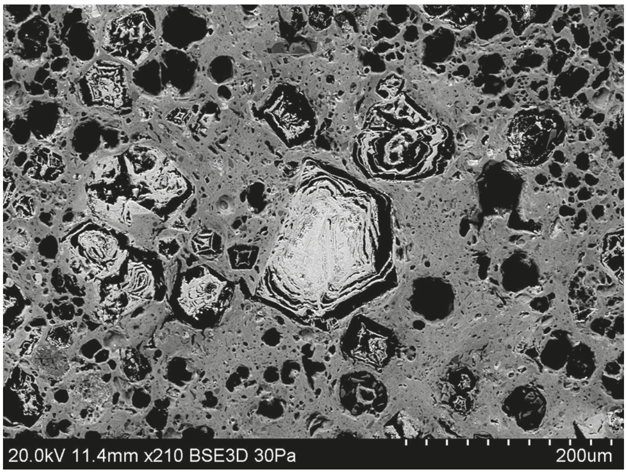
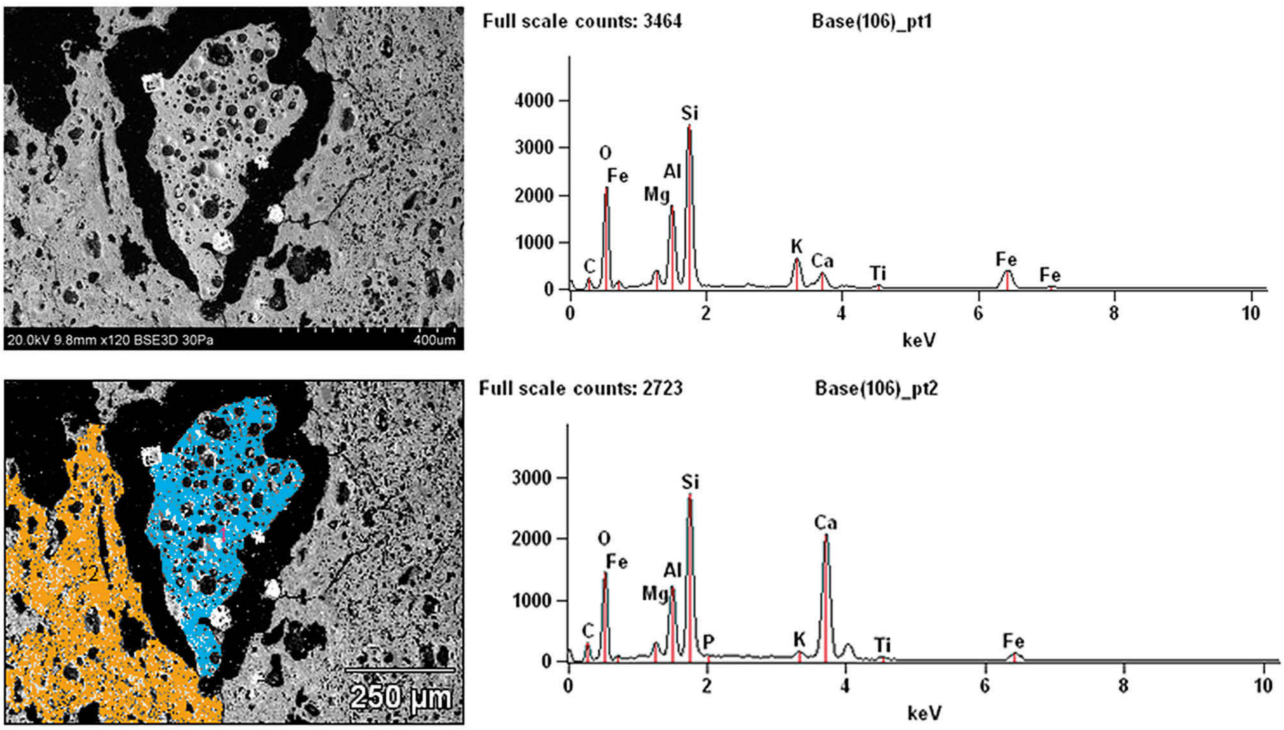


Fig. 70. SG IV.E. Specimen SBc-33, electron micrograph of ferro-manganese nodules embedded in 'black ball'

What distinguishes this subgroup is the presence of numerous black opaque balls of black-reduced soil containing single ferruginous ooliths. The presence of *Hedbergella* sp., *Heterohelix* sp. and *Globigerinelloides* sp. puts the age of the material at Late Cretaceous.

SOV-139 is a sample from an oven fired to a light-creamy colour. On optical examination its matrix is light yellow. It was made of calcareous marl containing an admixture of chalk. The composition of the preserved foraminifers: *Globigerinelloides* aff. *bentonensis* (Morrow), *Heterohelix* aff. *moremani* (Cushman), *Hedbergella* sp., and *Hedbergella* aff. *infracretacea* (Glaessner) as well as the presence of fairly numerous cross-sections of very small plant fragments (charophytes?) put the age of the material at Late Cretaceous (not older than the Albian because



	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3
Base(106)_pt1	3.72	18.88	48.82	0.00	6.59	4.44	1.01	16.54
Base(106)_pt2	2.62	14.81	40.34	1.10	1.24	33.45	0.95	5.49

Fig. 71. SG IV.E. Specimen SB-28. Electron micrograph, the spectra and chemical composition of a 'black ball' (blue) and a marly matrix (yellow)

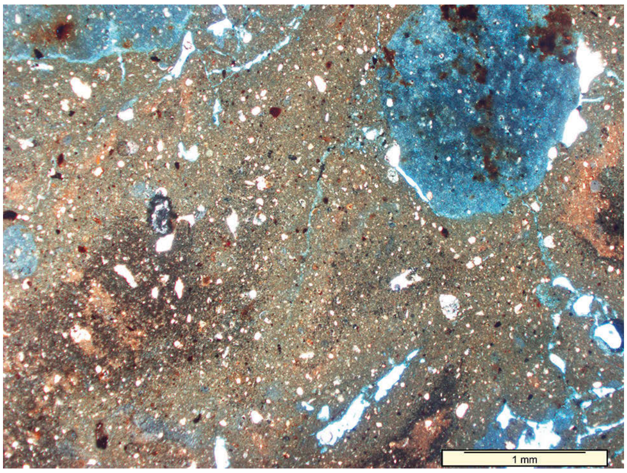


Fig. 72. SG IV.E. Specimen SOV-139 –photomicrograph of a thin section (CPL)

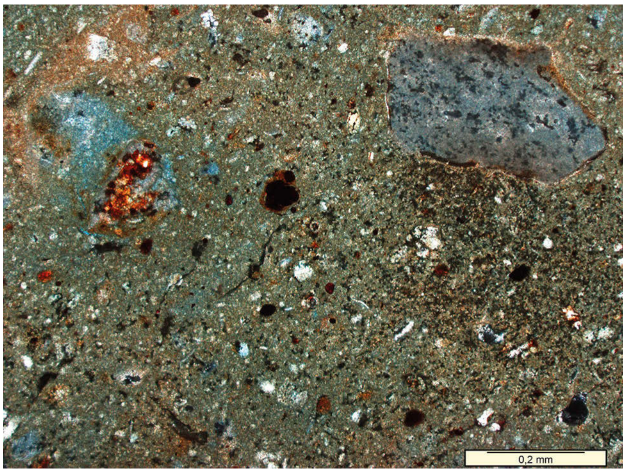


Fig. 73. SG IV.E. Specimen SOV-139, photomicrograph of a thin section at higher magnification (CPL)

of the presence of the genus *Heterohelix*). Hence this sample is made of a material similar to that of group IV.E, but chemically is different.

Subgroup IV.F (Figs. 74–75)

Eocene chalky marl with mica particles.

SE-100 stands out for the presence of numerous fine schists of mica, oxidised biotite, and colourless muscovite. The matrix is grey-yellow in colour, with spots of red, mostly amorphous, with ca. 5% of dispersed quartz silt. The dispersed red pigment comes in part from biotite and in part from the admixture of ferric clay.

The preserved microfauna: *Angulogerina* sp., *Globigerinoides* sp., *Tenuitella* sp., *Brizalina* sp., *Globigerina* sp., and *Lingulina* sp., indicate the Eocene as the age of the material.

Subgroup IV.H (Figs. 76–77)

Grey-fired Eocene chalky marl + ferruginous *Globigerina* ooze.

Specimens: SA-5[278], SA-7, grey-fired ceramics with features of SG I.A1.

Macroscopically buff, pale yellow (2.5Y 8/2), on optical examination its matrix is mostly amorphic, grey with a touch of green, locally coloured with iron compounds to brown-red, usually black. This pigmentation goes with accumulations of microfauna, especially *Globigerina* sp. There are also streaky chalk clasts of fuzzy contours, slightly de-pigmented when compared with the matrix, containing single shells of *Acarina* sp., the presence of which sets the age of the material at Late Paleocene/Eocene. There are very few sand-sized grains, less than 5% of the volume. Those are grains of micritic limestone, perhaps bioclasts and monocrystalline medium-sand quartz. Also present are single cherts.

The above characteristics, especially the pigmentation with iron compounds clustered around *Glo-*

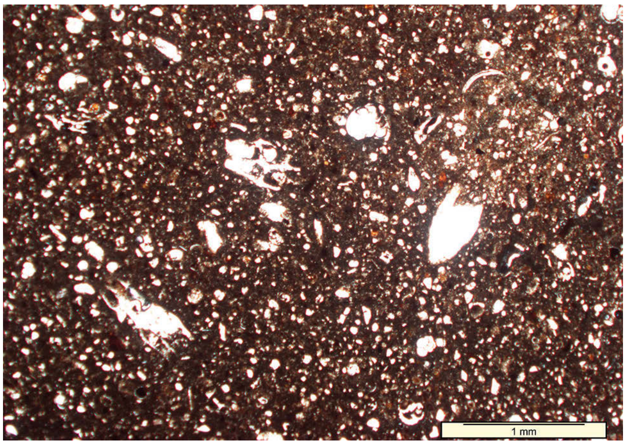


Fig. 74. SG IV.F. Specimen SE-100, photomicrograph of a thin section (PPL)

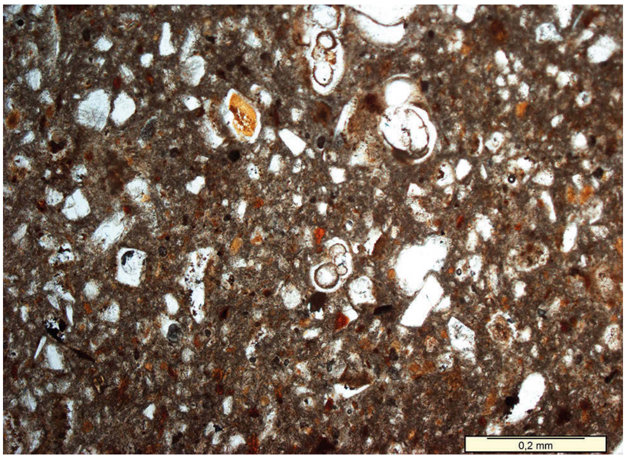


Fig. 75. SG IVF. Specimen SE-100, photomicrograph of a thin section at higher magnification (PPL)

278 In Michniewicz & Młynarczyk 2017, SA-5 is assigned to petrographic subgroup IV.D. What makes it similar to SA-7 is the chemical composition.

Fig. 76. SG IV.H. Fragment of specimen SA-7

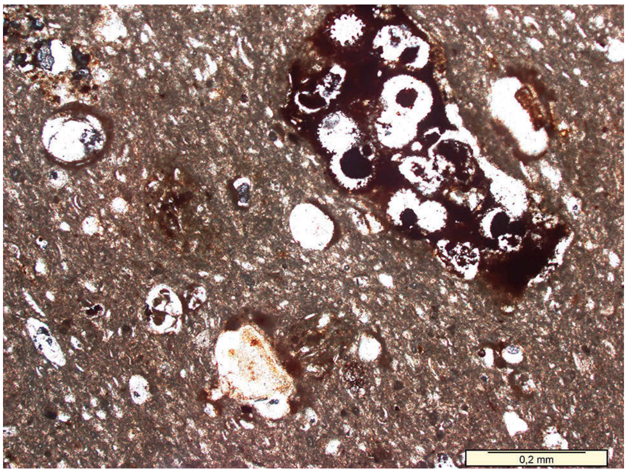


Fig. 77. SG IV.H. Specimen SA-7, photomicrograph of a thin section – note the clast of reddish-black ferruginous globigerina ooze (PPL)

bigerina, make this material similar to the SG I.A1 ceramics, but fired in reduced-oxygen conditions.

Analogies for subgroups IV.A-F, H: Yodefat(?),[279] Mamluk-Period Khirbat Din'Ila[280]

Petrographic Group V (Figs. 78–88)

Amorphic dense calcareous marl plus *terra rossa* balls plus volcanic component plus 15/20% quartz/calcareous sand – high temperature of firing.

In terms of the colour of sherds, the samples fall into two subgroups:

- cream-beige in colour: SA-12, SBc-14, SBc-17, SBc-18, SC-38, SD1-58, SD1-60, SOV-249, and
- bright orange in colour: SA-4, SBc-27, SBc-29, SBc-30 (?), SBc-31[281], SBc-32, SD1-133.

The whole group has a micro-granular texture disappearing with an increase in the sintering of the groundmass.

The cream-beige vessels are creamy on the surface (2.5Y 8/3) and beige on the fracture (10 YR 7/3). The bright-orange group is light-red (5 YR 6/4), which is due to an elevated content of dispersed red soil or a lower degree of reduction of the iron compounds that it contains. The remaining set of petrographic features is similar to those of the cream-beige subgroup.

The matrix is composed of highly calcareous marl, in PPL dark grey, greenish-grey in incident light, optically inactive apart from carbonates. Its micro-porosity is high and takes the form of tiny vermiform fractures.

The characteristic features include fragments of light-grey marly shales varying in size and shape, clasts of chalk rich in fine microfossils (*Globigerina*?), and pellets or streaks of dispersed clayey ferruginous soil.

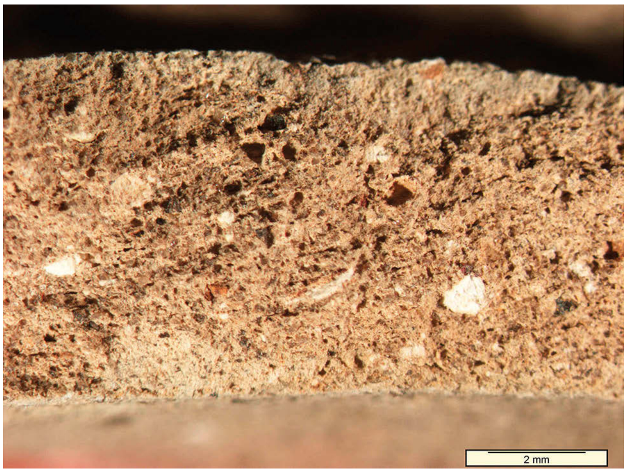


Fig. 78. PG V (cream beige type). Specimen SB-14, photomicrograph of a fresh break

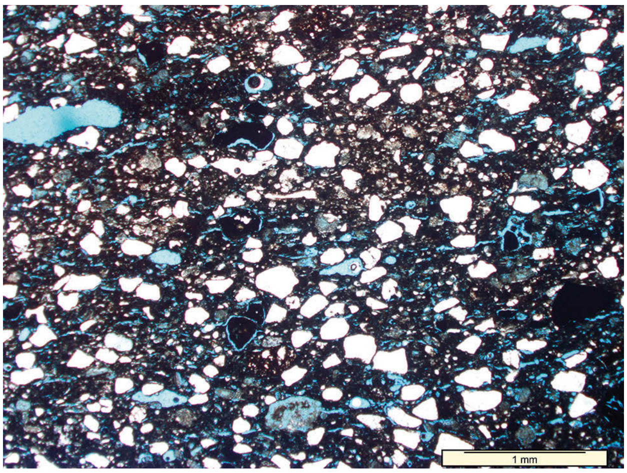


Fig. 79. PG V (cream-beige type). Specimen SB-14, photomicrograph of a thin section (PPL)

[279] Cf. Wieder & Adan-Bayewitz 1999: 338–339; Avshalom-Gorni & Shapiro 2015: 83–84.

[280] Cf. Shapiro 2014: 110, fig. 5.

[281] The assignment of the SBc-30 sample to PG V raises doubts because of the Late Eocene age of the material untypical of this group; also geochemically it is closer to the PG I.A ceramics.

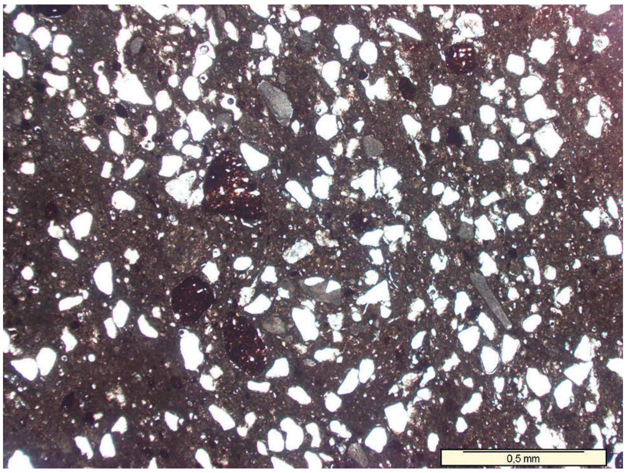


Fig. 80. PG V (cream-beige type). Specimen SD1-60, photomicrograph of a thin section – note the high amount of quartz sand (PPL)

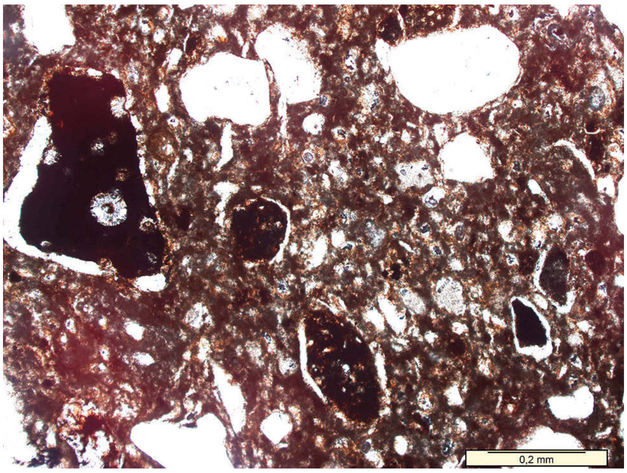


Fig. 81. PG V (cream-beige type). Specimen SB-17, photomicrograph of a thin section (PPL) – on the left a dark fragment of hyaloclastite

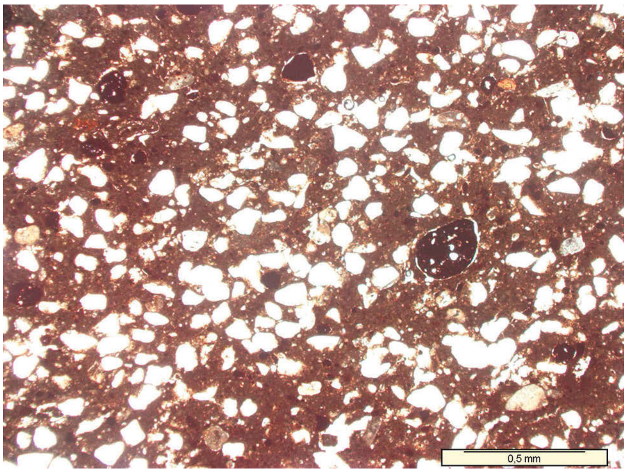


Fig. 82. PG V (bright orange type). Specimen SB-29, photomicrograph of a thin section (PPL)

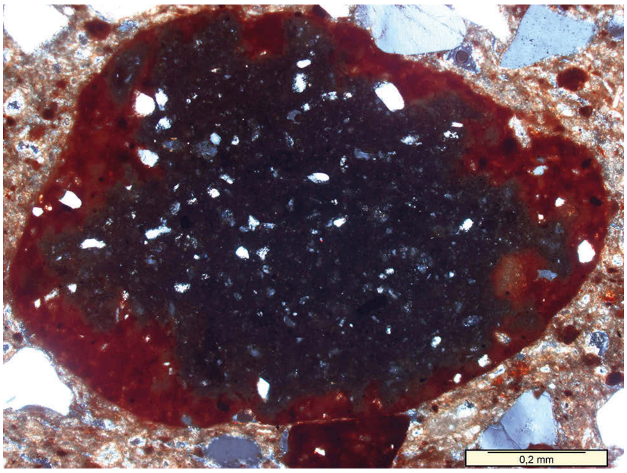
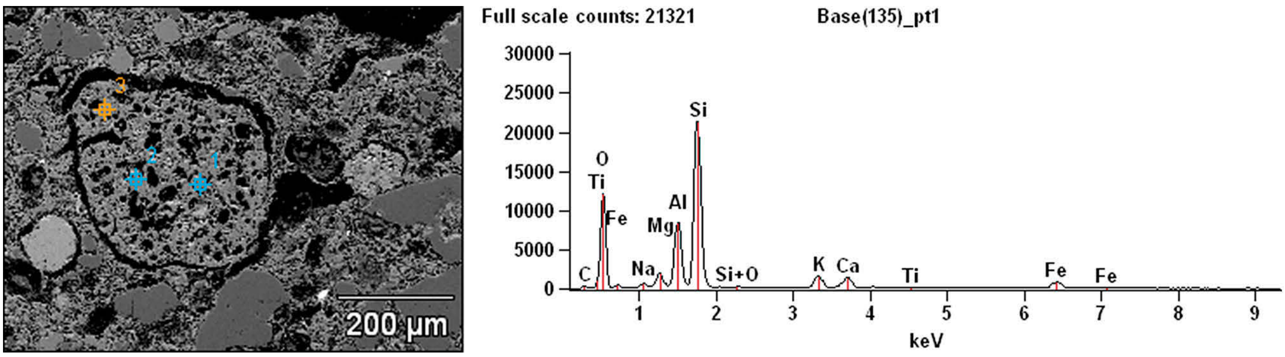


Fig. 83. PG V (bright orange type). Specimen SB-29, photomicrograph of a thin section – a partially reduced *terra rossa* ball (CPL)



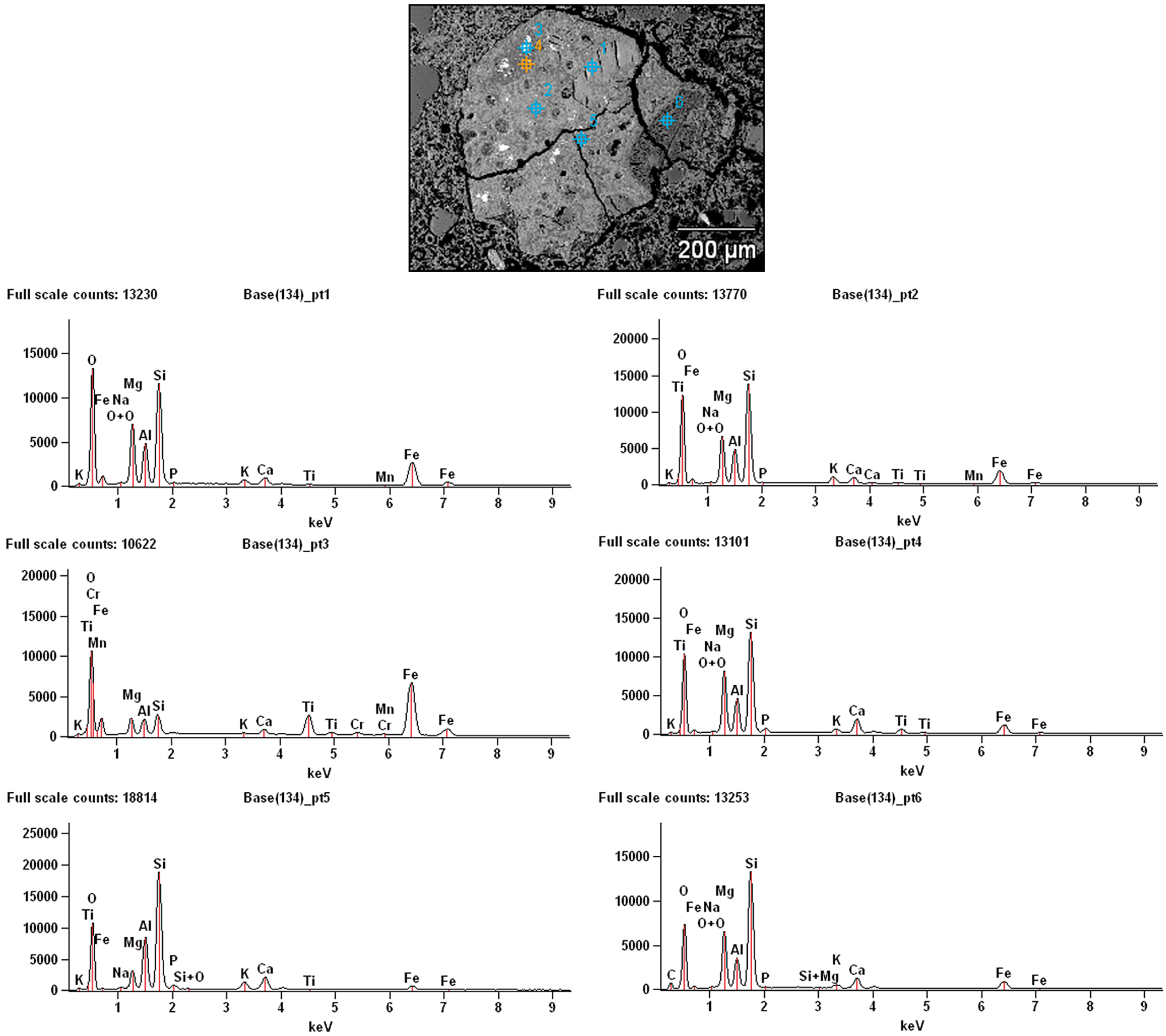
	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3	Tl_2O_3
Base(135)_pt1	0.92	3.79	18.79	61.13	3.51	3.92	0.52	7.41	0.00
Base(135)_pt2	0.46	3.68	18.27	59.09	1.91	5.31	0.38	10.89	0.00
Base(135)_pt3	0.40	4.31	18.15	61.39	2.86	3.34	0.43	8.65	0.47

Fig. 84. PG V. Specimen SBc-30, electron micrograph and the chemical composition in selected points of a 'black ball'

Fine golden carbonates scattered in the groundmass give it a pseudo-granular texture; they are remnants of decomposed microfauna. At a high temperature they disappear, entering into a reaction with argillaceous minerals.

Iron compounds included in marl and the admixture of red soil have undergone reduction and sintering. As a result, its pellets have turned black.

The group stands out for its substantial sand admixture (15–25% of the volume). Quartz predominates (over 80%), mostly in its monocrystalline form 0.08–0.55 mm in diameter. It is variably rounded, usually subangular-subrounded, its grains showing both undulose and uniform light extinction. The proportion of polycrystalline quartz is small – those are fragments of metamorphic shales and quartzitic limestones.



	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Cr_2O_3	MnO	Fe_2O_3
Base(134)_pt1	0.61	18.55	13.08	38.01	0.49	1.21	2.43	0.30	0.00	0.23	25.10
Base(134)_pt2	0.53	17.20	12.89	44.15	0.44	2.20	2.61	1.22	0.00	0.32	18.43
Base(134)_pt3	0.00	7.62	6.41	8.37	0.27	0.00	1.97	12.38	2.01	0.88	60.09
Base(134)_pt4	0.39	20.35	11.87	42.95	2.29	1.27	5.95	3.00	0.00	0.00	11.94
Base(134)_pt5	0.56	6.55	19.43	56.19	2.59	2.74	6.31	0.46	0.00	0.00	5.16
Base(134)_pt6	0.39	19.67	11.28	52.47	0.54	1.14	4.56	0.00	0.00	0.00	9.94

Fig. 85. PG V. Specimen SBc-32, electron micrograph, EDX spectra and chemical analysis in selected points of the hyaloclastic yellow fragment

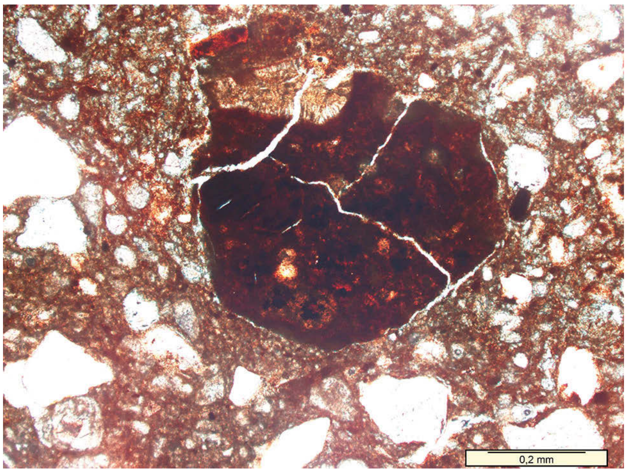


Fig. 86. PG V. Specimen SBc-32, photomicrograph of a thin section – a yellow fragment in plain polarized light (PPL)

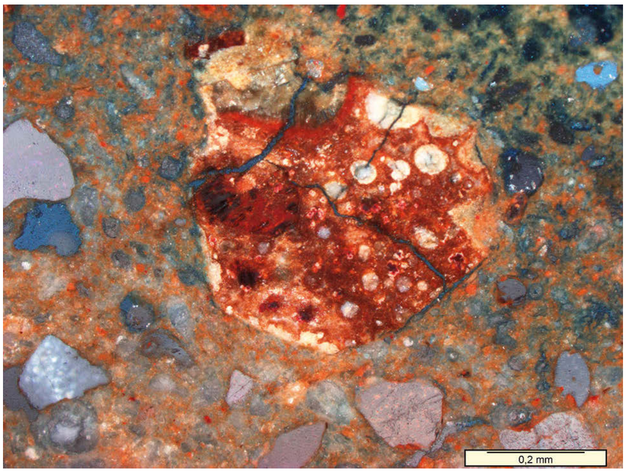


Fig. 87. PG V. Specimen SBc-32, photomicrograph of a thin section – a yellow fragment in reflected polarized light (CPL)

Sand-sized carbonates have undergone decomposition; today they form irregular clusters of secondary micrite. The remains of calcareous skeletons are numerous very fine oval voids.

Secondary components of the temper include feldspars, usually 'clear' and polysynthetically twinned (pagioclases); one can also find specimens with a cross-hatched pattern (microcline). Also characteristic is the presence of glassy 'yellow fragments' which, like *terra rossa*, have mostly turned black. The yellow-honey colour of those clasts is then visible only on their margins. On examination, their chem-

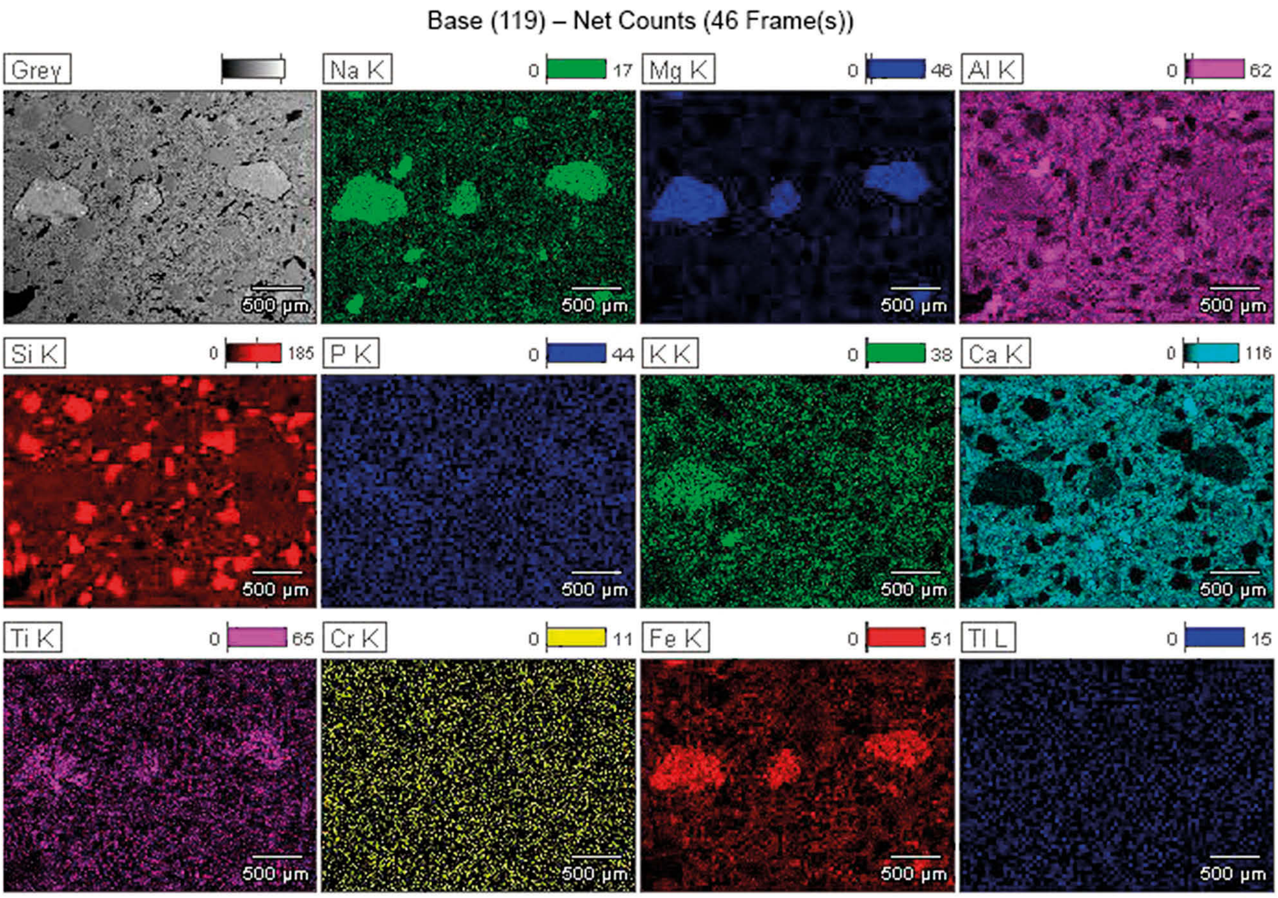


Fig. 88. PG V. Specimen SB-27. electron micrograph and EDS individual element mapping of a thin section for specimen SB-27. Note the presence of 3 hyaloclastite grains rich in magnesium and iron, and the absence of calcium

ical composition shows the presence of silica, aluminium, magnesium and a few percent of calcium, which is close to the composition of pyroxenes. Other particles are much more close to basaltoids.

Accessory components are colourless sand-sized pyroxenes, fine, yellow, orange-oxidised and green amphiboles, particles of colourless glass, and crystals of dark-orange rutile.

The age of the material is hard to determine because of the high temperature of firing. The identifiable foraminifers have only been preserved in samples SBc-18, SBc-30 and SD1-133. Those are mostly *Globigerina* sp., *Chiloguembelina* sp. and *Angulogerina* sp., making the Eocene the probable age of the material. In turn, sample SA-4 contains single *Heterohelicidae*, which can put its age at Cretaceous.

Fig. 89. PG VI. Fragment of specimen SD-48

Petrographic Group VI (Figs. 89–90)

Red sandy soil (*hamra*).
Specimens: SDc-48, SA-123.

Two vessels of dark-red colour (2.5 YR 5/6) with dull-red, ferruginous matrix, inactive in PPL, of varying amounts of quartz silt, rich in the sand fraction (0.1–0.3 mm) accounting for 30–40% of the volume. Sand grains are mostly (95%) monocrystalline quartz, showing both uniform and undulose extinction; the remaining 5% includes K-feldspars and plagioclases, some heavy minerals, chiefly amphiboles, and sparse cherts. The samples are identical to *hamra* soil occurring in the Haifa region.

Similarities: Tel Dor,[282] Akko, Tel Megadim, Atlit, Tell el-Hesi, Tel Megadim, Ashdod Fort, Ashkelon,[283] Kommos in Crete.[284]

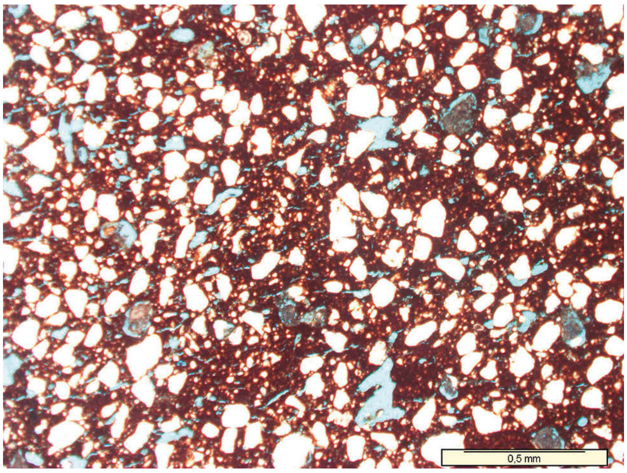


Fig. 90. PG VI. Specimen SD-48, photomicrograph of a thin section (PPL)

Petrographic Group VII (Figs. 91–93)

Dolomitic silt, rich in 'red fragments'.
Specimens: SD1-63 and SD1-68.

The two specimens are made of dense ferruginous marl rich in dolomitic silt. Macroscopically identical, heavily sintered, with sharp margins of the fracture. Both on the surface and inside they are of a characteristic red colour with numerous fine white spots of carbonates.

The matrix in PPL is dark-red, with numerous fine rhombohedral dolomite particles accompanied by irregular medium-sand grains of dolomitic rock and oval grains of micrite carbonates, up to 1.3 mm in size. Variously preserved associations of foraminifers i.e. *Hedbergella* sp. and *Heterohelix* sp. put the age of the material at Late Cretaceous.

What distinguishes the two samples is the presence of densely scattered pedofeatures: red fragments of ferruginous aluminium silicates of an intensive red colour. Some of them are amorphic, the rest are transparent with a laminar texture, showing undulose light extinction.

Analogies: not known.

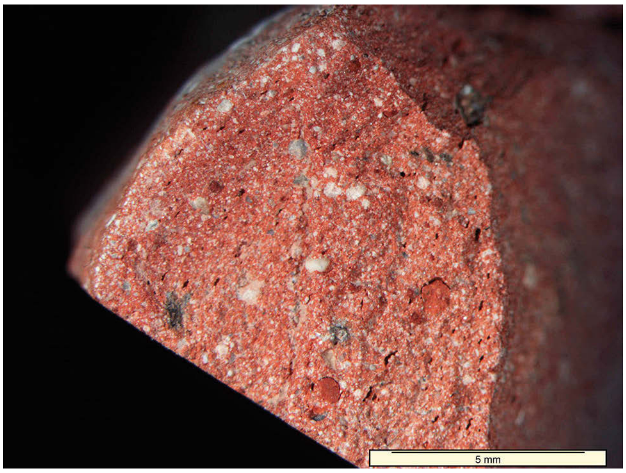


Fig. 91. PG VII. Fragment of specimen SD1-68

282 Eliyahu-Behar et al. 2008: 2901 (Group 4); Bettles 2003b: 293
283 Bettles 2003b (Fabric class 2A): Appendix IV,
284 Gilboa et al. 2015: 82, fig. 5.

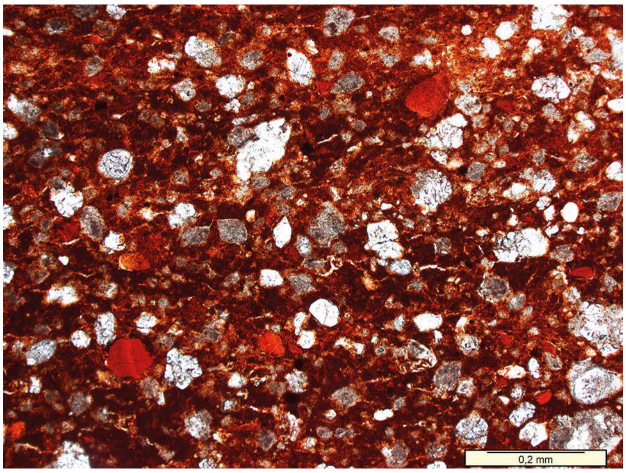


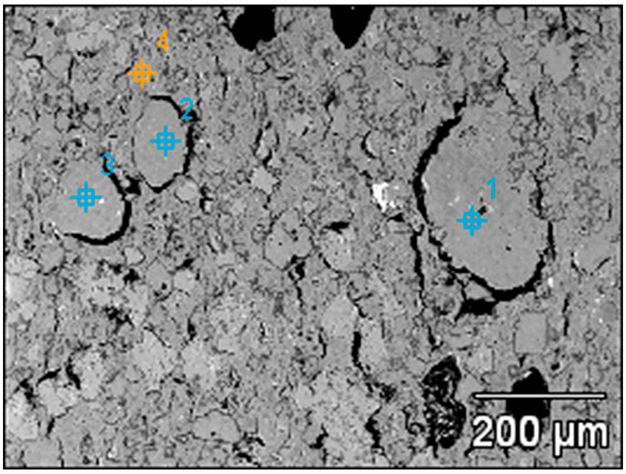
Fig. 92. PG VII. Specimen SD1-68, photomicrograph of a thin section (PPL), note numerous "red fragments" and whitish foraminifer shells

Petrographic Group VIII (Figs. 94–99)

Dolomitic sand.
Specimens: SBc-19, SD1-70, SD2-78.

This is a macroscopically non-uniform group, and its common feature is the presence of sand-sized rhomb-shaped dolomites. Due to the non-uniform character of the group each specimen was described separately.

Sample SBc-19 is a fragment of a thin-walled vessel, light-red on the surface (5 YR 7/6), dark-grey inside. Under the microscope, the calcareous matrix is devoid of quartz silt, reddish brown, optically active, with scattered rhombohedral crystals of dolomitic silt and single dark *terra rossa* balls. Oval sand-sized grains are those of micritic limestone (15% of the volume) and sparse angular polycrystalline do-



	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3
Base(74)_pt1	0.84	2.76	21.45	61.38	0.00	0.99	2.93	1.37	8.27
Base(74)_pt2	1.11	3.93	23.38	54.23	0.00	1.24	3.74	1.89	10.48
Base(74)_pt3	0.69	3.58	22.37	58.98	0.00	0.90	3.67	0.94	8.87
Base(74)_pt4	0.64	3.47	20.07	52.48	0.78	0.93	11.88	1.11	8.64

Fig. 93. PG VII. Specimen SD1-68. electron micrograph and the chemical composition of 'red fragments'

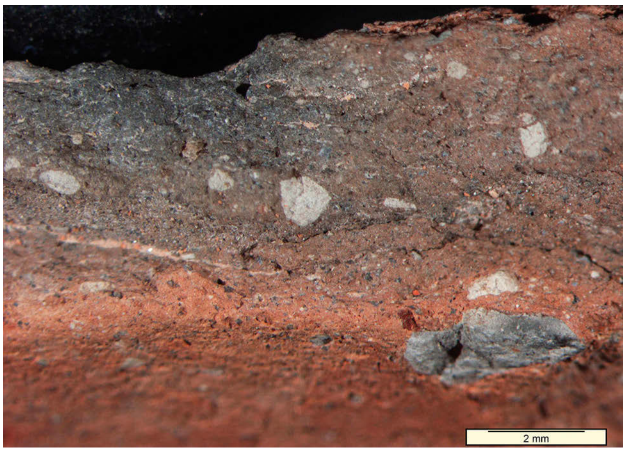


Fig. 94. PG VIII. Fragment of specimen SBc-19

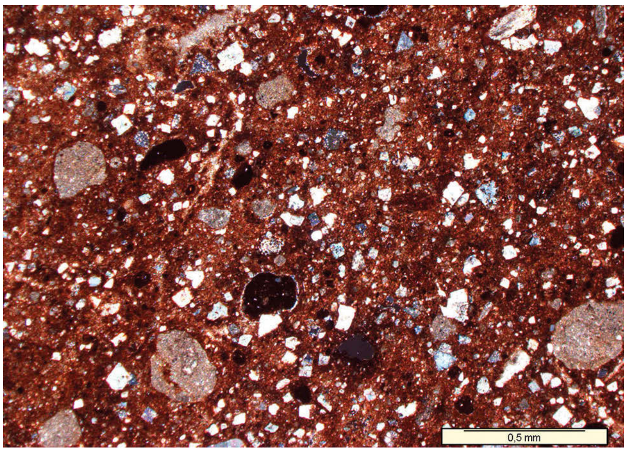


Fig. 95. PG VIII. Specimen SBc-19, photomicrograph of a thin section (CPL)

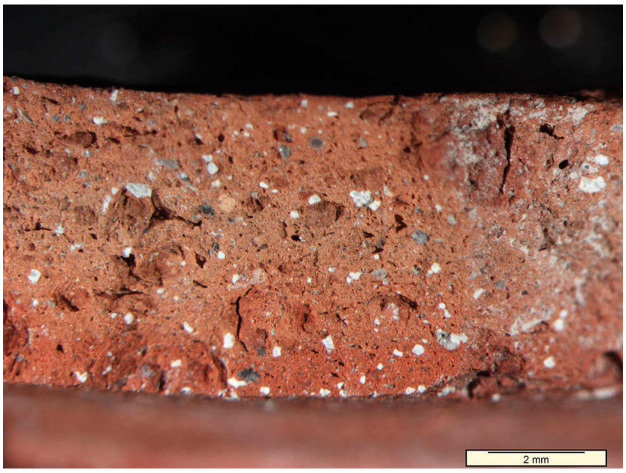


Fig. 96. PG VIII. Fragment of specimen SD1-70

lomite crystals. The presence of foraminifers: *Marssonella* sp. (?*lodoensis*), *Angulogerina* sp., *Tenuitella* sp. is indicative of the Paleogene.

Sample SD1-70 is a thin-walled piece of pottery fired to a light-red colour (2.5 YR 6/8), light-brown on the fracture. In transmitted light the groundmass is dark-brown, residually optically active, rich in carbonate silt, which accounts for about 15% of the volume. Because of the high temperature of firing its carbonate content is hard to determine. The content of quartz silt is much lower, at about 5% of the volume. The material is enriched with an admixture of *terra rossa* in the form of oval pellets.

In spite of the relatively high temperature of firing, numerous *Globigerinelloides* cf. *bentonensis* (Morrow) and *Heterohelix* cf. *reussi* (Cushman) foraminifers have been preserved, setting the age of the material at Late Cretaceous. The sand-sized admixture consists of angular crystals of dolomite, micritic on margins or replaced completely by micrite; their proportion is ca. 10% of the volume.

As to the chemical composition, those samples are not similar to each other; on the similarity dia-

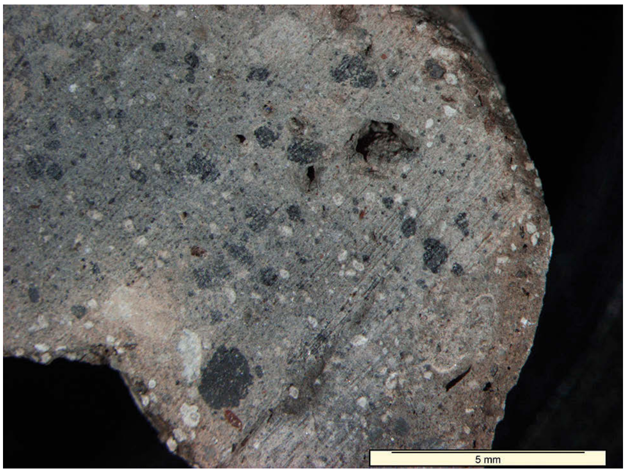


Fig. 98. PG VIII. Fragment of specimen SD2-78

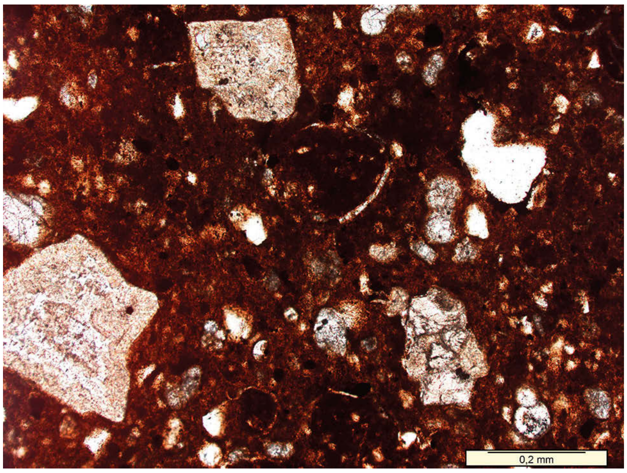


Fig. 97. PG VIII. Specimen SD1-70, photomicrograph of a thin section (PPL), sand-sized dolomites in a foraminifera-rich matrix

gram SD2-78 is close to two samples of Petrographic Group VII, SBc-19 appears in Petrographic Group V, and SD1-70 on the margins of PG II.

Sample SD2-78 is fired in reduced-oxygen conditions to steel-grey, made of marl with an admixture of dolomitic sand. Its matrix is dark-brown in transmitted light, partly optically active, with a few-millimetre elliptic clasts of dolomitic marl (with numerous fine rhombohedral dolomite particles embedded in its light-brown argillaceous groundmass), smaller, irregular clasts of micritic chalk (light-grey of very high porosity), and oval grains of non-transparent pure slag or sintered *terra rossa*. Quartz silt appears sporadically.

An aplastic admixture is represented by rhombohedral dolomites 0.2–0.5 mm fraction.

Similarities: Amarna tablets.[285]

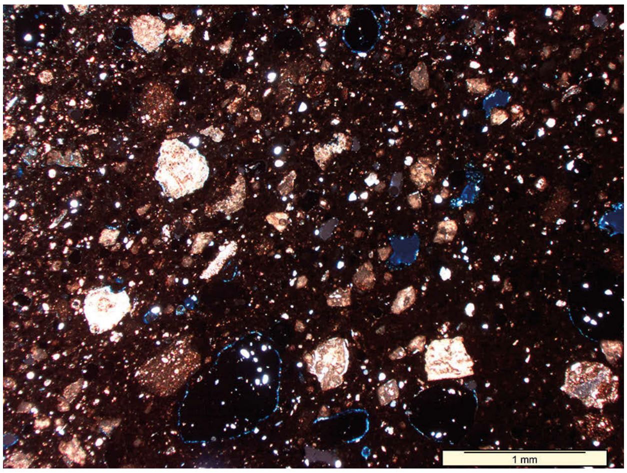


Fig. 99. PG VIII. Specimen SD2-78, photomicrograph of a thin section (CPL)

[285] Goren 1995; Goren et al. 2004: 262–269.

Unassigned ceramics (Figs. 100–120)

Sample SD2-82 – macroscopically, a vessel light-red on the surface (2.5 YR 6/6) and light-brown inside, of substantial porosity made of clay rich in ultramaphic rock fragments. Clearly visible are milky-white and black grains of the tempering admixture.

On optical examination the matrix is dark-grey, in many places with red streaks, partly anisotropic. The proportion of silt does not exceed 1% of the volume; those are single grains of feldspar and quartz. The vessel is characterised by very great porosity (ca. 15% of the volume). What makes it distinct is the composition of the sand admixture. Those are 0.4–3.0 mm grains making up ca. 30% of the volume, represented by angular mono- and polycrystals (0.4–3.0 mm) of yellow-pleochroic fibrolitic amphiboles, colourless pyroxenes, polysynthetically twinned plagioclases, equally large alkaline feldspars twinned in a cross-hatched way, serpentinised polymineral olivines, and feldspars poikilitically intergrown with fibrolites. There are also fragments of colourless, highly porous glass. The vessel is certainly imported. The age unknown (no microfossils were found).

Sample SE-88 – a thin-walled vessel, red on the surface (2.5 YR 5/6), brown-grey on the fracture, the internal surface is light-red (5 YR 7/6).

In parallel Nicol prisms the matrix is dark-brown, amorphic. It shows substantial micro-porosity, which is an effect of the decomposition of a carbonate silt. The proportion of quartz silt does not exceed 5–8% of the volume. It also contains irregular clasts of chalk and oval pellets of glassy *terra rossa* or tephra.

The sand fraction is grains of micritic limestone differing in size; also present are single fine-sand pyroxenes, diabasic grains (automorphic plagioclases with intergrowths of pyroxene), quartz-plagioclase-biotite grains (biotite oxidised to red). The age unknown (no microfossils were found).

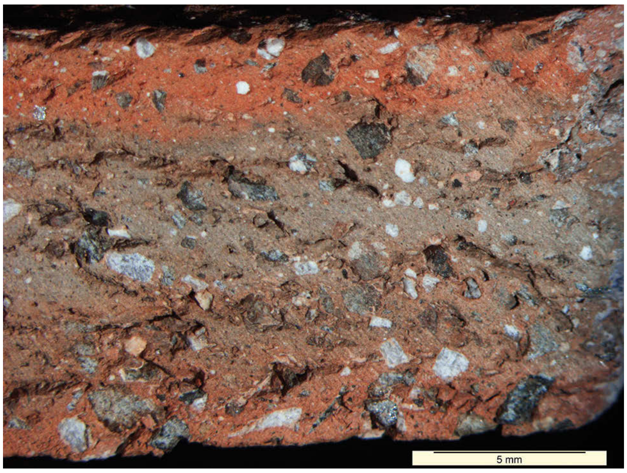


Fig. 100. Unassigned ceramics. Fragment of specimen SD2-82

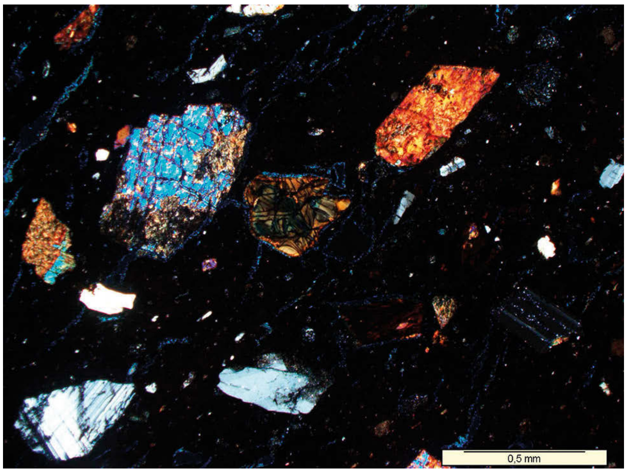


Fig. 101. Unassigned ceramics. Specimen SD2-82, photomicrograph of a thin section (CPL) – diagnostic is the presence of pyroxene, serpentinized olivine and plagioclase

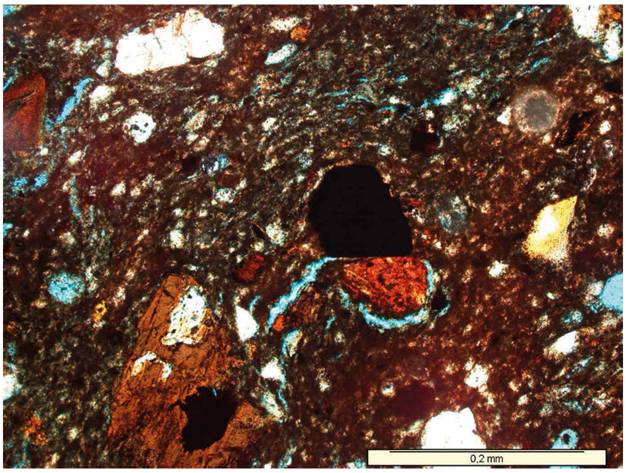


Fig. 102. Unassigned ceramics. Specimen SD2-82, photomicrograph of a thin section (PPL)

Fig. 103. Unassigned ceramics. Fragment of specimen SE-88

Sample SF-109 with matrix reddish grey, partially active, rich in numerous oval, dark-red infillings varying in the content of quartz silt – an effect of the activity of earthworms or of clay mixing. Some of them are grey in colour, anisotropic, glassy and porous, resembling slag. The material contains ca. 10% of quartz silt and some oval clayey balls rich in silt-sized rhombohedral dolomites. The sand-sized admixture (0.1–0.25 mm) consists predominantly of monocrystalline quartz grains, very little plagioclase (2–5%), and very rare amphiboles (<0.5%). Also present are coarse (0.2–0.5 mm) micritic limestones, dolomites, and some biogenic grains, mostly of *Corallinaceae*.

Sample SBc-20 – is pale pink on the fracture (5 YR 7/4-7/6). In transmitted light its matrix is light-grey, inactive, locally pigmented with diffusional iron compound, containing single balls of *terra rossa* of which those that have undergone reduction are dark-grey, isotropic. Quartz silt accounts for ca. 10–15% of the volume. Sand-sized grains (0.1–0.25 mm) are irregularly scattered, their proportion does not exceed 10% of the volume. The few preserved foraminifers: *Acariniana* sp. and *Turborotalia* aff. *frontosa*, indicate the Eocene as the age of the material.

Sample SFx-111 is, macroscopically, light-brown in colour, with a high porosity. It is lightly fired, made of marl containing 5–8% of quartz silt mixed with a large amount of silty *terra rossa*. The sample also contains numerous chalk clasts and straw remnants in the form of elongated voids. Geochemically similar to group I.A2, but unlike vessels in this group it does not contains an admixture of sand-sized quartz. The age is unknown (no microfossils were found).

Sample SFx-116 – ceramics made of marly soil; light-creamy on the surface, light-brown on the fracture (5 YR 6/8). In transmitted light the matrix is reddish-grey with oval red mottles coming from the admixture of oval pellets of red *terra rossa*. Also present are elongated clasts of chalk. Quartz silt consti-

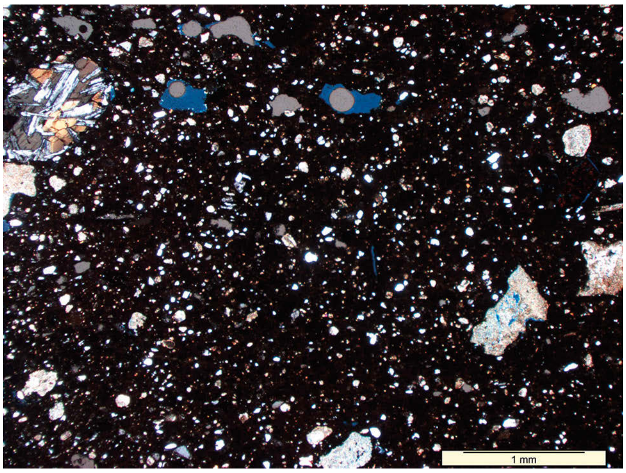


Fig. 104. Unassigned ceramics. Specimen SE-88., photomicrograph of a thin section (CPL), note the presence of a dolerite fragment (upper left)

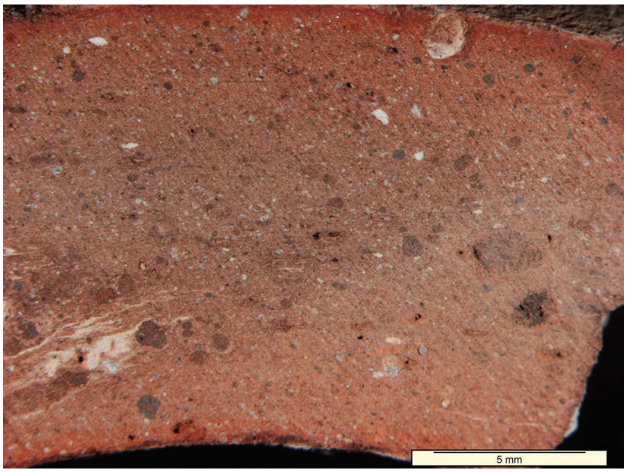


Fig. 105. Unassigned ceramics. Fragment of specimen SF-109

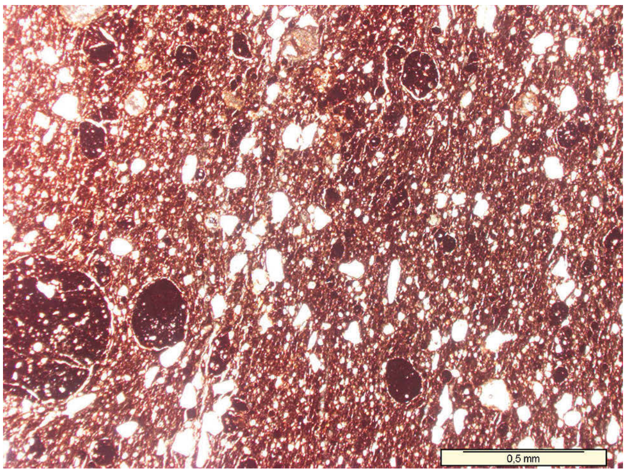


Fig. 106. Unassigned ceramics. Specimen SF-109, photomicrograph of a thin section (PPL)

Fig. 107. Unassigned ceramics. Fragment of specimen SBc-20

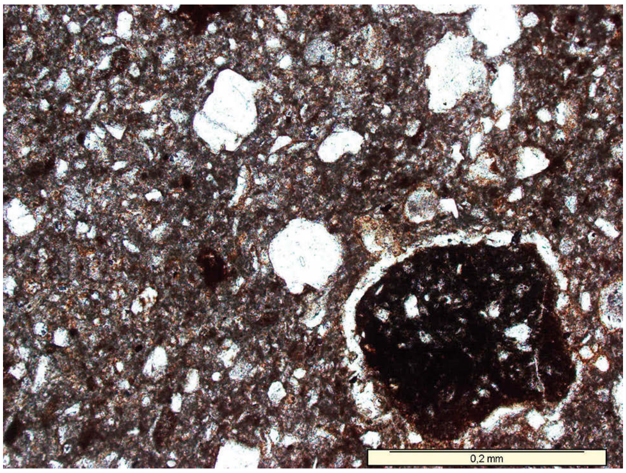


Fig. 108. Unassigned ceramics. Specimen SBc-20, photomicrograph of a thin section (PPL) – a black reduced *terra rossa* ball (down, right)

tutes 5–8% of the volume. The aplastic admixture is sand of the 0.1–0.25 mm fraction. Grains are predominantly of monocrystalline quartz, usually angular or subangular, with sparse plagioclases and even more rare microclines. The coarse-sand fraction includes single clasts of volcanic rock with a micro-diabasic texture. It is formed by plagioclases intergrown with light-pink pyroxene; also present is a clast of pumice. No microfossils were found.

Sample SBc-122 is a fragment of a vessel, red on the surface (10R 6/6), on the fracture steel-black after reduction made of ferruginous soil. The matrix is argillaceous, dark red on the margins, black inside, optically active. The contents of quartz silt is lower than 5% of the volume; also present are *terra rossa* grains, oval, black, only locally showing some red. The aplastic admixture accounts for 15–20% of the volume. It is made of subrounded grains of micritic and fine-sparite coarse-sand-sized limestone. Their proportion is 15–20% of the volume. Notable is the

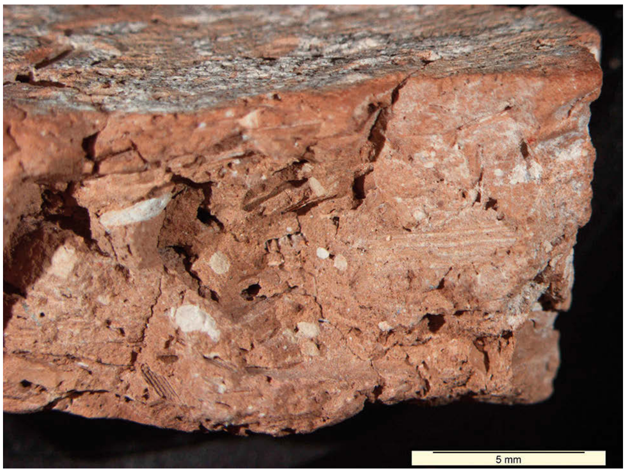


Fig. 109. Unassigned ceramics. Fragment of specimen SFx-111

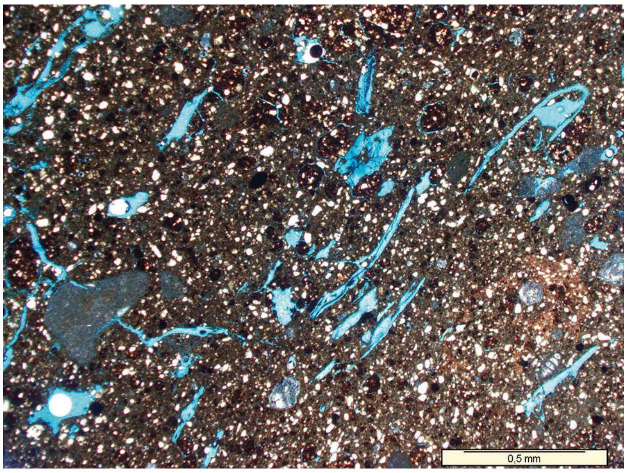


Fig. 110. Unassigned ceramics. Specimen SFx-111, photomicrograph of a thin section (PPL), numerous straw remnants

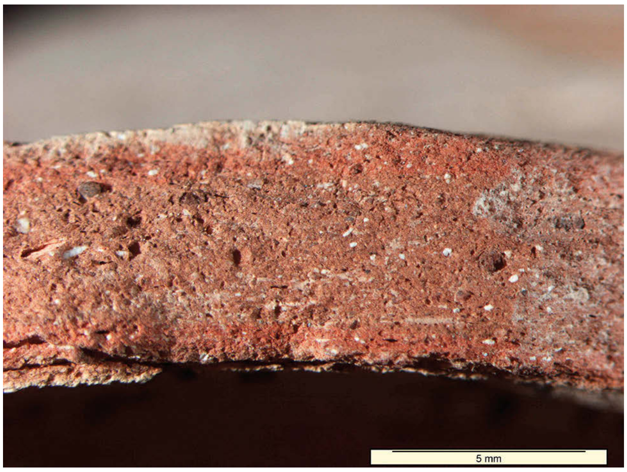


Fig. 111. Unassigned ceramics. Fragment of specimen SFx-116

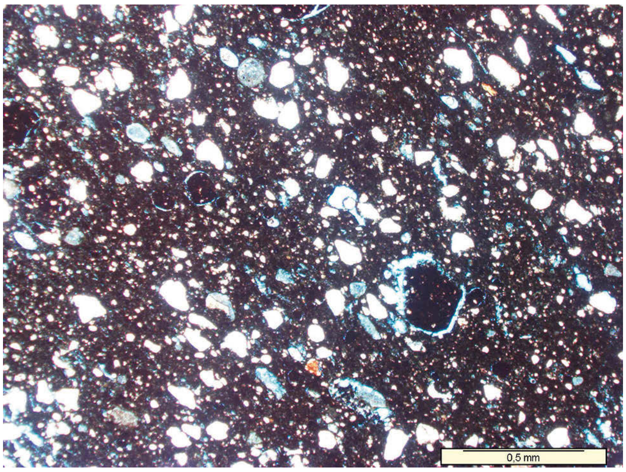


Fig. 112. Unassigned ceramics. Specimen SFx-116, photomicrograph of a thin section (PPL)

Fig. 113. Unassigned ceramics. Fragment of specimen SBc-122

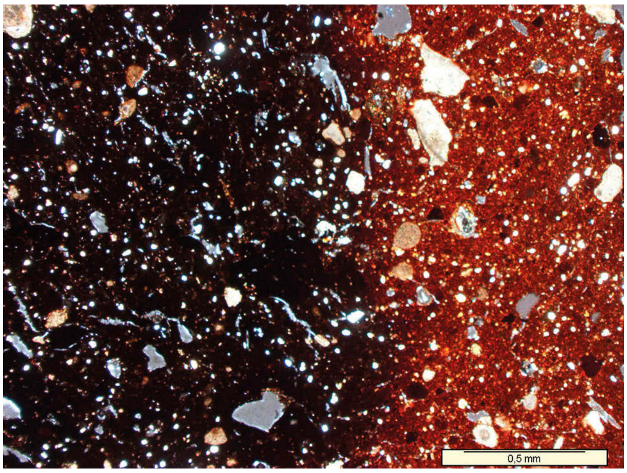


Fig. 114. Unassigned ceramics. Specimen SBc-122, photomicrograph of a thin section (CPL)

presence of medium-sized sand grains of volcanic rock of porphyritic texture: embedded in the black, partly non-transparent groundmass are laths of doubly and polysynthetically twinned feldspars, as well as elongated pyroxene crystals or weakly pleochroic amphiboles with intergrowths of intensively red crystals of oxidised hornblende or biotite. A manifestation of pedogenic processes is the presence of single ferruginous ooliths.

Sample SDc-131 – calcareous marl, its matrix greenish grey (5 YR 7/4) with red stains and numerous *terra rossa* balls, some chalk, some quartz silt (< 2% of the volume), a few fine pyroxenes. The age of the material is not known (no microfossils were found). The vessel seems to be related to Subgroup I.A3.

Sample SBc-132 is of light-red colour (5 YR 7/6) on the surface and greyish on the fracture. On optical examination its groundmass is light-grey in colour, on margins reddish-grey, with numerous pores running parallel to the vessel walls. There are a great number of oval micrite particles accounting for ca. 30% of the volume. They are mostly remnants of decomposed microorganisms. Grains of quartz silt appear sporadically. There are pellets of *terra rossa*.

The aplastic admixture is substantial, making up over 20% of the volume. Those are 0.1–0.3 mm grains of monocrystalline quartz, variably rounded, sometimes with margins of a carbonate binding agent, and of micritic and bio-micritic limestone, sand-sized fragments of micritic foraminifers, fragments of *Corallinaceae* and single feldspars. The age of the material was determined as Eocene.

Sample SOV-136 is a fragment of a brick. It is light red (5 YR 7/8) and light grey in colour (5 YR 8/1), relatively lightly fired, with a porous, fine-grain texture (coarse surface texture). On optical examination, the groundmass is light-grey, mottled pale orange, highly calcareous, rich in spread micrite, anisotropic. The content of quartz silt is less than 5% of the volume.

Fig. 115. Unassigned ceramics. Fragment of specimen SDc-131

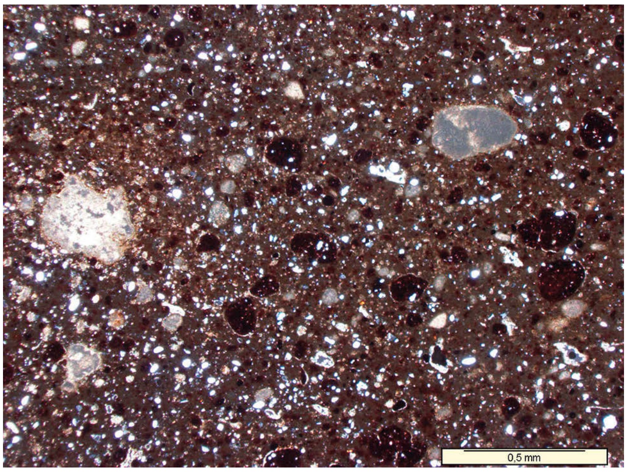


Fig. 116. Unassigned ceramics. Specimen SDc-131, photomicrograph of a thin section (CPL)

Fig. 117. Unassigned ceramics. Fragment of specimen SBc-132

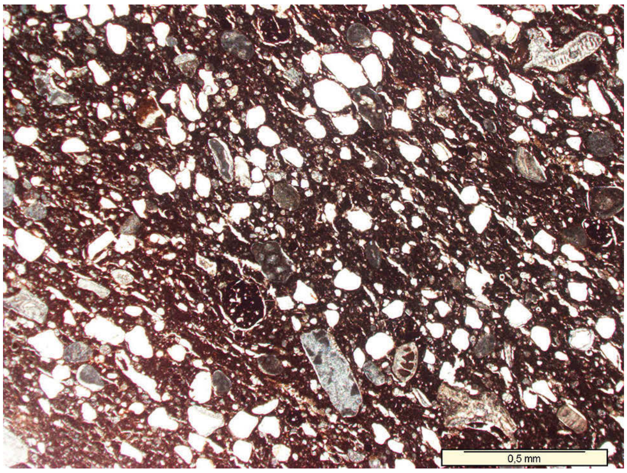


Fig. 118. Unassigned ceramics. Specimen SBc-132, photomicrograph of a thin section (PPL)

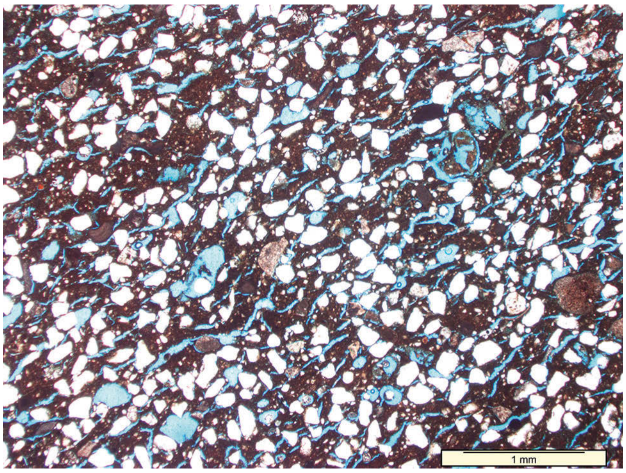


Fig. 119. Unassigned ceramics. Specimen SOV-136, photomicrograph of a thin section (PPL)

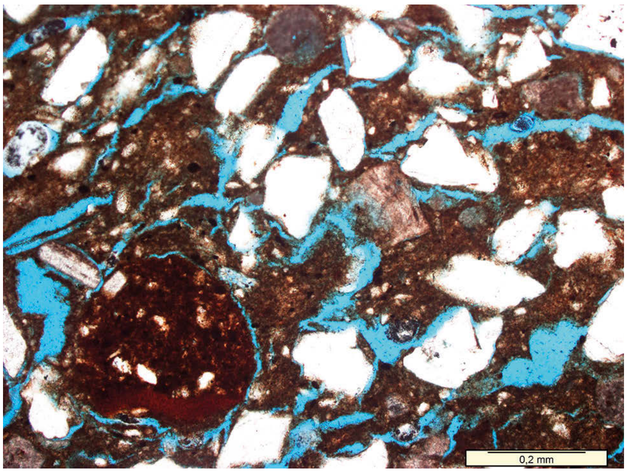


Fig. 120. Unassigned ceramics. Specimen SOV-136, photomicrograph of a thin section (PPL)

The diagnostic feature is a very high sand content, 40–50% of the volume, of fine and medium fractions, 0.12–0.40 mm. Those are mostly monocrystal quartz grains (80%), variously, poorly and moderately rounded, usually with undulose extinction. The remaining 20% are carbonates, often bioclastic (foraminifers, snails, *Corallinacea*), as well as less numerous polysynthetically twinned feldspars, varying in the level of alteration, in many cases fresh, single fine yellow-green amphiboles, zoisite, and volcanic glass fragments. A red soil admixture is visible in the form of single oval, dark silty balls. The presence of foraminifers: *Pararotalia* cf. *lithothamnica* (Uhlig), *Korobkovella* sp., *Maslinella* sp., *Chiloguembelina* sp., *Globigerina* sp., *Tenuitellinata* sp., show the age of the material to be Paleogene (Eocene?).

In chemical terms, this sample stands out (probably because of a high quartz content), but is similar to petrographic subgroups IA2-IA3. Both the fraction and mineral composition of sand are similar to the modern sands of Haifa Bay (cf. Fig. 119, 233).

5.4. Sha'ar-Ha'Amakim chemical database

The chemical INAA, ICP data are presented in Table 3.

Among the 50 elements determined, the contents of Au, Ag, Cd, Mo, Be, Bi, Br, Cs, Hg, Ir, Rb, Se, Ta, In, Sn, and Tb in most samples were lower than the detection level of the method used, sodium has high mobility, especially in the vicinity of marine environments, therefore those elements were not taken into further consideration. Ultimately, the analysis was made on the basis of 32 elements: Cu, Pb, Ni, Zn, S, Al, As, Ba, Ca, Co, Cr, Eu, Fe, Hf, K, Li, Mg, Mn, P, Sb, Sc, Sr, Ti, Th, U, V, Y, La, Ce, Nd, Sm, and Yb.

Principal components analysis

In the research on the correlation of ceramics, principal components analysis (PCA) is now a standard procedure employed. It helps us to visualise the mutual location of points (math. *cases*) in a multi-dimensional space.

Each dimension of this space corresponds to the concentration of one chemical element. The method involves a replacement of this multi-dimensional space with a system of a few vectors – principal components – which are a linear combination of the original variables and on the basis of which one can map actual differences among the original variables with the smallest possible error.

While useful, this method distorts the mapping of mutual distances and angles between objects, analogously to the difference between the actual shape of an object in a three-dimensional space (its length, width and height) and the image of its shadow, which is a projection onto a plane. Simplifying, the PCA method can be said to consist in the choice of such an 'illumination angle' for samples lying in a multi-dimensional space as to make their 'shadows' reflect their mutual positions as closely as possible.[286] The geometric relations between the objects (i.e. the specimens analysed), in our case a 32-dimensional space after projection onto the plane of the first two principal components PC1 and PC2, were preserved in 58.79% of cases of actual distances and angles between the objects (Table 4).

The first principal component PC1 is mainly determined by the variation of rare-earth elements, Fe, Mn, Co, Sc, the second principal component PC2, by the variation of P, U and Sr (Table 5). In other words, a comparison of the concentrations of those elements is the best way to distinguish groups of ceramics with a similar chemical composition.

In the diagram the individual petrographic groups form main four clusters (Fig. 121). Especially outstanding is most of the pottery in group IV (a separate cluster is also formed by Petrographic Group II). Petrographic Groups III and V make up a common cluster. The central part of the diagram is occupied by PG I (i.e. subgroups I.A1 and I.A2 + I.A3), which seems to be related to PG IV and PG V.

Table 4. Results of an analysis of the first six principal components based on the correlation matrix of the Sha'ar-Ha'Amakim pottery

Principal component number	Eigenvalue	Percentage of variance explained	Cumulative % of total variance
1	14.23	44.76	44.76
2	4.46	14.03	58.79
3	2.38	7.49	66.28
4	2.12	6.67	72.95
5	1.43	4.51	77.46
6	1.12	3.53	80.99

Table 5. PCA of the Sha'ar-Ha'Amakim pottery. Determination coefficient $R^2 \times 100\%$ for the first two principal components PC1 and PC2

Element	PC1	PC2
Cu	11.52	4.14
Pb	52.31	1.84
Ni	54.55	13.59
Zn	50.40	30.47
As	6.05	17.65
Ba	2.86	0.65
Co	**79.50**	4.45
Cr	59.96	18.68
Eu	63.41	1.09
Hf	58.88	13.61
Li	25.71	0.99
Mn	**73.43**	5.21
Sb	23.74	14.83
Sc	**65.47**	1.18
Sr	4.20	**58.72**
Th	56.64	3.37
U	3.38	**60.95**
V	3.72	21.38
Y	61.66	21.20
La	**90.35**	1.36
Ce	**89.70**	3.09
Nd	48.55	0.04
Sm	**93.28**	0.02
Yb	**85.29**	3.72
S	45.83	26.48
Al	61.69	3.81
Ca	54.13	28.99
Fe	**82.73**	5.12
K	9.46	0.01
Mg	6.38	1.97
P	0.97	**78.46**
Ti	6.61	1.92

286 Cf. Krzyśko et al. 2008: 360–384; Cogswell et al. 1995, Michniewicz 2009: 52–53.

Table 3. Chemical INAA and ICP data of Sha'ar-Ha'Amakim ceramics

Element	Au	Ag	Cu	Cd	Mo	Pb	Ni	Zn	S	Al	As	Ba	Be	Bi	Br	Ca	Co	Cr	Cs	Eu	Fe	Hf	Hg	Ir	K	Li
Unit	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	%	ppm
Detection limit	2	0.3	1	0.3	1	3	1	1	0.01	0.01	0.5	50	1	2	0.5	0.01	1	2	1	0.2	0.01	1	1	5	0.01	1
Analysis method	INAA	INAA / TD-ICP	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA / TD-ICP	INAA / TD-ICP	TD-ICP	TD-ICP	INAA	INAA	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	TD-ICP	TD-ICP
SA-1	< 2	< 0.3	43	< 0.3	< 1	< 3	83	101	0.15	4.54	12.1	960	1	< 2	6.2	20.9	16	199	< 1	1.8	2.93	2	< 1	< 5	0.64	19
SA-2	< 2	0.4	20	0.6	2	9	44	91	0.13	5.78	6	950	2	< 2	5	14.8	9	112	5	2.2	3.21	4	< 1	< 5	1.65	31
SA-3	< 2	< 0.3	40	0.6	1	4	120	120	0.15	3.91	8.7	1160	1	< 2	5.7	20.2	12	206	< 1	2.2	2.44	2	< 1	< 5	0.6	18
SA-4	< 2	< 0.3	15	< 0.3	3	5	33	50	0.1	4.98	6	340	1	< 2	5.2	14.8	10	69	3	1.3	2.8	4	< 1	< 5	0.83	21
SA-5	< 2	0.4	30	0.6	< 1	10	56	127	0.19	7.04	5.3	480	2	< 2	4.2	15.6	12	115	< 1	2.6	3.76	4	< 1	< 5	2.02	39
SA-6	< 2	0.3	29	0.6	< 1	9	46	107	0.09	6.51	5.9	850	2	< 2	3.6	14.2	7	91	5	2.3	2.91	3	< 1	< 5	1.62	26
SA-7	< 2	0.4	30	< 0.3	< 1	10	62	118	0.09	8.51	3.8	930	2	< 2	< 0.5	14.2	14	133	6	2.5	4.2	3	< 1	< 5	0.76	42
SA-8	< 2	< 0.3	28	0.6	2	10	39	97	0.11	5.75	4.8	560	2	< 2	< 0.5	15.3	8	85	< 1	1.4	2.75	2	< 1	< 5	2.02	23
SA-9	< 2	< 0.3	40	< 0.3	4	< 3	89	106	0.12	4.34	9.1	1130	1	< 2	< 0.5	19.8	13	200	< 1	2.3	2.73	5	< 1	< 5	0.77	21
SA-10	< 2	< 0.3	36	0.4	1	7	68	73	0.07	6.92	8.1	550	2	< 2	2.5	11	19	152	7	2.3	4.3	8	< 1	< 5	1.76	28
SA-11	< 2	< 0.3	23	0.6	2	6	38	77	0.14	4.22	3.6	460	1	< 2	< 0.5	19.3	6	89	< 1	1.9	2.42	3	< 1	< 5	1.64	21
SA-12	< 2	< 0.3	12	< 0.3	1	< 3	25	39	0.12	3.71	5.6	760	< 1	< 2	5.1	16.3	9	64	< 1	1.2	2.29	2	< 1	< 5	0.74	18
SA-13	< 2	< 0.3	36	0.3	< 1	5	64	102	0.09	3.61	12.1	480	< 1	< 2	2.9	14.4	8	133	< 1	1.7	2.4	4	< 1	< 5	1.1	11
SBc-14	< 2	< 0.3	23	< 0.3	< 1	4	53	59	0.1	6.56	3.7	500	2	< 2	7.8	11.4	19	111	< 1	2	4.13	4	< 1	< 5	1.3	26
SBc-15	< 2	< 0.3	13	< 0.3	2	4	26	48	0.15	3.7	5.4	600	< 1	< 2	1.7	20.6	9	53	1	1	2.2	2	< 1	< 5	0.93	11
SBc-16	< 2	< 0.3	32	< 0.3	< 1	12	63	89	0.13	7.48	9	490	2	< 2	< 0.5	13.3	17	118	10	2.4	3.84	8	< 1	< 5	1.58	26
SBc-17	< 2	< 0.3	21	< 0.3	< 1	5	57	62	0.12	6.15	6.4	390	1	< 2	3.3	13.2	17	114	< 1	2.3	3.89	4	< 1	< 5	1.19	24
SBc-18	< 2	< 0.3	20	< 0.3	1	7	47	49	0.1	5.47	6.2	460	1	< 2	< 0.5	16.5	13	82	< 1	1.5	3.17	4	< 1	< 5	0.94	21
SBc-19	< 2	< 0.3	14	< 0.3	< 1	6	33	59	0.1	5.31	4.9	< 50	1	< 2	< 0.5	15.2	11	86	< 1	1.4	3.28	4	< 1	< 5	1.36	18
SBc-20	< 2	0.4	25	0.5	3	9	50	102	0.06	5.3	5.1	1260	2	< 2	< 0.5	8.83	14	130	4	2.6	3.83	7	< 1	< 5	1.58	30
SBc-21	< 2	< 0.3	39	< 0.3	3	< 3	70	86	0.13	4.09	10.2	1010	1	< 2	3.4	21.7	11	164	2	2.8	2.68	4	< 1	< 5	1.07	15
SBc-22	< 2	< 0.3	25	< 0.3	1	13	57	74	0.06	6.13	7.9	930	2	< 2	< 0.5	9.23	26	122	< 1	2.6	4.64	9	< 1	< 5	1.21	17
SBc-23	< 2	< 0.3	37	0.4	< 1	8	99	113	0.22	4.63	6.4	3000	1	< 2	8.7	19.8	16	185	< 1	1.1	2.48	2	< 1	< 5	1.15	23
SBc-24	< 2	< 0.3	45	0.3	3	9	78	99	0.13	6.3	24.2	740	2	< 2	< 0.5	18.7	13	194	8	1.2	3.63	3	< 1	< 5	1.57	20
SBc-25	< 2	< 0.3	41	< 0.3	2	5	69	99	0.15	5.23	15.6	970	1	< 2	4.3	20.2	9	190	7	1.1	3.09	2	< 1	< 5	1.31	16
SBc-26	< 2	< 0.3	34	0.4	< 1	7	92	103	0.16	3.93	8.6	2020	1	< 2	6.7	18.5	12	157	< 1	1.4	2.92	3	< 1	< 5	0.73	16
SBc-27	< 2	< 0.3	19	< 0.3	< 1	3	49	57	0.08	5.86	6.5	480	1	< 2	3.7	12.9	14	95	3	1	3.74	3	< 1	< 5	1.29	20
SBc-28	< 2	< 0.3	41	0.5	1	8	74	100	0.13	7.65	16.7	450	2	< 2	4.3	16.8	13	165	12	0.9	4.3	3	< 1	< 5	1.28	26
SBc-29	< 2	< 0.3	8	< 0.3	< 1	5	25	42	0.09	4.54	5.3	240	< 1	< 2	2.9	13	8	67	3	0.6	2.44	2	< 1	< 5	1.12	22
SBc-30	< 2	< 0.3	88	0.3	< 1	9	38	80	0.1	4.96	3.5	670	2	< 2	4.6	12.6	16	89	< 1	1.2	2.95	4	< 1	< 5	1.59	23
SBc-31	< 2	< 0.3	25	0.5	4	8	46	83	0.08	5.3	5.7	690	2	< 2	2.4	10.3	13	113	3	1.2	3.57	4	< 1	< 5	1.48	28
SBc-32	< 2	< 0.3	18	< 0.3	2	5	35	36	0.1	5.02	6.9	290	1	< 2	2.3	15	11	67	< 1	0.7	2.88	3	< 1	< 5	0.9	18
SBc-33	< 2	< 0.3	49	0.4	3	5	66	106	0.14	5.45	21.3	490	1	< 2	3.4	21.2	10	200	6	1	2.93	3	< 1	< 5	1.6	16
SBc-34	< 2	< 0.3	48	0.6	< 1	9	97	115	0.16	4.56	11.8	1350	1	< 2	4.7	18	10	221	< 1	1.3	2.61	2	< 1	< 5	1.26	20
SBc-35	< 2	< 0.3	18	< 0.3	< 1	7	40	59	0.11	5.47	7.4	470	1	< 2	4.5	13.8	14	93	< 1	0.8	3.15	3	< 1	< 5	0.99	15
SC-36	< 2	< 0.3	39	0.6	< 1	13	91	102	0.1	7.46	10.6	1230	2	< 2	5.8	10.4	34	241	4	1.8	4.81	8	< 1	< 5	1	26
SC-37	< 2	< 0.3	34	< 0.3	< 1	< 3	93	102	0.15	3.9	7.3	830	1	< 2	5.1	18	11	197	< 1	1.3	2.24	2	< 1	< 5	0.52	19
SC-38	< 2	< 0.3	10	< 0.3	< 1	< 3	28	44	0.11	4.68	4.6	560	< 1	< 2	4.5	13.5	9	85	4	0.7	2.23	2	< 1	< 5	0.93	25
SC-39	< 2	0.4	36	0.7	2	10	46	108	0.1	6.12	4.2	2080	2	< 2	4.3	15.2	7	128	5	1.3	2.77	3	< 1	< 5	1.51	25
SC-40	< 2	0.5	29	0.6	4	8	86	94	0.22	3.89	5.9	2640	1	< 2	6.2	22.9	10	212	< 1	< 0.2	1.86	1	< 1	< 5	0.59	19
SC-41	< 2	< 0.3	24	0.5	3	9	43	86	0.13	5.29	4.8	1440	2	< 2	3.8	18	10	126	3	1.1	2.67	2	< 1	< 5	1.3	21
SDc-42	5	0.4	40	0.4	< 1	8	94	93	0.08	5.01	6.2	1370	2	6	5.7	8.12	27	192	4	2.1	4.8	7	< 1	< 5	1.06	27
SDc-43	< 2	< 0.3	39	0.5	< 1	12	90	111	0.07	7.29	9	510	2	< 2	3.5	8.19	35	271	2	2.1	5.28	8	< 1	< 5	1.25	29
SDc-44	2	< 0.3	41	0.4	< 1	13	83	103	0.07	7.53	7.2	580	2	< 2	3.7	8.5	27	263	5	2	5.03	7	< 1	< 5	1.11	30
SDc-45	< 2	< 0.3	33	< 0.3	< 1	11	77	81	0.08	6.18	5.5	750	2	< 2	2.9	10.4	33	168	< 1	1.6	4.85	16	< 1	< 5	1.06	22
SDc-46	< 2	< 0.3	33	0.4	< 1	11	81	74	0.09	5.66	7.1	720	2	< 2	4.9	11.3	31	158	3	1.4	4.46	13	< 1	< 5	1.01	20
SDc-47	< 2	< 0.3	320	0.3	< 1	11	73	93	0.1	7.1	7.8	540	2	< 2	3.2	12.2	27	206	< 1	1.6	4.97	12	< 1	< 5	1.07	27
SDc-48	< 2	< 0.3	25	< 0.3	< 1	10	49	57	0.09	4.9	5.9	710	2	< 2	5.1	4.38	18	113	1	1.3	3.28	8	< 1	< 5	0.83	16
SDc-49	< 2	< 0.3	31	0.3	2	15	70	91	0.02	7.28	7.2	820	2	< 2	< 0.5	1.43	28	175	< 1	1.8	5.09	18	< 1	< 5	1.44	18
SDc-50	5	< 0.3	36	0.4	< 1	12	82	85	0.1	5.89	5.8	1060	2	< 2	5.3	12.9	29	165	< 1	1.5	4.4	11	< 1	< 5	0.93	20
SDc-51	< 2	< 0.3	23	0.4	4	7	60	55	0.15	3.68	6.2	1400	1	< 2	3.6	19.6	13	103	< 1	0.7	2.64	6	< 1	< 5	1.11	10
SDc-52	< 2	< 0.3	35	0.4	< 1	13	81	109	0.05	7.27	7.4	760	2	< 2	< 0.5	5.21	34	188	< 1	1.9	5.72	12	< 1	< 5	1.27	30
SDc-53	< 2	< 0.3	34	0.4	< 1	10	86	81	0.11	5.86	6.7	840	2	< 2	4.6	14.2	27	154	1	1.5	4.68	12	< 1	< 5	0.95	18
SDc-54	< 2	< 0.3	32	0.5	< 1	11	74	74	0.1	5.62	7.2	840	2	< 2	5	12.2	26	150	< 1	1.4	4.36	14	< 1	< 5	1.01	19
SDc-55	< 2	< 0.3	39	< 0.3	< 1	11	88	114	0.06	7.46	11.8	520	2	< 2	4	6.91	32	223	3	2.3	5.75	16	< 1	< 5	1.19	27
SDc-56	< 2	< 0.3	33	< 0.3	< 1	9	86	93	0.08	6.62	7.2	730	2	< 2	7.1	10.3	36	196	< 1	1.8	5.61	14	< 1	< 5	1.29	23
SDc-57	< 2	< 0.3	34	0.4	< 1	10	74	74	0.1	5.6	5.8	890	2	< 2	5.8	11.7	25	162	< 1	1.4	4.54	13	< 1	< 5	1.06	20
SD1-58	< 2	< 0.3	17	< 0.3	< 1	< 3	35	42	0.1	5.11	5.4	840	1	< 2	5.3	14.1	11	75	< 1	0.7	2.97	4	< 1	< 5	0.74	19
SD1-59	< 2	< 0.3	37	< 0.3	< 1	7	106	116	0.21	3.13	5.7	1960	< 1	< 2	7.6	18.5	12	177	< 1	1	2.06	2	< 1	< 5	0.29	13
SD1-60	< 2	< 0.3	17	< 0.3	< 1	3	32	42	0.09	4.84	6.7	960	1	< 2	3.6	14.1	11	75	3	0.6	2.68	4	< 1	< 5	0.92	26
SD1-61	< 2	< 0.3	38	0.4	1	6	94	104	0.15	4.21	9.6	1430	1	< 2	4.8	20.7	13	186	< 1	1.3	2.53	3	< 1	< 5	0.39	17
SD1-62	< 2	< 0.3	25	0.5	4	6	37	81	0.12	5.14	4.8	790	2	< 2	3.6	17.5	8	92	4	0.9	2.63	3	< 1	< 5	1.42	21
SD1-63	< 2	0.4	30	< 0.3	< 1	< 3	65	76	0.11	6.57	7	1480	2	< 2	3.6	13.2	14	129	< 1	1	4.32	5	< 1	< 5	0.6	28
SD1-64	< 2	< 0.3	36	< 0.3	2	11	75	79	0.08	7.59	12.2	1200	2	< 2	3	12	17	174	8	1.4	4.57	9	< 1	< 5	1.61	26
SD1-65	< 2	0.3	35	0.3	< 1	8	69	74	0.07	7.22	9.1	600	2	< 2	3.7	11.8	18	164	< 1	1.4	4.05	8	< 1	< 5	1.84	29
SD1-66	< 2	< 0.3	20	< 0.3	1	6	34	52	0.11	5.04	5.2	2260	1	< 2	5.3	14.4	9	71	< 1	0.6	2.67	4	< 1	< 5	0.69	12
SD1-67	< 2	< 0.3	27	0.8	3	11	45	101	0.11	6.07	5.1	2100	2	< 2	4.4	15.5	9	100	2	1.5	2.98	3	< 1	< 5	1.5	22
SD1-68	< 2	< 0.3	26	0.4	< 1	< 3	58	67	0.12	6.2	6.4	1430	2	< 2	3.3	14.5	14	130	3	1.2	3.96	3	< 1	< 5	0.57	27
SD1-69	< 2	0.4	33	0.5	4	9	87	99	0.06	5.61	8.7	800	2	3	5.1	8.42	35	216	< 1	2.7	5.51	9	< 1	< 5	1.02	26
SD1-70	< 2	< 0.3	35	0.5	< 1	9	78	95	0.08	7.03	7.5	1430	2	< 2	4.3	10.8	23	189	2	2.2	4.77	6	< 1	< 5	0.77	21
SD2-71	< 2	0.3	23	0.5	4	21	38	81	0.13	5.38	4.6	1670	2	< 2	4.2	16	9	100	3	1.4	2.56	2	< 1	< 5	1.29	20
SD2-72	< 2	< 0.3	38	0.5	2	6	87	101	0.15	6.09	6	3610	1	< 2	7.1	13.8	27	163	< 1	1.1	4.58	3	< 1	< 5	0.44	17
SD2-73	< 2	< 0.3	35	0.4	< 1	15	83	96	0.09	7.39	9.3	970	2	< 2	5	10.1	30	194	< 1	2.4	5.26	9	< 1	< 5	1.1	28
SD2-74	< 2	< 0.3	41	< 0.3	1	< 3	117	168	0.14	7.82	2.4	530	2	< 2	< 0.5	19.9	18	245	3	2.1	3.48	3	< 1	< 5	0.46	60
SD2-75	< 2	< 0.3	33	0.4	3	10	84	103	0.07	6.55	7	1820	2	< 2	5	8.56	35	188	< 1	2.3	4.68	8	< 1	< 5	0.84	17

Table 3. cont.

Element	Mg	Mn	Na	P	Rb	Sb	Sc	Se	Sr	Ta	Ti	Th	U	V	W	Y	La	Ce	Nd	Sm	Sn	Tb	Yb	Lu	Mass
Unit	%	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	g
Detection limit	0.01	1	0.01	0.001	15	0.1	0.1	3	1	0.5	0.01	0.2	0.5	2	1	1	0.5	3	5	0.1	0.01	0.5	0.2	0.05	
Analysis method	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
SA-1	0.86	412	0.41	0.34	< 15	0.5	10.2	< 3	494	< 0.5	0.08	7	9	91	< 1	41	35.4	59	57	5	< 0.01	2.3	3.8	1	1.02
SA-2	0.73	133	0.25	0.169	60	0.3	11.1	< 3	503	< 0.5	0.37	12.1	3.9	77	< 1	19	37.5	78	39	5.3	< 0.01	< 0.5	2.8	0.52	1.04
SA-3	1.06	291	0.16	0.3	< 15	0.4	9.9	< 3	497	< 0.5	0.08	4.2	6.7	89	< 1	37	30.8	40	57	4.6	< 0.01	< 0.5	2.7	0.96	1.1
SA-4	0.76	278	0.22	0.062	40	0.2	9.1	< 3	358	< 0.5	0.22	5.1	3.2	53	< 1	13	18.3	43	34	2.9	< 0.01	< 0.5	1.5	0.3	1.31
SA-5	1.27	249	0.25	0.165	52	0.5	12	< 3	517	< 0.5	0.3	12.6	4.5	68	< 1	23	40.6	79	64	5.8	< 0.01	2.3	2.4	0.69	0.874
SA-6	0.83	105	0.15	0.138	78	0.4	10.2	< 3	409	< 0.5	0.37	12.4	4.2	77	< 1	22	34.1	66	61	5	< 0.01	< 0.5	2.2	0.68	0.997
SA-7	1.17	227	0.95	0.26	< 15	0.3	14.1	< 3	595	< 0.5	0.36	16.3	4.6	95	< 1	28	46.7	94	62	6.9	< 0.01	< 0.5	2.8	0.59	0.907
SA-8	0.73	138	0.2	0.112	59	0.2	9.3	< 3	316	< 0.5	0.35	11.3	4.3	73	< 1	19	29.4	64	71	4.4	< 0.01	< 0.5	2.3	0.79	0.918
SA-9	0.83	203	0.28	0.43	< 15	0.3	10.9	< 3	500	< 0.5	0.06	7	8.1	76	< 1	41	31.2	46	34	4.6	< 0.01	< 0.5	3.6	1.02	0.936
SA-10	2.04	425	0.19	0.252	107	0.5	13.9	< 3	261	< 0.5	0.27	12.4	8	94	< 1	25	33.3	70	31	5	< 0.01	< 0.5	3	0.89	1.02
SA-11	0.61	187	0.17	0.115	38	0.2	7.3	< 3	488	< 0.5	0.24	7.7	4.3	63	< 1	19	25.6	62	43	4	< 0.01	< 0.5	2.1	0.64	0.812
SA-12	1.52	221	0.26	0.098	< 15	0.2	7.4	< 3	347	< 0.5	0.26	4.1	2.4	58	< 1	7	12.2	29	16	2.2	< 0.01	< 0.5	1.2	0.39	1.04
SA-13	0.3	239	0.19	0.163	< 15	0.9	8.2	< 3	428	< 0.5	0.08	5.8	9.9	67	< 1	19	19.1	39	29	2.9	< 0.01	< 0.5	2.5	0.71	0.716
SBc-14	1.21	318	0.47	0.086	< 15	0.3	12.8	< 3	281	< 0.5	0.19	6.7	1.8	48	< 1	14	26.1	58	27	4.2	< 0.01	< 0.5	1.9	0.6	0.772
SBc-15	0.46	130	0.14	0.047	< 15	< 0.1	7.1	< 3	421	< 0.5	0.18	3.9	2.4	45	< 1	8	12.7	26	27	2.1	< 0.01	< 0.5	1	0.28	0.969
SBc-16	1.92	396	0.17	0.159	89	0.9	13.3	< 3	270	< 0.5	0.45	13.5	4.5	89	< 1	22	34.8	88	32	5.1	< 0.01	< 0.5	2.8	0.76	1.26
SBc-17	1.47	363	0.19	0.1	42	0.4	12.6	< 3	261	< 0.5	0.22	8	3.1	59	< 1	15	25.4	60	45	4.2	< 0.01	< 0.5	1.8	0.48	1.2
SBc-18	1.09	309	0.22	0.072	44	0.3	10.1	< 3	287	< 0.5	0.18	6.1	2.7	38	< 1	13	20.5	45	22	3.3	< 0.01	< 0.5	1.5	0.37	1.26
SBc-19	2.19	295	0.17	0.03	28	0.3	9.9	< 3	188	< 0.5	0.11	5.7	3.6	24	< 1	10	17.1	44	27	2.9	< 0.01	< 0.5	1.8	0.39	0.965
SBc-20	0.8	201	0.3	0.139	40	1	12.9	< 3	401	< 0.5	0.51	14	0.8	83	< 1	19	41.5	86	85	6.6	< 0.01	< 0.5	3.3	0.72	0.918
SBc-21	0.67	307	0.2	0.298	50	1	9.2	< 3	499	< 0.5	0.08	5.3	7.3	83	< 1	33	31.6	45	36	4.7	< 0.01	2.3	2.8	0.83	0.912
SBc-22	0.52	959	0.32	0.035	50	0.6	12.9	< 3	248	< 0.5	0.18	10.7	3.1	30	< 1	27	38.1	102	55	6.7	< 0.01	2.3	3.7	0.96	1.23
SBc-23	1.7	296	0.18	0.507	47	0.9	10.5	< 3	517	< 0.5	0.04	4.1	8.4	88	< 1	34	30.2	35	20	4.3	< 0.01	< 0.5	3	0.12	1.11
SBc-24	1.13	167	0.13	0.322	87	1.6	12.4	< 3	407	< 0.5	0.13	7.8	9	96	< 1	25	29.2	44	15	4.1	< 0.01	< 0.5	2.5	< 0.05	1.04
SBc-25	1	91	0.15	0.263	< 15	0.9	10.8	< 3	469	< 0.5	0.11	5.4	9.2	107	< 1	23	26.7	41	34	3.7	< 0.01	0.8	2	< 0.05	1.04
SBc-26	1.07	328	0.35	0.282	< 15	0.9	10.9	< 3	439	< 0.5	0.09	3.9	6.2	71	< 1	34	30.2	43	34	4.7	< 0.01	1.3	3.4	0.09	0.889
SBc-27	1.26	305	0.19	0.127	73	0.5	11.3	< 3	238	< 0.5	0.42	5	1	83	< 1	13	22.3	50	29	3.7	< 0.01	< 0.5	1.5	0.07	1.07
SBc-28	1.79	182	0.56	0.283	195	1.2	14.5	< 3	380	< 0.5	0.31	8.6	6.6	97	< 1	22	31.2	58	31	4.4	< 0.01	< 0.5	2.6	< 0.05	1.16
SBc-29	1.06	197	0.24	0.039	34	0.4	8.3	< 3	290	< 0.5	0.17	3.4	3.2	43	< 1	9	14.8	32	15	2.4	< 0.01	< 0.5	1.3	< 0.05	1.33
SBc-30	0.61	165	0.17	0.146	65	0.4	9.5	< 3	337	< 0.5	0.31	7.7	3.5	55	< 1	19	29.9	63	28	4.7	< 0.01	< 0.5	2.4	0.06	0.748
SBc-31	0.7	211	0.2	0.164	84	0.6	11.2	< 3	293	< 0.5	0.44	8.3	2.8	89	< 1	19	34	69	31	5.2	< 0.01	0.9	2.4	0.25	1.28
SBc-32	0.71	192	0.18	0.058	< 15	0.2	9.9	< 3	256	< 0.5	0.26	4.2	1.9	54	< 1	10	16.5	38	20	2.7	< 0.01	< 0.5	1.3	< 0.05	1.16
SBc-33	0.94	121	0.16	0.338	92	1.3	10.8	< 3	491	< 0.5	0.07	5.8	8.9	95	< 1	26	26.5	44	20	3.8	< 0.01	1.7	2.3	0.05	1.16
SBc-34	1.06	313	0.24	0.241	63	0.7	10.3	< 3	503	< 0.5	0.13	3.9	3.8	105	< 1	30	29.4	44	21	4.6	< 0.01	1	2.5	0.14	1.26
SBc-35	0.92	252	0.19	0.077	29	0.3	10.4	< 3	249	< 0.5	0.17	4.4	1.8	42	< 1	13	20.6	47	21	3.6	< 0.01	0.9	1.6	< 0.05	1.11
SC-36	0.88	1390	0.24	0.153	71	0.9	15.2	< 3	342	< 0.5	0.25	8	4.2	77	< 1	32	42.9	115	55	7.5	< 0.01	1.3	4.1	0.32	1.32
SC-37	0.96	338	0.27	0.291	< 15	0.6	9.5	< 3	500	< 0.5	0.08	3.3	5.6	81	< 1	34	29	39	41	4.6	< 0.01	< 0.5	3.2	0.15	1.17
SC-38	1.19	238	0.24	0.092	71	0.3	8.1	< 3	336	< 0.5	0.3	3.2	1.8	62	< 1	10	15.4	31	24	2.6	< 0.01	0.9	1.6	< 0.05	1.36
SC-39	0.73	182	0.2	0.203	119	1.1	10.1	< 3	476	< 0.5	0.26	7	2.4	76	< 1	22	33.3	70	35	5.2	< 0.01	1.1	2.5	< 0.05	0.955
SC-40	0.7	286	0.15	0.41	17	0.8	8.8	< 3	596	< 0.5	0.06	3.5	6.7	85	< 1	31	26.1	32	21	3.6	< 0.01	< 0.5	2.6	< 0.05	1.3
SC-41	0.69	125	0.15	0.14	60	0.7	8.9	< 3	442	< 0.5	0.29	6.7	3	68	< 1	20	31	62	29	4.8	< 0.01	1	2.3	< 0.05	1.16
SDc-42	1.05	1190	0.27	0.119	95	0.4	15.8	< 3	235	< 0.5	0.75	7.9	2.8	123	< 1	28	45.9	98	45	7.8	< 0.01	2.1	4.5	0.55	1.41
SDc-43	0.97	1290	0.3	0.192	119	0.9	16.3	< 3	242	< 0.5	0.31	8.7	3.6	89	< 1	33	45.8	120	48	8.2	< 0.01	1.6	4.5	0.56	1.26
SDc-44	0.89	1090	0.24	0.152	84	0.7	16.1	< 3	259	1.2	0.26	8.5	4.4	62	< 1	34	44.3	102	46	7.7	< 0.01	1.7	4.6	0.6	1.43
SDc-45	1.18	1200	0.38	0.084	83	0.7	14.6	< 3	205	< 0.5	0.16	11.9	1.3	34	< 1	27	39.1	106	42	6.8	< 0.01	0.8	3.6	0.09	1.35
SDc-46	1.1	1090	0.28	0.076	43	0.9	13.3	< 3	197	< 0.5	0.11	10.3	3.4	28	< 1	27	36.6	97	48	6.2	< 0.01	1.2	3.3	0.08	1.22
SDc-47	0.83	941	0.24	0.115	127	0.6	16	< 3	310	2.4	0.2	12	3	52	6	32	40.7	100	40	7	< 0.01	1	3.5	0.1	1.18
SDc-48	0.68	600	0.59	0.044	< 15	0.5	10.1	< 3	191	< 0.5	0.11	8	2.3	30	< 1	24	28.9	67	32	4.9	< 0.01	0.5	2.3	0.1	1.38
SDc-49	0.4	944	0.33	0.031	40	0.8	16.3	< 3	120	< 0.5	0.08	13.9	1.6	19	< 1	33	44.9	113	67	8	< 0.01	0.6	3.8	0.19	1.24
SDc-50	1.08	963	0.26	0.078	55	1	13.5	< 3	208	< 0.5	0.12	9.9	2.2	29	< 1	29	36	91	62	6.1	< 0.01	0.7	3.2	0.08	1.23
SDc-51	0.4	512	0.17	0.081	< 15	0.9	8.4	< 3	258	< 0.5	0.29	6	1.3	46	< 1	20	23.5	47	24	4	< 0.01	0.5	1.9	< 0.05	1.12
SDc-52	1.03	1010	0.33	0.188	72	1	16.9	< 3	219	< 0.5	0.21	12.6	4.6	64	< 1	32	42.7	110	45	7.5	< 0.01	1.4	3.7	0.17	1.33
SDc-53	1	921	0.27	0.082	67	0.8	13.8	< 3	205	< 0.5	0.11	9.9	1.4	26	< 1	29	37.4	89	36	6.3	< 0.01	0.9	3.3	0.05	1.39
SDc-54	1.19	932	0.34	0.078	49	1	13.3	< 3	210	< 0.5	0.11	10.3	2.1	29	< 1	27	34.8	89	41	6.1	< 0.01	1.3	3	0.08	1.29
SDc-55	1.23	1050	0.33	0.181	109	0.9	17.3	< 3	202	< 0.5	0.23	11.9	4.2	80	< 1	32	44.7	106	53	7.8	< 0.01	0.8	3.7	0.16	1.21
SDc-56	1.11	1140	0.52	0.073	< 15	0.8	15.1	< 3	202	< 0.5	0.2	13.3	1.4	34	< 1	30	42.1	109	56	7.9	< 0.01	1	3.7	0.09	0.809
SDc-57	1.34	937	0.34	0.076	58	0.7	12.1	< 3	209	< 0.5	0.19	11.1	1.9	37	< 1	26	34.9	83	50	6.3	< 0.01	1.3	3	0.08	1.11
SD1-58	0.91	286	0.19	0.06	47	0.6	9.4	< 3	285	< 0.5	0.25	6	3.2	54	< 1	12	20.1	39	37	3.3	< 0.01	< 0.5	1.5	< 0.05	1.17
SD1-59	2.63	321	0.18	0.346	< 15	0.8	9	< 3	419	< 0.5	0.04	4.5	5	72	< 1	36	27.8	36	41	4.3	< 0.01	0.8	2.9	< 0.05	1.08
SD1-60	1.28	245	0.24	0.052	59	0.1	8.8	< 3	327	< 0.5	0.21	5.5	2.4	45	< 1	10	14.9	35	15	2.6	< 0.01	< 0.5	1.5	< 0.05	1.12
SD1-61	1.01	278	0.21	0.253	< 15	1.3	9.7	< 3	482	< 0.5	0.09	4.4	6.1	86	< 1	31	26.7	38	35	4.1	< 0.01	< 0.5	2.5	< 0.05	1.13
SD1-62	0.71	111	0.15	0.121	72	0.6	8.2	< 3	422	< 0.5	0.28	10.3	2	67	< 1	18	27.3	56	35	4.5	< 0.01	< 0.5	2	< 0.05	1.05
SD1-63	2.04	373	0.2	0.112	49	0.6	11.8	< 3	228	< 0.5	0.4	8.3	2.4	102	< 1	16	22.5	53	45	4	< 0.01	0.6	1.6	< 0.05	1.14
SD1-64	1.67	328	0.16	0.275	100	1	14.4	< 3	299	< 0.5	0.47	13.9	9	122	< 1	26	35.6	70	37	5.5	< 0.01	0.7	2.8	0.09	1.4
SD1-65	2.11	436	0.19	0.317	141	1	13.2	< 3	276	< 0.5	0.33	13.4	5.4	104	< 1	25	31	72	45	4.9	< 0.01	< 0.5	2.6	0.09	1.44
SD1-66	0.66	383	0.18	0.058	33	0.5	8.4	< 3	322	< 0.5	0.24	5.4	2.1	57	< 1	12	16.5	34	17	2.7	< 0.01	0.5	1.3	< 0.05	1.17
SD1-67	0.67	147	0.19	0.175	57	0.8	9.8	< 3	416	< 0.5	0.31	9.3	3.2	77	< 1	21	33.9	64	30	5.4	< 0.01	< 0.5	2.1	< 0.05	1.07
SD1-68	2.09	324	0.21	0.102	< 15	0.5	11.2	< 3	279	< 0.5	0.36	5.8	2.8	104	< 1	15	23.7	44	36	4.1	< 0.01	< 0.5	1.7	< 0.05	0.949
SD1-69	0.84	1650	0.31	0.188	116	0.9	15.8	< 3	276	< 0.5	0.77	10.3	6.1	149	< 1	28	48.4	122	41	8.1	< 0.01	1.9	3.9	0.15	1.24
SD1-70	0.97	807	0.26	0.142	79	0.9	14.2	< 3	295	< 0.5	0.37	8.3	6.6	98	< 1	31	40.3	84	39	6.9	< 0.01	1.7	3.1	0.11	1.23
SD2-71	0.67	131	0.21	0.105	84	0.6	8.9	< 3	379	< 0.5	0.32	7.3	2.5	65	< 1	18	30.5	56	37	4.8	< 0.01	1.1	1.9	< 0.05	1.12
SD2-72	0.65	460	0.45	0.137	51	0.8	13.3	< 3	431	< 0.5	0.23	5.2	4.2	61	< 1	20	28.1	56	35	5.3	< 0.01	2.6	1.9	< 0.05	1.09
SD2-73	1.03	1210	0.26	0.127	76	0.8	15	< 3	251	< 0.5	0.17	10.2	4	60	< 1	31	43.3	102	75	7.7	< 0.01	< 0.5	3.3	0.11	1.44
SD2-74	1.37	471	0.31	0.393	< 15	0.6	13.8	< 3	682	< 0.5	0.15	7.3	8.4	103	< 1	39	41.7	62	42	6.2	< 0.01	1.3	3	< 0.05	1.46
SD2-75	0.7	1310	0.31	0.171	67	0.5	13.5	< 3	322	< 0.5	0.32	8.5	4.8	85	< 1	31	40.1	103	137	6.9	< 0.01	1.5	3	0.12	1.34

Table 3. cont.

Element	Au	Ag	Cu	Cd	Mo	Pb	Ni	Zn	S	Al	As	Ba	Be	Bi	Br	Ca	Co	Cr	Cs	Eu	Fe	Hf	Hg	Ir	K	Li
Unit	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	%	ppm
Detection limit	2	0.3	1	0.3	1	3	1	1	0.01	0.01	0.5	50	1	2	0.5	0.01	1	2	1	0.2	0.01	1	1	5	0.01	1
Analysis method	INAA	INAA / TD-ICP	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA / TD-ICP	INAA / TD-ICP	TD-ICP	TD-ICP	INAA	INAA	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	TD-ICP	TD-ICP
SD2-76	< 2	< 0.3	37	0.4	< 1	11	89	108	0.07	7.62	8.4	720	2	< 2	4.4	8.13	35	208	< 1	2.6	5.37	9	< 1	< 5	1.16	28
SD2-77	< 2	< 0.3	39	< 0.3	< 1	10	95	104	0.07	7.64	10.5	670	2	< 2	4.3	9.3	38	215	< 1	2.7	5.71	9	< 1	< 5	1.18	28
SD2-78	6	< 0.3	16	< 0.3	1	4	45	61	0.14	6.72	8.9	1160	1	< 2	4.1	14.5	14	124	3	1.2	3.66	3	< 1	< 5	1.16	39
SD2-79	26	0.5	42	0.5	2	10	89	126	0.09	7.56	10.2	1100	2	2	5.5	10.9	32	219	< 1	2.5	5.39	6	< 1	< 5	1.4	26
SD2-80	< 2	< 0.3	37	0.5	< 1	13	90	107	0.06	7.51	9.1	1110	2	< 2	4.3	7.88	34	211	< 1	2.3	5.2	8	< 1	< 5	1.26	23
SD2-81	< 2	< 0.3	36	0.7	1	14	79	97	0.09	7.13	10	880	2	< 2	6.2	10.6	26	199	< 1	2.3	4.61	7	< 1	< 5	1.11	24
SD2-82	< 2	< 0.3	96	< 0.3	< 1	< 3	153	55	0.06	9.2	3.4	540	1	< 2	< 0.5	7.47	35	274	3	0.8	5.17	1	< 1	< 5	0.88	23
SD2-83	< 2	< 0.3	31	0.4	2	12	88	95	0.11	6.79	12.8	2300	2	< 2	4.2	9.46	32	188	1	2.3	4.46	8	< 1	< 5	1.19	18
SD2-84	< 2	< 0.3	35	< 0.3	< 1	12	80	102	0.09	7.56	8.3	910	2	< 2	< 0.5	9.09	30	196	< 1	1.6	5.07	7	< 1	< 5	1	28
SD2-85	< 2	< 0.3	27	< 0.3	< 1	14	69	90	0.06	7.26	7.6	2330	2	< 2	2.1	6	28	147	2	2.6	4.6	9	< 1	< 5	1.12	19
SE-86	< 2	< 0.3	35	1.1	5	9	57	96	0.13	5.72	6.5	1290	2	< 2	5	16.6	8	105	< 1	1.3	2.72	3	< 1	< 5	1.24	30
SE-87	< 2	< 0.3	39	< 0.3	< 1	14	98	113	0.06	8.55	9.4	620	2	< 2	6.5	6.96	36	219	< 1	2.6	5.65	8	< 1	< 5	1.24	31
SE-88	< 2	< 0.3	37	0.4	< 1	< 3	91	76	0.11	6.02	8	1110	1	6	7.7	13.3	32	190	2	2.1	5.47	4	< 1	< 5	0.84	18
SE-89	< 2	0.5	43	0.4	< 1	11	93	118	0.08	6.83	6.3	1080	2	< 2	5.5	11.5	24	173	< 1	1.9	5.03	8	< 1	< 5	0.94	25
SE-90	< 2	0.3	30	< 0.3	< 1	6	41	70	0.12	5.49	8.1	1230	1	< 2	5.1	15.4	12	114	2	0.9	3.51	3	< 1	< 5	0.87	28
SE-91	< 2	< 0.3	62	0.3	< 1	12	91	115	0.05	8.09	8.5	640	2	< 2	< 0.5	7.73	29	188	< 1	2.1	6.13	9	< 1	< 5	1.23	31
SE-92	< 2	< 0.3	47	< 0.3	< 1	11	91	112	0.07	7.61	8.3	780	2	< 2	< 0.5	9.29	35	185	< 1	2	5.51	9	< 1	< 5	1.09	29
SE-93	< 2	< 0.3	42	0.3	< 1	11	86	107	0.07	8.01	9.9	590	2	< 2	8.6	8.77	26	203	< 1	2.1	5.97	9	< 1	< 5	1.02	29
SE-94	< 2	0.3	16	< 0.3	< 1	5	36	48	0.13	5.51	8	1480	< 1	< 2	3.7	14.4	9	76	3	< 0.2	3.08	3	< 1	< 5	0.81	25
SE-95	< 2	0.4	51	0.5	< 1	8	113	149	0.07	7.89	6.2	930	2	< 2	9.3	10.5	23	228	5	2.3	5.52	7	< 1	< 5	1.63	25
SE-96	< 2	< 0.3	39	0.3	< 1	12	89	117	0.08	7.79	7.7	610	2	< 2	4.3	9.61	26	177	3	2.1	5.7	8	< 1	< 5	1.08	29
SE-97	13	< 0.3	29	< 0.3	< 1	< 3	35	57	0.1	5.2	5.4	1700	< 1	< 2	4.1	13.9	9	77	< 1	0.6	3.08	4	< 1	< 5	0.8	19
SE-98	< 2	< 0.3	33	0.5	< 1	11	71	90	0.09	7.18	8.3	840	2	< 2	< 0.5	11.4	25	164	3	1.9	5.22	8	< 1	< 5	1.02	27
SE-99	< 2	0.4	42	0.4	3	5	80	99	0.07	5.65	8.6	1350	2	7	5.9	7.86	25	180	3	2	5.75	9	< 1	< 5	1.04	25
SE-100	< 2	< 0.3	18	< 0.3	< 1	6	97	85	0.12	6.72	5.2	1040	2	< 2	7	13.1	17	160	8	0.9	3.27	4	< 1	< 5	1.71	43
SE-101	< 2	< 0.3	30	< 0.3	< 1	6	64	72	0.11	5.13	4.6	1920	1	< 2	< 0.5	13.5	19	114	< 1	1.5	3.88	5	< 1	< 5	0.88	12
SF-102	< 2	< 0.3	12	< 0.3	< 1	4	30	41	0.13	4.72	6.7	1230	< 1	< 2	6.2	17.2	7	75	< 1	0.4	2.3	2	< 1	< 5	0.69	15
SF-103	< 2	< 0.3	36	0.5	< 1	13	95	94	0.08	7.09	4.7	1210	2	< 2	7	8.62	30	149	2	2	4.98	10	< 1	< 5	1.05	29
SF-104	< 2	< 0.3	38	0.4	< 1	15	78	100	0.09	7.4	7.8	930	2	< 2	5.8	10.5	24	176	4	1.9	4.99	8	< 1	< 5	1.18	28
SF-105	< 2	< 0.3	14	< 0.3	< 1	< 3	31	42	0.15	5.02	7.7	1410	< 1	< 2	5.1	17.2	8	75	< 1	0.4	2.64	2	< 1	< 5	0.91	15
SF-106	< 2	< 0.3	40	0.6	< 1	11	89	112	0.08	8.09	9.7	660	2	< 2	5	9.36	29	189	4	1.8	5.09	9	< 1	< 5	1.15	29
SF-107	< 2	0.3	34	0.4	< 1	10	74	84	0.07	7.24	6.8	1350	2	< 2	3.9	10.5	27	166	< 1	1.8	4.91	9	< 1	< 5	0.86	23
SF-108	< 2	< 0.3	24	< 0.3	< 1	10	56	83	0.08	6.78	6.3	2190	2	< 2	7.9	11.3	13	113	2	0.8	3.78	5	< 1	< 5	0.97	19
SF-109	< 2	< 0.3	26	< 0.3	< 1	12	59	70	0.1	6.42	7.7	900	2	< 2	12.4	8.8	26	142	3	1.8	4.59	8	< 1	< 5	1.19	25
SF-110	< 2	< 0.3	47	0.5	2	12	94	115	0.09	5.87	8.5	1230	2	< 2	< 0.5	14.3	28	247	< 1	2.1	4.8	8	< 1	< 5	0.63	20
SFx-111	< 2	< 0.3	53	0.3	< 1	12	80	87	0.09	5.4	4.8	2080	2	< 2	5.7	12.1	24	139	< 1	1.3	3.87	10	< 1	< 5	0.66	16
SFx-112	< 2	< 0.3	28	< 0.3	< 1	10	69	71	0.09	4.74	1.6	2610	1	< 2	3.2	9.56	19	124	< 1	1.4	3.44	6	< 1	< 5	0.75	14
SFx-113	< 2	< 0.3	18	0.5	< 1	< 3	30	48	0.13	4.9	6.1	1510	< 1	< 2	5.4	15.8	8	69	< 1	0.5	2.68	3	< 1	< 5	0.73	17
SFx-114	< 2	< 0.3	13	< 0.3	< 1	4	32	52	0.15	4.99	7.2	1950	< 1	< 2	5.4	15.5	9	79	< 1	0.4	2.82	4	< 1	< 5	0.77	19
SFx115	< 2	< 0.3	24	0.6	2	9	44	82	0.11	6.14	4.1	2050	2	< 2	4.2	15.9	13	101	< 1	1.2	2.86	3	< 1	< 5	1.42	21
SFx-116	< 2	< 0.3	26	< 0.3	< 1	11	54	64	0.09	5.89	6.9	750	2	< 2	7.1	11.1	23	132	< 1	1.3	4.14	8	< 1	< 5	1.13	24
SFx-117	< 2	< 0.3	14	< 0.3	< 1	< 3	35	48	0.14	5.08	8.3	1370	< 1	< 2	5.4	16.3	10	68	< 1	0.5	2.7	2	< 1	< 5	0.76	16
SFx-118	< 2	< 0.3	38	0.4	< 1	11	82	104	0.08	7.68	8.3	960	2	< 2	3.2	9.31	31	189	< 1	1.7	5.54	11	< 1	< 5	1.2	28
SX-119	< 2	0.4	29	0.7	< 1	7	44	89	0.11	5.89	3.1	640	2	< 2	6.4	15.8	9	88	< 1	0.8	2.75	3	< 1	< 5	1.44	28
SA-120	< 2	< 0.3	39	< 0.3	< 1	5	91	104	0.16	3.81	5.7	2060	1	< 2	4.4	21.5	10	149	< 1	1.3	2.8	5	< 1	< 5	0.23	16
SD1-121	< 2	< 0.3	44	0.4	1	19	98	103	0.01	8.55	9	470	3	< 2	< 0.5	1.52	51	199	< 1	2.5	6.56	17	< 1	< 5	1.11	37
SBc-122	< 2	< 0.3	34	0.4	< 1	13	76	117	0.07	6.8	6.3	800	2	< 2	5.4	9.48	31	130	< 1	1.5	5.09	9	< 1	< 5	1.71	20
SA-123	< 2	< 0.3	63	0.3	< 1	13	68	86	0.07	6.94	8	620	2	< 2	5.7	4.74	23	137	< 1	1.4	4.55	7	< 1	< 5	1.39	27
SF-124	< 2	< 0.3	40	< 0.3	2	6	51	66	0.11	3.87	4.4	2200	1	< 2	5	15.7	13	94	< 1	0.9	2.53	8	< 1	< 5	0.6	15
SD1-125	< 2	< 0.3	19	< 0.3	2	4	33	51	0.1	4.99	7.4	2020	1	< 2	4.4	14.3	10	61	< 1	0.6	2.51	4	< 1	< 5	0.68	12
SA-126	< 2	0.6	31	0.6	< 1	12	63	113	0.12	7.9	6.5	1170	2	< 2	< 0.5	13.8	16	132	< 1	1.2	3.7	5	< 1	< 5	1.87	39
SA-127	< 2	0.4	24	0.4	2	5	32	48	0.2	4.88	7.6	1750	1	< 2	6.4	13.7	10	66	< 1	0.7	2.45	5	< 1	< 5	0.76	13
SA-128	< 2	0.4	33	0.6	2	11	66	94	0.1	5.43	3.5	1780	2	< 2	7.2	14.9	20	132	< 1	1.2	3.94	6	< 1	< 5	0.85	13
SX-129	< 2	0.3	25	0.7	< 1	11	52	96	0.13	6.78	4.3	560	2	< 2	2.3	17.3	12	113	7	1.3	3.29	3	< 1	< 5	1.59	38
SA-130	< 2	< 0.3	30	0.4	3	< 3	49	63	0.15	3.68	6.6	1850	< 1	< 2	3.5	21.5	9	146	< 1	0.8	2.16	3	< 1	< 5	0.54	11
SDc-131	< 2	< 0.3	38	0.3	< 1	8	92	86	0.14	6.24	4.1	1170	2	< 2	6.2	14.6	29	148	3	1.3	4.77	8	< 1	< 5	0.98	22
SBc-132	< 2	< 0.3	16	< 0.3	2	6	35	53	0.15	4.71	5.5	480	1	< 2	4.8	14.9	12	69	< 1	0.7	2.54	4	< 1	< 5	1.19	18
SD1-133	< 2	< 0.3	15	< 0.3	2	6	28	43	0.13	4.58	3.7	1550	1	< 2	6	17	11	64	2	0.6	2.4	4	< 1	< 5	0.72	17
SE-134	< 2	< 0.3	39	0.7	2	9	87	85	0.11	5.01	2.9	2050	1	< 2	6.1	16	18	145	< 1	1.1	3.74	7	< 1	< 5	0.6	11
SX-135	< 2	0.4	26	0.6	< 1	8	52	100	0.16	6.65	5.7	840	2	< 2	3.3	16.4	10	105	4	1	3.08	3	< 1	< 5	1.65	38
SOV-136	< 2	< 0.3	23	< 0.3	< 1	18	62	66	0.06	4.84	5.2	2730	1	< 2	5.7	5.82	19	122	< 1	1.3	2.89	8	< 1	< 5	1.82	18
SOV-137	< 2	< 0.3	32	< 0.3	2	13	66	73	0.04	6.88	4.1	2390	2	< 2	4	6.66	28	129	< 1	1.5	4.65	13	< 1	< 5	0.89	19
SOV-137'	< 2	0.6	68	0.6	4	11	44	73	0.19	1.71	11.1	1050	< 1	< 2	5	24.8	10	161	< 1	1	1.7	1	< 1	< 5	1.13	16
SOV-139	< 2	< 0.3	16	< 0.3	< 1	< 3	18	29	0.18	1.03	1.9	210	< 1	< 2	8.8	28.9	3	60	< 1	0.2	0.75	1	< 1	< 5	0.08	3
SX-141	< 2	< 0.3	41	0.5	< 1	10	91	114	0.08	7.71	8.6	700	2	< 2	5.6	8.08	33	218	4	1.8	5.39	12	< 1	< 5	1.35	28
SX-142	< 2	< 0.3	36	0.4	< 1	12	76	91	0.08	7.17	6.7	1020	2	< 2	4	11.7	27	177	< 1	1.5	5.15	9	< 1	< 5	0.97	26
SX-143	< 2	< 0.3	26	0.5	3	10	39	82	0.12	5.19	5.2	1590	2	< 2	4.4	17.5	10	91	4	1	2.62	3	< 1	< 5	1.34	22
SX-144	12	< 0.3	38	0.4	< 1	13	90	105	0.07	7.94	9.2	950	2	< 2	6.2	9.26	33	214	3	1.9	5.55	10	< 1	< 5	1.01	28
SX-145	< 2	< 0.3	35	< 0.3	< 1	9	98	103	0.08	7.45	8.9	860	2	< 2	4.4	10.6	37	194	< 1	2.9	5.4	9	< 1	< 5	1.05	28
SX-146	< 2	< 0.3	24	0.7	4	6	36	69	0.13	4.89	4.1	1310	2	< 2	5.5	18.4	8	87	1	1.3	2.4	2	< 1	< 5	1.27	19
SX-147	< 2	< 0.3	33	< 0.3	< 1	12	83	90	0.07	7.65	9.2	600	2	< 2	6.8	9.33	32	195	< 1	2.6	5.3	8	< 1	< 5	1.27	28
SX-148	< 2	< 0.3	48	0.5	< 1	15	93	119	0.08	6.91	7.4	1010	2	< 2	7.8	9.37	25	202	1	2.5	4.8	9	< 1	< 5	1.12	29
SFx-149	< 2	< 0.3	11	< 0.3	< 1	< 3	31	45	0.15	5.41	11.6	1230	< 1	< 2	5.6	16.5	8	75	2	0.7	2.83	1	< 1	< 5	0.89	17
SX-150	< 2	< 0.3	11	< 0.3	< 1	4	32	44	0.1	5.18	7.1	1250	< 1	< 2	5.6	15.9	7	76	< 1	0.7	2.72	2	< 1	< 5	0.8	14
SX-151	< 2	0.5	39	0.5	< 1	13	107	107	0.06	7.74	8.6	1240	2	< 2	3.5	8.25	45	187	< 1	2.8	5.31	9	< 1	< 5	1.27	28
SOV-249	< 2	< 0.3	13	< 0.3	< 1	4	31	51	0.14	5.08	4.5	590	1	< 2	3.7	17.9	11	97	6	0.7	3.27	2	< 1	< 5	0.95	28
SOV-250	< 2	< 0.3	41	0.4	2	11	95	118	0.08	8.27	10.8	590	2	< 2	8.5	10.9	33	269	< 1	2.1	6.38	9	< 1	< 5	1.22	31

Table 3. cont.

Element	Mg	Mn	Na	P	Rb	Sb	Sc	Se	Sr	Ta	Ti	Th	U	V	W	Y	La	Ce	Nd	Sm	Sn	Tb	Yb	Lu	Mass
Unit	%	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	g
Detection limit	0.01	1	0.01	0.001	15	0.1	0.1	3	1	0.5	0.01	0.2	0.5	2	1	1	0.5	3	5	0.1	0.01	0.5	0.2	0.05	
Analysis method	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
SD2-76	1.16	1410	0.28	0.109	< 15	0.8	15.9	< 3	240	< 0.5	0.23	10.2	3.1	61	< 1	30	44.1	110	50	8	< 0.01	2.1	3.8	0.11	1.44
SD2-77	0.98	1470	0.29	0.156	100	1	16.4	< 3	244	< 0.5	0.3	10.2	3.8	79	< 1	34	48.7	121	70	8.5	< 0.01	3.1	4.2	0.16	1.01
SD2-78	2.11	291	0.13	0.101	59	0.6	12.5	< 3	204	< 0.5	0.38	5	2.4	96	< 1	13	21.2	43	59	3.7	< 0.01	0.9	1.6	< 0.05	1.17
SD2-79	1.03	979	0.27	0.259	101	1	16.7	< 3	291	< 0.5	0.73	8.6	4	142	< 1	32	45.2	98	109	8.4	< 0.01	2.3	4	0.13	0.747
SD2-80	0.83	1370	0.3	0.1	52	1.1	15.8	< 3	285	< 0.5	0.13	9.8	3.7	44	< 1	31	42.4	116	56	8.1	< 0.01	< 0.5	3.8	0.14	1
SD2-81	0.81	965	0.25	0.165	54	0.8	14.5	< 3	276	< 0.5	0.23	8.2	3.3	82	< 1	34	41.4	98	42	7.7	< 0.01	2.1	3.5	0.11	1.38
SD2-82	3.77	890	0.47	0.033	55	0.4	35	< 3	188	< 0.5	0.29	4.5	1.1	247	< 1	11	14.9	26	15	2.6	< 0.01	< 0.5	1.8	< 0.05	1.53
SD2-83	0.76	1460	0.25	0.178	60	0.7	13.6	< 3	315	< 0.5	0.41	8.3	3.1	104	< 1	32	39.1	102	61	7.5	< 0.01	2.1	3.6	0.11	1.18
SD2-84	1.4	969	0.3	0.183	107	0.9	15.7	< 3	260	< 0.5	0.27	9.3	4.4	80	< 1	32	42.4	102	56	8.1	< 0.01	2.2	3.7	0.11	1.12
SD2-85	0.6	1020	0.36	0.047	< 15	0.7	14.7	< 3	219	< 0.5	0.17	9.7	1.9	33	< 1	31	42.1	101	59	8.3	< 0.01	1.9	3.7	0.13	1.2
SE-86	0.76	148	0.28	0.168	62	1.4	9.1	< 3	483	< 0.5	0.25	7.3	4.5	87	< 1	23	31.4	63	42	5.5	< 0.01	< 0.5	2.5	< 0.05	1.16
SE-87	1.01	1420	0.29	0.104	102	0.9	17.4	< 3	251	< 0.5	0.26	9.7	7.5	65	< 1	33	43.7	119	50	8.3	< 0.01	2.1	4.3	0.14	1.25
SE-88	1.09	776	0.36	0.106	55	1.2	15.2	< 3	210	< 0.5	0.79	5.7	0.9	131	< 1	22	29	64	43	5.9	< 0.01	1.3	2.6	< 0.05	1.33
SE-89	0.94	867	0.26	0.076	< 15	0.5	15.4	< 3	298	< 0.5	0.31	9.1	4.7	86	< 1	31	42.8	81	51	7.5	< 0.01	1.3	3.7	0.55	1.32
SE-90	2.07	260	0.18	0.137	< 15	0.7	12.2	< 3	414	< 0.5	0.19	4.9	5	79	< 1	21	23.7	35	17	3.7	< 0.01	0.6	2.3	0.12	1.22
SE-91	1.01	1030	0.35	0.187	64	0.6	18.3	< 3	249	< 0.5	0.2	10.5	4.7	74	< 1	34	49.8	107	48	8.2	< 0.01	1.6	4.2	0.71	1.42
SE-92	0.9	1500	0.28	0.218	101	0.7	16.5	< 3	269	< 0.5	0.31	10.4	5.8	87	< 1	35	50.6	98	63	8.2	< 0.01	1.6	4.1	0.65	1.33
SE-93	1.06	1000	0.28	0.22	70	0.8	17.6	< 3	295	< 0.5	0.35	11.7	5.9	93	< 1	36	49.8	99	60	8.1	< 0.01	< 0.5	4.2	0.8	1.31
SE-94	4.15	146	0.12	0.06	53	0.4	10.8	< 3	166	< 0.5	0.28	4	6.2	79	< 1	8	15	25	11	2.4	< 0.01	< 0.5	1	< 0.05	1.28
SE-95	1.28	812	0.48	0.42	70	0.8	17.5	< 3	416	< 0.5	0.48	9	13.1	138	< 1	49	51.7	86	58	8.3	< 0.01	1.9	4.7	0.9	1.44
SE-96	1.23	1100	0.31	0.193	130	0.4	16.4	< 3	321	< 0.5	0.48	9.9	6.4	107	< 1	35	48.3	96	49	8.2	< 0.01	2	4.4	0.62	1.46
SE-97	3.55	205	0.14	0.094	56	0.2	10.1	< 3	142	< 0.5	0.32	3.8	3.7	70	< 1	9	15.3	24	19	2.6	< 0.01	< 0.5	1.3	< 0.05	0.986
SE-98	0.98	906	0.31	0.13	59	0.6	15.6	< 3	244	< 0.5	0.19	9.3	3.6	59	< 1	31	43.4	86	42	7.3	< 0.01	1.6	3.6	0.37	1.26
SE-99	0.9	984	0.35	0.159	43	1	16.6	< 3	255	< 0.5	0.8	10.4	5.4	150	< 1	26	46.4	82	41	7.7	< 0.01	< 0.5	4	0.67	1.01
SE-100	1.47	597	0.7	0.095	100	0.6	12.2	< 3	452	< 0.5	0.31	8.3	4.3	90	< 1	17	29.5	58	19	5	< 0.01	< 0.5	2.5	0.08	1.1
SE-101	0.89	657	0.3	0.073	< 15	0.5	11.5	< 3	280	< 0.5	0.17	5.3	0.9	33	< 1	22	30	57	26	5.7	< 0.01	1.1	2.5	< 0.05	1.24
SF-102	2.65	87	0.08	0.041	< 15	0.4	8.7	< 3	179	< 0.5	0.15	3	3	46	< 1	6	9.9	24	6	1.8	< 0.01	< 0.5	0.8	< 0.05	1.21
SF-103	1.11	1230	0.26	0.088	43	0.6	16.4	< 3	246	< 0.5	0.12	9.1	2.1	37	< 1	37	46.2	98	38	8.6	< 0.01	< 0.5	4.2	0.27	1.35
SF-104	1.05	927	0.36	0.11	48	0.6	15.4	< 3	288	< 0.5	0.19	8.6	4.1	49	< 1	30	41.7	89	32	7.5	< 0.01	1.4	3.4	0.22	1.36
SF-105	2.91	91	0.09	0.037	< 15	0.3	9.7	< 3	178	< 0.5	0.18	3.3	2.4	48	< 1	6	11.4	23	15	2.1	< 0.01	< 0.5	0.7	< 0.05	1.07
SF-106	0.86	1080	0.27	0.146	< 15	0.7	16.4	< 3	317	< 0.5	0.31	8.6	4.4	81	< 1	33	42.9	97	38	7.9	< 0.01	0.9	3.7	0.3	1.59
SF-107	0.94	1030	0.25	0.086	< 15	0.4	15.2	< 3	247	< 0.5	0.24	8.2	6.8	48	< 1	29	38.7	92	23	7.2	< 0.01	1.3	3.4	0.2	1.32
SF-108	1.9	394	0.17	0.046	< 15	0.4	13.4	< 3	191	< 0.5	0.2	6.3	4.4	38	< 1	16	24.7	50	16	4.2	< 0.01	< 0.5	2.2	0.09	1.07
SF-109	1.77	937	0.77	0.086	< 15	0.8	13.9	< 3	255	< 0.5	0.13	7.7	3	46	< 1	27	38.7	82	31	7.3	< 0.01	< 0.5	3.2	0.25	1.19
SF-110	0.57	937	0.22	0.093	< 15	0.7	14.8	< 3	476	< 0.5	0.42	7.6	7	110	< 1	31	41.5	92	34	7.5	< 0.01	< 0.5	3.4	0.22	1.12
SFx-111	0.9	915	0.33	0.067	< 15	1.3	10.8	< 3	315	< 0.5	0.13	9.4	1.8	28	< 1	29	36	80	62	5.8	< 0.01	< 0.5	3.3	0.07	1.27
SFx-112	0.95	597	0.34	0.125	30	0.6	10.4	< 3	322	< 0.5	0.39	9.4	< 0.5	66	< 1	30	31.1	61	58	5.2	< 0.01	< 0.5	3	0.07	1.12
SFx-113	2.52	105	0.14	0.094	64	0.3	8.7	< 3	192	< 0.5	0.27	5.7	2.1	80	< 1	7	10.9	21	11	1.7	< 0.01	< 0.5	1	< 0.05	1.15
SFx-114	3.37	108	0.13	0.077	34	0.5	8.9	< 3	152	< 0.5	0.19	4.5	2.4	66	< 1	7	12.4	28	12	1.8	< 0.01	< 0.5	0.7	< 0.05	1.14
SFx115	0.72	148	0.16	0.108	63	0.6	9.8	< 3	328	< 0.5	0.32	10.3	1.6	72	< 1	20	31.8	60	38	4.7	< 0.01	0.9	2.1	< 0.05	1.18
SFx-116	1.45	852	0.56	0.091	< 15	0.6	11.6	< 3	249	< 0.5	0.15	9.4	2.2	41	< 1	25	34.6	78	63	6.1	< 0.01	1.2	2.8	0.08	1.21
SFx-117	2.36	105	0.12	0.046	< 15	0.5	8.6	< 3	174	< 0.5	0.19	4.2	3.6	54	< 1	6	10.4	18	17	1.7	< 0.01	< 0.5	0.8	< 0.05	1.08
SFx-118	0.9	1030	0.34	0.137	81	0.8	15.6	< 3	313	< 0.5	0.21	11.2	4.5	62	< 1	32	44.4	114	44	7.3	< 0.01	1.7	3.7	0.11	1.17
SX-119	0.89	129	0.28	0.129	85	0.6	9.3	< 3	488	< 0.5	0.28	10.4	3.3	69	< 1	21	30.8	61	41	4.7	< 0.01	< 0.5	1.9	< 0.05	0.981
SA-120	1.42	378	0.38	0.238	< 15	0.6	9.6	< 3	521	< 0.5	0.08	5.2	5	64	< 1	32	27.4	41	27	4.4	< 0.01	< 0.5	2.9	< 0.05	1.1
SD1-121	0.65	2090	0.3	0.024	54	1.5	18.6	< 3	109	< 0.5	0.15	17	4.3	35	< 1	44	60.3	160	91	10.6	< 0.01	< 0.5	5.2	0.24	1.1
SBc-122	1.39	1100	0.32	0.258	77	0.7	14.4	< 3	209	< 0.5	0.6	9.5	3.4	111	< 1	26	39.9	95	50	6.7	< 0.01	0.6	2.7	0.07	1.36
SA-123	1.48	854	0.7	0.144	46	0.7	14.2	< 3	289	< 0.5	0.23	12.4	1.2	70	< 1	28	38.3	89	40	6.6	< 0.01	< 0.5	2.9	0.12	1.28
SF-124	0.75	475	0.23	0.107	< 15	0.9	8.4	< 3	335	< 0.5	0.34	6.2	3.3	60	< 1	22	24	47	36	3.7	< 0.01	< 0.5	2.1	< 0.05	1.11
SD1-125	0.67	350	0.18	0.059	< 15	0.5	9	< 3	328	< 0.5	0.21	6.2	2.1	48	< 1	12	17.8	37	22	2.9	< 0.01	< 0.5	1.2	< 0.05	1.11
SA-126	0.98	187	0.32	0.193	69	1.3	13.4	< 3	577	< 0.5	0.41	13.7	4.4	97	< 1	27	44	94	63	6.8	< 0.01	1.1	2.7	0.06	1.05
SA-127	0.62	281	0.32	0.052	33	0.5	9.1	< 3	518	< 0.5	0.28	6	0.9	65	< 1	12	18.6	39	16	3.2	< 0.01	< 0.5	1.3	< 0.05	1.26
SA-128	0.52	581	0.24	0.145	64	0.5	12	< 3	497	< 0.5	0.44	8.4	1.6	97	< 1	26	32.5	66	61	5.3	< 0.01	< 0.5	2.6	0.05	1.27
SX-129	1.03	139	0.19	0.131	99	0.4	11.8	< 3	547	< 0.5	0.27	11	2.6	79	< 1	23	37.4	75	56	5.9	< 0.01	0.5	2.2	< 0.05	1.14
SA-130	0.41	237	0.19	0.184	< 15	1	7.8	< 3	490	< 0.5	0.11	4.8	4.9	74	< 1	19	22	35	33	3.3	< 0.01	0.5	1.6	< 0.05	1.08
SDc-131	1.57	965	0.27	0.085	18	1	13.7	< 3	199	< 0.5	0.12	9	< 0.5	28	< 1	25	34.3	82	64	6	< 0.01	0.6	2.7	0.05	1.14
SBc-132	0.73	417	0.33	0.064	39	0.3	8.9	< 3	544	< 0.5	0.23	6.3	1.5	55	< 1	13	17.8	40	30	3.1	< 0.01	< 0.5	1.3	< 0.05	1.33
SD1-133	0.64	281	0.2	0.056	< 15	0.3	8.4	< 3	329	< 0.5	0.18	5	1.2	41	< 1	11	16.7	33	18	2.7	< 0.01	< 0.5	1.2	< 0.05	1.28
SE-134	0.77	566	0.26	0.094	49	0.6	11.7	< 3	231	< 0.5	0.21	7.4	2.3	37	< 1	24	28.9	65	56	4.8	< 0.01	0.9	2.2	< 0.05	1.28
SX-135	1.44	146	0.24	0.153	140	0.9	11.1	< 3	506	< 0.5	0.33	11.8	3.6	86	< 1	22	33.8	68	31	5.3	< 0.01	< 0.5	2.2	< 0.05	1.13
SOV-136	1	643	0.55	0.159	67	0.6	9.8	< 3	330	< 0.5	0.39	6.9	2.4	86	< 1	31	30.2	53	33	5	< 0.01	0.8	2.5	0.11	1.49
SOV-137	0.55	1100	0.32	0.033	124	0.7	14.6	< 3	172	< 0.5	0.26	11.9	1.6	37	< 1	32	40.9	105	68	7.4	< 0.01	0.9	3.4	0.13	1.54
SOV-137'	0.35	123	0.28	0.878	23	1.5	6.9	< 3	662	< 0.5	0.03	2.9	11.7	75	< 1	46	27.2	26	30	3.6	< 0.01	0.5	3.2	0.06	1.13
SOV-139	0.21	68	0.02	0.18	< 15	0.2	2.3	< 3	187	< 0.5	0.04	1.1	2.2	31	< 1	6	6.1	9	< 5	0.9	< 0.01	< 0.5	0.4	< 0.05	1.21
SX-141	1.06	1300	0.37	0.177	72	1.1	17.2	< 3	293	< 0.5	0.27	12.7	5.7	76	< 1	33	43.3	122	65	7.7	< 0.01	0.8	3.6	0.16	1.23
SX-142	1.04	912	0.23	0.1	< 15	0.7	15.7	< 3	264	2.1	0.12	11.2	1.6	43	< 1	30	40.3	93	46	7.2	< 0.01	1	3.3	0.11	1.37
SX-143	0.71	155	0.17	0.111	86	0.7	9.1	< 3	441	< 0.5	0.28	9.6	3.2	61	< 1	21	29.7	58	46	4.6	< 0.01	< 0.5	1.9	< 0.05	0.861
SX-144	0.96	1080	0.29	0.209	57	0.9	17.2	< 3	298	< 0.5	0.26	12.1	5.1	92	< 1	38	44.9	105	68	8	< 0.01	< 0.5	3.7	0.13	1.19
SX-145	0.93	1650	0.32	0.196	54	1.1	15.6	< 3	272	< 0.5	0.27	9.2	3.6	84	< 1	35	48.5	123	66	8.5	< 0.01	2.2	4.1	0.13	1.28
SX-146	0.66	134	0.17	0.106	64	0.3	8.1	< 3	389	< 0.5	0.28	5.9	2.8	57	< 1	18	29.6	51	36	4.6	< 0.01	1	1.7	< 0.05	1.06
SX-147	0.84	1300	0.36	0.097	129	0.8	15.6	< 3	228	< 0.5	0.29	9.8	2.9	61	< 1	30	46.9	113	79	8.1	< 0.01	2.2	3.9	0.12	1.35
SX-148	1.26	884	0.33	0.219	68	0.7	14	7	344	< 0.5	0.48	8.7	6.1	102	< 1	34	42.1	94	51	7.1	< 0.01	2.5	3.8	0.12	1.44
SFx-149	3.05	93	0.13	0.046	36	0.5	10.1	< 3	198	< 0.5	0.28	3.4	2.6	79	< 1	7	12.8	26	28	2.2	< 0.01	< 0.5	1	< 0.05	1.11
SX-150	2.95	88	0.1	0.039	22	0.3	9.8	< 3	175	< 0.5	0.25	2.9	2.6	72	< 1	6	12.8	26	10	2.1	< 0.01	< 0.5	0.8	< 0.05	1.22
SX-151	0.88	2110	0.3	0.109	63	1	15.6	< 3	271	< 0.5	0.19	9.7	3.1	53	< 1	35	48.6	124	44	8.5	< 0.01	2.5	4.1	0.14	1.33
SOV-249	1.35	241	0.25	0.075	< 15	0.5	10	< 3	339	< 0.5	0.28	5.1	2.8	55	< 1	10	15.1	36	22	2.8	< 0.01	< 0.5	1.5	< 0.05	1.11
SOV-250	0.88	1230	0.26	0.176	45	0.8	17.7	< 3	356	< 0.5	0.25	10.4	7.4	85	2	34	44.2	110	56	8.1	< 0.01	1.4	4.4	0.57	1.18

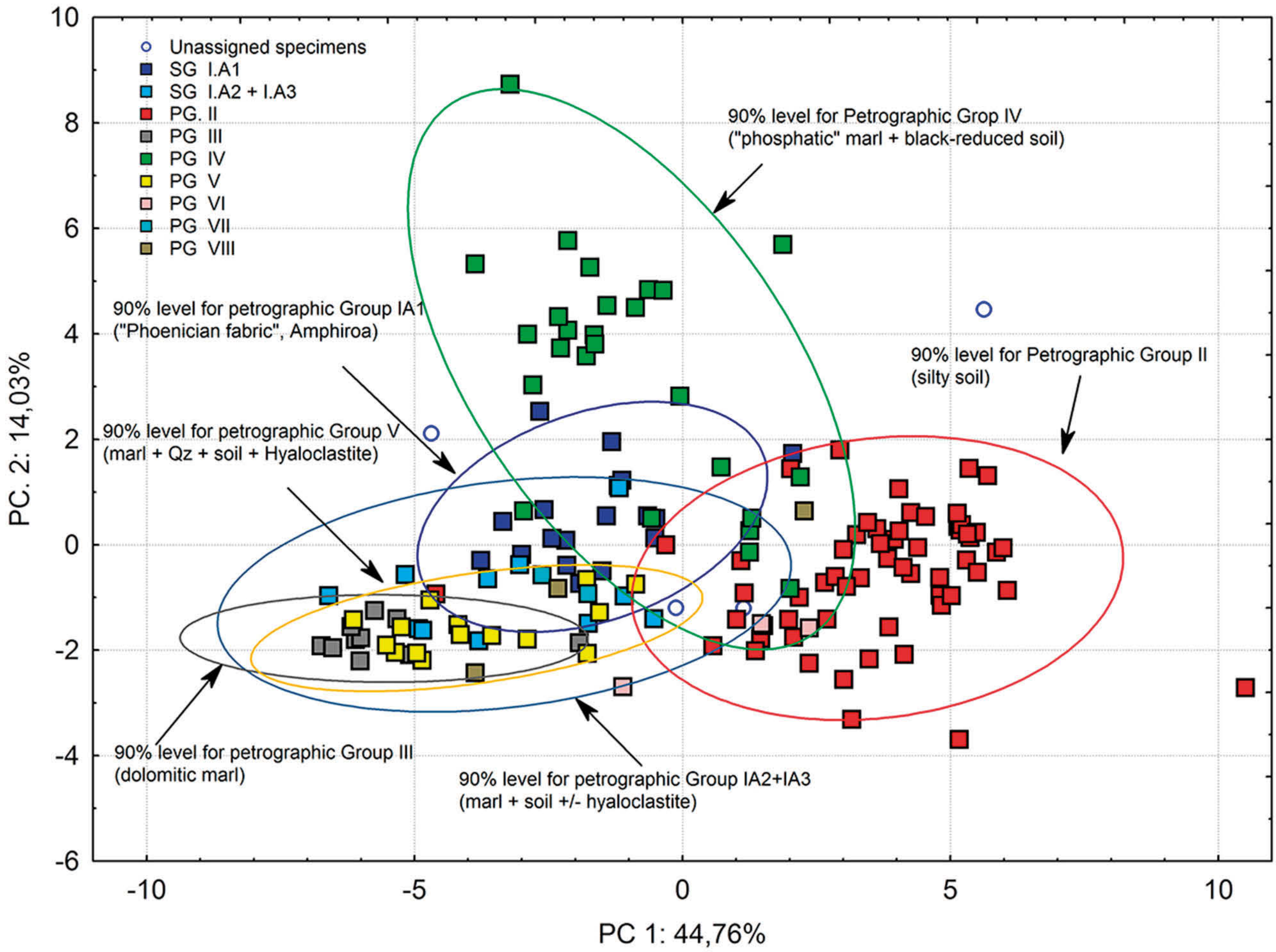


Fig. 121. Principal components analysis: a set of Sha'ar-Ha'Amakim ceramics in the PC1-PC2 coordinate system. Note especially the separateness of the majority of Petrographic Groups II and IV

Spanning tree

The principal components analysis (PCA) does not provide an objective criterion of distinguishing groups of vessels significantly dissimilar in statistical terms. Besides, the reduction of the multi-dimensional space distorts the actual angles and distances between the variables, and thus distorts the degree of their similarity.[287] Hence, PCA was supplemented with a method of dendritic ordering, free of the distortions resulting from the reduction of spatial dimensions. The method is known as the Wrocław taxonomy.[288] With the help of a table of between-point Euclidean distances, successively closest pairs of points were connected, thus producing a dendrite (a spanning tree[289]). The distances between the points are a measure of their similarity: the shorter the distance, the greater the similarity. The values of the distances (D) between the jar specimens are presented in Table 6[290]. The diagram obtained on the basis of those data is presented in Fig. 122.

The structure of the dendrite reflects the relations of chemical similarity, the location of samples side by side means the highest degree of similarity between them, the distance between them is a measure of this similarity, individual petrographic groups are marked with different colours.

The mean (M) of all the shortest distances between points on the dendrite equaled 2.71, and standard deviation (δ) = 1.69. If we set the criterion of the division into subgroups at M + 2σ = 6.09, which corresponds to a 95.5% probability that the specimens separated in this way are actually different, then the specimens significantly different statistically are SOV-139[291] (clay of the local oven wall), 82 (SD2-82, imported *pithos*), 47 (SDc-47, body sherd of Roman jar), and 74 (SD2-74, rim of ER jar).

[287] Cf. Michniewicz 2009: 56.
[288] Florek et al. 1951; Perkal 1958: 79–82.
[289] Cf. *Encyclopedia of Statistical Sciences* 1982: 302–305, Krzyśko et al. 2008: 384.
[290] e.g. the Euclidean distance D between specimens 3 and 37 equals 2.53.
[291] SOV = Sha'ar-Ha'Amakim oven.

Table 6. Values of the shortest Euclidean distances between the successively closest points representing samples of Sha'ar-Ha'Amakim jars in the 32-dimensional space of the elements analysed

Pairs	Distance	Pairs	Distance	Pairs	Distance	Pairs	Distance	Pairs	Distance	Pairs	Distance
1–3	3.05	146–41	2.26	118–52	2.03	35–27	3.12	134–101	2.86	148–79	4.71*
3–37	2.53	41–143	1.67	52–55	2.44	4–32	1.88	101–108	3.77	148–122	3.98
37–26	2.88	143–62	1.98	118–76	2.21	32–29	2.02	134–111	3.72	93–153	2.37
26–23	4.12	62–119	1.79	76–80	2.02	29–38	1.99	111–50	2.78	153–87	2.48
23–40	3.53	119–31	3.24	76–147	1.97	38–12	2.68	50–46	1.58	144–141	2.04
23–139	7.49**	31–30	3.37	147–73	1.92	15–140	5.66*	46–45	1.99	98–89	2.37
26–34	3.48	119–129	2.89	73–75	4.75*	12–113	3	45–56	2.01	89–70	2.72
34–25	3.77	129–2	2.79	147–77	1.98	113–150	1.84	56–49	3.96	70–110	3.06
25–13	4.07	2–6	2.38	77–43	2.29	150–97	2.29	46–54	1.22	98–104	1.59
25–33	2.91	6–8	2.58	43–44	1.98	97–94	2.52	54–53	1.44	98–107	2.51
33–24	2.57	6–20	4.33	77–145	1.36	150–102	1.76	54–57	1.53	98–109	2.49
24–28	4.07	129–5	3.46	76–151	2.62	102–105	1.34	57–116	2.27	142–103	2.51
26–61	2.49	129–7	4.77*	151–121	6.31	105–114	1.91	116–48	3.44	142–123	3.11
61–130	4	7–74	6.98**	84–144	2.15	105–149	2.2	50–131	2.39	123–16	4.40*
130–124	3.82	129–135	2.78	144–93	1.72	102–117	1.42	50–142	2.45	16–65	3.52
124–51	3.14	135–100	3.58	93–92	1.87	38–60	2.01	142–98	1.81	65–10	2.8
124–66	3.24	135–126	3.89	92–91	2.24	38–152	2.08	98–22	3.29	65–64	2.95
66–125	1.19	143–71	3.25	93–96	2.27	152–90	3.5	22–85	3.01	123–47	10.25**
125–58	2.62	143–115	1.95	96–42	4.12	90–68	3.12	85–137	2.9	134–112	3.26
58–4	2.12	115–67	1.94	42–99	3.29	68–63	1.56	98–81	2.1	112–128	3.15
4–18	1.75	67–39	1.85	99–69	3.01	68–78	3.09	81–84	2.18	112–136	4.57*
18–14	2.9	39–86	2.66	99–88	4.59*	4–132	2.74	84–36	2.24	26–120	2.65
14–17	1.94	66–133	2.04	88–82	10.99**	132–127	3.18	36–83	3.29	120–59	3.37
18–19	2.72	124–134	3.62	96–95	5.27*	132–146	3.13	84–106	2.02	1–9	2.64
18–35	1.85	134–72	4.55*	96–148	2.38	146–11	2.6	106–118	1.87	9–21	3.62

MEAN (M) = 2.71; Standard deviation (σ) = 1.69; *M+ σ = 4.40; **M+ 2σ = 6.09

With a probability of 68% (M + σ = 4.40) also different are specimens: SA-2, (Early Roman jar, SG I.A3), SD2-75 (Early Roman jar, SG II.C), SD2-79 (Early Roman sherd, SG II.B), SE-88 (shoulder of Roman jar, P.G. II (?) with volcanic temper), SE-95 (Early Roman jar, significantly different) and set: [SB-16 (Hellenistic jar, SG IV.C)+SD1-65 (Hellenistic jar, PG IVc) + SA-10 (Persian-period jar, PG IVc) + SD1-64 (Hellenistic bag shaped jar, PG II.B)].

We can see that the greatest geochemical similarity basically fits the division into eight petrographic groups distinguished, partially verifying it.

Subgroup PG IV is statistically different: (SA-10, SB-16, SD1-65), and in the other petrographic groups the following samples are statistically different:

SG I.A3: SD2-72;

PG II: SDc-47, SD2-75, SD2-79, SE-88 (containing volcanic grains),

PG III: SF-108

PG IV: (SA-10, SB-16, SD1-65), SA-7, SD2-74, SBc-20, SOV-139

PG V: SBc-30, SBc-31;

PG VI: – projection points of this group are dispersed among PG II.

PG VIII: (SD2-78, SBc-19) – the two samples are chemically different.

The averaged chemical composition of the individual petrographic groups after the exclusion of outliers is presented in Table 7.

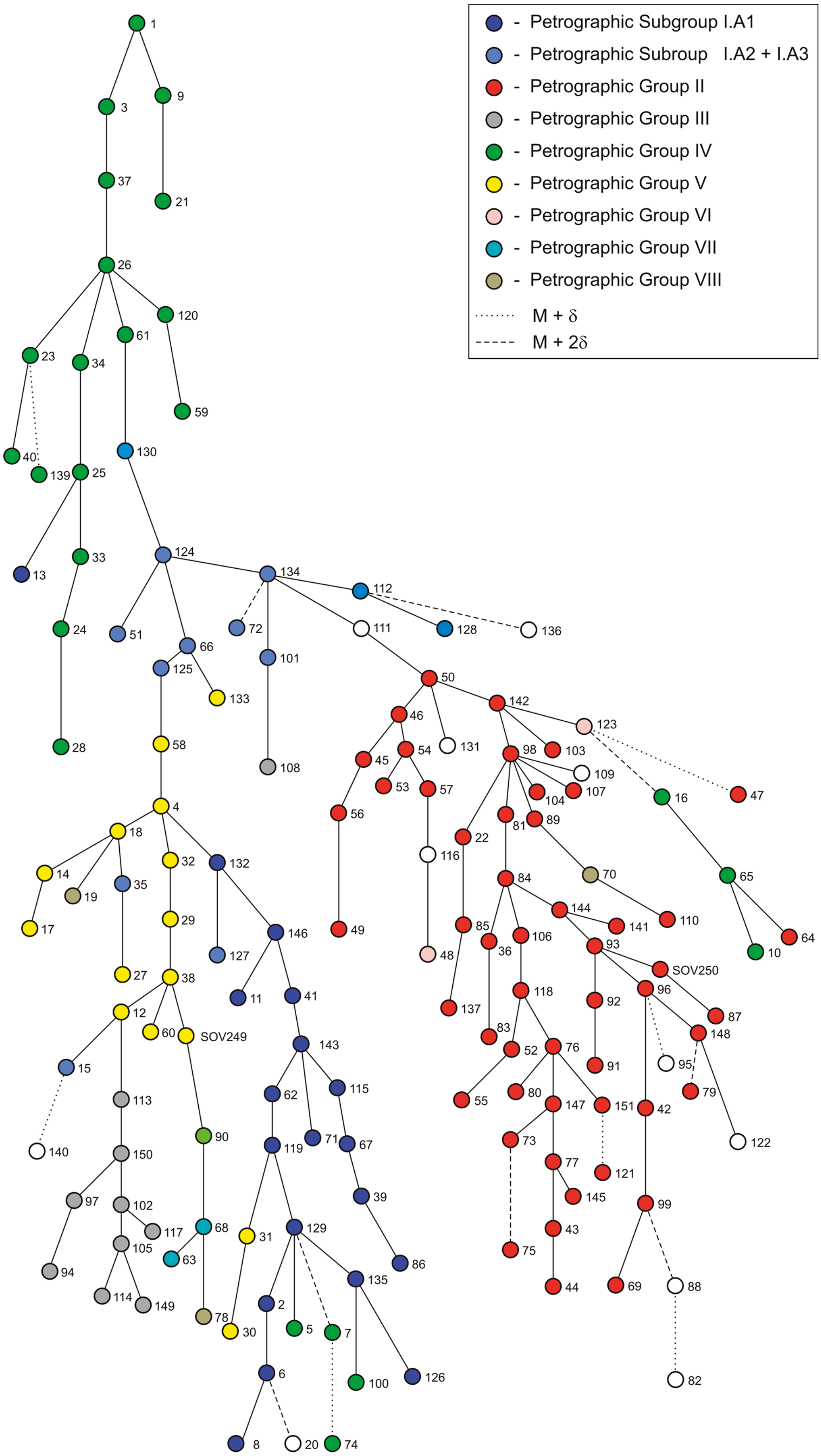


Fig. 122. Spanning tree presenting the greatest similarity (closeness) between the jars from Sha'ar-Ha'Amakim

Table 7. Mean and standard deviation values of groups and subgroups of Sha'ar-Ha'Amakim ceramics (without outliers)

Element	I.A1 n=18		I.A2 n=3		I.A3 n=7		II n=56		III n=9		IV n=19		V n=13		VI n=3		VII n=2		VII n=3	
	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ	mean	σ
Cu (ppm)	27.3	4.7	20.0	6.1	27.7	9.3	37.0	6.8	15.3	5.6	37.5	7.3	16.0	4.4	38.0	21.7	28.0	2.8	21.7	11.6
Pb (ppm)	9.3	3.5	5.3	1.5	6.9	2.0	11.7	2.3	3.6	0.7	6.1	2.2	4.3	1.3	11.7	1.5	3.0	0.0	6.3	2.5
Ni (ppm)	45.9	8.5	39.3	18.1	54.0	20.2	82.6	12.4	32.4	2.3	84.3	18.5	36.8	10.9	58.7	9.5	61.5	4.9	52.0	23.3
Zn (ppm)	92.1	12.0	50.3	4.0	65.1	12.2	96.7	15.4	47.2	5.0	102.6	13.2	47.4	8.1	71.0	14.5	71.5	6.4	71.7	20.2
As (ppm)	5.3	1.9	6.4	1.1	4.8	2.1	7.9	2.0	7.6	1.8	10.4	5.5	5.5	1.1	7.2	1.1	6.7	0.4	7.1	2.0
Ba (ppm)	1157.2	564.0	1250.0	589.5	1932.9	682.9	1010.2	484.8	1458.9	240.1	1313.2	716.8	612.3	353.1	743.3	142.9	1455.0	35.4	880.0	731.4
Co (ppm)	9.3	2.4	10.7	2.1	14.6	4.2	29.7	6.1	8.3	1.0	12.2	2.2	11.8	3.2	22.3	4.0	14.0	0.0	16.0	6.2
Cr (ppm)	104.3	16.2	74.0	25.9	100.3	29.6	182.9	38.3	74.4	3.6	178.5	29.9	81.9	17.4	130.7	15.5	129.5	0.7	133.0	52.1
Eu (ppm)	1.4	0.4	0.8	0.2	1.0	0.4	1.9	0.5	0.5	0.2	1.4	0.7	1.1	0.6	1.5	0.3	1.1	0.1	1.6	0.5
Hf (ppm)	3.0	0.8	4.3	2.1	5.3	1.8	9.8	2.8	2.6	1.0	2.9	1.1	3.2	0.9	7.7	0.6	4.0	1.4	4.3	1.5
Li (ppm)	25.3	7.5	11.3	1.5	13.0	1.6	24.8	4.9	17.4	3.3	21.3	7.9	21.9	3.6	22.7	5.9	27.5	0.7	26.0	11.4
Mn (ppm)	149.1	32.1	307.7	192.4	468.6	147.1	1117.6	315.3	114.2	38.5	285.2	112.4	267.2	50.3	797.0	175.6	348.5	34.6	464.3	296.8
Sb (ppm)	0.7	0.4	0.5	0.4	0.6	0.2	0.8	0.2	0.4	0.1	0.8	0.3	0.3	0.1	0.7	0.2	0.6	0.1	0.6	0.3
Sc (ppm)	9.7	1.5	8.2	1.0	10.0	1.4	15.2	1.8	9.5	0.8	10.7	1.4	9.7	1.7	12.7	2.3	11.5	0.4	12.2	2.2
Sr (ppm)	446.6	69.4	399.0	131.4	295.3	42.0	264.8	77.0	172.9	17.7	478.8	50.6	302.6	38.8	245.0	49.8	253.5	36.1	229.0	57.7
Th (ppm)	9.4	2.4	5.3	1.2	6.3	1.6	10.2	1.8	3.9	0.9	5.8	2.3	5.2	1.3	9.4	2.6	7.1	1.8	6.3	1.7
U (ppm)	3.7	1.8	1.5	0.8	1.9	0.9	3.8	1.9	3.2	1.3	6.6	1.8	2.4	0.8	2.2	0.9	2.6	0.3	4.2	2.2
V (ppm)	73.2	10.0	52.0	11.3	49.0	12.4	66.9	32.1	66.0	13.5	85.4	11.9	53.3	11.6	48.7	20.1	103.0	1.4	72.7	42.2
Y (ppm)	20.7	2.3	13.3	6.1	19.3	7.0	30.9	4.4	6.9	1.1	30.1	6.8	11.3	2.3	26.3	2.1	15.5	0.7	18.0	11.4
La (ppm)	31.7	5.2	18.3	5.4	24.1	6.0	42.2	6.0	12.3	1.9	29.6	3.7	18.3	4.3	35.3	5.5	23.1	0.8	26.2	12.4
Ce (ppm)	63.7	11.5	37.3	10.6	49.7	11.8	100.3	17.7	23.9	3.0	45.1	11.3	40.7	10.1	79.3	11.2	48.5	6.4	57.0	23.4
Nd (ppm)	42.3	12.5	22.3	5.7	33.7	17.0	52.5	13.0	14.3	6.4	32.8	14.3	24.9	9.2	34.3	4.9	40.5	6.4	41.7	16.2
Sm (ppm)	4.9	0.8	3.1	1.0	4.1	1.2	7.4	1.1	2.0	0.3	4.4	0.5	3.0	0.7	6.3	1.2	4.1	0.1	4.5	2.1
Yb (ppm)	2.2	0.3	1.4	0.5	2.0	0.7	3.7	0.6	0.9	0.2	2.8	0.5	1.5	0.2	2.8	0.5	1.7	0.1	2.2	0.8
S (wt %)	0.1	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0
Al (wt %)	5.7	1.0	4.1	0.7	4.9	0.5	7.0	0.9	5.1	0.2	4.9	1.3	5.1	0.7	6.1	1.1	6.4	0.3	6.4	0.9
Ca (wt %)	16.2	1.5	18.0	3.7	13.9	2.1	9.6	2.7	15.9	1.1	19.0	2.5	14.6	1.9	6.0	2.5	13.9	0.9	13.5	2.4
Fe (wt %)	2.8	0.3	2.4	0.2	3.1	0.6	5.1	0.7	2.8	0.2	2.9	0.6	3.0	0.6	4.1	0.7	4.1	0.3	3.9	0.8
K (wt %)	1.5	0.2	0.9	0.2	0.7	0.1	1.1	0.2	0.8	0.1	1.0	0.5	1.0	0.2	1.1	0.3	0.6	0.0	1.1	0.3
Mg (wt %)	0.8	0.2	0.5	0.1	0.8	0.1	1.0	0.3	3.1	0.6	1.2	0.5	1.1	0.3	1.3	0.6	2.1	0.0	1.8	0.7
P (wt %)	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.3	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.1	0.1
Ti (wt %)	0.3	0.1	0.3	0.1	0.2	0.1	0.3	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.4	0.0	0.3	0.2

6. Tell Keisan

6.1. Subject of study

As mentioned above, the site of Tell Keisan, after having been shortly excavated by the British (G. Garstang, 1935–1936),[292] was explored by the team of the Ecole Biblique et Archéologique in Jerusalem during 1971–1976, which resulted in a most widely cited publication.[293] However, the results of two seasons of renewed excavations by the same institution (1979–1980) have remained unpublished, except for minor articles.[294] A selection of fragmentary vessels from those additional seasons were examined by one of the present authors (Jolanta Młynarczyk). Those ceramics were found in secondary fills (*fosses*), and were attributed to the Late Persian and Early Hellenistic periods. The study in question was the first approach ever to distinguish a range of local/regional fabrics on the base of visual examination, disregarding the cooking vessels on one hand, and imported vessels on the other. At that early stage of the research, three main wares were distinguished within the local/regional group in question: the "Light White ware" (LWW), "Hard Orange ware", "Phoenician Semi-fine ware" (with a number of macroscopically distinct variations) and regional Colour-Coated ware.

In the Light White ware the fabric is light, porous, pinkish white or yellowish white at the break (Munsell 10 YR 8/2, 10 YR 8/3, 2.5 Y 8/2) with the surface just a hue paler (2.5 YR 8/2 or 10 YR 8/2) which in the table vessels is wet-smoothed. If there are any inclusions visible by the naked eye (in the case of bigger vessel forms), they are occasional white lumps (lime?) and some flat grits: black, brown or red in colour (grog?).[295] This fabric may perhaps be regarded as a version of the Phoenician White ware recognized at Tel Anafa, present also at Mizpe Yammim which, however, is said to have been very dense, and no dark-coloured grits (black, dark red) have been reported in it.[296] In Tell Keisan it is very common (represented by our shape groups 1a, 2a, 3a), unlike in Sha'ar-Ha'Amakim where the examples of this ware are limited to storage jars only (shape group 1a and just one item of jar group 2b).

The Hard Orange ware has its fabric rather fine but granular in texture, usually dark orange in the break (near 5 YR 6/4, 7/4, 7/6 and 5 YR 7/6), with some grey and dark red/brown grits and occasionally white ones. The surface, of a gritty feel, is fired pink to yellowish pink (7.5 YR 7/4, 5 YR 8/4). Occasionally, the fabric is pale-coloured, almost white, but it is more dense than the standard Light White Ware is. The Hard Orange ware has been represented at Tell Keisan by a widest range of vessel shapes, from storage vessels (jars shape group 2a) through serving to table and personal vessels, however, it is not as common there as it is in Sha'ar-Ha'Amakim.[297]

The third distinct ware of plain or semi-decorated vessels is the Phoenician Semi-fine ware, among which three variants have been distinguished in Tell Keisan.[298] The jars of our shape group 1a occur only in a standard version of the ware as first described by A. Berlin,[299] alongside a few other closed forms. Their fabric can be pink or light red (5 YR 7/4 and 7/6), pinkish orange (5 YR 6/6), pinkish brown (5 YR 6/4) or brownish orange (7.5 YR 6/6). The texture is dense, but often slightly granular in appearance, with red inclusions (up to large) as well as occasional grey and/or white grits. The surface firing is mostly pink (5 YR 7/4 or 7.5 YR 7/4), but sometimes turning yellow to yellowish white; a distinctive feature is its smooth, "powdery" feel.[300] This ware has also been

[292] Cf. Humbert 1981:373; Humbert 1993:863.
[293] Briend & Humbert 1980.
[294] Humbert 1981; Humbert 1993.
[295] Młynarczyk 2001: 240–241, fig. 2 and fig. 3:9–18.
[296] Berlin 1997a: 10–11; also Berlin & Frankel 2012: 41 ("Phoenician White ware, a grittier, paler version of semi-fine ware also manufactured in the vicinity of Tyre").
[297] Młynarczyk 2001: 245, fig. 3:19–21 and fig. 4:22–23.
[298] Młynarczyk 2001:247–251.
[299] Berlin 1997a: 9–10; see also Berlin & Frankel 2012: 41.
[300] Młynarczyk 2001: 247, fig. 4:24–39.

attested in Sha'ar-Ha'Amakim, in vessels of shape groups1a and 1b. The Semi-fine variant "a" is characterized by the presence of chalk lumps in the fabric, while Semi-fine variant "b", clearly pertaining to the Persian period, is represented by small vessels, self-slipped with some linear decoration in red.

6.2. The sampled vessels

The difference between the sampled material from Sha'ar-Ha'Amakim and that from Tell Keisan is threefold. First, the geographical situation of the two sites, despite a relatively small distance between them (ca. 16 km), is rather different. Sha'ar-Ha'Amakim enjoyed a truly interregional location. It stood on an inland branch of Via Maris, providing an easy access to the hill country of the Lower Galilee (Sepphoris and Shikhin etc.), but also commanding the pass between the Akko plain and the Yezreel Valley. The nearest sea haven was that of Shiqmona 17 km to the west; on the other hand, the road through Yokne'am pass (just 8 km to the south of Sha'ar-Ha'Amakim) towards Dor provided another possible connection with the sea. One can imagine that the site's inhabitants lived out not only from the agriculture (viticulture? olive oil production?), but also from the trade. As to Tell Keisan, during the Persian and Hellenistic periods (and apparently later), it was a settlement relaying on its agricultural production, playing the role of the garden and granary of Akko (distant by ca. 9 km).[301] However, it should be remembered that Tell Keisan was in all probability also situated on the road connecting Akko to Sepphoris, which made it a potential exchange place of trade goods, ceramic vessels included, especially during the *floruit* of Sepphoris in the Roman period.

Secondly: a large part of the material from Sha'ar-Ha'Amakim comes from dated layers, while the samples from Tell Keisan are most often un-stratified, having been found in mixed contexts, in fills of some pits or even on the surface.

Thirdly, the samples from either site differ in their time range. While the chronology of the jars from Sha'ar-Ha'Amakim covers the period from the late Iron Age (7th/6th century BC) to the latter part of the Roman period (3rd/4th century AD), the dating of the samples from Tell Keisan (**Figs. 12–13**) extends from the late Iron Age to the Byzantine period, with at least six examples of jars probably of the 6th century AD (our shape group 2c, absent at Sha'ar-Ha'Amakim).[302] The most numerous (22–24 examples)[303] are fragments of group 1a. Not represented at all, perhaps by chance, is shape group 1b, while 1c is present in a single example. Shape group 2a (Persian and Hellenistic baggy jars) is represented by four to the maximum of seven samples, group 2b (Roman-period baggy jars) by 11 samples, and 2c (Byzantine-period baggy jars) by six samples. Four samples may have come either from shape group 2b (Roman) or 2c (Byzantine), and as many as nine samples pertain either to shape group 2a or 3a.

The list of the samples that follows is arranged after the running number of the sample (marked TK – for Tell Keisan) with information about the context such as could be extracted from the excavation diary.

6.3. List of sampled pottery from Tell Keisan with their context information, arranged by sample number (followed by excavation data)

TK-152 (context 8.36.55: Persian and Hellenistic): body sherd of jar, group 2a? Fabric light brown (10 YR 6/3) with many white grits (large eruptions on inner surface), exterior 'white" (10 YR 8/2), interior with a pinkish hue). Persian or Hellenistic. **PG: IX.**

TK-153 (context 8.36.31: Persian to Early Hellenistic, with intrusive(?) Roman-Byzantine potsherds): handle with wall fragment of jar, group 2a(?). Fabric rather clean, with minute voids(?), 7.5 YR 8/4 (pink), surface white. Persian/Hellenistic. **SG: IV.H.**

TK-154 (context 8.36.05: Persian and Hellenistic; in fieldnotes: *chalco à byzantine*): body sherd of jar, rather bag-shaped (group 2a) than carinated-shoulder form, misfired. Fabric light grey (5 Y 7/2), surface 2.5 Y 8/2 ("white"). Persian or Hellenistic. **SG: IV.H.**

TK-155 (context 8.36.02: Late IA? and Persian to Hellenistic periods, with intrusive(?) Roman-Byzantine potsherds): handle of jar, group 2b or 2c. Fabric red (2.5 YR 5/8) with purple core, small white (and black?) grits; surface coarse reddish brown (5 YR 6/3 light reddish brown). Roman or Late Roman. **SG: VI.D.**

TK-156 (context 8.38.28: mixed material, from Persian through Byzantine periods): body sherd of jar, group 2b. Fabric red (2.5 YR 6/6), with lots of tiny white grits and large eruptions to inner surface. Exterior mildly ribbed, of coarse feel, fired beige-pink. Roman. **SG: VI.A.**

[301] Humbert 1981:378.
[302] Landgraf 1980.
[303] Not always it has been possible to properly identify the vessel shape, especially while dealing with small fragments of rims or with body sherds.

TK-157 (context 8.34.07: prevailing material is of IA II, but with later intrusions down to Byzantine): ribbed body sherd of jar, group 1c. Fabric very dense pink, banded beige inside, with some tiny dark grits? Surface slightly gritty in feel, yellowish pink (between 5 YR 7/4 and 7/6). Early(?) Roman. **PG: III.**

TK-158 (context 8.36.66: material mixed, dated from IA to Hellenistic period): body sherd of large jug, group 3a, visually close to Phoenician Semi-Fine class(?); fabric deep pink, porous, with some white grits (up to large), surface pale pink. Persian or Early Hellenistic. **SG: IV.D.**

TK-159 (context 8.36.31: Persian to Early Hellenistic, with intrusive(?) Roman-Byzantine potsherds): handle fragment of jar, group 2b (or 2c?); fabric very gritty red 2.5 YR 6/8 (light red) with voids and occasional white grits? Surface rough, light red (5 YR 7/6 reddish yellow). Roman (or Byzantine?). **SG: I.A1 ?**

TK-160 (context 8.36.03: IA, Persian, Hellenistic): rim of jar, group 1a, similar by form to TK-183, but in different fabric: red (5 YR 6/6 reddish yellow) with tiny white and red grits (and voids?); surface very smooth, paler than the break (ca 5 YR 7/6 reddish yellow). Cf. Briend & Humbert 1980, pl. 26:8–9 (*niveau* 4), and/or Briend & Humbert 1980, pl. 18:6–7 (*niveau* 3). Late IA II or Persian period. **SG: I.A1.**

TK-161 (context 8.74.01: prevailing material is IA II, but with some Persian and Hellenistic-period potsherds): body sherd of thick-walled jar, misfired, group1a or 2a. Fabric very pale brown, greenish (2.5 Y 7/2 light grey) with many voids; surface “white” (near 10 YR 8/2). Persian or Hellenistic. **SG: IV.H.**

TK-162 (context 8.74.01: prevailing material is of IA II period, but with some Persian and Hellenistic-period potsherds): body sherd of a thick-walled carinated-shoulder jar, group 1a. Fabric (overfired? Misfired?) very hard, dense (few minute voids), dark grey banded light red, some minute white grits and occasional large eruptions; surface grey inside, yellowish pink outside. Late IA II? **SG: I.A1?**

TK-163 (context 8.38.27: mixed material, from Persian through Byzantine period): body sherd of jar, group 2c. Fabric very hard and dense (near 5 YR 6/6 reddish yellow) with a thin grey core; tiny white grits and few black ones. Surface light brown inside, ‘black’ (near 5 YR 4/2 dark reddish grey) outside, with white linear decoration; Byzantine. **PG: XI.**

TK-164 (context 8.74.02: prevailing material is of IA II period, but with some Persian and Hellenistic potsherds): fragment of strap handle (oval-sectioned with median cavity) of jar/storage jug, group 2a or 3a, Hellenistic. **SG: IV.D.**

TK-165 (context 8.38.37: mixed): body sherd of jar, group 1a? Very hard red fabric, near Phoenician Semi-Fine class. Persian or Hellenistic. **SG: I.A1**.

TK-166 (context 8.38.37: mixed): body sherd (shoulder fragment) of jar, group 2c. Fabric very gritty, dark reddish brown (2.5 YR 5/6 red) with purple core(?), with many tiny white grits and tiny voids; surface coarse in feel, brown (5 YR 5/2 reddish grey). Late Roman – Byzantine. **SG: VI.B.**

TK-167 (context 8.36.02: Late IA? and Persian to Hellenistic periods, with intrusive(?) Roman-Byzantine potsherds): shoulder/neck of jug, group 3a. Fabric near 10 YR 8/4, with many angular white grits and some red dust(?); surface smooth, nearly white (10 YR 8/3 very pale brown), slightly paler than the break. Persian or Early Hellenistic. **SG: IV.D.**

TK-168 (surface find: TK2): body sherd of *pithos* or jar, with finger-pinched decoration, group 2a. Fabric visually dense and clean, fired 10 YR 8/3 both at break and surface. Persian or Hellenistic. **SG: IV.D.**

TK-169 (context 8.36.02: Late IA? with Persian to Hellenistic, with intrusive(?) Roman-Byzantine potsherds): rim of carinated-shoulder jar, group 1a (**Fig. 12:7**). Fabric pale orange (7.5 YR 7/6 reddish yellow), rather dense, with occasional small to tiny red and white (and dark brown?) grits; surface powdery, pale pink (7.5 YR 8/4). See Briend & Humbert 1980, pl. 26:5 (*niveau* 4); also related pl. 10:7 (*niveau* 2). Persian period. **SG: I.A1.**

TK-170 (context 8.34.11: potsherds from IA/Persian to Hellenistic, with Byzantine-period intrusions): rim of thick-walled storage jug, group 3a **(Fig. 13:6).** Fabric dense pale pink (7.5 YR 8/4 pink) with small to large white grits (and some brown ones?); surface coarse in feel, 10 YR 8/3 (very pale brown, nearly white); Late Persian to Hellenistic period. **SG: IV.D.**

TK-171 (context 8.36.31: Persian to Early Hellenistic, with intrusive? Roman-Byzantine): rim of jar or jug, group 2a or 3a (**Fig. 13:5).** Fabric light brown (7.5 YR 6/4), rather soft, with many voids, with white, grey, dark grey and brown grits of all sizes; surface very pale brown (10 YR 7/3) with traces of very pale red slip(?) and multi-coloured eruptions of all sizes. Late Persian/Early Hellenistic period. **SG: I.A1.**

TK-172 (context 8.36.34: IA II period to Persian and Hellenistic, with a Byzantine intrusion): rim of carinated-shoulder jar, group 1a **(Fig. 12:3)**. Fabric pale red (5 YR 7/6 reddish yellow) with some voids (including deep ones), small red grits (one very big lump) and fewer tiny white ones; surface wet-smoothed very pale yellow (near 10 YR 8/4 very pale brown). Cf. Briend & Humbert 1980, pl. 18:2 (*niveau* 3). Persian period. **SG: I.A1?**

TK-173 (context 8.34.11: potsherds from IA/Persian to Hellenistic period, with Byzantine-period intrusions): rim of carinated-shoulder jar, group 1a (**Fig. 12:2**). Fabric reddish yellow (between 7.5 YR 7/4 and 7/6: pink/reddish yellow) with some oblong voids, some minute reddish-brown grits, occasional large pale yellow/white grit; surface pale pink (near 7.5 YR 8/4) with powdery feel. Late Persian/Early Hellenistic. **SG: I.A1.**

TK-174 (surface find: TK4): rim of jar, group 2b (**Fig. 13:11**). Fabric ash-grey in section, some small white and occasional small black grits; both surfaces light reddish brown (2.5 YR 6/4) with some clay accretions. Roman period. **SG: II.B.**

TK-175 (context 8.36.31: Persian to Early Hellenistic period, with intrusive(?) Roman-Byzantine potsherds): rim of carinated-shoulder jar, group 1a (**Fig. 12:5**). Fabric hard, light red (5 YR 6/6 reddish yellow) with oblong voids from tiny to large, red grits from tiny to medium-sized, occasional tiny to small white grits; surface light orange (5 YR 7/6 reddish yellow). Persian to Early Hellenistic? **SG: I.A1.**

TK-176 (context 8.38.23: mixed material, from Persian through Hellenistic to Roman periods): rim of carinated-shoulder jar, group 1a or group 1b? (**Fig. 12:11**). Fabric reddish yellow (7.5 YR 7/6) with just tiny voids, several tiny red grits; surface pink (7.5 YR 8/4) with slightly powdery feel. Near Briend & Humbert 1980, pl. 7:8 (*niveau* 2). Hellenistic. **SG: I.A1.**

TK-177 (context 8.74.02: prevailing material is of IA II period, but with some Persian and Hellenistic potsherds): rim of jar, group 2a (**Fig. 13:1**). Fabric very pale brown (10 YR 8/2), nearly white, with many tiny voids, occasional tiny red/brown grits and some minute black(?) ones; surface wet-smoothed, white (near 10 YR 8/2). Hellenistic. **SG: IV.D.**

TK-178 (context 8.38.23: mixed material, from Persian through Hellenistic to Roman): rim of *pithos*, profile near to group 2a. Fabric pale brown (7.5 YR 7/4 pink), rather soft, with light grey core; rather many voids, occasional tiny white grits; surface wet-smoothed pale beige (paler than 10 YR 7/3 very pale brown). Persian period? **SG: IV.A.**

TK-179 (context 8.36.34: IA II to Persian and Hellenistic, with a Byzantine-period intrusion): rim of *pithos*, group 4 (**Fig. 13:10**). Fabric pale brown banded light red, partial grey core at rim; rather numerous large brown, some large white/pale grey and dark grey grits, surface wet-smoothed, white (10 YR 8/2). Cf. Briend & Humbert 1980, *pithos*, pl. 21:8 (*niveau* 3). Late IA II or Persian(?). **PG: IX.**

TK-180 (context 8.36.05: Persian and Hellenistic periods; in fieldnotes: *chalco à byzantine*): rim of jar/jug, group 2a or 3a (**Fig. 13:3**). Fabric light brown banded light red, with small to medium white and light grey grits, and occasional larger circular dark brown and dark grey grits; pink surface (close to 5 YR 8/3) with numerous eruptions of rather large dark brown (and some dark grey?) grits. Cf. Briend & Humbert 1980, pl. 8:1 (*niveau* 2). Late Persian or Early Hellenistic. **PG: ?**

TK-181 (surface find: TK3): rim of support(?), group 4. Fabric very pale brown (10 YR 8/4) with voids, some tiny black grits, occasional tiny white ones; surface wet-smoothed, slightly paler, almost white (10 YR 8/3 very pale brown). Persian or Hellenistic period. **SG: IV.D.**

TK-182 (context 8.36.03: IA, Persian and Hellenistic periods): rim/shoulder of jar, group 1a (**Fig. 12:9**). Fabric porous pale pinkish beige (near 7.5 YR 8/4 pink); surface wet-smoothed (cf. TK-181), white (near 10 YR 8/2). Cf. Briend & Humbert 1980, pl. 18:5 (*niveau* 3). Persian period. **SG: IV.D.**

TK-183 (context 8.34.13: mostly late IA, with some later intrusions down to Islamic period): rim of jar, group 1a (**Fig. 12:8**). Fabric very pale brown (10 YR 8/2) with tiny voids, some tiny red/brown grits, surface semi-coarse, white (near 10 YR 8/2). Persian period. **SG: IV.G.**

TK-184 (context 8.36.31: Persian to Early Hellenistic, with intrusive(?) Roman-Byzantine potsherds): rim of bag-shaped jar or storage jug, group 2a or 3a (**Fig. 13: 4**). Fabric pale beige (10 YR 8/2 white) with many small light brown grits and some tiny white ones; many black grits on pale beige surface (near 10 YR 8/2 white). Late Persian/Early Hellenistic. **PG: ?**

TK-185 (context 8.36.07: Persian to Hellenistic periods): rim of jar, group 1a (**Fig. 12:4**). Fabric with "sandwich" firing: pale red (5 YR 6/8 reddish yellow) outside, yellowish beige inside; oblong voids, some tiny white and red grits; surface wet-smoothed, pale yellow. Cf Briend & Humbert 1980, pl. 18:1–2 and 4 (*niveau* 3). Persian period. **SG: I.A1.**

TK-186 (context 8.36.20: IA period, but with some later intrusions): rim of jar, probably group 1a (**Fig. 12:6**). Fabric yellowish beige (10 YR 7/4 very pale brown), many small to medium-size white grits, few small brown ones, some voids; surface wet-smoothed white (10 YR 8/2). Persian period(?). **SG: IV.H.**

TK-187 (context 8.36.50: late IA to Persian and Hellenistic periods): rim of big jar (*pithos*?), group 2a (**Fig. 13:8**). Fabric yellowish beige (7.5 YR

7/4 pink) with many mineral inclusions, small to large and very large: white, dark grey, pale grey, brown, reddish-brown; surface wet-smoothed, pale pinkish beige (10 YR 8/3 very pale brown) with multicoloured eruptions of all sizes (and traces of very pale red slip?). Visually the same ware as TK-171. For profile, see Briend & Humbert 1980, pl. 8:3 and 7? (*niveau* 2). Persian(?) period. **SG: I.A2 (?).**

TK-188 (surface find: TK6): rim of jar (group 2b, **Fig. 13:13).** Fabric (visually like TK-219), hard and dense, light red (2.5 YR 6/6) with some small white grits and red ones (?); surface fired like evenly light reddish brown (2.5 YR 6/4). Roman. **SG: II.B.**

TK-189 (context 8.34.02: mixed sherds, from IA II to Roman period): small fragment of jar rim, group 2b (**Fig. 13: 12**). Fabric dark grey banded brown, with some small white grits and occasional oblong voids; surface evenly fired light yellowish beige with some gloss inside (slightly vitrified?) and some small white eruptions (10 YR 7/3: very pale brown). Early Roman. **SG: II.B.**

TK-190 (context 8.38.27: mixed material, from Persian through Byzantine periods): rim of jar, group 1a(?) (**Fig. 12:10).** Fabric very pale brown (near 10 YR 8/4) with tiny voids, some small white grits and occasional tiny brown and black ones; surface semi-coarse in feel, with occasional white eruptions, white to very pale brown (10 YR 8/2 to 8/3); cf. Briend & Humbert 1980, pl. 8:1c (*niveau* 2). Hellenistic period. **SG: IV.D.**

TK-191 (context 8.36.46, according to fieldnotes: Persian): "collared" rim of jar, group 1a **(Fig. 12:1).** Fabric pale red (5 YR 7/6 reddish yellow) with tiny oblong voids, white, red and dark brown(?) grits; surface with pale yellow self-slip (10 YR 8/4 very pale brown). Cf. Briend & Humbert 1980, pl. 25:8 (*niveau* 4), also for the fabric. IA II/III period. **SG: I.A1.**

TK-192 (context 8.34.06: mixed sherds, from Persian to Byzantine period): rim of jar, group 2a (**Fig. 13:2**). Fabric dense brown (5 YR 5/4 reddish brown) with rather many minute white grits, some bigger dark brown and occasional orange ones; partial grey core at rim; surface wet-smoothed, fired grey (5 YR 5/1). IA III? Persian(?) period. **PG: XI.**

TK-193 (context 8.36.29: late IA and Persian to Hellenistic periods, with later intrusions): fragment of "cupped" rim of table jug, group 4 (**Fig. 13:7).** Fabric light red (2.5 YR 6/8) with some small voids, small white grits and occasional larger dark reddish brown ones; surface deep pink inside, very pale yellow (10 YR 8/3 very pale brown) outside, with deep pink spots on rim. Persian or Early Hellenistic. **SG: I.A2.**

TK-194 (context 8.38.23: mixed material, from Persian through Hellenistic to Roman period): ribbed body sherd of jar, group 2b. Fabric very hard, with "sandwich" section (brick red interior, light brown exterior), exterior surface very pale brown (10 YR 8/2 "white") with many minute white grits. Early Roman(?). **SG: VI.B.**

TK-195 (context 7.16.44: *hellénistique homogène*): body sherd of jar/jug, group 2a or 3a. Fabric: beige with pink core, some voids, occasional white grits (and eruptions); surface with fine "bubbles", pink inside, beige (with pink spots) outside (10 YR 8/3 very pale brown). Hellenistic period. **SG: IV.E**

TK-196 (context 8.38.27: mixed material, from Persian through Byzantine period): body sherd of jar, group 2c. Fabric hard, very dense, red (5 YR 5/6 yellowish red) with tiny white grits; surface (exterior) 2.5 YR 6/4 (light reddish brown) with white linear decoration. Byzantine period. **SG: VI.A.**

TK-197 (context 8.34.11: potsherds from IA/Persian to Hellenistic period, with Byzantine-period intrusions): shoulder/neck of jug, group 3a. Fabric brown (7.5 YR 6/4 light brown) with deep voids and tiny white grits. Surface thickly wet-smoothed, beige (near 10 YR 8/3-8/4). For the form, see Briend & Humbert 1980, pl. 9:10 (*niveau* 2). Persian(?) period. **SG: I.A2?**

TK-198 (context 8.36.02**:** late IA? to Persian and Hellenistic, with intrusive? Roman-Byzantine): handle root of jar/jug, group 2a or 3a. Fabric pale beige (10 YR 8/3) with fine red grits? Surface rather smooth, white. Persian or Early Hellenistic. **SG: IV.D.**

TK-199 (context 8.34.11: potsherds from IA/Persian to Hellenistic, with Byzantine-period intrusions): bottom part of jar, ribbed, group 2b. Fabric bright red (2.5 YR 5/6) with minute white grits. Surface pale orange to beige with white eruptions. Roman to Late Roman period. **SG: VI.A.**

TK-200 (context 8.36.03: IA, Persian, Hellenistic periods): rim and band handle of jug, group 3a. Fabric pale beige (10 YR 8/4 very pale brown), with occasional white and brown (and dark grey?) grits; surface white, smooth. Cf. Briend & Humbert 1980, pl. 9:7 and 10 (handle pl. 9:10). Persian or Early Hellenistic period. **SG: IV.E.**

TK-201 (surface find: TK7): handle of jar, group 2b. Fabric very hard, red, with many tiny and small white grits, very large white eruptions on surface; exterior fired pale red (5 YR 7/4 pink), interior light grey-brown. Roman period. **SG: II.B.**

TK-202 (context 8.34.29: Persian, possibly into Hellenistic, with some Byzantine-period intrusions): shoulder/wall/ handle root of heavy carinated-shoulder jar, group 1a. Fabric hard, red (2.5

YR 6/6 light red), with small voids, many small white grits; surface fired orange (7.5 YR 7/6 reddish yellow) with some mineral eruptions (red, grey). Late IA or Early Persian period(?). **SG: VI.C.**

TK-203 (context 8.36.05: contents *chalco à byzantine*, material mostly Persian and Hellenistic): rim of jar, group 1a; form and fabric like TK-185, but of different, pale red surface firing (near 5 YR 7/6 reddish yellow). Persian or Early Hellenistic. **SG: I.A1.**

TK-204 (context 8.34.29: Persian period, possibly into Hellenistic, with Byzantine intrusions): ridged shoulder fragment of jar, group 2c. Fabric very hard and dense, dark orange/red (near 7.5 YR 6/6) with white grits. Surface greyish brown inside, dark grey outside, which suggests a "Beisan" type, but no traces of white paint. Late Roman-Byzantine. **PG: XI.**

TK-205 (surface find: TK8): body sherd of jar, group 2c. Fabric red (5 YR 5/6 yellowish red) with some minute white grits and bigger red ones; surface gritty red inside, reddish brown (near 5 YR 6/4 light reddish brown) outside; white painted decoration. Late Roman-Byzantine. **SG: VI.A.**

TK-206 (surface find: TK9): ridged shoulder fragment of jar, group 2c. Fabric very hard and dense, orange-brown (near 7.5 YR 6/6 reddish yellow), with many tiny white grits and partial dark grey core. Surface dark brownish grey. Late Roman – Byzantine. **PG: XI.**

TK-207 (context 8.38.28: mixed material, from Persian through Byzantine period): body sherd of jar, group 2b or 2c. Fabric hard and dense, orange-red (near 5 YR 6/6 reddish yellow) with lots of tiny white grits. Both surfaces fired between 5 YR 5/1 (grey) and 4/1 (dark grey). Roman to Byzantine. **PG: XI.**

TK-208 (context 8.36.02: Late IA? and Persian to Hellenistic, with intrusive Roman-Byzantine period sherds): shoulder/handle root of jar, group 1a. Fabric dense red (5 YR 6/6 reddish yellow) with some minute white (and red?) grits and occasional large white eruptions; surface pale yellowish pink (near 5 YR 8/4). Persian period(?). **SG: I.A1?**

TK-209 (context 8.36.36, according to fieldnotes: *niveau* 4 = late IA): body sherd of jar, group 1a. Misfired, with "sandwich" section. Fabric light red (2.5 YR 6/6) with grey (beige-grey) core and lime lumps; surface wet-smoothed, pale yellow (7.5 YR 8/4 pink); fabric looks much like that of TK-172, but has large white eruptions. IA III period (6th century BC)? **SG: I.A1.**

TK-210 (context 8.34.06: mixed sherds, from Persian to Byzantine period): ribbed body sherd of cooking pot or jar (group 4 or 2b), "metallic" firing, bright red (near 10 R 6/8 light red) with tiny white grits (and minute voids?); surface reddish brown (near 10 R 3/4). Early Roman, **PG: X.**

TK-211 (context 8.34.11: potsherds from IA/Persian to Hellenistic period, with Byzantine-period intrusions): fragment of strap handle of jar/jug, group 2a or 3a. Fabric light, porous, very pale brown (7.5 YR 8/4 pink), with many white inclusions; surface white, with slightly gritty feel. Visually the same fabric as TK-198 and TK-170. Early(?) Hellenistic. **SG: IV.D.**

TK-212 (context 8.34.29: Persian, possibly into Hellenistic period, with Byzantine intrusions): rim of carinated-shoulder jar, group 1a, with very metallic firing (the same shape as TK-183): light red (5 YR 6/6 reddish yellow) with rather many voids and some minute white grits. Paler surface, reddish yellow (5 YR 7/6), fairly smooth, with occasional lime eruptions. Cf. Briend & Humbert 1980, pl. 7:3 (*niveau* 2, different fabric), but also *niveau* 3, pl. 18:1–4 and 7. Persian period. **SG: I.A1.**

TK-213 (context 8.34.06: mixed sherds, from Persian to Byzantine period): ridged neck/shoulder fragment of jar, group 2b. Fabric very hard, with sandwich section: beige (7.5 YR 7/4) outside, grey (near 10 YR 6/2) inside; some black grits and rare white ones; circular voids? Surface slightly gritty in feel, pink (between 5 YR 7/4 and 7/6). Early Roman. **SG: II.C.**

TK-214 (context 8.37.04: late IA to Persian, with Hellenistic-period intrusions): fragment of handle/shoulder of jar, group 1a. Fabric light red, fine, dense, with many small white grits, some small red ones. Late IA or Persian period. **SG: I.A1.**

TK-215 (context 8.34.11: potsherds from IA/Persian to Hellenistic, with Byzantine-period intrusions): thick grooved handle of jar, group 2b or 2c. Fabric overfired(?) to very dark grey. Fabric very hard and dense; surface 10 YR 6/2 with remains of pinkish beige slip. Roman or Byzantine period. **PG: ?**

TK-216 (context 8.38.28: mixed material, from Persian through Byzantine): body sherd of cooking pot or perhaps water jug, group 4 or 3b. Fabric very hard and dense (2.5 YR 6/8 light red) with small white grits. Surface light red inside (2.5 YR 6/6), unevenly fired outside: reddish brown to orange. Early Roman period. **PG: X.**

TK-217 (context 8.36.29: late IA and Persian to Hellenistic, with later intrusions): fragment handle of carinated-shoulder jar, group 1a. Fabric red (near 5 YR 7/8 reddish yellow), with small white and larger red grits; surface near 5 YR 7/6 (reddish yellow). Persian or Early Hellenistic period. **SG: I.A1.**

TK-218 (surface find: TK1): rim of jar, group 1a **(Fig. 12:12).** Fabric dense very pale brown (10 YR 8/3) with some dark grey and brown grits and occasional large white eruptions; surface wet-smoothed, white (10 YR 8/2). Hellenistic. **SG: IV.D.**

TK-219 (surface find: TK5): fragment ridged shoulder/neck of jar, group 2b. Fabric dense, red (2.5 YR 5/6) with minute white grits; surface metallic reddish brown (near 5 YR 6/3 light reddish brown). Early Roman. **SG: II.B.**

TK-220 (context 8.74.02: prevailing material is of IA II period, but with some Persian and Hellenistic sherds): rim of jar, group 1a. Fabric very hard beige with light red core (5 YR 6/6 reddish yellow) and rather large "soft" white lumps; surface smooth, pale yellow (10 YR 8/4 very pale brown). Early(?) Persian period**. SG: I.A1.**

TK-221 (context 8.34.29: Persian, possibly into Hellenistic? plus Byzantine-period intrusions): rim of carinated-shoulder jar, group 1a. Fabric (the same variant as TK-212) dense, bright red (2.5 YR 6/8), with minute dark grits or voids? Occasional small white grits and large eruptions; surface from pale yellow to pink. Cf. Briend & Humbert 1980, pl. 26:7 (*niveau* 4) ("pâte rouge vif, très fine"). Early(?) Persian period. **SG: I.A3/I.A1.**

TK-222 (context 8.74.02: prevailing material is of IA II period, but with some Persian and Hellenistic sherds): rim of jar or water jug, group 2a or 3a. Fabric very dense, very pale beige (10 YR 8/3 very pale brown) banded pink outside, with many minute white grits and larger eruptions. Surface smooth, very pale brown (10 YR 8/4) with pink spots on rim. Hellenistic. **SG: IV.D.**

TK-223 (context 8.34.12: mostly late IA period, with some later intrusions): shoulder/ridged neck of jar, group 2b. Fabric very dense, brick red with grey core and fine white grits; reddish brown surface inside and outside (2.5 YR 6/4 light reddish brown). Early Roman. **SG: II.B.**

TK-224 (context 8.38.27: mixed material, from Persian through Byzantine period): body sherd of jar, group 2b, misfired. Fabric very hard, with sandwich firing (very dark grey, banded brick red on exterior) with many small white grits and tiny voids. Exterior surface fired unevenly: beige-brown-dark brown. Early Roman. **PG: XI.**

TK-251 (context 8.34.29: Persian, possibly into Hellenistic period, with Byzantine intrusions): handle fragment of baggy jar/jug, group 2a or 3a. Fabric porous and rather clean (10 YR 8/3: very pale brown, almost white), surface white. Persian or Early Hellenistic. **SG: IV.D.**

6.4. Tell Keisan petrographic database (followed by Sha'ar-Ha'Amakim petro-groups)

A study was made of 74 ceramic samples from Tell Keisan. They included 22–24 fragments of jars of shape group 1a, and only one of group 1c; four-to-seven fragments of jars shape group 2a, 11 fragments of jars group 2b, six fragments of jars shape group 2c (baggy jars of the Late Roman – Byzantine period), four fragments of baggy jars either of group 2b or group 2c five fragments of storage jugs group 3a. Nine samples could belong to either baggy jars (group 2a) or baggy jugs (group 3a), and the remainder is of uncertain attribution in terms of the vesselshape (Table 8).

When compared with the Sha'ar-Ha'Amakim ceramics, there is no petro-fabric corresponding to petrographic groups and subgroups: I.A3; IVB; IVC; IVF; V; VII; VIII. On the other hand, among the material from Tell Keisan there are petrographic groups: IX; X; XI, that are absent from Sha'ar-Ha'Amakim.

The petrography profile of Tell Keisan ceramics under investigation looks as follows:

Petrographic Group I.A – "Algae"

Subgroup I.A1 (Figs. 123–124)

Eocene foraminiferous 'light' marl with sparse algae, chalk rich in ferruginous-globigerina ooze**,** 5–8% quartz sand, occasionally minute red soil balls.

Specimens: TK-159 (?)*[304] TK-160, TK-165, TK-169, TK-171, TK-172(?)[305], TK-173, TK-175, TK-176, TK -185, TK-191, TK-203, TK-212, TK-214, TK-217(?)*, TK-220[306].

Those are the vessels light-red on the surface (2.5 YR 7/6), on the fracture slightly darker (2.5 YR 7/7-6/8) or light-brown (5 YR 7/4). The micromass of most samples in this group is optically active. Only samples TK-191 and TK-172 are isotropic (they were fired at a higher temperature). The composition of the material is marly-argillaceous, pale-yellowish, bright orange or pale grey in colour. A characteristic feature is the presence of numerous ferruginous-manganese opaque or dark-red mottles with blurred, more rarely clear and sharp boundaries. Those are Fe-Mn concentrations and hypocoatings observed especially near accumulations of *Globige-*

304 Samples TK159 and TK217 stand out for their high content of the quartz sand admixture.

305 TK172 – notable is the presence of pedogenic ferruginous oolith and an isotropic background (a different technology?).

306 TK-220 contains a calcarenite clast in which a grain of micritic limestone and a fragment of *Corallinaceae* are bonded together with sparite cement (*kurkar*?).

Table 8. Descriptive information and petrographic group assignment of the analysed ceramics from Tell Keisan

Sample symbol	Excavation inv.no.	Fragment description	Dating	Vessel form	PETRO GROUP
TK-152	8.36.55	body sherd of jar	Persian or Hellenistic	2a?	IX
TK-153	8.36.31(d)	handle/wall of jar	Hellenistic	2a?	IV.H
TK-154	8.36.05(c)	body sherd of jar	Persian or Hellenistic	2a	IV.H
TK-155	8.36.02(e)	handle of jar	Roman or Late Roman	2b	VI.D
TK-156	8.38.28 (a)	body sherd of jar	Roman	2b	VI.A
TK-157	8.34.07	body sherd of jar	Early(?) Roman	1c	III
TK-158	8.36.66	body sherd of jug(?)	Persian or early Hellenistic	3a	IV.D
TK-159	8.36.31(e)	handle of jar	Roman or Byzantine	2b or 2c	I.A1?
TK-160	8.36.03(a)	rim of jar	Late IA II or Persian	1a	I.A1
TK-161	8.74.01(b)	body sherd of jar, misfired	Persian or Hellenistic	1a or 2a	IV.H
TK-162	8.74.01(a)	body sherd of jar, misfired	Late IA II(?)	1a	I.A1?
TK-163	8.38.27(2)c	body sherd of jar	Byzantine	2c	XI
TK-164	8.74.02(d)	handle of jar or storage jug	Hellenistic	2a or 3a	IV.D
TK-165	8.38.37(a)	body sherd of jar	Persian or Hellenistic	1a?	I.A1
TK-166	8.38.37(b)	body sherd of jar	Late Roman to Byzantine	2c	VI.B
TK-167	8.36.02(d)	shoulder of jug	Persian or Early Hellenistic	3a	IV.D
TK-168	TK.2	body sherd of pithos?	Persian or Hellenistic	2a	IV.D
TK-169	8.36.02(a)	rim of jar	Persian	1a	I.A1
TK-170	8.34.11(f)	rim of storage jug?	Persian	3a	IV.D
TK-171	8.36.31(c)	rim of jug (or jar?)	Late Persian/Early Hellenistic	3a or 2a	I.A1
TK-172	8.36.34(a)	rim of jar	Persian	1a	I.A1?
TK-173	8.34.11(a)	rim of jar	Late Persian/Early Hellenistic	1a	I.A1
TK-174	TK4	rim of jar	Roman	2b	II.B
TK-175	8.36.31(a)	rim of jar	Persian or Early Hellenistic	1a	I.A1
TK-176	8.38.23(a)	rim of jar	Hellenistic	1a or 1b	I.A1
TK-177	8.74.02(a)	rim of jar	Hellenistic	2a	IV.D
TK-178	8.38.23(b)	rim of pithos	Persian?	2a/4	IV.A
TK-179	8.36.34(b)	rim of pithos	Late IA II (Persian?)	4	IX
TK-180	8.36.05(b)	rim of jar or storage jug	Persian or Early Hellenistic	2a or 3a	?
TK-181	TK3	support?	Persian or Hellenistic	4	IV.D
TK-182	8.36.03(b)	rim of jar	Persian	1a	IV.D
TK-183	8.34.13(TK1)	rim of jar	Persian	1a	IV.G
TK-184	8.36.31(b)	rim of jar or storage jug	Hellenistic	2a or 3a	?
TK-185	8.36.07	rim of jar	Persian	1a	I.A1
TK-186	8.36.20	rim of jar	Persian?	1a?	IV.H
TK-187	8.36.50	rim of pithos	Persian?	2a	I.A2?
TK-188	TK6	rim of jar	Early Roman/Roman	2b	II.B
TK-189	8.34.02	rim of jar	Early Roman	2b	II.B
TK-190	8.38.27(a)	rim of jar	Hellenistic	1a	IV.D
TK-191	8.36.46	rim of jar	IA III (6th century BC)	1a	I.A1
TK-192	8.34.06(c)	jar rim	IA III? Persian?	2a	XI
TK-193	8.36.29(b)	rim of table jug (reference sample)	Persian or Early Hellenistic	4	I.A2
TK-194	8.38.23(c)	body sherd of jar	Early Roman?	2b	VI.B
TK-195	7.16.44	body sherd of jar	Hellenistic	2a or 3a	IV.E

Sample symbol	Excavation inv.no.	Fragment description	Dating	Vessel form	PETRO GROUP
TK-196	8.38.27(b)	body sherd of jar	Byzantine	2c	VI.A
TK-197	8.34.11(e)	shoulder of big jug(?)	Persian?	3a	I.A2?
TK-198	8.36.02(c)	handle root of jar or jug	Persian or Early Hellenistic	2a or 3a	IV.D
TK-199	8.34.11(d)	base of jar	Roman to Late Roman	2b	VI.A
TK-200	8.36.03 (c)	rim/handle of big jug	Persian or Early Hellenistic	3a	IV.E
TK-201	TK7	handle of jar	Roman	2b	II.B
TK-202	8.34.29(c)	handle/wall frg of jar	Early Persian	1a	VI.C
TK-203	8.36.05 (a)	rim of jar	Persian or Early Hellenistic	1a	I.A1
TK-204	8.34.29(e)	shoulder of jar	Late Roman-Byzantine	2c	XI
TK-205	TK8	body sherd of jar	Late Roman-Byzantine	2c	VI.A
TK-206	TK9	shoulder of jar	Late Roman-Byzantine	2c	XI
TK-207	8.38.28(b)	body sherd of jar	Roman to Byzantine	2b or 2c	XI
TK-208	8.36.02(b)	shoulder/handle of jar	Persian (or Hellenistic?)	1a	I.A1?
TK-209	8.36.36	body sherd of jar	IA III, 6th century BC(?)	1a (?)	I.A1
TK-210	8.34.06(b)	body sherd of cooking pot or jar	Early Roman	4 or 2b	X
TK-211	8.34.11(b)	handle of jar/jug	Early(?) Hellenistic	2a or 3a	IV.D
TK-212	8.34.29(a)	rim of jar	Persian	1a	I.A1
TK-213	8.34.06(a)	neck/shoulder of jar	Early Roman	2b	II.C
TK-214	8.37.04	shoulder/handle of jar	IA III to Persian	1a	I.A1
TK-215	8.34.11(c)	jar handle	Roman or Byzantine	2b or 2c	?
TK-216	8.38.28(c)	body sherd of cooking pot(?)	Early Roman	4	X
TK-217	8.36.29(a)	handle of jar	Persian or Early Hellenistic	1a	I.A1
TK-218	TK1	rim od jar	Hellenistic	1a?	IV.D
TK-219	TK5	shoulder/neck of jar	Early Roman	2b	II.B
TK-220	8.74.02(b)	rim of jar	Persian (early)?	1a	I.A1
TK-221	8.34.29(b)	rim of jar	Persian (early?)	1a	I.A3/I.A1
Tk-222	8.74.02(c)	rim of jar/jug	Hellenistic	2a or 3a	IV.D
TK-223	8.34.12	shoulder/neck of jar	Early Roman	2b	II.B
TK-224	8.38.27(d)	body sherd of jar	Early Roman	2b	XI
TK-251	8.34.29(d)	jar or jug	Persian or Early Hellenistic	2a or 3a	IV.D

rina shells – planktonic foraminifers with globular chambers and coarsely perforated walls.

The microfossils embedded in the matrix are relatively numerous, usually evenly distributed. They include representatives of various sedimentation environments: planktonic foraminifers, less often radiolarians – indicators of the outer shelf[307], and detritic ones – sand-sized fragments of *Corallinaceae*, living in the outer parts of lagoons. The age of those associations is Late Eocene. There are sporadic light-grey marl clasts with preserved original lamination and a similar composition of microfossils, but with no Fe-coloured spots[308]. The content of quartz silt is negligible, usually less than 2% of the volume.

Aplastic inclusions are of a fine-sand fraction; their proportion varies, in most samples not exceeding 5%. In a decided majority they are grains of fine (0.1–0.25 mm) monocrystalline quartz of angular/subangular shape, showing both uniform and undulose light extinction. Accessory minerals are cross-hatched, polysynthetically twinned feldspars and microcrystalline flints. A characteristic feature is the presence of automorphic elongated apatite crystals.

Samples TK-171 and **TK-214** differ in temper composition which is dominated by clasts of micritic limestones (0.25–0.5 mm in diameter), whereas quartz is less frequent. The carbonate composition

307 Arni 1965, fide B. Olszewska 2014.

308 The origin of those clasts is hard to determine; according to the author, it is rather what has been left of the original lamination of the raw material; intentional clay mixing cannot be ruled out.

of the sand-size temper suggests derivation from the northward part of the Levant coast.

What distinguishes samples TK-159 and TK-217 is an elevated level of fine-sand quartz, 25% and 15%, respectively (as in the Sha'ar-Ha'Amakim sample SA-13).

Ceramics related to SG I.A1 (Figs. 125–128)

Sample TK-162 – macroscopically, the sample is red on the surface (10 YR 6/8) and steel-grey on the fracture (after reduction). Optical examination indicates a high degree of sintering of sherd. In comparison with vessels of SG I.A1, the micromass is more ferruginous, mostly inactive, rich in micropores left by decomposed particles of carbonate silt. Quartz silt accounts for less than 2% of the volume.

The aplastic admixture is sand-sized quartz making up 10% of the volume. The next 6% go to grains of micritic limestones of indeterminate origin; one can also find sparse flints. The sample contains single fragments of *Corallinaceae*. The preserved foraminifers: *Cibicides* sp. *Brizalina* sp. and *Globigerina*, are indicative of Eocene age.

Sample TK-208 is slightly sintered, light red (2.5 YR 7/8), on the fracture light brown (7.5 YR 6/4). In transmitted light, the clayey matrix is similar to that of the other vessels of group I; it is light orange, partially light grey, optically active, with Fe-coloured spots as in the other vessels of group I.A. It contains evenly dispersed microfossils of *Chiloguembelina* sp. and *Globigerina* ex gr. *praebulloides-officinalis*, which are diagnostic of the Late Eocene–Oligocene.

What distinguishes the sample is 15–20% content of the tempering admixture of the 0.1–0.25 mm fraction composed of quartz and detritic grains of micritic limestone, clam shells, and numerous *Corallinaceae*. The proportion of quartz to carbonates is 3:1.[309]

Sample TK-221 is, macroscopically, uniformly light-red in colour (2.5 YR 7/8). Its matrix is red, mottled grey, inactive, porous as a trace of decomposed microfossils. The content of quartz silt does not exceed 1% of the volume, there appear fine, silt-sized oxidised amphiboles (?) and serpentinised olivines (?).

The few preserved microfossils are mostly *Globigerina* surrounded by and filled with iron oxides. The sand fraction is represented by sparse angular/subangular grains of monocrystalline quartz. Also present are clasts of grey chalk, biomicrite rich in foraminifers, and single fine clasts of glass.

[309] According to Cohen-Weinberger & Goren 2004, the predominance of *Corallinaceae*-rich carbonate components over quartz can be observed in Levantine coastal sands north of Akko, where they form nearly 70% of the sand components. The present author's research has corroborated this observation. However, the granulometry of those sediments and the composition of carbonate detritus are not identical with those of the aplastic admixture in the vessels under examination.

The chemical composition of the samples makes them similar to the ceramics of group I.A1, and in their petrography they are similar to those of Subgroup I.A3.

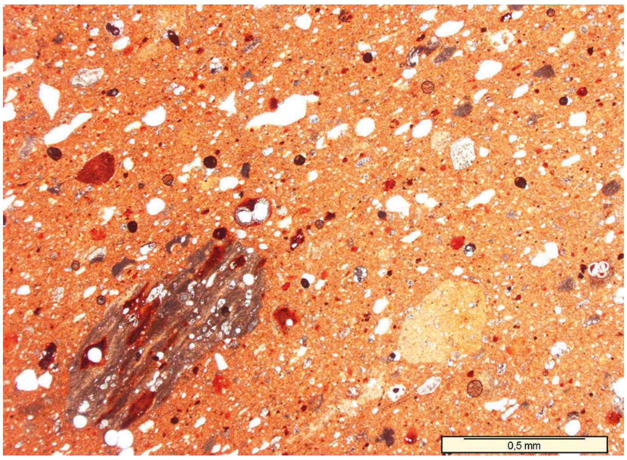


Fig. 123. SG.I.A1. Specimen TK-185, photomicrograph of a thin section (PPL)

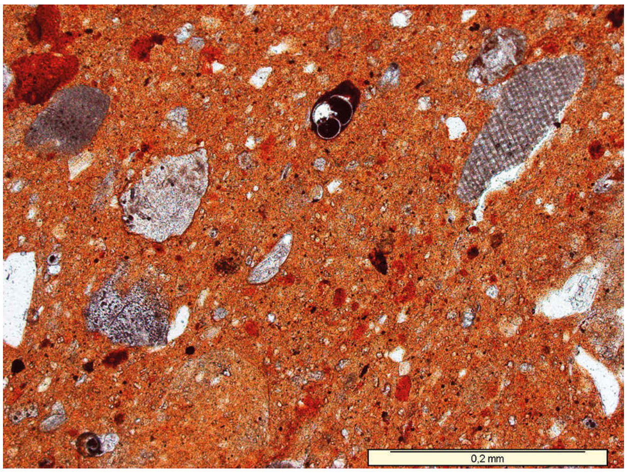


Fig. 124. SG.I.A1. Specimen TK-185, photomicrograph of a thin section at higher magnification (PPL) – numerous fragments of *Corallinaceae*

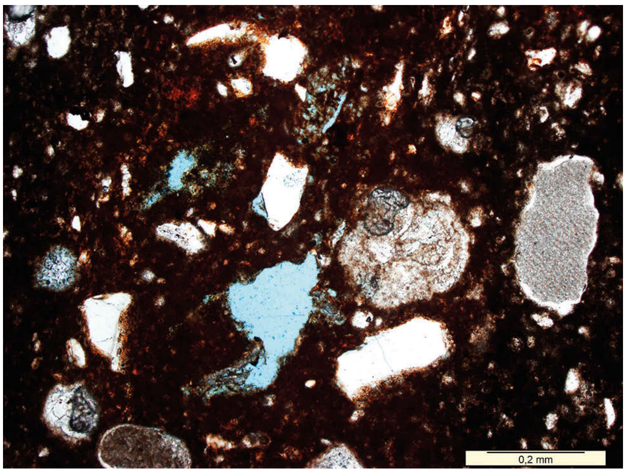


Fig. 125. SG. I.A1 (?). Specimen TK-162, photomicrograph of a thin section (PPL)

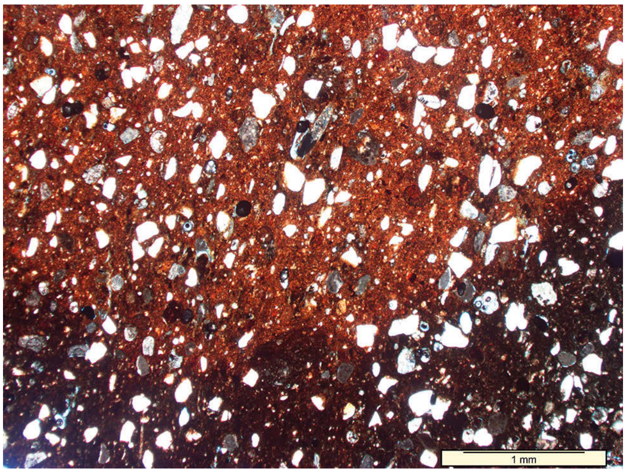


Fig. 126. SG. I.A1 (?). Specimen TK-208, photomicrograph of a thin section (PPL) – note the high amount of quartz-sand

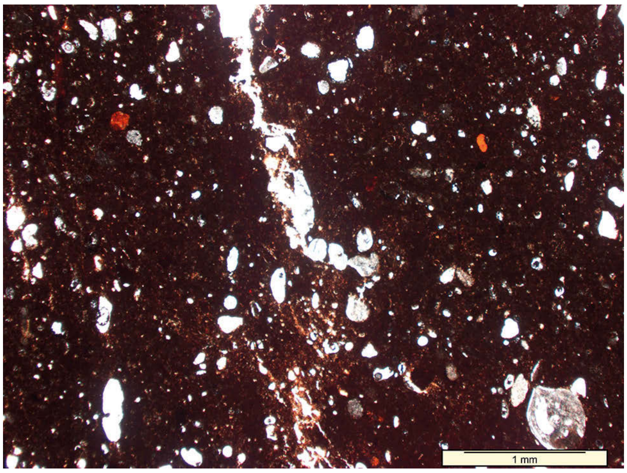


Fig. 127. SG. I.A1 (?). Specimen TK-221, photomicrograph of a thin section (PPL)

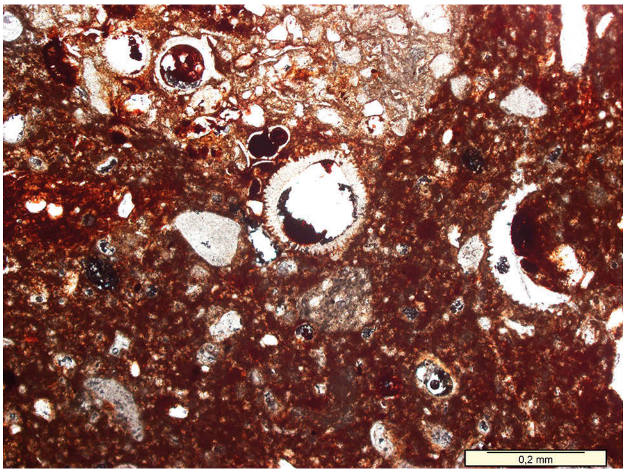


Fig. 128. SG.I.A1(?). Specimen TK-221, photomicrograph of a thin section at higher magnification (PPL)

Subgroup I.A2.Eo (Figs. 129–132)

Eocene foraminiferous 'light' marl + red soil balls + quartz sand (devoid of ferruginous globigerina ooze).

Specimens: TK-187(?), TK-193, TK-197(?).

Sample TK-193 is light-red (2.5 YR 6/6), the other two are light-grey, locally light-brown. What distinguishes this group from the TK I.A.1 ceramics is a significant admixture of soil, possibly affecting the colour of the sherd.

Under the microscope, the matrix of TK-193 is pale red, and of the other two samples (**TK-187, TK-197**) light grey.

The groundmass is optically active, rich in microorganisms, especially foraminifers representing the carbonate platform (*Pararotalia* sp.) and open-sea waters (*Globigerina* sp.); there are also single *Corallinaceae*. The presence of *Chilogumbelina* sp. and *Globigerina* ex gr. *praebulloides-officinalis* indicates the Eocene as the age of the material used (Olszewska 2014).

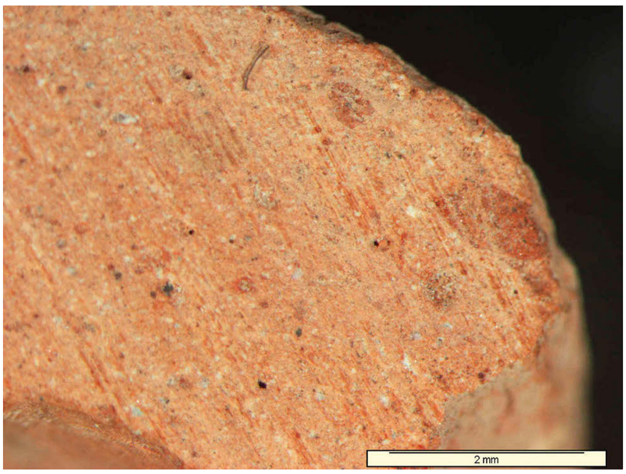


Fig. 129. SG.I.A2.Eo. Fragment of specimen TK-193

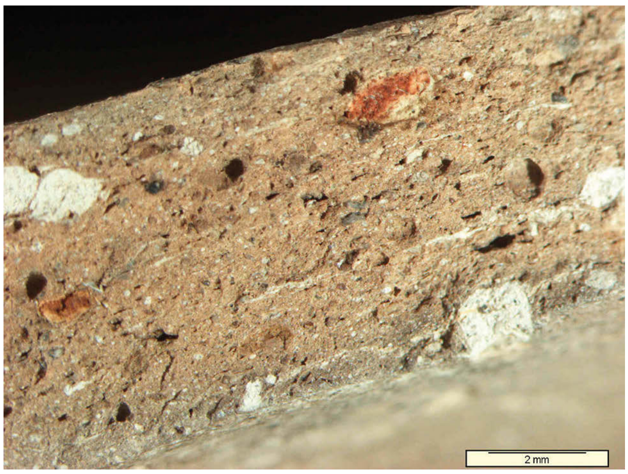


Fig. 130. SG.I.A2.Eo. Fragment of specimen TK-197

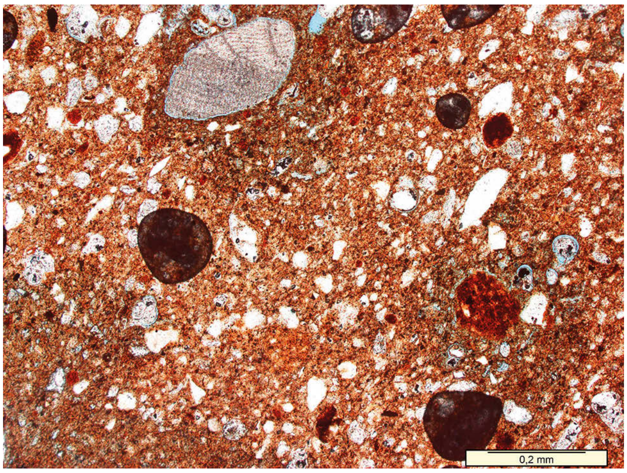


Fig. 131. SG.I.A2.Eo. Specimen TK-193, photomicrograph of a thin section (PPL)

Quartzose silt in the sample accounts for less than 5% of the volume. The vessel was made adding silty soil, visible in the form of numerous oval balls. Also present are clasts of grey chalk rich in microfossils, some of them impregnated with Fe-Mn oxides.

Grains of the fine-sand are rare (<2%) in samples TK-193 and TK-197; in sample TK-187 it is much larger, accounting for ca. 8% of the volume. This is predominantly monocrystalline quartz, variably rounded, usually showing uniform light extinction; sporadically one can also find some (very rare) feldspars.

Sample TK-187 contains a pedogenic ferric oolith. Sample TK-197 contains a fragment of volcanic glass.

In geochemical terms, jars TK-187, TK-193 and TK-197 are not related to the I.A2 ceramics from Sha'ar-Ha'Amakim, but are closer to those of group I.A1 (TK-187, TK-197).

Subgroup I.A3

Eocene foraminiferous 'light' marl plus red soil balls plus quartz sand plus hyaloclastite elements.

TK-221 is a sample with features of subgroup I.A1; what may indicate a possible connection with subgroup I.A3 is the presence of a single fragment of volcanic glass. In geochemical terms, the sample is close to I.A1.

Petrographic Group II

Red soil, silty clay, almost devoid of sand-sized admixture.

Subgroup II.B (Figs. 133–134)

Cretaceous foraminifers: silty soil + chalk rich in *Globigerinoides*.

Specimens: TK-174, TK-188, TK-189, TK-201, TK-219, TK-223.

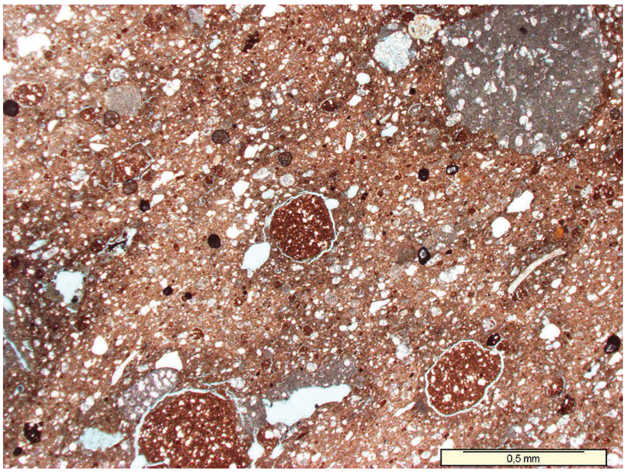


Fig. 132. SG.I.A2.Eo. Specimen TK-197, photomicrograph of a thin section (PPL)

Samples of vessels heavily sintered, red on the surface, and on the fracture either red (2.5Y 5/6): TK-188, TK-219 or grey: TK-174, TK-201.

Fig. 133. SG.II.B Fragment of specimen TK-201

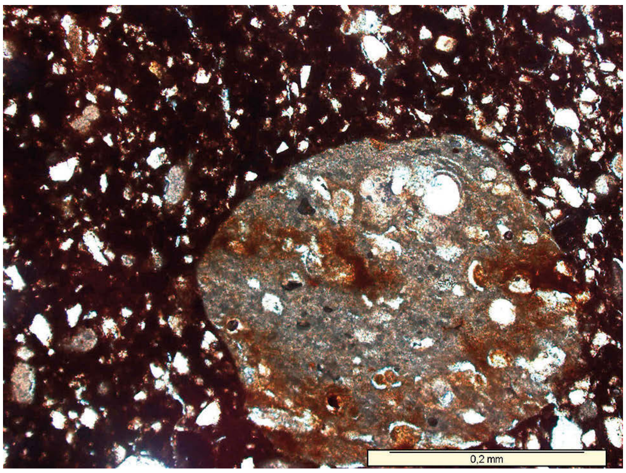


Fig. 134. SG.II.B. Specimen TK-201, photomicrograph of a thin section (PPL), note the gray ball of foraminiferous chalk

The matrix of vessels is red on optical examination (TK-188, TK-201, TK-219), and of the other samples brown-black, usually optically inactive. Characteristic features include a high content of quartz silt (15–20% of the volume) and a variable presence of carbonate silt. Also the few feldspars and heavy minerals (amphiboles, pyroxenes) are of the silt fraction. The sand fraction is represented by sparse oval clasts of decomposed limestones. Samples TK-188, TK-189, TK-201, TK-219, and TK-223 contain clasts of grey foraminiferous chalk.

The foraminifers contained in the material, *Globigenelloides* sp., *Hedbergella* sp. and *Heterohelix* sp. as well as sea-urchin spines, put its age at Late Cretaceous. Notable is the presence of ferro-manganese concretions in the form of ooliths.

Subgroup II.C (Figs. 135–136)

Cretaceous foraminifers: silty soil + chalk rich in *Globigerinelloides*.
Specimen TK-213, ceramic fragment light-red in colour (5 YR 7/6), massive, made of a soil (rendzina) rich in Cretaceous foraminifers (*Spiroplectinella* sp., *Globigerinelloides*, *Hedbergella*, *Heterohelix*).

In transmitted light the groundmass is light-brown, optically active. In many places there are variously ferro-impregnated red-soil balls and ferro-manganese nodules. Quartz silt can only be found in red soil.

Grains of the sand fraction are those of micritic and biomicritic, less often sparite, limestone as well as single flints.

Petrographic Group III (Figs. 137–138)

Cretaceous dolomitic marl.
Specimen TK-157.

A vessel fired light-red (2.5 YR 7/6), beige on the fracture (5 YR 7/4). Its matrix in transmitted light is mottled light/dark-brown, optically active, rich in numerous small dolomite rhombohedral grains (0.04–0.15 mm in diameter).

The material was enriched with an admixture of pure argillaceous shale fragments, the dispersed par-

Fig. 135. SG.II.C. Fragment of specimen TK-213

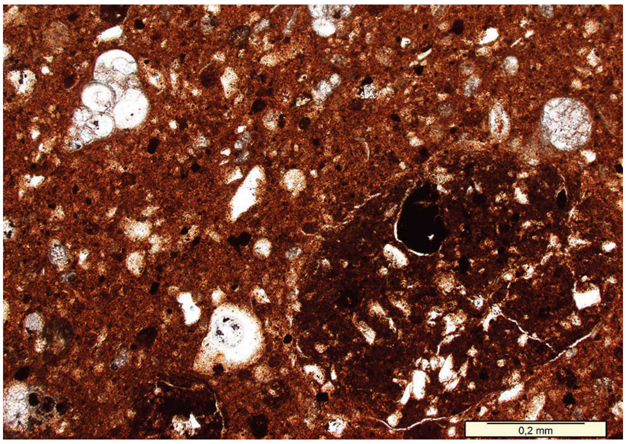


Fig. 136. SG.II.C. Specimen TK-213, photomicrograph of a thin section (PPL)

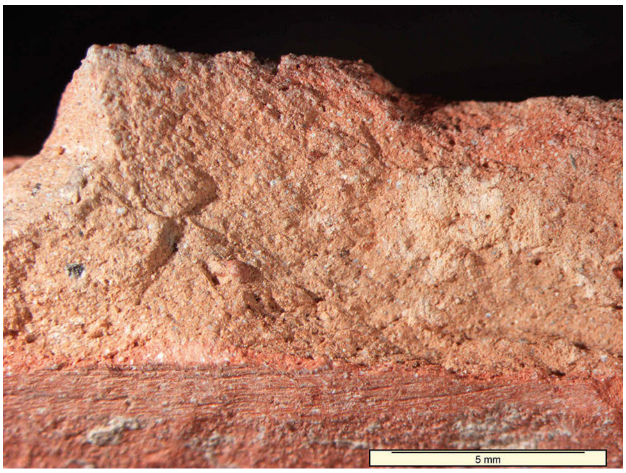


Fig. 137. PG.III. Fragment of specimen TK-157

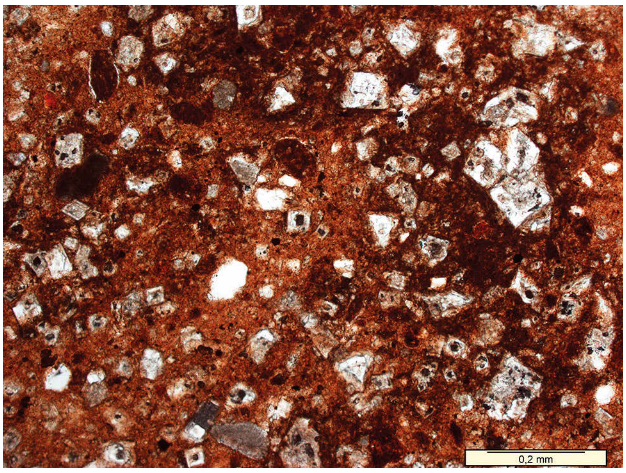


Fig. 138. PG.III. Specimen TK-157, photomicrograph of a thin section (PPL), note fine dolomite crystals

ticles of which are a source of numerous dark-brown pigmented spots as well as oval, less frequently irregular, pellets.

There are also some silty argillaceous balls. Their presence makes the sample especially close to the two Sha'ar-Ha'Amakim amphorae: SE-97 and SF-108.

Petrographic Group IV

'Creamy pottery': chalky marl and *terra rossa* balls or ferruginous argillaceous shale.

Subgroup TK IV.A (Figs. 139–140)

Paleogene pure marl, little red soil admixture.

Sample TK-178 is a vessel creamy-grey in colour (7.5 YR 8/2), massive, containing single grey–cherry-red pellets. The matrix is golden-grey, optically active, very rich in well-preserved foraminifers dating the sediment to the Early Paleogene. The silt content is less than 0.05% of the volume; usually those are grains of feldspar, less often quartz, single amphiboles and pellets of glass. Also present are very scarce, oval brown-grey pellets of silty soil and fine orange-yellow fragments of shales. The sand fraction is represented by clasts of micrite and biomicrite rich in foraminifers (0.8–1.2 mm in diameter), accounting for ca. 10% of the volume.

Fig. 139. SG.IV.A. Fragment of specimen TK178

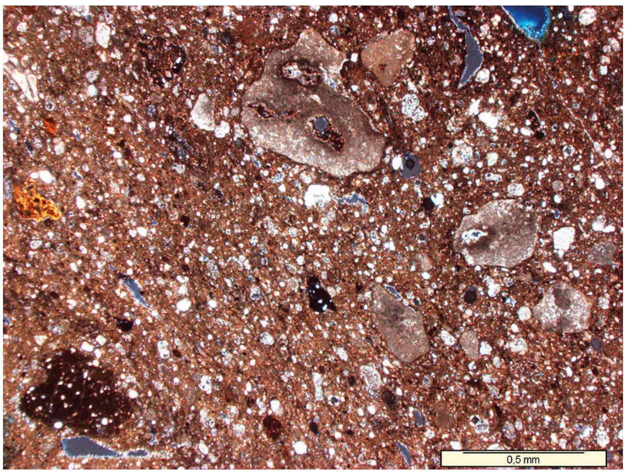


Fig. 140. SG.IV.A. Specimen TK-178: the numerous white spots visible in the groundmass are fine foraminifers (CPL))

Subgroup IV.D (Figs. 141–142)

Paleogene marl + 5–8% quartz sand.

Specimens: TK-158, TK-164, TK-167, TK-168, TK-170, TK-177, TK-181, TK-182, TK-190, TK-198, TK-218, TK-211, TK-212, TK-222(?)[310], TK-251.

A highly uniform subgroup, geochemically separated from subgroups IV.A, IV.H and IV.E.

The samples TK-164, TK-168, TK-170, TK-181, TK-190, TK-198 were uniformly fired to a white colour (10 YR 8/2), while specimens: TK-153, TK-167, TK-170, TK-182, TK-211, and TK-218, are also white on the surface, but pinkish white on the fracture (7.5 YR 8/2). The vessels were fired at various temperatures, which is reflected in the diversified level of anisotropy of their groundmass.

On optical examination the matrix is light-grey with a slight green or grey hue and numerous yellow, brown or dark red spots. Those spots are an effect of the diffusion of iron compounds, very often they cover voids left by the decomposition of skeletal fragments. They also occur as irregular dots and smudges (textural concentration features).

Each sample contains very few small pellets of red soil which have assumed a brown, dark red or black hue, depending on the firing atmosphere conditions.

The presence of foraminifers in the matrix, especially well preserved in less heavily sintered parts, allows determining the age of the material as Paleogene.

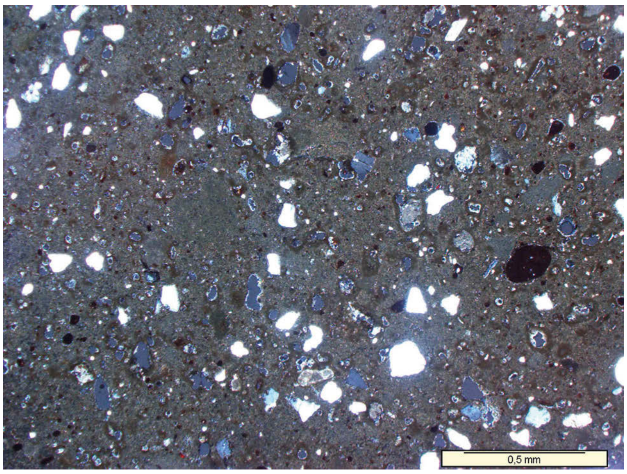


Fig. 141. SG.IV.D. Specimen TK-218, photomicrograph of a thin section (CPL)

310 Sample TK-222 has no quartz sand admixture but a few *terra rossa* pellets. The preserved foraminifers, Hedbergella? and Heterohelix?, may be indicative of the Late Cretaceous.

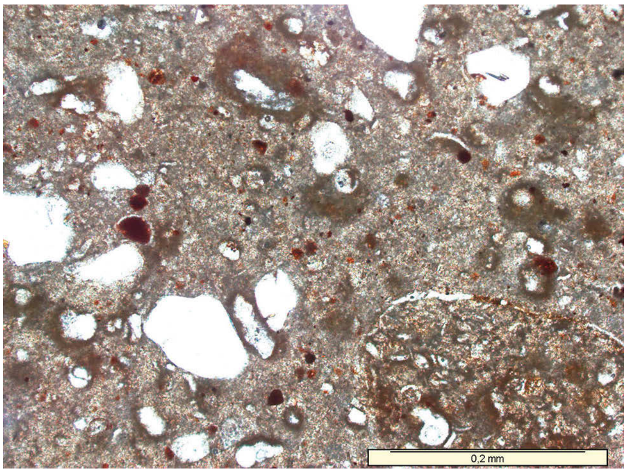


Fig. 142. SG.IV.D. Specimen TK-218, photomicrograph of a thin section at higher magnification (PPL)

The temper makes up 5–8% of the volume. This is almost monomineral sand, poorly rounded, with a dominant fraction of 0.1–0.3 mm in diameter. It is mostly composed of grains of monomineral, less often polymineral, quartz (95%), the remaining 5% going to 'clear' feldspars, twinned polysynthetically, less frequently in a pericline form, and some very fine red iddingsite? fragments.

Subgroup IV.E (Figs. 143–146)

Cretaceous marl plus amorphic clayey soil or slag with 5–8% fine quartz sand.

Specimens: TK-195 (?), TK-200.

The two samples are moderately similar:

Sample TK-195 comes from a vessel made of calcareous soil of unknown age. The sherd is creamy on the surface (7.5 YR 8/3) with a light pink hue, and pink inside (10R 7/6). Its matrix is brownish-red, mottled with milky-grey spots, rich in decomposed microfossils. It contains numerous nodules and angular clasts of isotropic red soil (chamotte?), rich in quartz. Notable are small red fragments (pedogenic?).

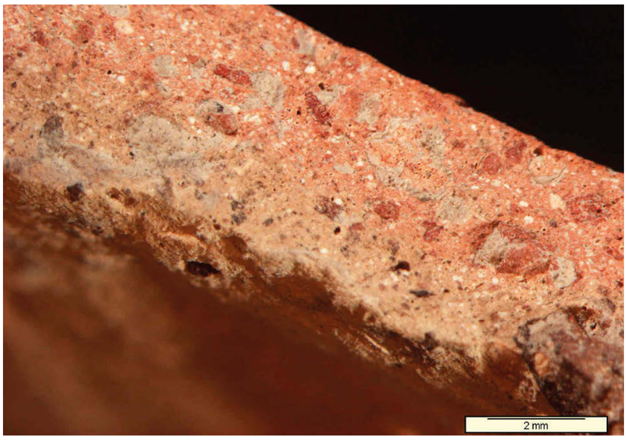


Fig. 143. SG.IV.E. Fragment of specimen TK-195

Sample TK-200 (a counterpart of SBc-24, SBc-28, SBc-33) – Cretaceous marl + clasts of amorphic soil (chamotte?) is a massive creamy sherd (7.5 YR 8/4), with brown amorphous clasts of an admixture em-

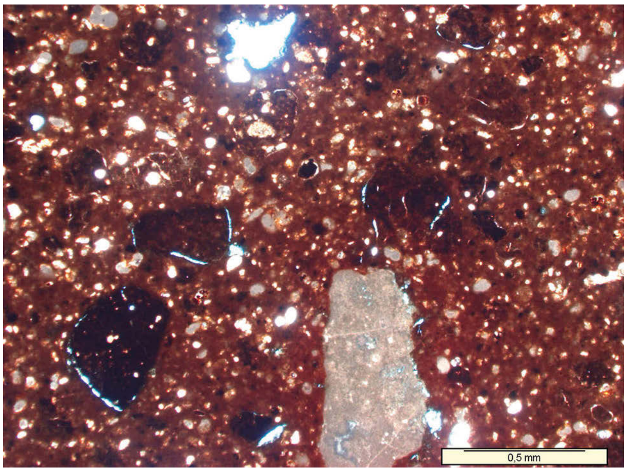


Fig. 144. SG.IV.E. Specimen TK-195, photomicrograph of a thin section (PPL), clasts of isotropic red soil (chamotte?)

Fig. 145. SG.IV.E. Specimen TK-200, photomicrograph of a fresh break

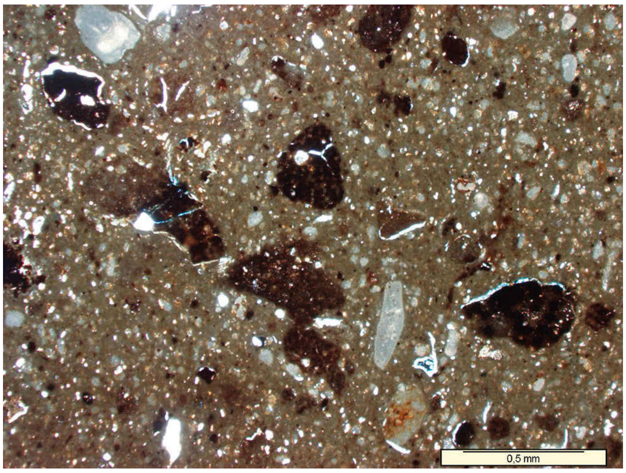


Fig. 146. SG.IV.E. Specimen TK-200, photomicrograph of a thin section (PPL), clasts of isotropic red soil (chamotte?)

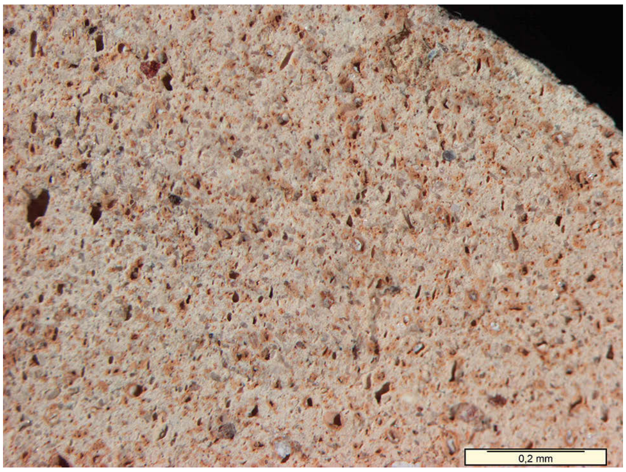


Fig. 147. SG.IV.G. Fragment of specimen TK-183

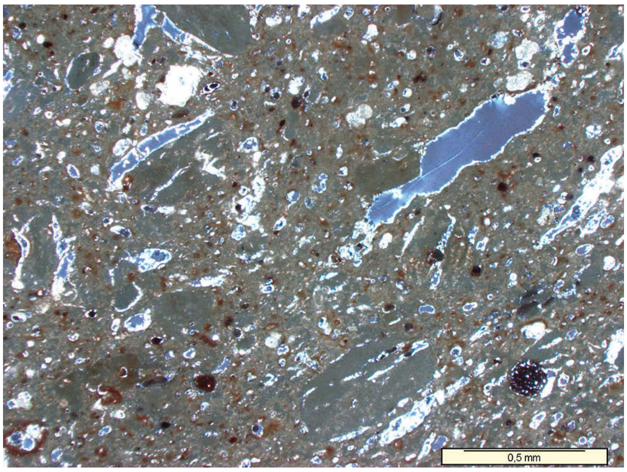


Fig. 148. SG.IV.G. Specimen TK-183, photomicrograph of a thin section (PPL)

bedded in it. Under the microscope, its matrix is yellow-green, inactive, with numerous Fe-coloured light spots of decomposed foraminifer skeletons. The few shells can indicate the Upper Cretaceous as the age of the material. The marly paste is completely devoid of quartz, but rich in numerous pellets of ferric soil heavily sintered in reduced-oxygen conditions. In petrographic terms, the sample is analogous to vessels of the Sha'ar-Ha'makim subgroup IV.E. The differences in colour between the two samples may be due to different atmosphere conditions during the firing of the ceramics.

Subgroup IV.G (present in Tell Keisan only) (Figs. 147–148)

Cretaceous marl.
Specimen TK-183.

Pottery made of Cretaceous marl, white on the surface, light-beige on the fracture. Under the microscope the matrix is light green with red mottles, inactive, with numerous elongated pores and oval pellets of micrite left by decomposed microorganisms. The age can be recognized as Cretaceous, geochemically similar to vessels of subgroup IV.D.

Subgroup IV.H (Figs. 149–152)

Almost pure marl with less than 5% of quartz sand and some red chalk admixture.
Specimens: TK-153; TK-154; TK-161; TK-186.

This subgroup is distinguished because of clasts of ferric chalk; it includes two sets of vessels differing in the colour of the sherd:

(TK-154, TK-161) – creamy-white vessels with grey-green hue on the fracture and numerous voids; and

(TK-153, TK-186) – a creamy-white vessel with light-pink hue on the fracture, massive.

On optical examination, the matrix of the samples TK-154, TK-161 and TK-153 is grey with a green hue, TK-186 yellowish grey, its spots being Fe-coloured to brown, optically slightly active or inactive. The source of those spots are sparse oval clasts and smudges of highly ferric chalk (varying in size, max. 0.2–0.5 mm in diameter) containing nu-

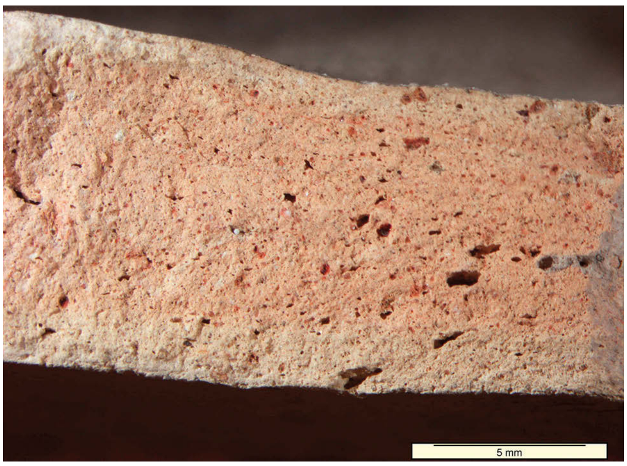


Fig. 149. SG.IV.H. Fragment of specimen TK-153

Fig. 150. SG.IV.H. Fragment of specimen TK-154

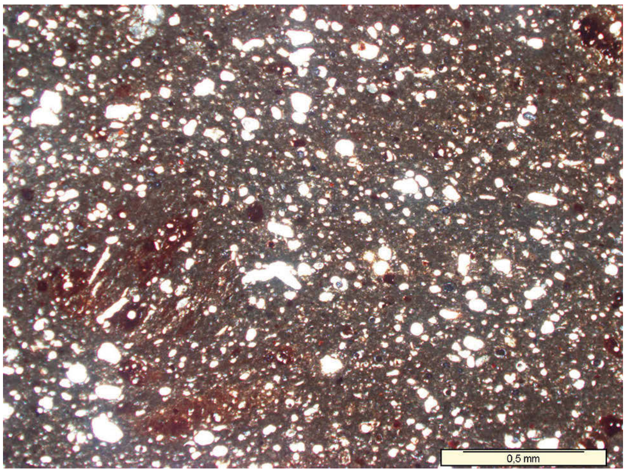


Fig. 151. SG.IV.H. Specimen TK-153, photomicrograph of a thin section (PPL)

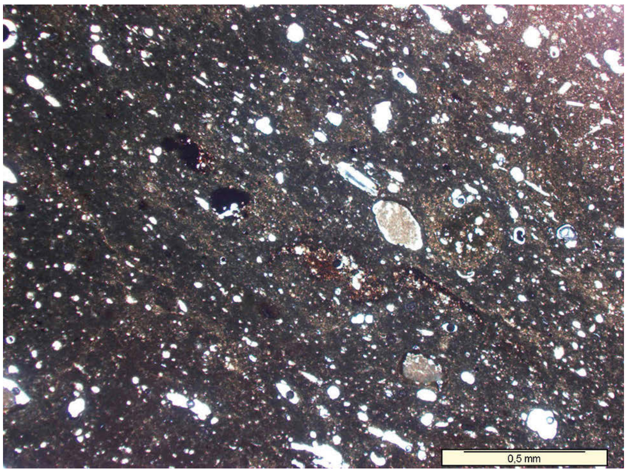


Fig. 152. SG.IV.H. Specimen TK-154, photomicrograph of a thin section (PPL)

merous voids with characteristic serrated contours left by decomposed *Globigerinae* (as in I.A.1., which is also corroborated by geochemistry).

The aplastic admixture is fine-grained monomineral quartz sand, unevenly dispersed in the matrix. Its content is smaller than 5%. It is probable that the ceramics in this group are related to group I.A1, but fired in reduced-oxygen conditions.

Petrographic Group VI

Red sandy soil (*hamra*) with varying amounts of silt + coarse quartz sand.

Subgroup VI.A (Figs. 153–154)

Red sandy soil with redeposited Cretaceous foraminifers.

Specimens: TK-199, TK-205; TK-196; TK-156.

Specimens TK-199 and TK-205 are red (2.5 YR 4/8 – 2.5 YR 5/8). In transmitted light their matrix is brown and dark-brown, optically active, containing 5–8% of quartz silt and numerous carbonate particles occupying the next 5–8% of the area. Relatively numerous foraminifers represent the Upper Cretaceous. TK-199 – *Hedbergellidae*, *Heterohelicidae*; TK-205 – *Preabulimina* sp., *Globigerinelloides* sp., *Heterohelix* sp.

The material is rich in sand (0.5–0.25 mm in diameter) amounting to 20–30% of the volume. Predominant in this fraction is monocrystalline quartz, showing both uniform or undulose light extinction, usually poorly, more rarely moderately rounded. The other few per cent are grains of polysynthetic feldspar, polycrystalline quartz, and coarse oval grains of micritic limestone. Also present are single pisolitic ferro-manganese ooliths.

Specimen **TK-196** – a fragment of uniform pottery, red (2.5 YR 5/6), in transmitted light reddish-brown, made of silty clay rich in quartz silt (30% of the volume). The grains of the sand fraction (0.5–0.4 mm in diameter) make up ca. 10%. Those are mostly grains of monocrystalline, poorly round-

Fig. 153. SG.VI.A. Fragment of specimen TK-199

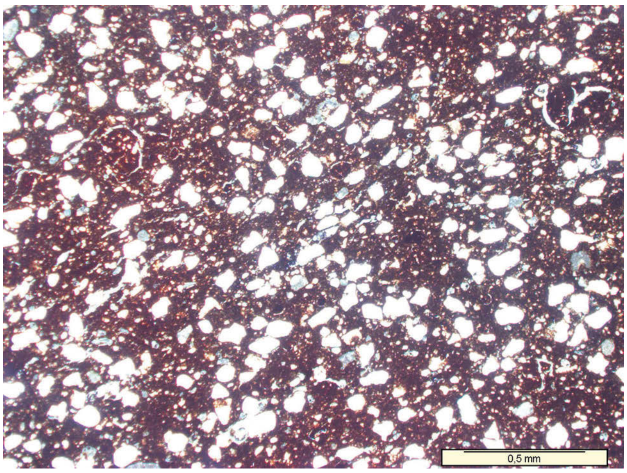


Fig. 154. SG.VI.A. Specimen TK-199, photomicrograph of a thin section (PPL)

ed quartz. Also present are single feldspars, flints and heavy minerals, especially yellow amphiboles, as well as single pisolitic ferro-manganese ooliths.

Specimen **TK-156** is a geochemically different sample, light-red in colour (2.5 YR 7/6). Its matrix is dark-red in transmitted light, rich in fine carbonate silt and some irregular chalk clasts. Its groundmass is also often rich in decomposed foraminifers, *Hedbergellidae* and *Heterohelicidae*, and has a few quartz silt. What distinguishes the sample is a high content of the sand fraction (0.8–0.3 mm in diameter) occupying 30–40% of the volume. In a decided majority those are grains of monocrystalline quartz, usually poorly, less often moderately rounded. Also found are single feldspars or grains of polycrystalline quartz.

Fig. 155. SG.VI.B. Fragment of specimen TK-166

Subgroup VI.B (Figs. 155–156)

Red sandy soil with Eocene foraminifers non-uniform subgroup).

Specimen TK-166 – the sample of a thick-walled vessel fired dark-red (2.5 YR 4/6), heavily sintered, with a uniform fracture and no traces of a tempering admixture. Under the microscope the matrix of the samples is dark reddish brown, almost black, inactive, rich in quartz silt (15–20% of volume), locally with irregular clasts of decomposed chalk. Grains of the sand fraction (0.08–0.25 mm in diameter) make up ca. 20% of the volume. They are mostly poorly rounded, monomineral quartz. Single feldspars show cross-hatched or polysynthetic twinning, usually unaltered. The sample contains sparse *Globigerina* sp.

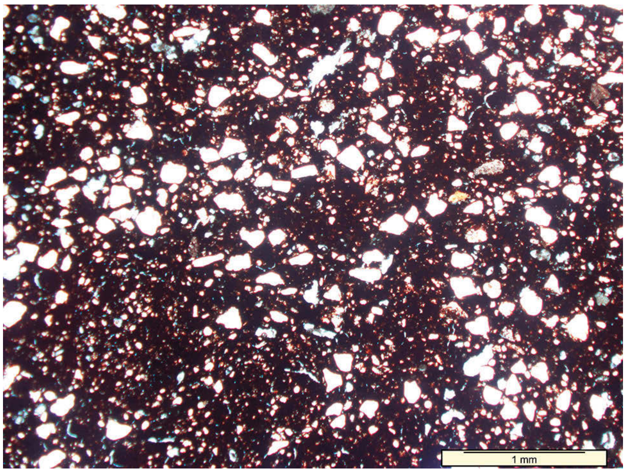


Fig. 156. SG.VI.B. Specimen TK-166, photomicrograph of a thin section (PPL)

Specimen TK-194 – ceramics of mottled light red/light brown colour, light beige on the surface. In transmitted light its matrix is reddish brown, locally black, rich in quartz-carbonate silt (10–15% of the volume). Also single colourless pyroxenes and yellow amphiboles are silt-sized. A characteristic feature is the presence of numerous light-grey clasts of foraminifer chalk, and single clasts of *kurkar* sandstones. Foraminifer shells abound in chalk clasts, they can also be found in the argillaceous groundmass; the predominant species is *Globigerina* from the *praebulloides-officinalis* group (Eocene).

Grains of the sand fraction (0.05–0.45 mm) make up ca. 20% of the volume. In a decided majority they are monocrystalline, angular/subangular quartz. There also appear single feldspars, and even basaltoids.

Subgroup VI.C (Figs. 157–158)

Red sandy soil mixed with Cretaceous/Paleogene foraminifers.

Specimen TK-202 – a light-red vessel (2.5 YR 6/8). In transmitted light its matrix is red, with a small amount of quartz silt and irregularly scattered pellets of ferruginous soil (*terra rossa*?), small clasts of grey chalk, and fragments of algae (*Dasycladacea*?). Numerous foraminifers represent Cretaceous plankton mixed with benthic foraminifers of the Paleogene.

The size-sand temper (0.12–0.4 mm in diameter) accounts for ca. 40% of the volume. Its is mostly

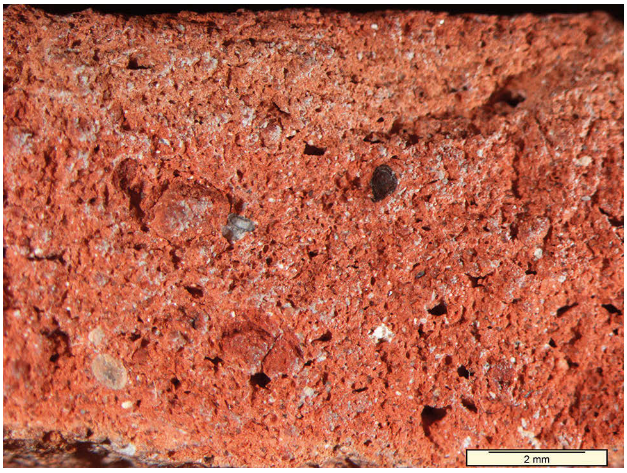


Fig. 157. SG. VI.C. Fragment of specimen TK-202

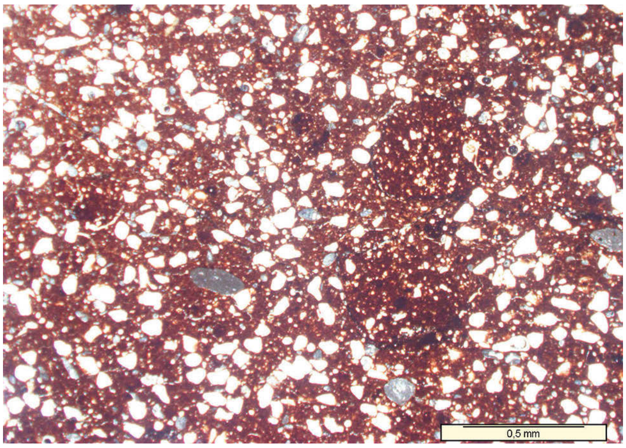


Fig. 158. SG.VI.C. Specimen TK-202, photomicrograph of a thin section (PPL)

composed of grains of monocrystalline quartz, usually poorly and moderately poorly rounded.

Feldspars are few, with yellow amphiboles as accessory minerals.

The Cretaceous/Paleogene age of the foraminifers included in the material shows their presence to be connected with the redeposition of the sediment.

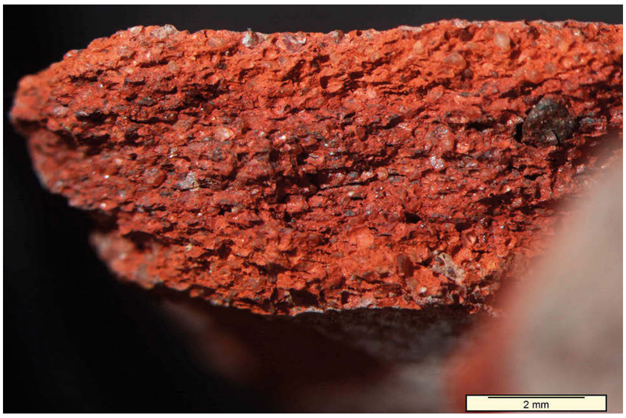


Fig. 159. SG.VI.D. Fragment of specimen TK-155

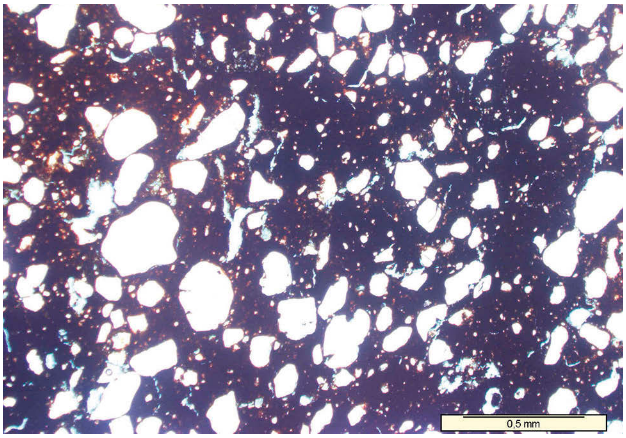


Fig. 160. SG.VI.D. Specimen TK-155, photomicrograph of a thin section (PPL)

Subgroup VI.D (Figs. 159–160)

Red sandy soil devoid of foraminifers.

Specimen TK-155 – a vessel red on the surface (10R 5/8), dark-red inside (10R 3/4), with a characteristic rough cross-section.

The matrix is red, highly ferruginous, optically slightly active, poor in quartz silt (less <5% of the volume), but rich in sand (0.2–0.7 mm in diameter) making up ca. 50% of the volume.

Predominant among grains of the sand fraction is monocrystalline quartz showing uniform light extinction, variably rounded (larger grains are usually better rounded). There are sporadic altered polycrystalline feldspars, or fine-crystal flints.

The vessel shows relatively high porosity (10% of the volume).

Petrographic Group IX (Figs. 161–162)

"Beige pottery" – calcareous clay + limestone grits + fine quartz sand.

Specimens: TK-152, TK-179.

The pottery is beige on the surface, dark-grey on the fracture, containing some white sand-sized grits.

In transmitted light the groundmass is grey with a reddish hue, optically inactive. Numerous voids are partially filled with or covered by decomposed chalk clasts (20% of the volume).

Relatively numerous are also reddish-black or greyish-black iron-rich pellets of various shapes and different quartz silt content. The content of silt in the matrix is less than 2% of the volume. The sand-sized temper consists of angular clasts of, well-sorted fine-sized quartz.

Limestone (3.0–1.3 mm in diameter) makes up 20% of the volume. It contains variously preserved skeletons of Late Eocene foraminifers (0.1–0.25 mm in diameter) accounting for 10–20% of the volume. Quartz is mostly monomineral, angular/ subangular,

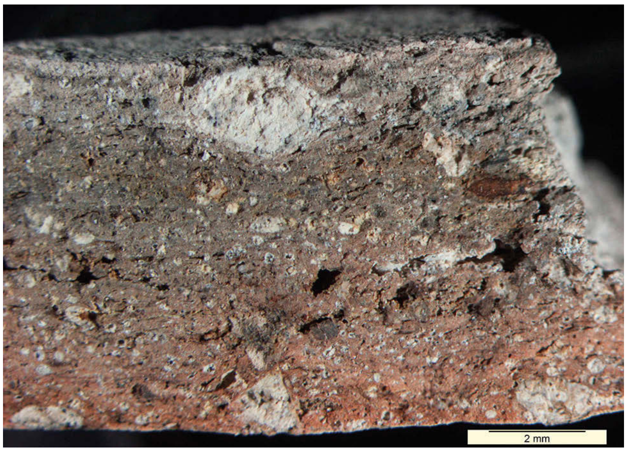


Fig. 161. PG.IX. Fragment of specimen TK-152

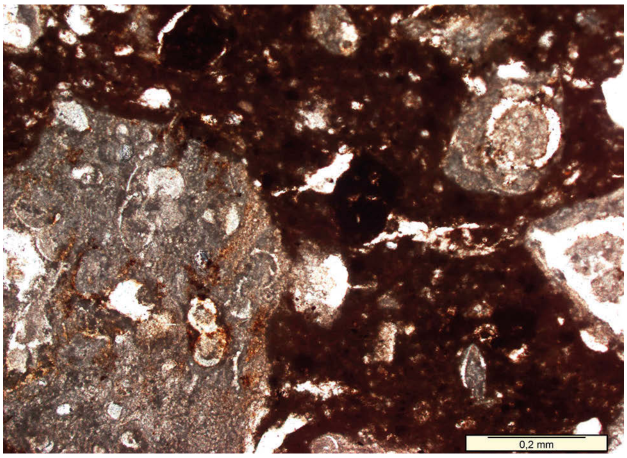


Fig. 162. PG.IX. Specimen TK-152, photomicrograph of a thin section (PPL) – Eocene chalk clasts embedded in an amorphic matrix

usually showing undulose light extinction. There are only a few 'clear' polysynthetically twinned feldspars among sand grains.

Petrographic Group X (Figs. 163–164)

A slightly silty red soil rich in chamotte admixture.
Specimens: TK-210, TK-216.

Thin-walled vessels red in colour (2.5 YR 5/6), rich in the admixture of *terra rossa*, perhaps fired before it had been added. The matrix is heterogeneous, light-orange, mottled dark red. The host is light orange, slightly silty (2% of the volume), inactive. It is mixed with dark-red, optically inactive clayey soil, with some translucent red textural concentration of features which have the form of angular fragments of varying size. They are accompanied by numerous Fe-Mn opaque minerals of various shapes and sizes. The admixture is also sand-sized monocrystalline quartz (10–15% of the volume), and relatively numerous flints. Feldspars appear only rarely; when they do, they are usually thermally altered.

The temper is mostly of the medium-sand fraction (0.1–0.25 mm in diameter), a few grains exceed 1 mm. They are predominantly angular or subangular in shape.

The tempering admixture makes up 10–15% of the volume. This is mostly monocrystalline quartz, accompanied by relatively numerous flints. Feldspars appear only rarely; when they do, they are usually thermally altered.

The grains of the admixture are mostly of the medium-sand fraction (0.1–0.25 mm in diameter), only a few exceed 1 mm. They are predominantly angular or subangular in shape.

Petrographic Group XI (Figs. 165–167)

Clayey shale fragments.
Specimens: TK-163, TK-192, TK-204, TK-206, TK-207, TK-224.

Thin-walled jars light brown/dark grey on the surface, brownish-red on the fracture (2.5YR 7/6).

The matrix is heterogeneous, inactive, brown, brownish-grey, mottled orange-red in colour, slightly silty (5% of the volume), almost devoid of sand-sized particles.

The diagnostic features are numerous massive red clayey shale fragments, elongated or irregular in shape, irregular decomposed chalk fragments, greyish-yellow silty lumps, and reddish-black Fe/Mn pisolites in which some quartz silt grains are embedded. Also diagnostic for this group are exotic clasts of quartzite mudstones. Geochemically, the group stands out from the others.

The absence of microfossils makes it impossible to determine the age of the material. The presence of fragments of fine-grained quartzite sandstones and

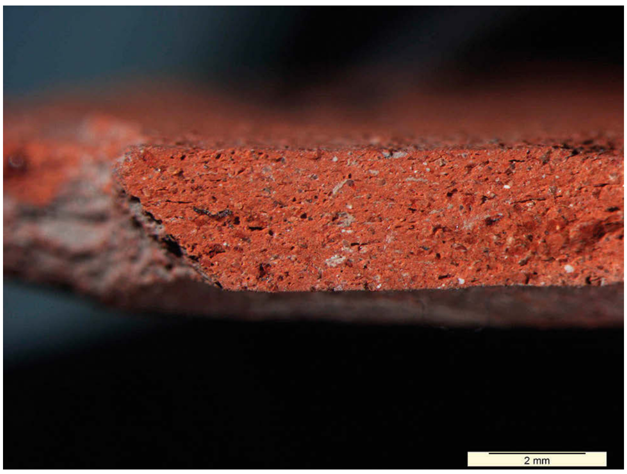


Fig. 163. PG.X. Fragment of specimen TK-210

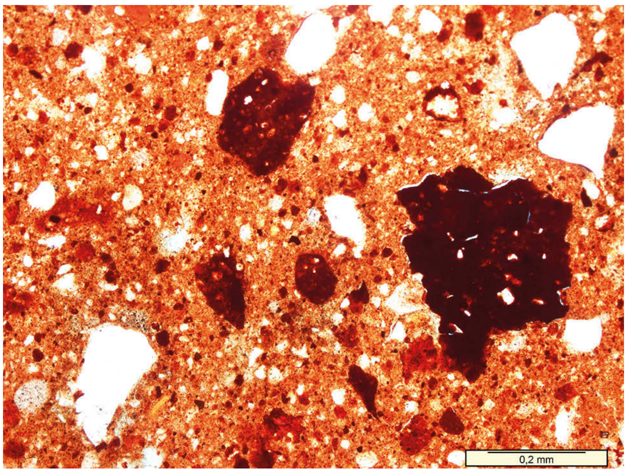


Fig. 164. PG.X. Specimen TK-210, photomicrograph of a thin section – angular fragments of chamotte (PPL)

shales can suggest its connection with the Lower Cretaceous.[311]

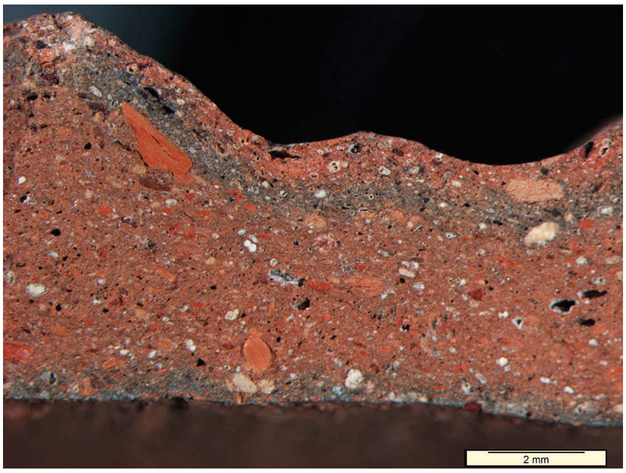


Fig. 165. PG.XI. Fragment of specimen TK-206

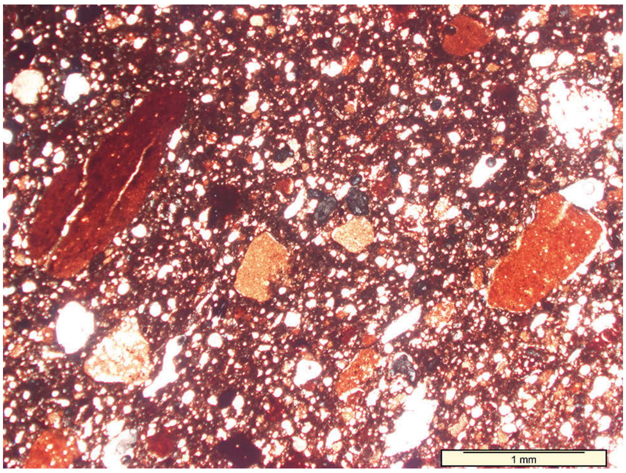


Fig. 166. PG.XI. Specimen TK-206, photomicrograph of a thin section – note red clayey shale fragments (PPL)

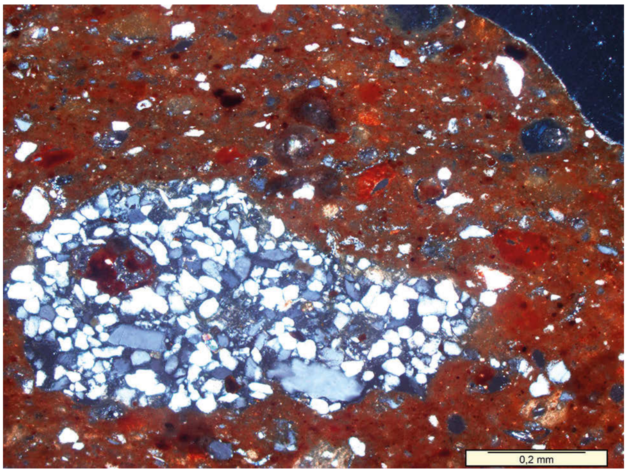


Fig. 167. PG.XI. Specimen TK-206, photomicrograph of a thin section at higher, magnification; a fragment of quartzite siltstone (CPL)

[311] Cf. Goren 1995, Greenberg Porat 1999, Choen-Wienberger&Goren 2011.

Unassigned ceramics (Figs. 168–173)

Specimen TK-180 (rich in diabase).

A ceramic fragment light-red on the surface (2.5 YR 7/6), light-brown on the fracture, with just a few small dark spots of the sand fraction.

Under the microscope, the matrix is reddish-grey, with densely spaced planar voids, optically inactive, devoid of quartz silt. It contains scattered foraminifer shells, unidentifiable because of the high temperature of firing.

The sand fraction contains grains of monocrystalline quartz (0.1–0.3 mm in diameter) and much bigger, irregular clasts of volcanic rock (0.8–2.0 mm in diameter), micritic limestones and flints. Most volcanic rocks have a diabasic texture created by automorphic, polysynthetically twinned plagioclases and by xenomorphic, slightly pinkish pyroxenes exhibiting no pleochroism, less often oxidised products of the transformation of olivines or amphiboles.

Fig. 168. Unassigned ceramics. Fragment of specimen TK-180

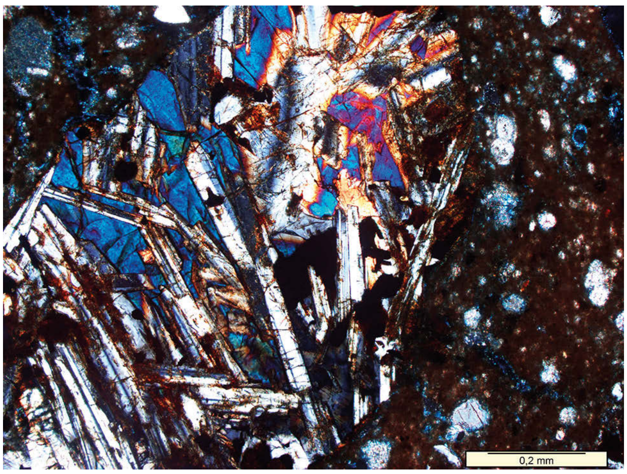


Fig. 169. Unassigned ceramics. Specimen TK-180, photomicrograph of a thin section (CPL) – fragment of dolerite

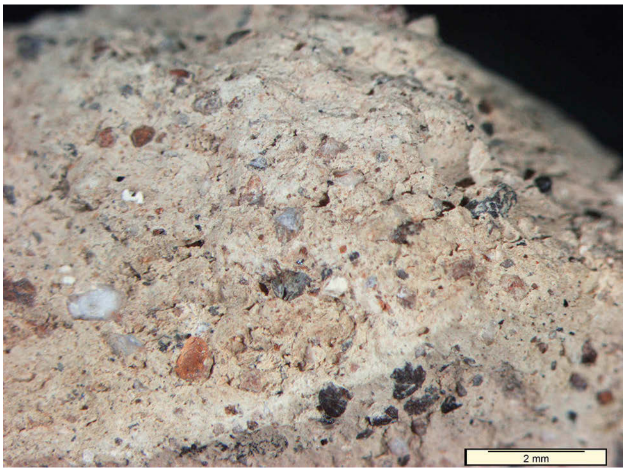


Fig. 170. Unassigned ceramics. Specimen TK-184

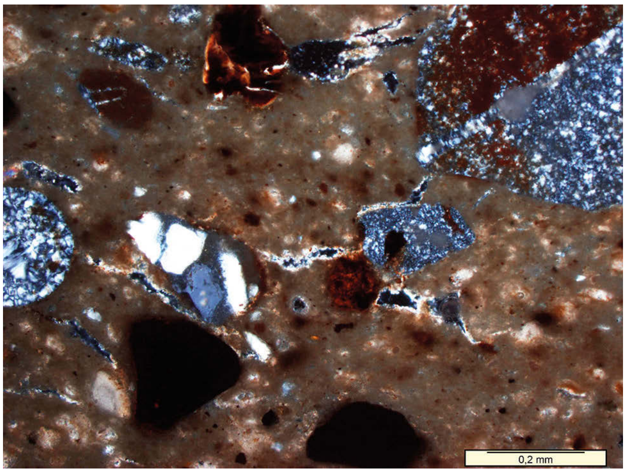


Fig. 171. Unassigned ceramics. Specimen TK-184, photomicrograph of a thin section – note numerous chert fragments (CPL)

Also present are grains of basaltoids in which thin strips of plagioclases are embedded in a black opaque aphanitic groundmass. Both pyroxenes and plagioclases occur in the form of monocrystals dispersed in an argillaceous matrix. Notable is the presence of iddingsite.

Age: unknown.

Specimen TK-184 (rich in cherts) – a vessel white-grey in colour (2.5 YR 5/6), containing numerous fine dark grits.

On optical examination the groundmass is grey-green, 'dense', locally pigmented by iron oxides containing pseudomorphoses of planktonic foraminifers ex gr *Spumellaria* representing the Paleogene (?), often forming oval ferro-manganese nodules.

What makes this sample unique among the other ones in this set is the admixture of angular fragments of flints as well as fine (less than 0.2 mm) pyroxenes and red olivines (?). Chemically, it is close to group IV, but it is statistically significantly different from it.

Age: unknown, Paleogene?

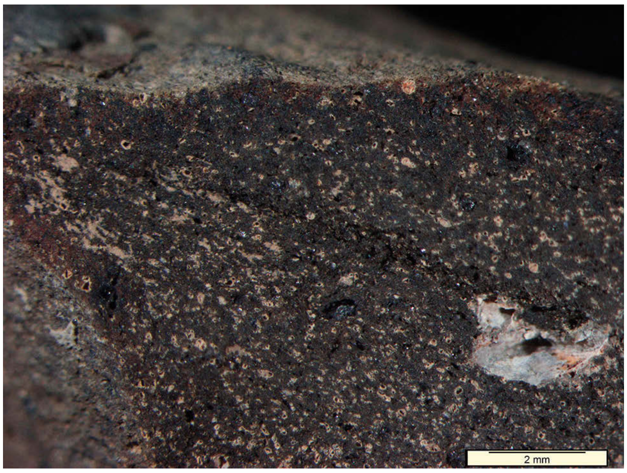


Fig. 172. Unassigned ceramics. Fragment of specimen TK-215

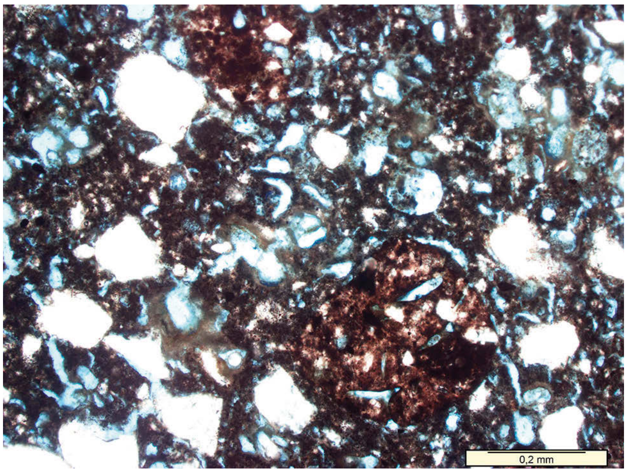


Fig. 173. Unassigned ceramics. Specimen TK-215, photomicrograph of a thin section (PPL)

Specimen TK-215

The matrix is grey-black (7.5 YR 2.5/1), in near-surface parts red-black, completely isotropic, with a dense network of small vermiform voids with blurred yellowish contours. Its content of quartz silt does not exceed 1% of the volume.

Sand-sized inclusions make up ca. 15% of the volume. Those are mostly grains of monocrystalline quartz, angular in shape, of the 0.1–0.25 mm fraction. Polysynthetically twinned plagioclases are very rare.

Age: unknown.

6.5. Tell Keisan chemical database

The chemical INAA, ICP data of Tell Keisan ceramics are presented in Table 9.

Calculations were performed in accordance with the same procedure employed for the Sha'ar-Ha'Amakim ceramics. In the calculations use was made of

Table 9. Chemical INAA and ICP data of Tell Keisan ceramics

Analyte	Au	Ag	Cu	Cd	Mo	Pb	Ni	Zn	S	Al	As	Ba	Be	Bi	Br	Ca	Co	Cr	Cs	Eu	Fe	Hf	Hg	Ir	K	Li
Unit	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	%	ppm
Detection limit	2	0.3	1	0.3	1	3	1	1	0.01	0.01	0.5	50	1	2	0.5	0.01	1	2	1	0.2	0.01	1	1	5	0.01	1
Analysis method	INAA	INAA / TD-ICP	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA / TD-ICP	INAA / TD-ICP	TD-ICP	TD-ICP	INAA	INAA	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	TD-ICP	TD-ICP
TK-152	< 2	< 0.3	29	< 0.3	< 1	10	76	92	0.15	5.58	12.9	770	2	< 2	11.7	11.2	21	138	< 1	2.3	3.71	6	< 1	< 5	1.53	18
TK-153	< 2	< 0.3	25	0.5	< 1	12	51	100	0.15	7.08	6	440	2	< 2	4.6	16.8	12	114	7	1.8	3.33	3	< 1	< 5	1.47	38
TK-154	< 2	< 0.3	25	0.7	< 1	11	61	117	0.14	8.36	6.6	500	2	< 2	3.6	14.6	15	140	9	2.6	3.96	3	< 1	< 5	1.73	38
TK-155	< 2	< 0.3	28	< 0.3	< 1	15	83	73	< 0.01	6.39	9.8	320	2	< 2	< 0.5	1.08	28	149	2	2.5	5.15	7	< 1	< 5	0.46	28
TK-156	8	< 0.3	78	0.4	1	6	80	120	0.09	4.31	16	410	1	< 2	4	14	13	167	< 1	1.4	2.82	2	< 1	< 5	0.49	18
TK-157	< 2	< 0.3	21	< 0.3	< 1	4	36	52	0.09	5.68	8.4	380	1	< 2	4.4	13.6	11	90	2	0.9	3.18	2	< 1	< 5	1.2	17
TK-158	< 2	< 0.3	51	0.6	< 1	6	92	103	0.23	4.26	6.1	1040	1	< 2	8.5	16.2	12	121	< 1	1.8	2.69	2	< 1	< 5	1.16	18
TK-159	< 2	< 0.3	30	0.5	2	9	51	79	0.04	5.51	6.4	410	2	< 2	2.3	5.53	14	99	2	1.4	3.51	4	< 1	< 5	1.12	17
TK-160	< 2	< 0.3	44	1.2	3	10	64	127	0.08	6.99	7.2	460	2	< 2	6.8	13.3	9	136	< 1	2	3.48	3	< 1	< 5	1.67	34
TK-161	< 2	0.4	30	0.8	< 1	12	65	126	0.15	8.69	6.1	580	2	< 2	6.3	14	15	155	< 1	2.3	4.29	3	< 1	< 5	1.65	39
TK-162	< 2	< 0.3	38	1	4	12	72	129	0.09	8.3	10.2	310	3	< 2	4.2	13.3	13	169	< 1	2.1	4.27	3	< 1	< 5	2.23	53
TK-163	< 2	0.4	21	0.4	2	18	73	156	0.05	10.5	7.2	320	3	< 2	< 0.5	5.63	27	224	3	3	4.63	19	< 1	< 5	1.27	110
TK-164	< 2	< 0.3	38	< 0.3	< 1	5	82	111	0.13	4.35	6.8	1090	1	< 2	6.6	20.8	12	184	2	1.2	2.65	2	< 1	< 5	0.67	20
TK-165	< 2	< 0.3	35	0.7	2	10	57	102	0.1	7.16	7.9	460	2	< 2	4.2	14.8	12	138	< 1	1.5	3.55	2	< 1	< 5	1.64	31
TK-166	< 2	< 0.3	34	0.7	2	16	81	87	0.03	7.38	9	350	2	< 2	3.4	4.18	29	173	2	2.5	5.16	10	< 1	< 5	1.13	32
TK-167	< 2	< 0.3	40	0.5	< 1	7	99	108	0.17	4.72	7.2	1470	1	< 2	5.2	18.4	15	175	2	2	2.72	3	< 1	< 5	0.93	20
TK-168	< 2	0.4	55	0.3	2	4	104	142	0.15	5.27	13.8	900	1	< 2	4.3	18.2	16	232	< 1	1.9	3.26	3	< 1	< 5	0.85	26
TK-169	< 2	< 0.3	32	0.9	3	8	49	89	0.12	4.86	5.5	630	2	< 2	6.6	18.4	8	102	2	1.2	2.4	2	< 1	< 5	1.41	25
TK-170	< 2	0.5	42	0.5	< 1	7	72	82	0.21	3.7	5.6	1170	< 1	< 2	5.8	19.2	9	118	< 1	1.4	2.1	2	< 1	< 5	0.82	19
TK-171	< 2	0.5	25	< 0.3	2	5	42	59	0.14	4.14	8.4	940	1	< 2	5.3	19	10	127	< 1	1.3	2.32	4	< 1	< 5	1.45	12
TK-172	< 2	< 0.3	26	0.6	2	10	52	97	0.11	7.24	5.8	510	2	< 2	2.8	14.3	12	118	6	1.6	3.38	2	< 1	< 5	1.57	37
TK-173	< 2	0.3	41	0.7	3	9	43	96	0.1	6.44	5.2	560	2	< 2	3.2	14.3	7	97	2	1.4	2.98	2	< 1	< 5	1.83	26
TK-174	< 2	< 0.3	35	0.5	2	11	82	100	0.07	7.71	8.2	250	2	< 2	4.3	10.4	28	194	2	2.2	5.08	8	< 1	< 5	1.14	27
TK-175	< 2	< 0.3	41	0.9	5	8	58	136	0.09	7.24	5.5	440	2	< 2	5.9	14.2	11	116	4	1.8	3.33	3	< 1	< 5	1.63	33
TK-176	< 2	0.3	39	0.7	3	9	52	105	0.12	5.99	7.6	720	2	< 2	5.1	15.8	9	103	< 1	1.3	3.05	2	< 1	< 5	1.85	25
TK-177	< 2	< 0.3	46	< 0.3	< 1	< 3	101	130	0.2	4.45	7.8	540	1	< 2	10	19.4	9	216	1	1.8	2.43	3	< 1	< 5	0.74	19
TK-178	< 2	0.5	41	0.4	2	6	72	90	0.25	4.49	4	5100	1	< 2	7.8	14.1	14	130	< 1	1.3	2.43	6	< 1	< 5	1.3	14
TK-179	< 2	0.4	31	< 0.3	< 1	7	76	75	0.19	5.16	4.6	2790	1	< 2	13.5	12.4	23	108	< 1	1.5	3.59	6	< 1	< 5	1.19	21
TK-180	< 2	0.4	30	2.2	< 1	6	88	100	0.11	4.97	4.4	1150	1	< 2	4.1	16.9	21	123	< 1	0.8	3.86	3	< 1	< 5	1.18	16
TK-181	< 2	< 0.3	45	< 0.3	< 1	< 3	89	110	0.13	4.39	6.7	1700	1	< 2	5.7	18.8	16	180	< 1	1.2	2.63	4	< 1	< 5	0.73	22
TK-182	< 2	< 0.3	52	< 0.3	2	< 3	120	150	0.09	5.48	7.4	1600	2	< 2	10.9	12.9	16	214	< 1	1.4	3.33	5	< 1	< 5	1.14	23
TK-183	< 2	< 0.3	44	< 0.3	1	< 3	85	109	0.16	5.25	10.4	2040	1	< 2	5.2	22.1	11	205	3	1.2	2.74	2	< 1	< 5	0.94	25
TK-184	< 2	0.4	47	< 0.3	< 1	7	201	92	0.14	4.48	8.1	810	1	< 2	6.6	15.2	35	4530	< 1	1.1	3.49	< 1	< 1	< 5	0.79	20
TK-185	< 2	< 0.3	34	1	3	11	64	116	0.11	7.01	6.5	590	2	< 2	4.6	13.9	10	135	7	1.4	3.32	3	< 1	< 5	2.15	35
TK-186	< 2	0.4	31	0.4	< 1	9	47	100	0.15	7.32	5.6	620	2	< 2	< 0.5	16.8	12	119	5	1.2	3.24	4	< 1	< 5	1.87	36
TK-187	< 2	0.3	21	< 0.3	2	6	40	62	0.11	4.53	7.6	460	1	< 2	9.5	16.1	14	111	< 1	1	2.94	5	< 1	< 5	1.68	11
TK-188	< 2	0.3	38	0.5	1	7	70	86	0.09	5.97	11.8	370	2	5	< 0.5	10.5	28	178	< 1	1.7	4.9	7	< 1	< 5	1.07	26
TK-189	< 2	< 0.3	36	0.3	< 1	12	90	106	0.04	7.6	11.9	590	2	< 2	7.7	7.72	34	242	4	2	5.98	13	< 1	< 5	1.12	30
TK-190	< 2	0.4	42	< 0.3	< 1	7	95	108	0.12	4.11	8.1	1040	1	< 2	8.8	16.5	11	185	< 1	1.3	2.47	3	< 1	< 5	0.93	17
TK-191	< 2	0.8	29	0.6	< 1	10	58	108	0.12	8.03	5.1	520	2	< 2	< 0.5	14.9	13	122	9	1.3	3.52	3	< 1	< 5	1.88	41
TK-192	< 2	< 0.3	23	< 0.3	2	14	87	93	0.05	12.3	10.7	340	3	< 2	4.8	7.21	24	188	7	1.9	4.32	7	< 1	< 5	1.34	124
TK-193	< 2	< 0.3	40	0.7	< 1	13	52	108	0.12	7.26	6.9	740	2	< 2	8.3	14	16	122	5	1.5	3.61	4	< 1	< 5	1.75	31
TK-194	3	< 0.3	40	0.6	2	13	74	97	0.05	6.88	8.6	710	2	< 2	6.6	8.07	26	168	2	1.5	4.64	9	< 1	< 5	1.14	28
TK-195	< 2	0.3	39	0.4	2	6	70	91	0.13	7.21	18.8	500	2	< 2	< 0.5	17.2	12	143	7	1	3.65	3	< 1	< 5	1.95	26
TK-196	< 2	< 0.3	32	0.3	1	13	75	91	0.05	6.51	9.1	690	2	< 2	3.9	5.45	32	158	3	1.5	4.34	14	< 1	< 5	1.12	19
TK-197	< 2	0.3	37	0.5	< 1	8	48	90	0.12	5	6.3	800	1	< 2	6.2	16.1	16	94	< 1	1	3.38	4	< 1	< 5	1.24	13
TK-198	< 2	< 0.3	33	< 0.3	< 1	< 3	93	102	0.14	4.36	4.8	1960	1	< 2	7.8	19.5	13	181	< 1	1.6	2.68	3	< 1	< 5	0.74	21
TK-199	< 2	< 0.3	35	0.4	3	8	70	90	0.05	6.18	6.7	570	2	< 2	9.4	8.36	18	141	< 1	1.4	4.05	6	< 1	< 5	1.23	15
TK-200	< 2	< 0.3	37	0.4	1	5	63	88	0.11	6.39	14.6	1200	2	< 2	3.3	17.3	10	144	6	0.7	3.08	3	< 1	< 5	1.6	22
TK-201	< 2	0.5	25	0.3	< 1	15	82	75	0.05	12.2	13	320	3	< 2	3.8	7.13	29	175	7	2.3	5.79	8	< 1	< 5	1.63	96
TK-202	< 2	< 0.3	39	0.5	2	11	74	103	0.05	6.18	6.6	610	2	< 2	5.5	8.33	24	176	< 1	1.4	4.35	7	< 1	< 5	1.1	16
TK-203	< 2	< 0.3	46	1	2	9	60	133	0.08	6.96	7	310	2	< 2	5.7	13.4	10	114	5	1.3	3.31	4	< 1	< 5	1.86	30
TK-204	< 2	0.4	35	< 0.3	2	21	91	160	0.03	13.1	9.8	350	3	< 2	4.7	4.26	29	215	6	2.4	4.44	9	< 1	< 5	1.49	109
TK-205	< 2	< 0.3	35	< 0.3	3	11	65	89	0.04	5.96	10.2	490	2	< 2	4	5.21	23	121	< 1	1.5	4.06	7	< 1	< 5	1.45	17
TK-206	< 2	< 0.3	25	< 0.3	2	16	83	108	0.04	12.4	9.8	410	3	< 2	< 0.5	5.66	30	209	6	2.1	4.67	9	< 1	< 5	1.41	119
TK-207	< 2	0.4	38	< 0.3	3	13	82	98	0.07	5.59	13.6	490	2	7	< 0.5	7.9	30	184	< 1	1.9	5.12	13	< 1	< 5	1.04	31
TK-208	10	0.3	36	0.8	1	13	69	109	0.08	7.69	8.2	360	2	< 2	4	13.5	12	136	6	1.2	3.84	4	< 1	< 5	1.63	35
TK-209	< 2	< 0.3	41	1	2	11	67	119	0.09	8.16	10.5	370	3	< 2	5.4	14	15	154	5	1.7	3.97	4	< 1	< 5	1.55	47
TK-210	< 2	< 0.3	28	< 0.3	1	18	91	101	< 0.01	10.4	23.5	< 50	2	< 2	< 0.5	0.64	22	223	4	1.6	6.05	11	< 1	< 5	0.77	22
TK-211	< 2	0.5	33	0.5	< 1	6	75	90	0.21	3.71	5.4	1230	1	< 2	7.6	19.4	13	141	< 1	1	2.12	3	< 1	< 5	0.67	17
TK-212	< 2	< 0.3	39	1.2	3	8	67	121	0.08	7.28	7	760	3	< 2	< 0.5	12.5	10	139	5	1.3	3.51	3	< 1	< 5	1.75	35
TK-213	< 2	< 0.3	40	0.5	2	15	90	108	0.08	7.07	10.8	1110	2	< 2	< 0.5	12.3	30	210	< 1	1.5	4.97	9	< 1	< 5	1.15	21
TK-214	< 2	< 0.3	136	0.7	< 1	11	52	104	0.13	7.58	4.3	530	2	< 2	< 0.5	16.2	14	121	3	1.4	3.47	3	< 1	< 5	1.73	38
TK-215	< 2	0.4	51	< 0.3	4	7	113	136	0.06	9.1	13.9	490	3	< 2	6.7	8.75	29	221	5	2.1	5.98	8	< 1	< 5	1.24	38
TK-216	< 2	< 0.3	35	< 0.3	1	18	92	87	< 0.01	11.2	10.2	< 50	2	< 2	< 0.5	0.47	15	233	9	1.5	5.73	9	< 1	< 5	0.64	27
TK-217	< 2	< 0.3	24	0.6	1	9	46	89	0.1	6.52	7.8	570	2	< 2	< 0.5	11.9	9	101	< 1	1	3.02	2	< 1	< 5	1.45	26
TK-218	< 2	< 0.3	40	0.4	2	5	88	111	0.18	4.04	8.5	1730	1	< 2	6.8	17.2	10	185	< 1	1.1	2.67	3	< 1	< 5	0.91	19
TK-219	< 2	< 0.3	39	0.5	3	14	88	104	0.04	7.65	13.6	550	2	< 2	< 0.5	5.26	33	232	< 1	2.1	5.89	17	< 1	< 5	1.22	32
TK-220	7	0.4	36	1	3	10	75	131	0.08	7.97	8.3	610	3	< 2	6.6	11.7	11	155	< 1	1.3	3.8	5	< 1	< 5	1.98	40
TK-221	< 2	< 0.3	38	1.2	3	12	72	122	0.12	8.01	9	390	3	< 2	5.8	14.8	11	154	< 1	1	3.91	5	< 1	< 5	2	48
Tk-222	6	< 0.3	43	0.5	1	7	125	131	0.15	3.89	12	780	1	< 2	9.7	19.7	13	190	< 1	1.1	2.59	2	< 1	< 5	0.88	17
TK-223	< 2	< 0.3	49	< 0.3	< 1	12	91	113	0.05	8.03	8.1	500	2	< 2	8.2	7.04	28	207	5	1.7	5.68	14	< 1	< 5	1.22	35
TK-224	< 2	0.4	27	2.6	1	8	57	106	0.1	8.06	10.7	< 50	2	< 2	33.6	8.22	17	145	7	1.6	5.23	7	< 1	< 5	2.16	42
TK-251	< 2	< 0.3	55	< 0.3	< 1	< 3	90	140	0.18	3.97	6.2	310	1	< 2	12.1	17.4	12	168	2	1.3	2.32	2	< 1	< 5	0.87	18

Table 9. cont.

Analyte	Mg	Mn	Na	P	Rb	Sb	Sc	Se	Sr	Ta	Ti	Th	U	V	W	Y	La	Ce	Nd	Sm	Sn	Tb	Yb	Lu	Mass
Unit	%	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	g
Detection limit	0.01	1	0.01	0.001	15	0.1	0.1	3	1	0.5	0.01	0.2	0.5	2	1	1	0.5	3	5	0.1	0.01	0.5	0.2	0.05	
Analysis method	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
TK-152	1.35	866	0.92	0.117	68	0.5	13.1	< 3	517	< 0.5	0.23	7.3	3.7	105	< 1	35	43	75	60	7	< 0.01	< 0.5	3.5	0.12	1.31
TK-153	1.05	135	0.4	0.157	109	0.7	12.1	< 3	514	< 0.5	0.35	9.4	4	64	< 1	22	42.2	77	31	6	< 0.01	2.6	2.4	< 0.05	1.16
TK-154	1.05	153	0.43	0.16	149	1.1	14.4	< 3	512	< 0.5	0.47	12.8	4.1	96	< 1	28	50.9	91	61	7.7	< 0.01	1.7	2.9	0.06	1.12
TK-155	0.53	691	0.14	0.02	< 15	0.9	14	< 3	72	< 0.5	0.07	9	2	23	< 1	36	46.3	94	49	7.9	< 0.01	1.1	3.5	0.16	1.35
TK-156	0.31	328	0.13	0.228	47	1	9.1	< 3	392	< 0.5	0.18	4	5.2	79	< 1	25	25.5	51	23	4.4	< 0.01	1.8	2.2	< 0.05	1.31
TK-157	2.79	175	0.13	0.068	51	0.3	11.3	< 3	148	< 0.5	0.28	4.1	3.1	86	< 1	9	15.3	32	14	2.6	< 0.01	< 0.5	1.3	< 0.05	1.08
TK-158	1.92	301	0.29	0.362	< 15	0.7	11.5	< 3	419	< 0.5	0.08	4.5	5.1	75	< 1	44	34.5	41	32	5.7	< 0.01	< 0.5	3.2	0.08	1.11
TK-159	0.5	438	0.29	0.098	72	0.8	10.7	< 3	213	< 0.5	0.29	7.4	2	60	< 1	22	27.7	57	47	4.9	< 0.01	< 0.5	2.5	0.15	1.35
TK-160	0.93	232	0.17	0.223	121	1.7	11.8	< 3	332	< 0.5	0.23	10.1	4.4	118	< 1	26	40.7	72	43	6.3	< 0.01	2	2.4	< 0.05	1.07
TK-161	1.07	143	0.54	0.167	145	0.8	14.9	< 3	509	< 0.5	0.48	13.4	3.8	99	< 1	29	49.6	92	54	7.9	< 0.01	1.9	3	0.05	1.19
TK-162	1.13	147	0.19	0.328	183	2.1	14	< 3	355	< 0.5	0.31	11.1	4.7	166	< 1	28	46.8	88	41	7.3	< 0.01	1.8	3	< 0.05	1.32
TK-163	0.76	318	0.19	0.131	77	0.6	20.9	< 3	265	3.4	0.31	15.1	5.1	46	< 1	30	61.9	125	84	9.1	< 0.01	2.2	5.2	0.21	1.19
TK-164	1.33	442	0.41	0.347	< 15	0.9	10.5	< 3	582	< 0.5	0.1	4.4	3.6	67	< 1	34	30.8	41	45	4.8	< 0.01	< 0.5	2.9	< 0.05	1.23
TK-165	0.88	181	0.14	0.251	32	1.6	12	< 3	332	< 0.5	0.34	9.7	4.7	122	< 1	26	40.6	79	29	6.3	< 0.01	1.5	2.6	< 0.05	1.03
TK-166	0.77	1150	0.33	0.078	90	1	15.4	< 3	159	2.3	0.17	10.1	3	37	< 1	32	44.1	100	46	7.9	< 0.01	2	3.8	0.17	1.68
TK-167	1.14	379	0.32	0.442	44	1	12	< 3	571	< 0.5	0.07	4.7	5.5	82	< 1	44	33.4	41	39	5.5	< 0.01	< 0.5	3.3	0.07	1.08
TK-168	1	393	0.36	0.485	68	1.5	12.8	< 3	551	< 0.5	0.2	5.6	5.8	96	< 1	36	32.2	54	39	5.6	< 0.01	< 0.5	3.2	0.07	1.01
TK-169	0.68	119	0.12	0.139	35	1	8.3	< 3	506	< 0.5	0.2	7	5.6	72	< 1	21	26	53	25	4.2	< 0.01	< 0.5	1.9	< 0.05	1.06
TK-170	1.54	332	0.23	0.293	< 15	0.7	9.2	< 3	465	< 0.5	0.07	3.8	3.7	61	< 1	33	25.3	37	34	4.4	< 0.01	1.9	2.4	< 0.05	1.2
TK-171	0.54	449	0.29	0.083	< 15	0.8	8.6	< 3	576	< 0.5	0.18	5.2	3.5	77	< 1	22	24.5	46	26	4.3	< 0.01	< 0.5	2.1	< 0.05	1.15
TK-172	0.83	161	0.21	0.159	132	0.7	12.2	< 3	460	< 0.5	0.39	9.8	3.2	80	< 1	22	36.5	68	50	5.8	< 0.01	1.6	2.1	0.05	1.28
TK-173	0.78	188	0.14	0.128	85	0.7	10.8	< 3	387	< 0.5	0.37	9.1	2.9	79	< 1	22	32.2	62	33	5.3	< 0.01	1.1	2.3	< 0.05	1.02
TK-174	0.82	1080	0.26	0.111	68	0.8	15.7	< 3	243	< 0.5	0.21	9	3.1	56	< 1	33	40.8	94	46	7.5	< 0.01	1.4	3.6	0.13	1.09
TK-175	0.85	121	0.14	0.195	73	1.1	11.3	< 3	400	< 0.5	0.39	9.7	4	99	< 1	25	34.7	66	42	5.4	< 0.01	< 0.5	2.4	< 0.05	0.998
TK-176	0.64	190	0.17	0.16	75	1	9.8	< 3	441	< 0.5	0.33	7.9	3.6	89	< 1	20	29.7	50	28	4.6	< 0.01	< 0.5	1.9	< 0.05	1.01
TK-177	1.33	421	0.4	0.567	< 15	0.9	11.4	< 3	533	< 0.5	0.05	4.5	7.9	75	< 1	42	32.3	45	22	5.4	< 0.01	1.8	3.3	0.05	1.02
TK-178	0.8	575	0.21	0.278	< 15	0.3	10.4	< 3	468	< 0.5	0.34	4.2	2.9	82	< 1	28	28.9	55	24	4.9	< 0.01	< 0.5	2.6	0.07	1.09
TK-179	1.45	907	0.82	0.099	< 15	0.6	12.3	< 3	336	< 0.5	0.25	6.4	2.3	91	< 1	32	34.4	73	23	6.1	< 0.01	< 0.5	3.2	0.12	1.23
TK-180	2.02	647	0.34	0.115	< 15	0.5	11.5	< 3	336	< 0.5	0.22	3.7	2.1	98	< 1	17	19.8	45	15	3.7	< 0.01	< 0.5	1.7	< 0.05	1.4
TK-181	1.06	306	0.39	0.37	26	1.1	11.8	< 3	521	< 0.5	0.06	4.3	5	75	< 1	43	32.5	49	27	5.3	< 0.01	< 0.5	3.3	0.14	1.06
TK-182	1.35	450	0.37	0.478	< 15	0.7	16.2	< 3	435	< 0.5	0.08	4.4	7.5	74	< 1	59	42.1	63	29	6.9	< 0.01	< 0.5	4.6	0.32	1.04
TK-183	1	204	0.15	0.317	19	0.8	11.4	< 3	626	1.8	0.16	4	6.7	104	< 1	32	29.6	39	22	4.3	< 0.01	< 0.5	2.6	0.06	1.21
TK-184	1.56	1540	0.21	0.226	26	0.6	13.2	< 3	401	< 0.5	0.28	4.6	2.2	107	< 1	35	32.5	71	23	5.1	< 0.01	< 0.5	3	0.09	1.09
TK-185	0.95	124	0.14	0.249	26	1.4	11.8	< 3	383	< 0.5	0.37	9.7	6.8	128	< 1	26	38.3	79	17	6	< 0.01	< 0.5	2.4	0.08	1.02
TK-186	1.27	152	0.2	0.198	106	0.5	12.5	< 3	533	< 0.5	0.35	9.6	2.7	82	< 1	24	39.8	82	31	6.2	< 0.01	< 0.5	2.2	< 0.05	1.33
TK-187	0.79	611	0.36	0.2	< 15	0.5	9.7	< 3	477	< 0.5	0.22	4.4	3.1	74	< 1	24	27.1	58	20	4.6	< 0.01	< 0.5	2.4	< 0.05	1.21
TK-188	1.14	874	0.23	0.14	37	0.7	15.7	< 3	251	< 0.5	0.7	7.7	3	130	< 1	28	39.9	101	31	7.2	< 0.01	< 0.5	3.4	0.14	1.23
TK-189	0.89	1150	0.34	0.135	< 15	1.1	18.5	< 3	232	< 0.5	0.25	10.6	3.5	62	< 1	35	52.4	107	107	9.4	< 0.01	1.5	4.9	0.3	0.872
TK-190	1.24	351	0.23	0.411	< 15	0.9	11.5	< 3	480	< 0.5	0.04	3.9	4.5	90	< 1	44	34.9	39	34	5.9	< 0.01	1.1	3.4	0.14	0.97
TK-191	1.05	144	0.19	0.157	68	0.7	13.5	< 3	512	< 0.5	0.37	10	3.5	89	< 1	26	43.4	77	34	6.9	< 0.01	1.8	2.8	0.1	1.15
TK-192	0.73	370	0.16	0.133	24	< 0.1	19.5	< 3	256	< 0.5	0.37	12	5.4	65	< 1	30	57.6	103	38	8.3	< 0.01	< 0.5	2.9	0.25	1.44
TK-193	0.84	351	0.39	0.168	48	0.7	13.1	< 3	403	< 0.5	0.38	8.8	3.6	95	< 1	24	39	74	26	6.2	< 0.01	< 0.5	3	0.07	1.02
TK-194	0.71	932	0.3	0.127	< 15	1.1	14.3	< 3	271	< 0.5	0.19	8.4	4.6	61	< 1	32	40.2	80	31	7.2	< 0.01	1	3.5	0.26	1.34
TK-195	1.66	178	0.12	0.191	78	1.3	12.8	< 3	349	< 0.5	0.39	7.1	5.2	99	< 1	17	26.6	46	25	4.1	< 0.01	< 0.5	1.9	< 0.05	1.31
TK-196	0.79	1240	0.34	0.126	< 15	1.1	14	< 3	209	< 0.5	0.21	7.9	3	50	< 1	33	40.6	124	31	7.3	< 0.01	< 0.5	3.8	0.27	1.33
TK-197	0.93	619	0.25	0.15	< 15	0.4	10.3	< 3	449	< 0.5	0.39	5	1.6	68	< 1	23	28.2	48	23	4.9	< 0.01	< 0.5	2.3	< 0.05	1.11
TK-198	0.94	478	0.33	0.502	< 15	0.8	12.5	< 3	511	< 0.5	0.04	4.4	5.5	82	< 1	51	37.5	42	38	6.4	< 0.01	< 0.5	4.1	0.21	1
TK-199	0.82	733	0.38	0.148	< 15	0.8	12.6	< 3	244	< 0.5	0.45	6.7	2.6	98	< 1	28	33.6	72	30	5.9	< 0.01	< 0.5	3.1	0.18	1.12
TK-200	2.21	129	0.14	0.176	30	1.1	12.1	< 3	384	< 0.5	0.17	7.1	5.5	85	< 1	20	28	46	15	4.2	< 0.01	< 0.5	2.3	< 0.05	1.27
TK-201	0.88	263	0.17	0.131	< 15	0.4	23.3	< 3	256	< 0.5	0.51	14.6	2.9	73	< 1	29	68.4	134	56	10.8	< 0.01	< 0.5	4.2	0.23	1.24
TK-202	0.6	800	0.29	0.199	< 15	0.8	13.3	< 3	254	< 0.5	0.52	6.8	3.8	94	< 1	31	36.4	74	33	6.6	< 0.01	< 0.5	3.1	0.24	1.16
TK-203	0.96	135	0.14	0.19	77	1.6	11.8	< 3	345	< 0.5	0.33	8.4	3.4	111	< 1	24	36.6	71	31	5.8	< 0.01	0.7	2.2	0.13	1.18
TK-204	0.68	334	0.16	0.195	86	0.7	23.5	< 3	300	3.9	0.28	14.1	4.7	58	< 1	36	69.6	137	50	10	< 0.01	< 0.5	4.2	0.39	1.24
TK-205	0.54	856	0.33	0.116	43	0.6	12.6	< 3	206	< 0.5	0.17	6.9	2.8	45	< 1	29	35.5	71	27	6.6	< 0.01	< 0.5	3.2	0.27	1.42
TK-206	0.72	312	0.2	0.101	97	0.7	22.6	< 3	290	< 0.5	0.28	16.4	3.3	42	< 1	27	64.4	131	51	9.5	< 0.01	< 0.5	3.7	0.3	1.26
TK-207	0.68	1180	0.26	0.182	108	0.7	16.4	< 3	219	< 0.5	0.77	9.5	3.2	136	< 1	30	45.8	106	36	8.5	< 0.01	1	4.2	0.32	1.42
TK-208	0.99	201	0.14	0.1	49	1.3	13.3	< 3	372	< 0.5	0.15	9.8	4.4	137	< 1	27	41.9	81	52	6.8	< 0.01	0.8	2.9	0.13	1.14
TK-209	1.15	140	0.16	0.143	67	1.8	14.4	< 3	378	< 0.5	0.17	10.2	4.8	149	< 1	29	44.8	84	32	7.3	< 0.01	1.1	2.6	0.14	1.19
TK-210	0.36	373	0.13	0.044	< 15	1	21.6	< 3	79	< 0.5	0.19	13.2	2.8	29	< 1	21	56.2	106	36	7	< 0.01	< 0.5	2.8	0.25	0.88
TK-211	0.96	304	0.27	0.452	< 15	0.5	9.5	< 3	541	< 0.5	0.05	4.3	5.7	69	< 1	35	26.3	32	28	4.3	< 0.01	< 0.5	3	< 0.05	1.03
TK-212	0.93	154	0.14	0.205	77	1.9	12.1	< 3	368	< 0.5	0.29	13.5	4	113	< 1	27	39.9	76	23	6.2	< 0.01	< 0.5	2.9	0.22	1.05
TK-213	0.37	1160	0.24	0.152	< 15	1.1	14.7	< 3	384	2.6	0.22	10.5	6.4	78	< 1	32	39.8	98	22	6.7	< 0.01	< 0.5	3.6	0.37	1
TK-214	0.95	157	0.2	0.164	101	0.7	12.5	< 3	516	< 0.5	0.38	13.2	2.2	81	< 1	24	41.8	82	33	6.6	< 0.01	< 0.5	2.5	0.13	1.19
TK-215	0.49	1030	0.28	0.332	46	1.2	19.8	< 3	315	< 0.5	0.6	12.5	8.2	139	< 1	48	54.7	112	77	9.1	< 0.01	< 0.5	4.8	0.36	1.6
TK-216	0.4	293	0.09	0.06	86	1.2	20.2	< 3	85	< 0.5	0.26	14	3	45	< 1	17	57	97	47	6	< 0.01	< 0.5	3	0.34	1.09
TK-217	0.69	151	0.16	0.117	< 15	0.7	10.5	< 3	350	< 0.5	0.35	10.1	4.4	74	< 1	20	32.5	53	21	4.8	< 0.01	< 0.5	2.3	< 0.05	1.05
TK-218	0.95	336	0.34	0.677	< 15	1	12.1	< 3	555	< 0.5	0.21	4.5	6.3	77	< 1	42	33.4	43	26	5.5	< 0.01	< 0.5	4	0.25	1.08
TK-219	0.84	1390	0.3	0.121	52	1	17.8	< 3	181	< 0.5	0.36	13.8	3.8	81	< 1	37	52.7	118	33	9.4	< 0.01	< 0.5	4.9	0.4	0.715
TK-220	0.97	172	0.18	0.263	145	1.7	13.2	< 3	351	< 0.5	0.36	12.9	6.8	137	< 1	28	41.5	72	28	6.4	< 0.01	< 0.5	2.8	0.16	1.12
TK-221	1.08	159	0.16	0.218	83	1.6	13.2	< 3	392	< 0.5	0.26	12.8	7.2	131	< 1	29	42.6	84	28	6.6	< 0.01	1	2.6	0.17	1.07
Tk-222	1.36	330	0.14	0.319	< 15	0.7	10.6	< 3	417	< 0.5	0.08	5.6	5.2	106	< 1	41	33.3	38	29	5.4	< 0.01	< 0.5	3.8	0.18	1.03
TK-223	0.89	1260	0.28	0.123	120	1.4	17	< 3	220	< 0.5	0.23	13.1	3.5	56	< 1	37	50.3	110	36	8.9	< 0.01	2.3	4.3	0.39	1.09
TK-224	1.75	360	0.58	0.226	< 15	< 0.1	17	3	281	< 0.5	0.51	11.2	4.4	121	< 1	26	37	71	31	6.7	< 0.01	2.1	3.2	0.18	0.71
TK-251	2.81	437	0.26	0.572	< 15	0.7	10.6	< 3	449	< 0.5	0.05	4.7	6.4	73	< 1	40	28.7	37	22	5.2	< 0.01	< 0.5	3.3	0.43	1.1

Table 10. Principal components analysis based on the correlation matrix of the chemical composition of the Tell Keisan ceramics

Principal component number	Eigenvalue	Percentage of variance explained	Cumulative % of total variance
1	12.05	38.20	38.20
2	4.20	14.01	52.21
3	3.51	11.14	63.35
4	1.87	5.93	69.28
5	1.56	4.96	79.24
6	1.28	4.08	83.32

the contents of the same 32 principal and trace elements.

The projection of the objects from a 32-dimensional space onto the plane of the first two principal components reflects only 52% of actual distances and angles between the objects (cf. Table 10, Fig. 174).

Clearly distinct clusters are mainly formed by ceramics belonging to petrographic groups I.A1 and IV, VI, XI (Fig. 174).

The first principal component, PC1, is mostly determined by: Fe, Sc, La, Ce, Sm, Pb, Ca, Al; the second, PC2, is determined by Y, Ni, Yb (Table 11).

The actual relations of similarity are reflected in the spanning tree (Fig. 175).

The values of the nearest Euclidean distances among the specimens are presented in Table 12.

The mean (M) of all the shortest distances between specimens equalled 3.40, while the standard deviation (σ) = 1.45. With M+2σ as the criterion, which corresponds to a 95.5% probability of the statistical separateness of samples, statistically different are most of the specimens assigned to petrographic group XI (shale rich, Lower Cretaceous?), two samples of petrographic group X ('rich in chamotte'), two samples of group IX, and those petrographically unassigned.

What attracts attention is the affinity between the ceramics of petrographic group VIII, made of sandy (*hamra*?) soil, and samples of group II (silty soil).

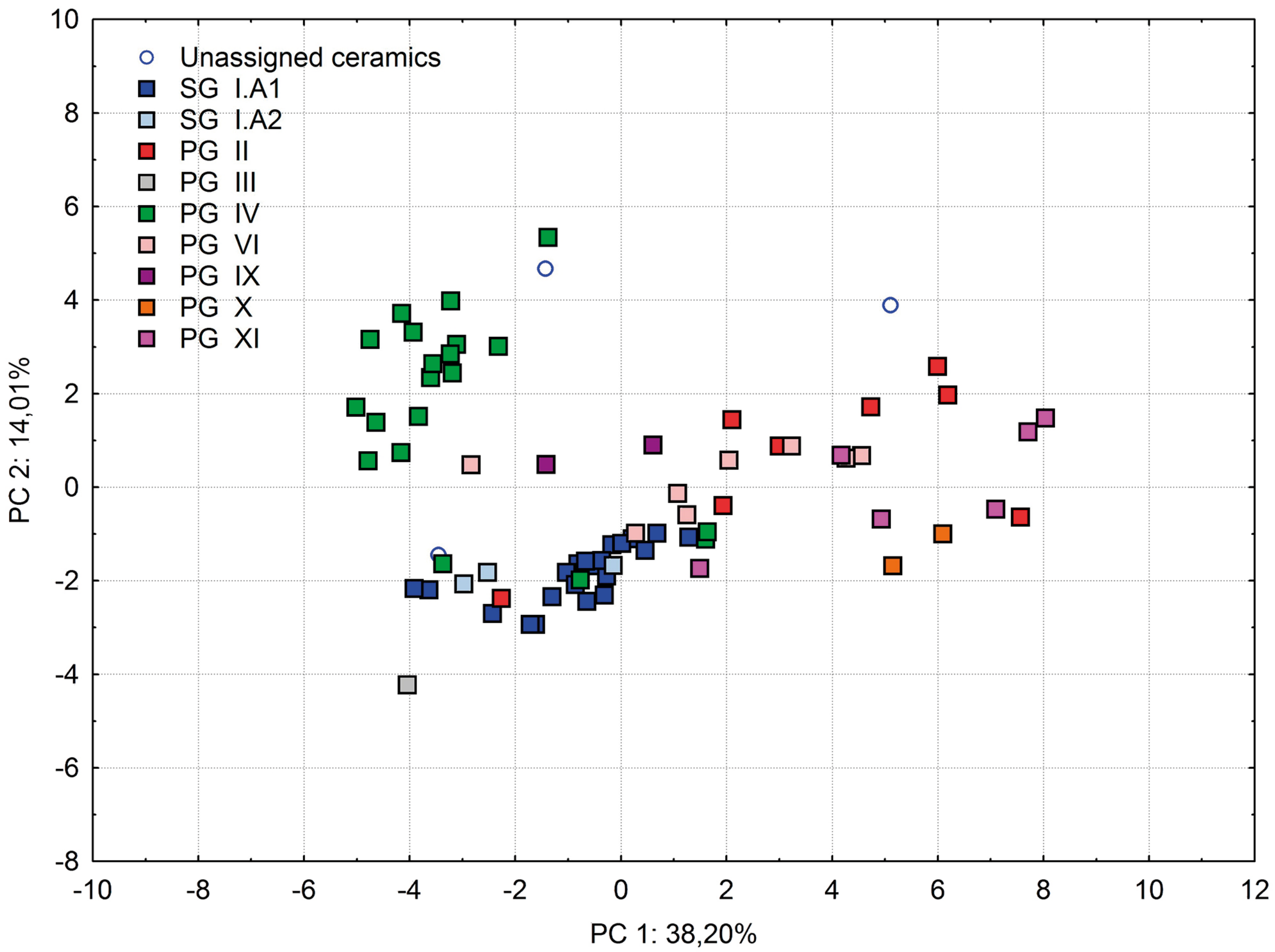


Fig. 174. Tell Keisan ceramics – principal components analysis. Petrographic groups of Tell Keisan jars in the PC1-PC2 coordinate system. Note the separateness of the majority of PG IV and SG I.A1

Table 11. PCA of the Tell Keisan jars. Determination coefficient $R2 \times 100\%$ for the first two principal components PC1 and PC2

Element	PC1	PC2
Cu	3.89	5.98
Pb	**73.45**	5.41
Ni	1.48	**66.16**
Zn	1.98	14.83
As	15.56	0.84
Ba	19.89	10.55
Co	56.19	13.42
Cr	0.01	9.72
Eu	47.96	5.17
Hf	64.70	3.85
Li	41.01	0.70
Mn	13.19	21.77
Sb	0.40	0.13
Sc	**81.32**	2.75
Sr	48.89	2.94
Th	66.81	8.54
U	3.95	17.91
V	4.04	1.49
Y	0.00	**83.72**
La	**80.32**	1.52
Ce	**90.65**	0.05
Nd	38.74	3.91
Sm	79.96	5.51
Yb	35.29	**50.71**
S	60.22	4.39
Al	69.11	7.50
Ca	**75.30**	0.76
Fe	**82.66**	0.01
K	1.00	**40.06**
Mg	20.88	0.54
P	27.01	**40.82**
Ti	16.46	16.78

Table 12. Values of the shortest Euclidean distances between the successively closest points representing samples of Tell Keisan jars in the 32-dimensional space of the elements analysed

Pairs	Distance	Pairs (c.t)	Distance	Pairs (c.t)	Distance
1–23	4.65	21–22	2.22	28–27	5.04*
23–15	2.53	22–25	1.88	46–29	4.03
15–4	2.99	25–18	2.63	29–6	5.02*
15–65	5.56*	18–19	4.41	25–44	4.67
65–59	4.40	19–13	2.93	44–49	3.04
23–41	6.43**	13–30	2.64	22–66	2.43
41–55	3.69	30–32	3.24	21–24	2.80
55–50	3.47	30–39	2.17	24–52	2.26
55–53	3.60	39–16	2.37	52–9	2.26
53–12	4.71	16–7	2.96	9–14	2.27
23–43	2.69	16–17	3.62	14–34	2.39
43–45	2.88	17–5	5.07*	34–69	2.29
45–72	3.56	16–26	3.23	69–70	1.79
72–38	5.10*	26–74	3.81	14–61	2.23
38–64	6.38**	16–47	2.59	9–58	2.71
72–68	3.01	47–31	4.49	58–11	2.89
43–51	3.11	47–67	3.17	58–57	2.61
51–37	3.57	39–71	2.77	40–10	3.42
37–56	3.28	71–33	10.85**	10–3	1.39
51–48	1.89	19–60	2.81	40–35	1.81
48–8	3.20	18–20	2.95	42–63	6.90**
48–42	3.59	20–36	2.44	42–73	4.58
42–40	2.11	36–46	2.83	43–54	2.79
40–2	2.30	46–28	4.90*	43–62	2.80

MEAN (M) = 3.4
Standard deviation (σ) = 1.45
*M+ σ = 4.85
**M+ 2σ = 6.3

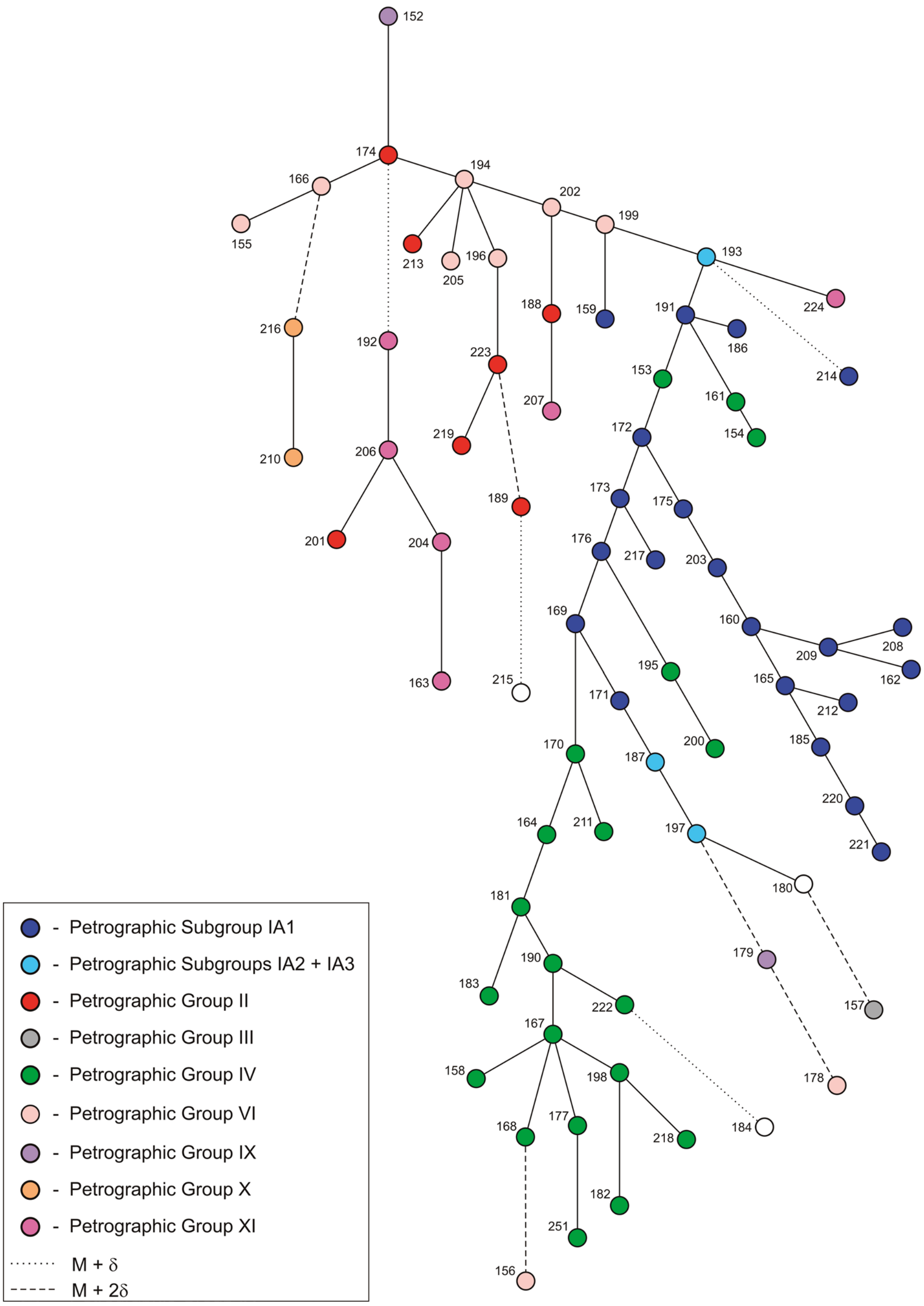


Fig. 175. Spanning tree presenting the greatest similarity (closeness) between the jars from Tell Keisan

7. Ceramics from Sha'ar-Ha'Amakim and Tell Keisan – searching for provenance of the raw materials

7.1. Contemporary practice

While the most desirable material for the production of white ceramics today is kaolinite-rich clay, pure of iron and calcium carbonate[312], in the past, since the Iron Age, white ware was made by firing of calcareous clay. This was a technology close to the contemporary production of cement, relying on the phenomenon of the thermal destruction of $CaCO_3$. The calcium oxide produced during the firing absorbed humidity and then CO_2 from the atmosphere, underwent recrystallisation, and thus led to the solidification of the product.[313]

An example of the indirect, currently employed pottery practice is the ware produced by the Bassam Musmar plant in Nazareth. Its owners, the Musmar brothers, take the material from many places near the city, and also near their shop. It is marl called 'yellow clay'. It is subjected to levigation in three basins located at the back of the shop, then broken up mechanically and mixed with fine-sandy, quartz-rich deposit of the h*amra* type (red sandy soil) and with *terra rossa*. Those components are mixed in the proportion of 70:15:15% of weight.

In the absence of a published sheet of a Nazareth map at the scale of 1:50,000, 'yellow clay' was subjected to an examination intended to establish its geological age by identifying the microorganisms found in the material. The 'yellow clay' samples obtained in the plant are rich in many foraminifer species: *Spiroplectinella dentata* (Alth), *Gaudryina rugosa* (d'Orbigny), *Clavulinoides* aff. *plummerae* (Sandidge), *Ammomarginulina*? sp., *Quadrimorphina allomorphinoides* (Reuss), *Allomorphina trochoides* Reuss, *Globorotalites michelinianus* (d'Orbigny), *Frondicularia* sp., *Neoflabellina* sp., *Praebulimina* cf. *laevis* (Beisel), *Pyramidina* cf. *prolixa* (Cushman & Parker), *Lenticulina* div. sp., *Hedbergella holmdelensis* Olsson, *Heterohelix globulosa* (Ehrenberg), *Globotruncana arca* (Cushman), *Contusotruncana fornicata* (Plummer), *Globotruncana wentricosa* White, *Gansserina gansseri* (Bolli), *Planoglobulina acervulinoides* (Egger), and *Globigerinelloides asperus* (Ehrenberg). This association sets the age of the material at the Late Cretaceous (Maastrichtian).

According to Sneh et al. (1996), deposits of those rocks (Ghareb Formation) are widespread in central Nazareth, especially in the southern and eastern parts of the city[314], where they are probably mined.

The basic material – 'yellow clay' – is composed (apart from carbonates) of expanded smectite (S) and some amounts of kaolinite (K), (cf. Fig. 180). In the other component, *terra rossa*, this proportion is reversed – the dominant minerals are non-expanding illite (I) and kaolinite (K), with a smaller amount of smectite (S) (Fig. 181). Also the sandy *hamra*, rich in quartz, has an elevated level of kaolinite (when compared with 'yellow clay'), (cf. Fig. 182).

The chemical composition of the 'yellow clay' samples (P-257, P-258/NYC) and two fragments of a flower pot made of this material (P-255, P-256/DO), fired to different colours (cf. Fig. 160) are presented in Table 13.[315]

The results show the essential change that 'yellow clay' undergoes after being mixed with 15% by weight of *terra rossa* and 15% by weight of sandy *ham-*

[312] In the course of firing $CaCO_3$ dissociates releasing carbon dioxide, which increases the porosity of vessels, while the calcium oxide CaO created in the process of hydration expands its volume, leading to the disintegration of the product.

[313] Cf. Shoval 2003, Shoval et al. 2011.

[314] Those marls are not easy to obtain because they are usually covered with massive as well as thick calcrete covers called 'nari' (cf. Itkin et al. 2012). This concerns the entire Levant. 'Nari' develop on poorly consolidated carbonate deposits, especially marls and chalk (Plate 162).

[315] To ensure the comparability of results, clay samples had been fired at 600°C. Sample 'Do-Y' is a fragment of a flower pot fired white, sample 'Do-R' – a fragment of one fired red (cf. Figs. 177–178).

Fig. 176. The Musmar brothers in their pottery plant

Table 13. Chemical composition of material sampled in the Nazareth Musmar pottery plant and the ceramics produced from it

Analyte Symbol		S	Al	Ca	Fe	K	Mg	Na	P	Ti	Cu	Pb	Ni	Zn	As	Ba	Co	Cr	Eu	Hf	Li	Mn	Sb	Sc	Sr	Th	U	V	Y	La	Ce	Nd	Sm	Yb
		%									ppm																							
P-257	NYC1	0.18	3.27	29.8	3.66	0.31	0.38	0.07	0.364	0.09	66	<3	116	126	30.1	<50	10	238	1.1	1	12	61	0.8	7.7	768	2.6	11.6	133	23	21.5	26	14	3.3	1.9
P-258	NYC2	0.19	3.24	30.2	3.63	0.32	0.38	0.06	0.390	0.12	67	<3	117	130	28.1	<50	10	242	1.2	<1	12	59	0.6	7.6	773	3.2	11.6	132	24	21.2	26	13	3.4	2.2
P-255	DO-Y	0.12	4.85	20.9	3.34	0.53	0.71	0.12	0.196	0.27	38	9	52	85	9.1	760	13	162	1.2	3	19	339	0.9	10.7	413	5.5	7.6	106	23	26.6	47	26	4.6	2.3
P-256	DO-R	0.12	3.94	18.8	3.27	0.48	0.64	0.13	0.216	0.31	33	9	46	77	9.8	720	13	160	1.3	4	17	330	0.8	10.1	371	5.7	7.5	98	20	26.8	44	21	4.4	2.2

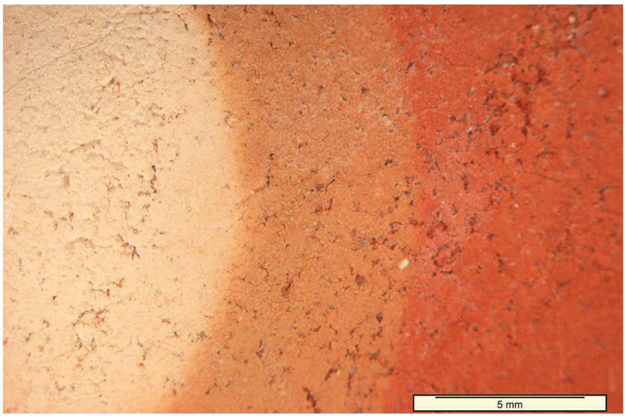


Fig. 177. Sample P-255: fragment of a pot fired in the Musmar workshop – made of a mixture of marl, *hamra* and *terra rossa*. The differences in colour reflect different degrees of the iron oxidation states

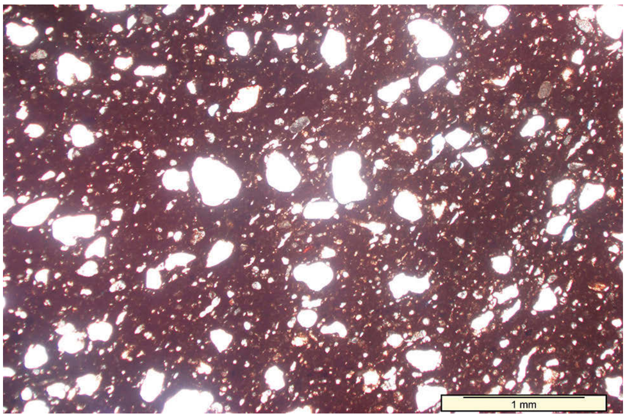


Fig. 178. Sample P-255, photomicrograph of a thin section (CPL). Highly sintered, isotropic matrix, quartz being the chief component of the non-plastic admixture

Fig. 179. Sephoris region, nari – thick carbonate calcrete developed on a chalky bedrock significantly hinders the excavation of the raw-material

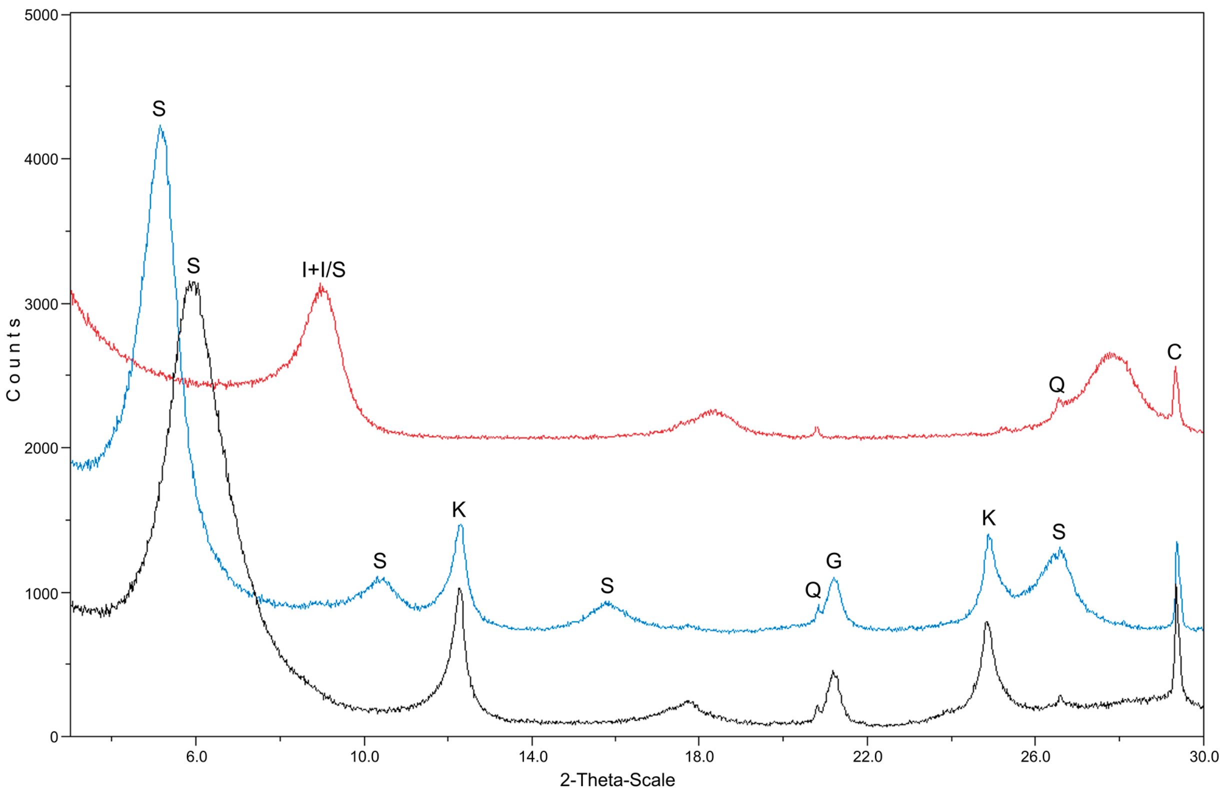


Fig. 180. XRD patterns of 'yellow clay' from Nazareth obtained as a result of dried-air oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). Clearly dominant are smectite peaks (S), also kaolinite (K), Goethite (G) and calcite (C) are present in smaller amounts

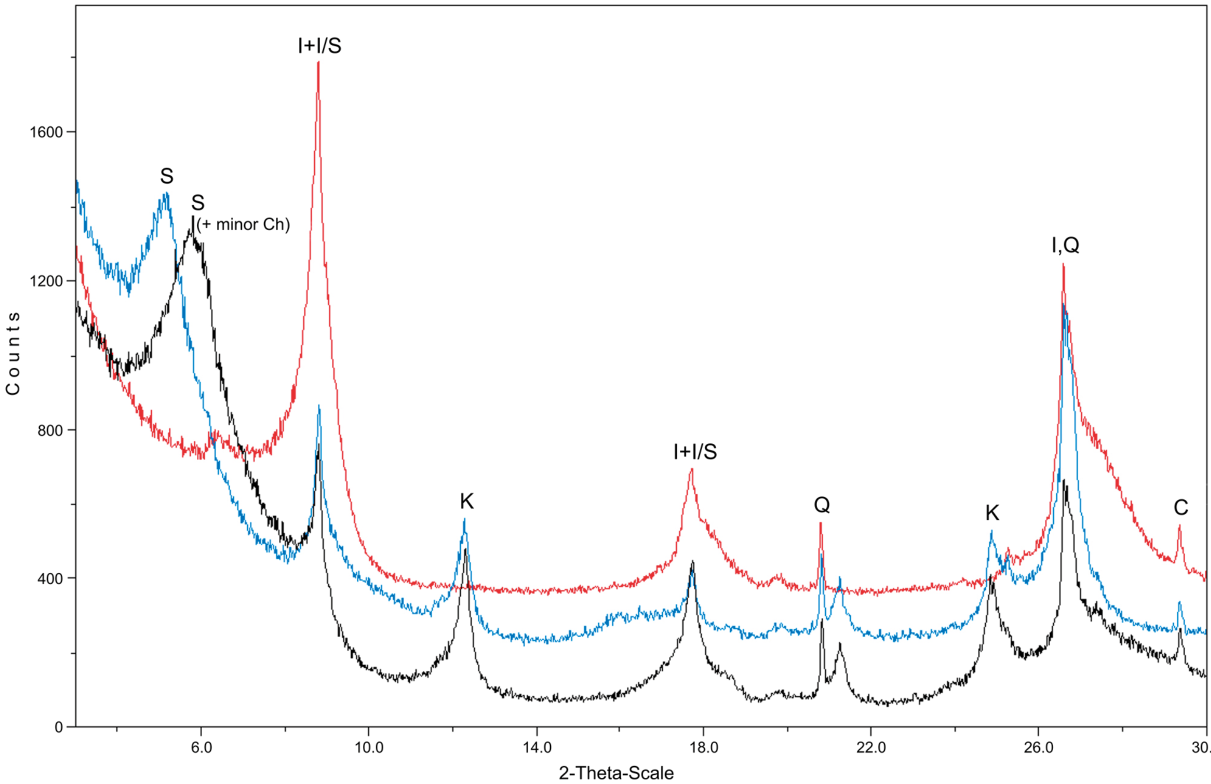


Fig. 181. XRD patterns of a *terra rossa* sample from Nazareth obtained as a result of oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). Notable is a high content of illite (I), kaolinite (K) and smectite (S), with minor amount of chlorite (Ch)

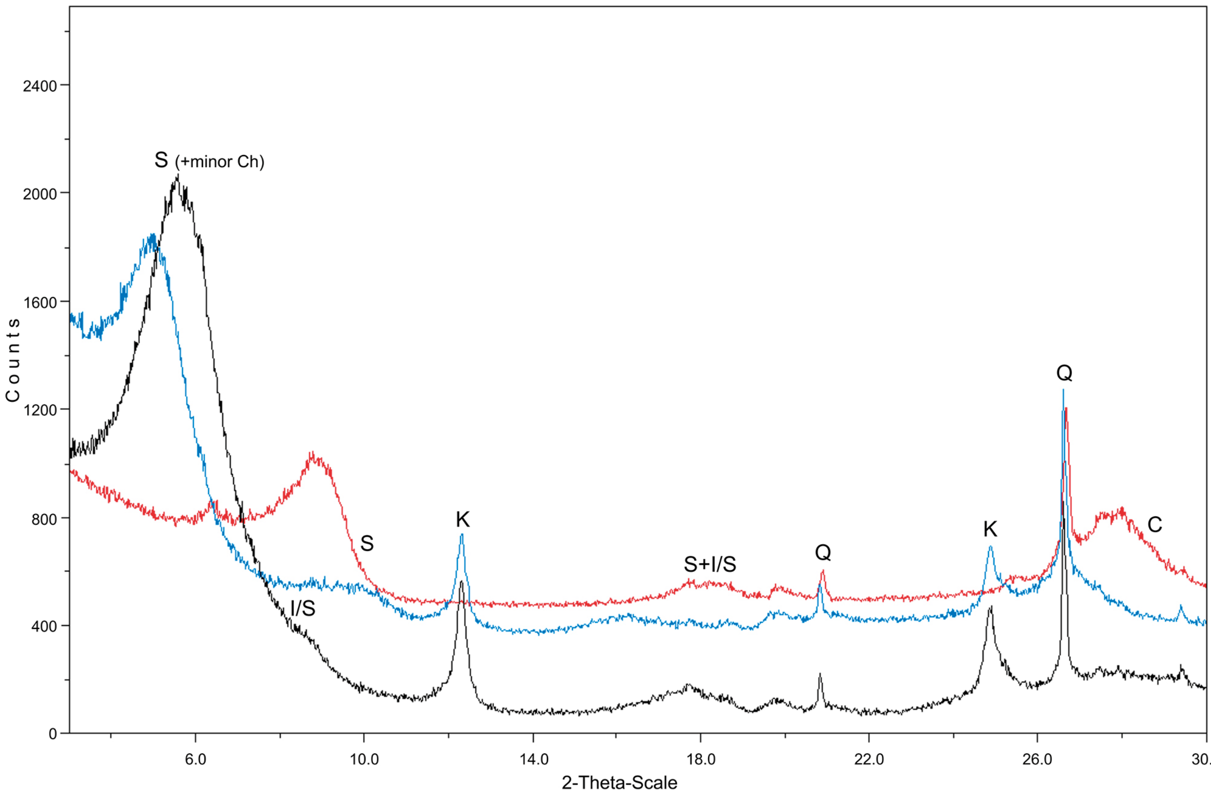


Fig. 182. XRD patterns of *hamra* soil from the Carmel coast, obtained as a result of oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). Symbols: smectite (S), kaolinite (K), quartz Q, calcite (C), chlorite (Ch)

ra. The basic effect of this technology is a substantial decrease of the levels of Ca, P, Cu, Ni, Zn, As, Cr, Sr, U, and V, which should be associated especially with a quartz dilution effect. At the same time there was an increase in the level of elements contained in the additives: Al, K, Na, Ti, Pb, Ba, Co, Mn, Sc, Th, La, Ce, Nd, and Sm, while the iron content did not change.

The Sr content in raw 'yellow clay' reflects the presence of microfossils, while elevated concentrations of Cu, Ni, Zn, Cr, U, and V are a geochemical signature of Maastrichtian depositional environment in today's Galilee[316].

A comparison of the mineral composition of 'yellow clay' with *terra rossa* and *hamra* justifies the practice of mixing those components. An increase in the proportion of the non-expanding kaolinite-illite type of minerals contained in *terra rossa* prevents excessive expansion of the ceramic paste, while *hamra* soil is a natural source of sandy quartz preventing changes in the volume, but keeping iron at the same level.

7.2. In search for potential clay deposits in the field

In looking for an answer to the question of the provenance of the vessels examined, a search was made for the potential raw-material base, i.e. primarily: 1) Santonian-Early Campanian Kabri marls occurring among rocks of the Senonian formation Menuha, 2) Maastrichtian Ghareb Formation marls, 3) Paleocene Taqiye marls, 4) soils of the *terra rossa* type developed mostly on rocks of Cretaceous age, 5) rendzina soil formed on soft chalks and marls of the Mount Scopus Group, and 6) *grumusols* and alluvia of the Zevulun Plain.

Fieldwork was conducted especially in the Tell Keisan region on the basis of detailed geological maps at the scale of 1:50,000, the Shefar'Am sheet,[317] and to a lesser extent in the Sha'ar-Ha'Amakim area, because so far no geological map of Nazareth has been published. Work in this area rested on a map at the scale of 1:200,000.[318]

The sediment samples taken in the field were experimentally fired in laboratory conditions. First, they were mixed with distilled water, then levigated in glass containers, finally brick-formed and fired at temperatures in the range of 600–900°C.

Unfortunately, most bricks formed in this way, including the samples of Eocene marls collected in Sha'ar-Ha'Amakim, disintegrated after firing because of the excessive content of either smectites or carbonates. Further work involved creating mixtures of the rock samples with *terra rossa* soil and h*amra*, also those obtained in the Musmar plant. The success was only partial.

The mineral composition of deposits that could perform the function of the raw material[319] was established using the X-ray diffraction. Before the X-ray analysis carbonates were removed using sodium citrate. The analyses were made after the samples were soaked with ethylene glycol and fired at 500°C.

The micro-paleontological studies conducted were intended to corroborate the age of those rocks[320].. Some samples were subjected to chemical analyses together with ceramic samples.

Because of the presence of volcanic glass found in the samples of petrographic subgroup IA3 and petrographic group V, also studied were samples of Maharal tuffs and those from the tuff levels exposed on the slopes of Nahal Rackefet. They were petrographically examined, and the basic chemical composition of the volcanic glass fragments contained in them was determined using the SEM-EDS method.

The samples that turned out to be at least partially permanent, hence potentially useful were those taken from the following places:

Marl from the foot of Tell Keisan (P.10–11), coord. 32.87472°N, 35.14940°E, Fig. 183.

In macroscopic terms it is white-cream in colour. A micro-paleontological analysis revealed the presence of two foraminifer associations:

Association I: *Verneuilina muensteri* Reuss, *Spiroplectinella dentata* (Alth), *Gyroidinoides nitidus* (Reuss), *Gavelinella* cf. *monterelensis* Marie, *Lenticulina* div. sp., *Nodosaria* sp., *Contusotruncana fornicata* (Plummer), *Globotruncanella havanensis* (Voorwijk), *Globotruncanita stuartiformis* (Dalbiez), *Heterohelix* div. sp., *Hedbergella* div. sp. – in a great mass, also sea-urchin spines and ostracods.

Age: Campanian – Maastrichtian.

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[316] Cf. Ilani et al. 1991: 200.

[317] Levy 1983, Sneh 2008.

[318] Sneh et al. 1998.

[319] An examination was made of rock samples from which it was possible to make experimental ceramics.

[320] Loose rock material was prepared for examination by macerating samples in a Glauber's salt (Na_2SO_4) solution and alternate heating and freezing in order to disintegrate them into small pieces. Then the samples were rinsed in running water on double copper laboratory sieves with a copper mesh of different diameters (a minimum of 0.064 mm). A micro-paleontological study involved mainly foraminifers. As a standard, however, the presence of other microfossils was recorded (and documented): radiolaria, ostracods, macrofaunal elements, algae. The age range of characteristic Cretaceous and Paleogene forms were determined on the basis of: Caron (1985), Gawor-Biedowa (1992), Bolli & Saunders (1985), Olsson et al.(1999), Pearson et al. (2006). The examination was performed by Prof. Barbara Olszewska ((PIG-PIB/OK).

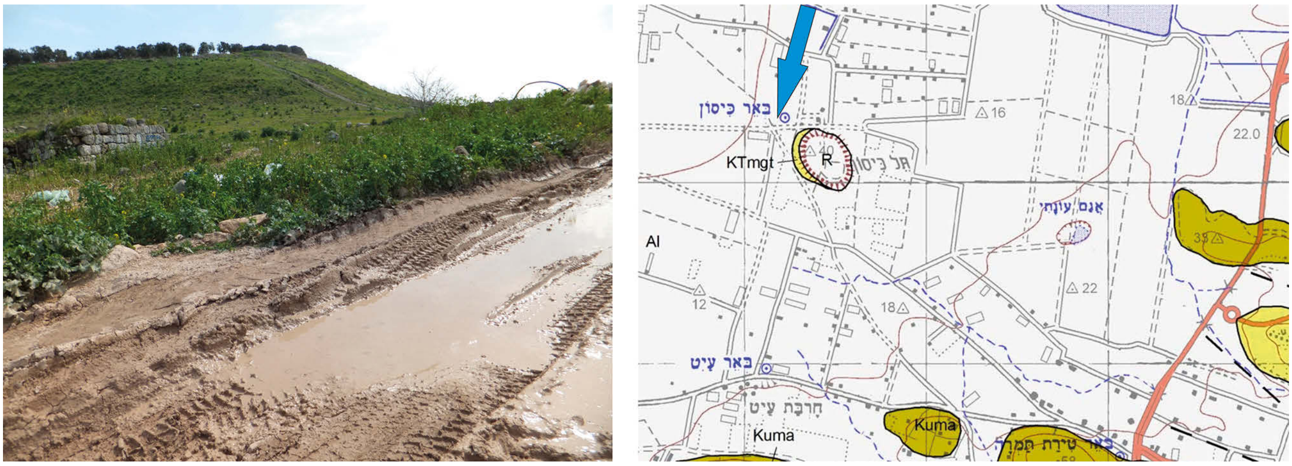


Fig. 183. White Senonian marls at the foot of Tell Keisan. On the right: a fragment of a geological map (Sneh 2008). The arrow indicates the place of sampling specimens P.10–11. Symbols: KTmgt – Senonian & Paleocene (Ghareb & Taqiye fm., undivided); NQp – Pliocene (Pleshet Fm.); R – ruin

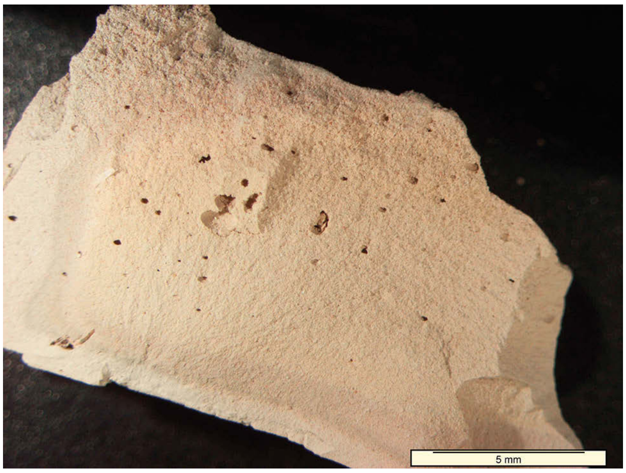


Fig. 184. Fragment of sample P.10–11 after firing at 600°C

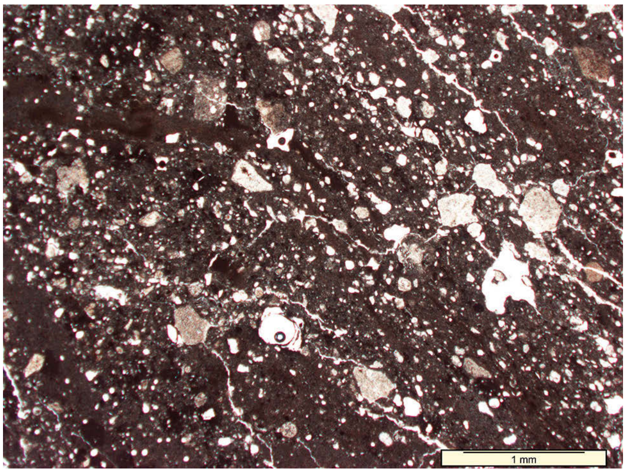


Fig. 185. Sample P.10–11, photomicrograph of a thin section (PPL)

Association II: *Acarinina bullbrooki* (Bolli), *Acarinina* cf. *nitida* (Martin), *Morozovella* aff. *lensiformis* (Subbotina), *Parasubbotina* sp.

Age: Early Eocene.

After firing, the brick kept its light-cream colour, showing substantial porosity and moderate compactness, especially after a slow hydration of samples (Fig. 184).

On optical examination, the sample is totally isotropic, non-plastic components being numerous lumps of carbonate rocks decomposed in the course of firing, the content of silt-sized quartz is less than 2%, notable are single crystals of rutile (Fig. 185).

The basic minerals are calcite[321] as the principal component of the material, and expanding smectites (Fig. 186).

[321] In spite of the process of carbonate dissolution performed in the standard way, the carbonates have not been completely eliminated.

Ahihud – rendzina soil (P.13), coord. 32.91463°N, 35.18164°E.

The sampling site is shown in Fig. 187.

The age of the deposit is confirmed by micro-paleontological analysis, especially the presence of *Gyroidinoides nitidus* (Reuss), *Globorotalites* sp., *Gavelinella* sp., *Praeglobotruncana* sp., *Heterohelix* cf. *globulosa* (Ehrenberg), *Globigerinelloides* aff. *ultramicra* (Subbotina), *Rugoglobigerina* cf. *macrocephala* Brönnimann, *Contusotruncana fornicata* (Plummer), *Globotruncana* cf. *arca* (Cushman), *Hedbergella* div. sp., co-occurring with an association of single Eocene foraminifers *Pseudohastigerina* sp., *Globigerina* sp., *Parasubbotina* cf. *pseudobulloides* (Plummer), *Morozovella* cf. *aequa* (Cushman & Renz), and *Morozovella* aff. *aragonensis* (Nuttall).

The ceramics obtained after firing were compact, heavily sintered, dark cherry-red in colour, but also showing many fractures (Fig. 188).

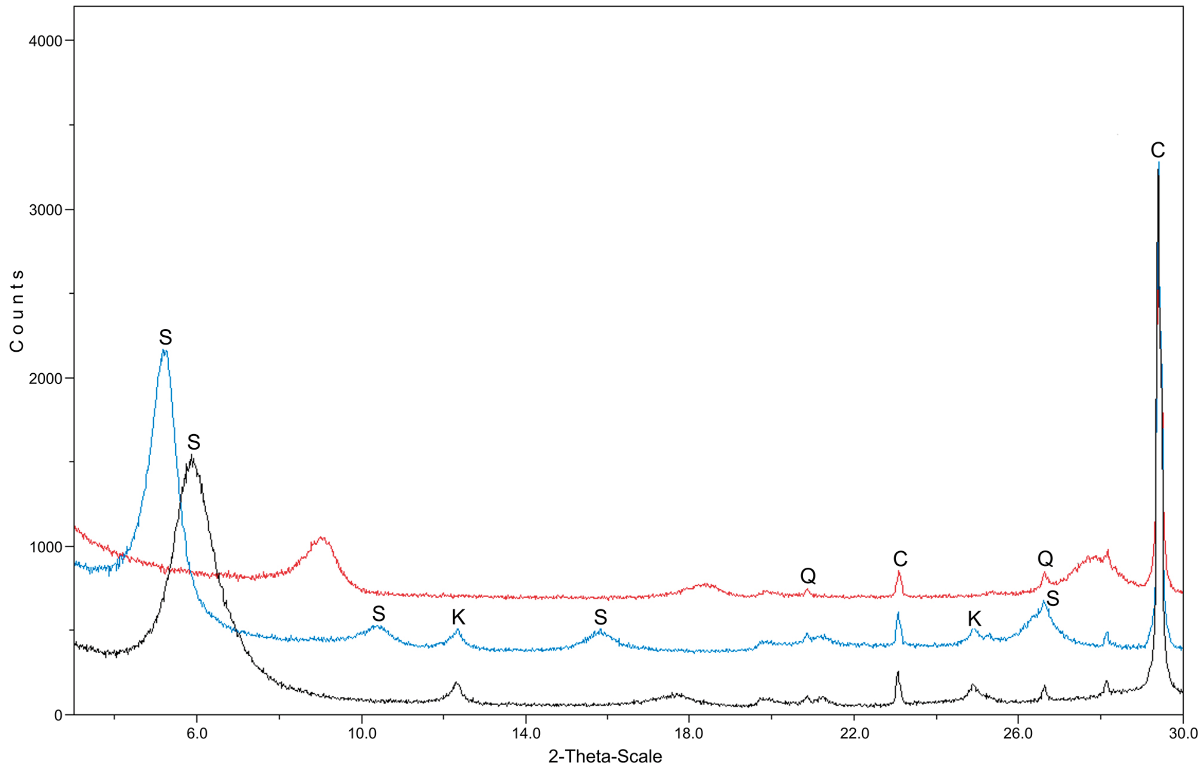


Fig. 186. XRD patterns of sample P.10–11 obtained as a result of oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). In spite of dissolving, calcite (C) has been preserved. Note high amount of smectite (S)

On optical examination, in transmitted light, the matrix is dark red, granular, rich in opaques (Fe-Mn oxides), the content of quartz silt is ca. 15% and of grains of the sand fraction <5% of the volume. Those are single quartz grains and flints. Also found are very few crystals of rutile (Fig. 189).

Tel Afek vicinity (P.22), coord. 32.84125°N, 35.11826°E.

A search for the potential material in the Tel Afek area revealed the presence of at least two kinds of rock, gray marl and brown grumusol (Fig. 190, 193).

P.22 is a sample of dark-grey marl occurring at various depths under a cover of alluvial soil (Fig. 190). A fired brick assumed a light brown colour 5YR 6/6 (Figs. 191–192).

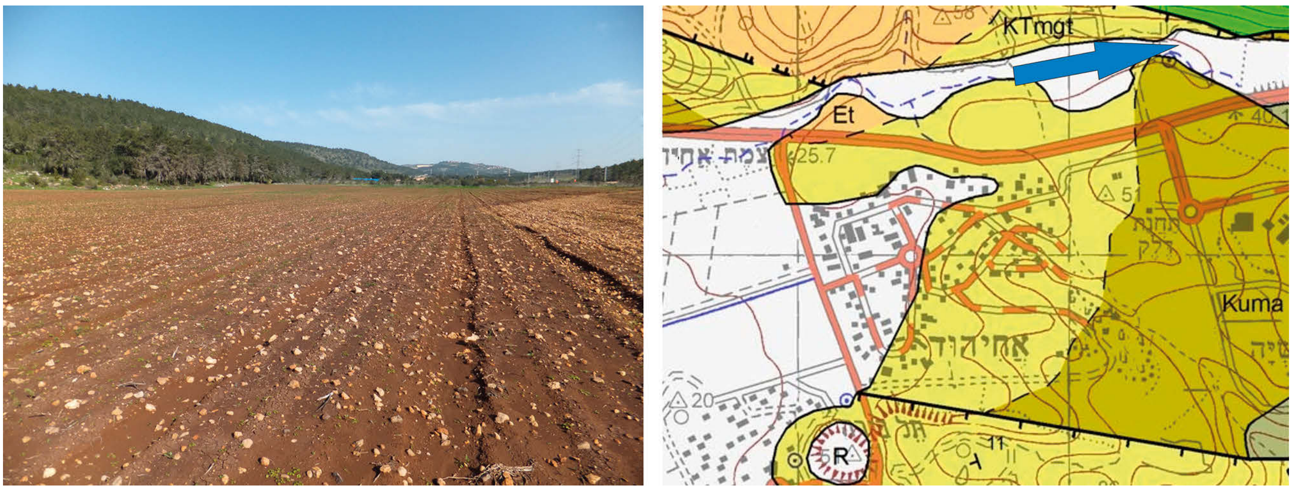


Fig. 187. The place of sampling specimen P.13, NE of Ahihud: rendzina soil developed on Late Cretaceous sediments. On the right a fragment of a geological map (Sneh 2008). The sampling site is indicated by an arrow. Symbols: Kuma-Senonian (Ahihud Mbr.); KTmgt Senonian & Paleocene (Ghareb & Taqiye fm.); Et-Eocene (Timrat Formation)

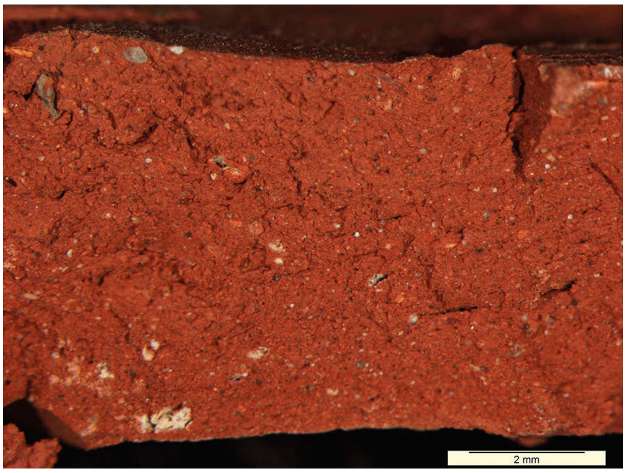


Fig. 188. Sample P.13 after firing at 750°C

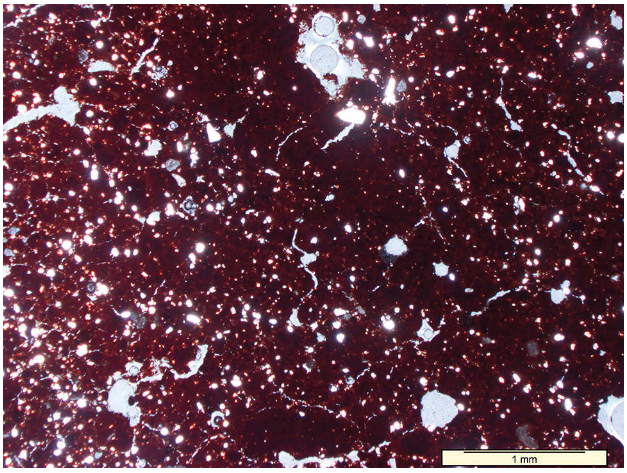


Fig. 189. Sample P.13, photomicrograph of a thin section (PPL)

Fig. 190. Near-surface outcrop of marl (sample P.22, Ghareb & Taqiye fm.). On the right a fragment of a geological map (Sneh 2008).The arrow indicates the sampling site. Symbols: Kub-Turonian (Bina Fm); Kumh-Senonian (Har Zefat Mbr.); Kuma-Senonian (Ahihud Mbr. incl. Kabri Marl). NQp – Pliocene (Pleshet Fm.)

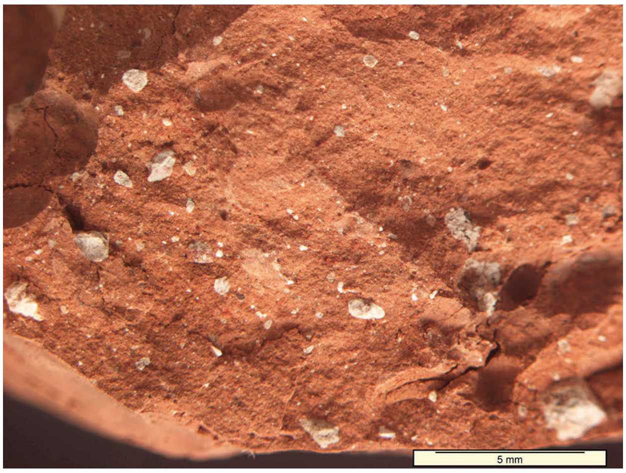


Fig. 191. Sample P.22 after firing at 750°C

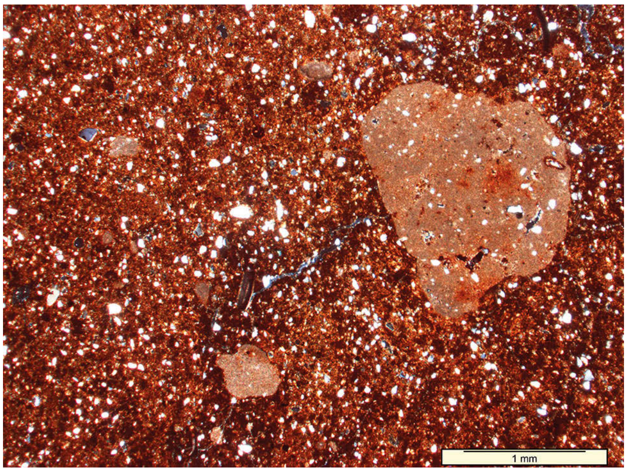


Fig. 192. Sample P.22, photomicrograph of a thin section (PPL)

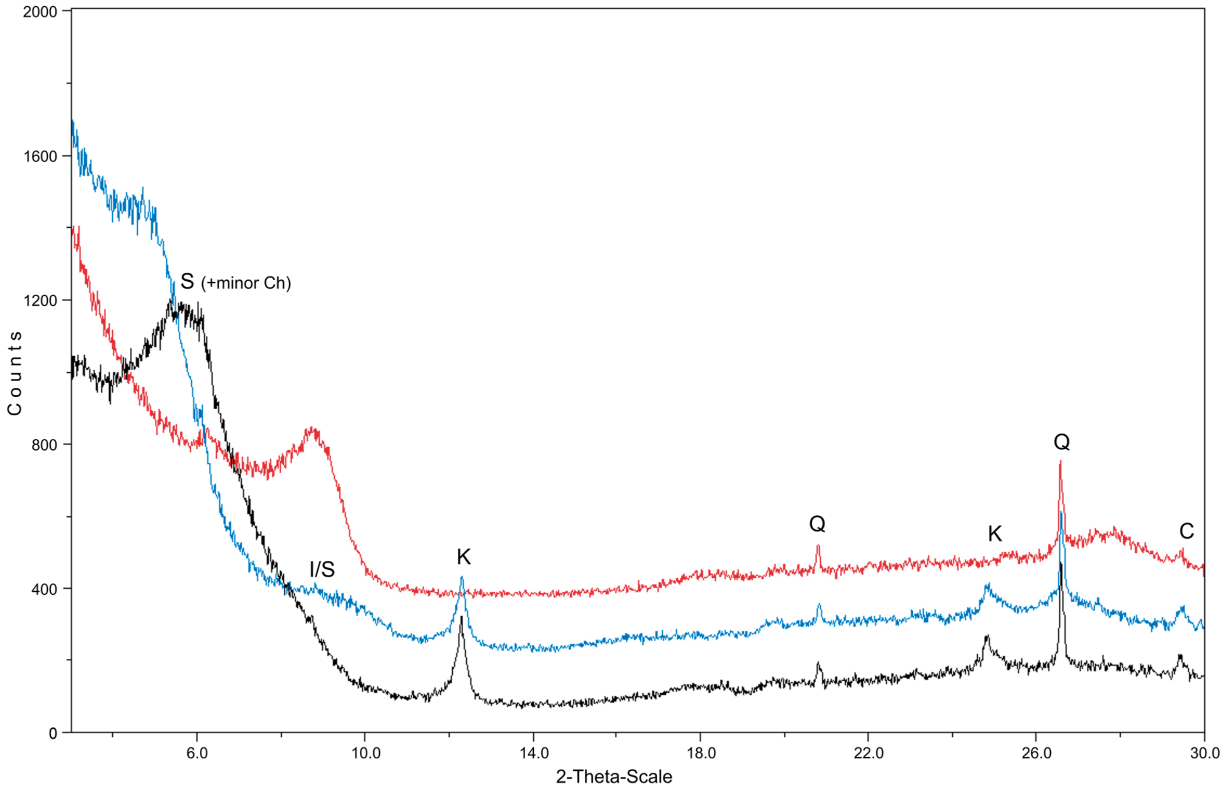


Fig. 193. XRD patterns of specimen P.22 (Zevulun Plain, Tel Afek vicinity) obtained as a result of oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). Symbols: smectite (S), kaolinite (K), quartz (Q), calcite (C), chlorite (Ch)

Foraminifer associations found in the deposit:

Association I: *Psammosiphonella cylindrica* (Glaessner) – two sherds coloured pink, *Glomospira charoides* (Jones & Parker), *Cibicidoides* sp. and *Cibicides* sp., *Gyroidina* sp., *Parasubbotina pseudobulloides* (Plummer), and *Globigerina* sp. determine its age at the Early Paleogene.

Association II: very small (up to 0.2–0.3 mm in diameter), transparent internal casts from the genera *Hedbergella* sp. and *Globotruncana* sp. are diagnostic for the Late Cretaceous.

Also found were fragments of contemporary (?) mollusc and radiolarian shells, a Echinoid spine, single elements of sponges, and a few ferruginous concretions.

Calcareous nanoplankton is diagnostic for the Early Paleocene.

The different ages of the two associations in sample P.22 indicate that this deposit is a mixture of the Ghareb/Taqiye Fm. (cf. Appendix 2).

The results of XRD analyses of sample P.22 reveal a high content of smectite, also present is kaolinite.

Tel Afek vicinity

Afek – Brown grumusol type of soil (P.26) coord. 32.84529°N, 35.11334°E, Fig. 194.

Fig. 194. Tel Afek vicinity – erosional dissection cut by an ephemeral stream. The arrow indicates the place of sampling site. Symbols – cf. Fig. 183

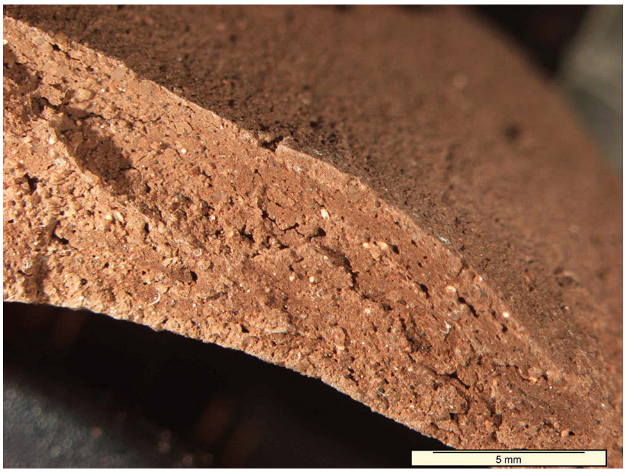


Fig. 195. Sample P.26 – an image of a brick before firing

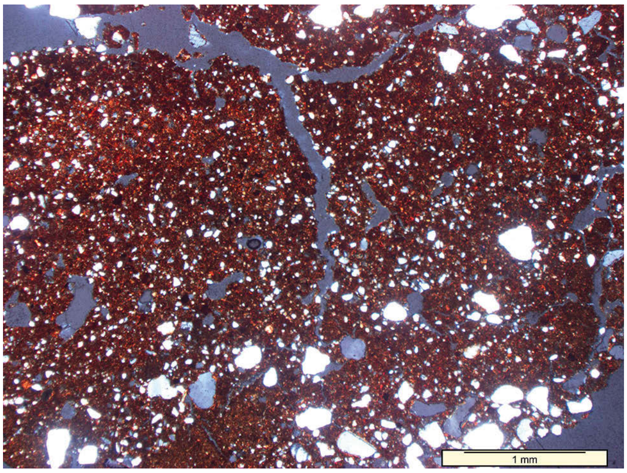


Fig. 196. Specimen P.26, photomicrograph of a thin section (CPL)

The ceramics obtained after firing assumed a reddish brown colour; the deposit is rich in silt-sized quartz (20% of the volume). Grains of the sand fraction account for 10% of the volume (90% of them are quartz, ca. 10% are variously weathered feldspars and silica rocks (Fig. 195, 196).

The results of XRD analyses of sample P.26 are presented in Fig. 197, they show that this deposit is mostly composed of smectites together with some amounts of kaolinite and chlorite (?).

Kefar – Masaryk, Danuk hill (P.27) coord. 32.87096°N, 35.11910°E.

Sample of brown verisol taken south of a cemetery (Fig. 198).

In macroscopic terms the soil is brown, after firing it turned brown (Fig. 199).

In plane polarised light the matrix is light brown. Quartz silt constitutes about 15% of the volume, the coarse sand constitutes less than 5%, those are carbonate grains, including single fragments of cor-

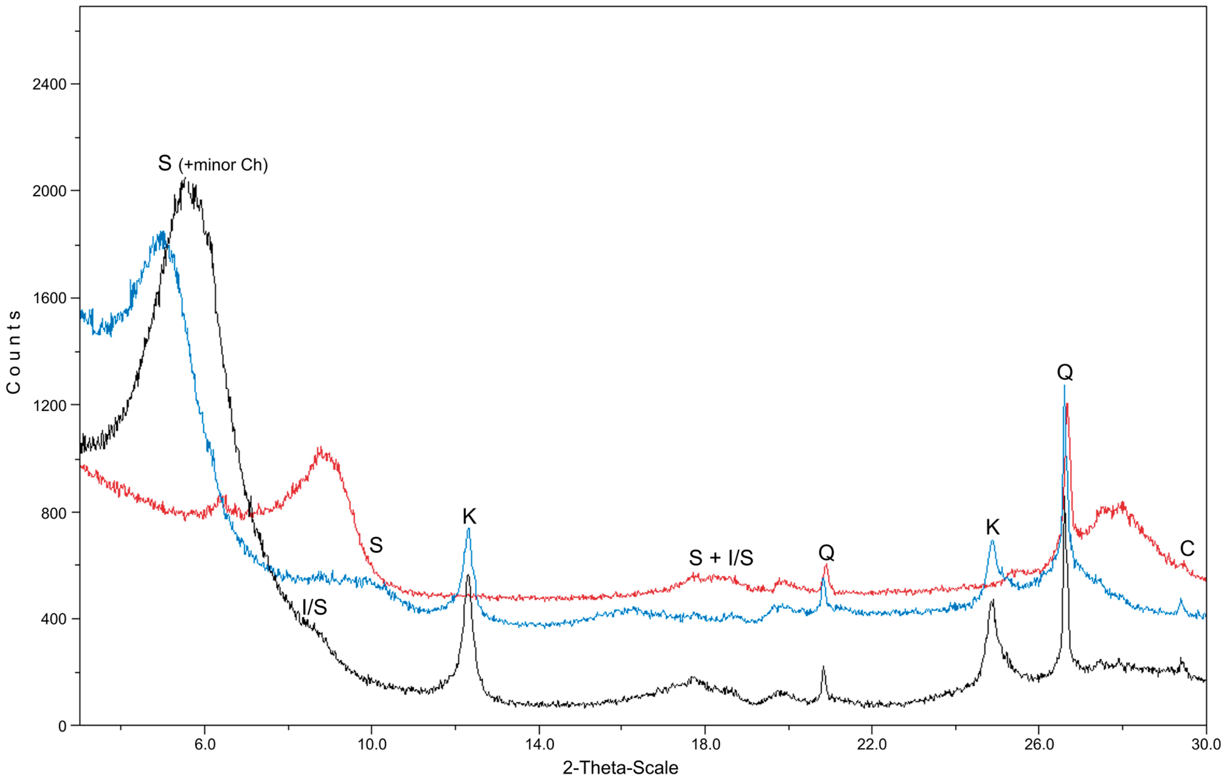


Fig. 197. XRD patterns of sample P.26 obtained as a result of oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). Symbols: smectite (S), chlorite (Ch), Illite (I), kaolinite (K), quartz (Q), calcite (C)

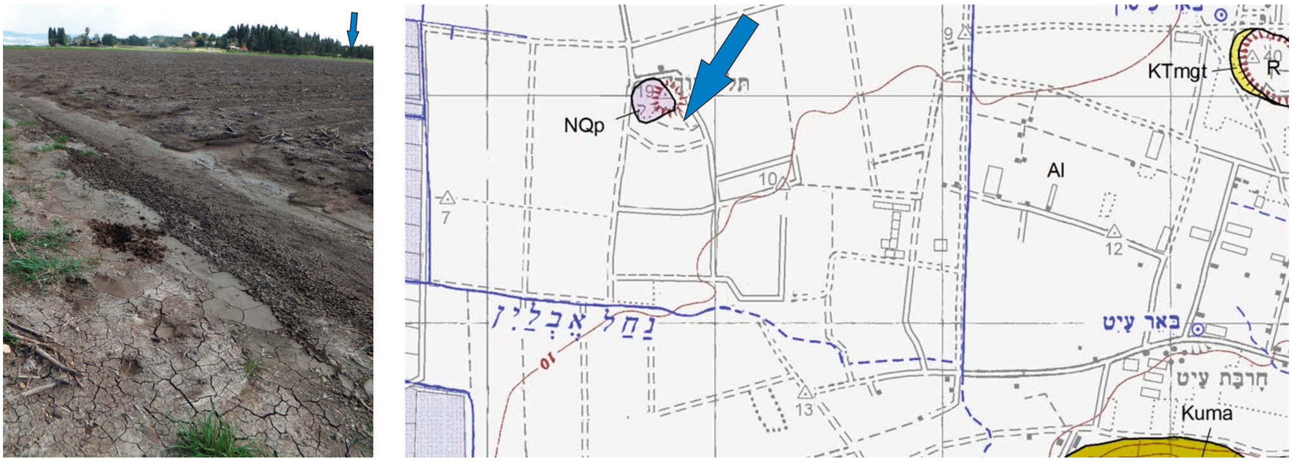


Fig. 198. Kefar-Masaryk (2.5 km west of Tell Keisan), Danuk hill – the place of sampling specimen P.27. On the right a fragment of a geological map (Sneh 2008).The arrow indicate the place of sampling the specimen P.27

alline algae (Fig. 200), grains of monocrystalline quartz and flints. Notable is the presence of single ferruginous ooliths.

Single specimens were found of *Cibicides* sp., *Globigerina* sp., *Globigerina* aff. *spirialis* Bolli, *Parasubbotina pseudobulloides* (Plummer), *Acarinina* aff. *angulata* (White), *Parvularuglobigerina* sp.; they represent the Early Paleogene (Paleocene).

An analysis of the mineral composition of the clay fraction revealed the presence of smectites, illite and kaolinite.

Ghareb Fm. marls.

The samples were taken in two places:

HaMovil Interchange, highway (spec. P.029, P.030) 79/77. coord. 32.80737°N, 35.14337°E (Fig. 201);

Sa'ab village, N of Kabul (spec. P.032, P.033). coord. 32.89283°N, 35.22621°E (Fig. 202).

The conducted experiments show that pure marl samples are useless in the production of ceramics (cf. Fig. 203, 204), while fairly satisfactory results were obtained by mixing them with *hamra* soil and *terra rossa* (specimen P.33H). The sherd obtained in this way assumed a light-red colour (5YR 8/4), similar to that of vessels of group I.A1 (Fig. 205).

On optical examination the matrix of the experimental sample is grey, in many places mottled red, partially orange.

The grey shade of the background is the effect of the dissociation of carbonates, red hues come from iron compounds present in the admixture of *hamra* and *terra rossa* (Figs. 207–208).

When compared with macroscopically similar Phoenician ceramics, sample P.033 contains much less clay minerals (Fig. 206), which in PG I.A1 are uniformly scattered within the matrix (the basic difference concerns the age of the material).

Fig. 199. Specimen P.27 after firing at 650°C

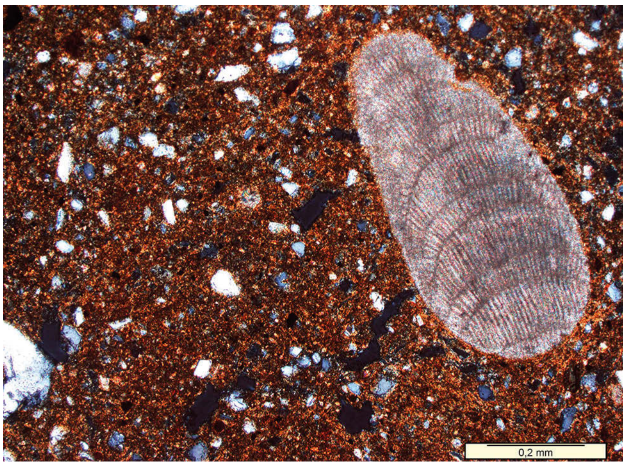


Fig. 200. Specimen P.27, photomicrograph of a thin section (CPL). Note the presence of a fragment of *Coralinaceae* sp. (*Amphiroa*?)

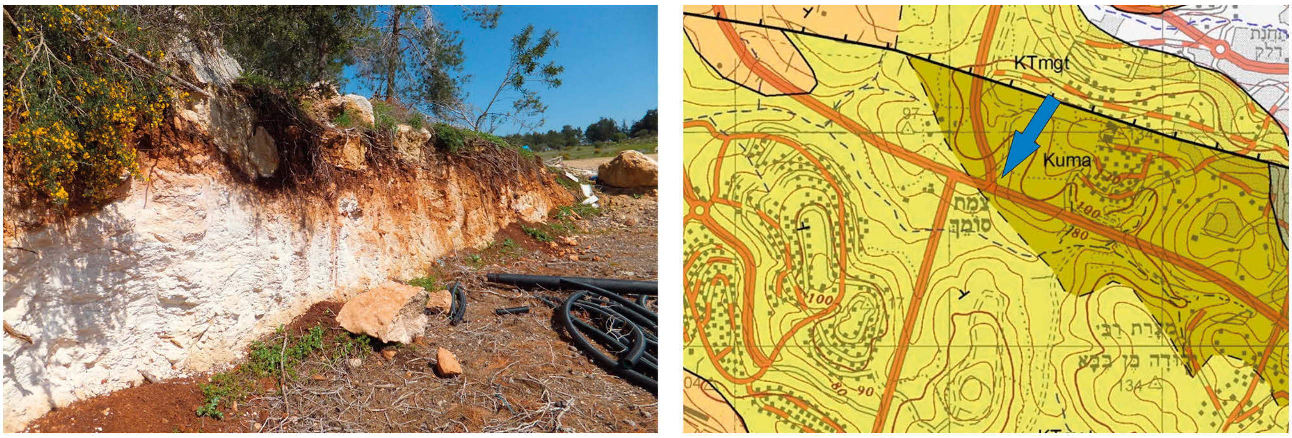


Fig. 201. HaMovil Interchange, outcrop of Ghareb Fm. Marls. On the right a fragment of a geological map (Sneh 2008). The arrow indicates the place of sampling specimens P.029 and P.030. Symbols: Kuma-Senonian (Menuha Fm.); KT-mgt – Senonian & Paleocene (Ghareb & Taqiye fm.)

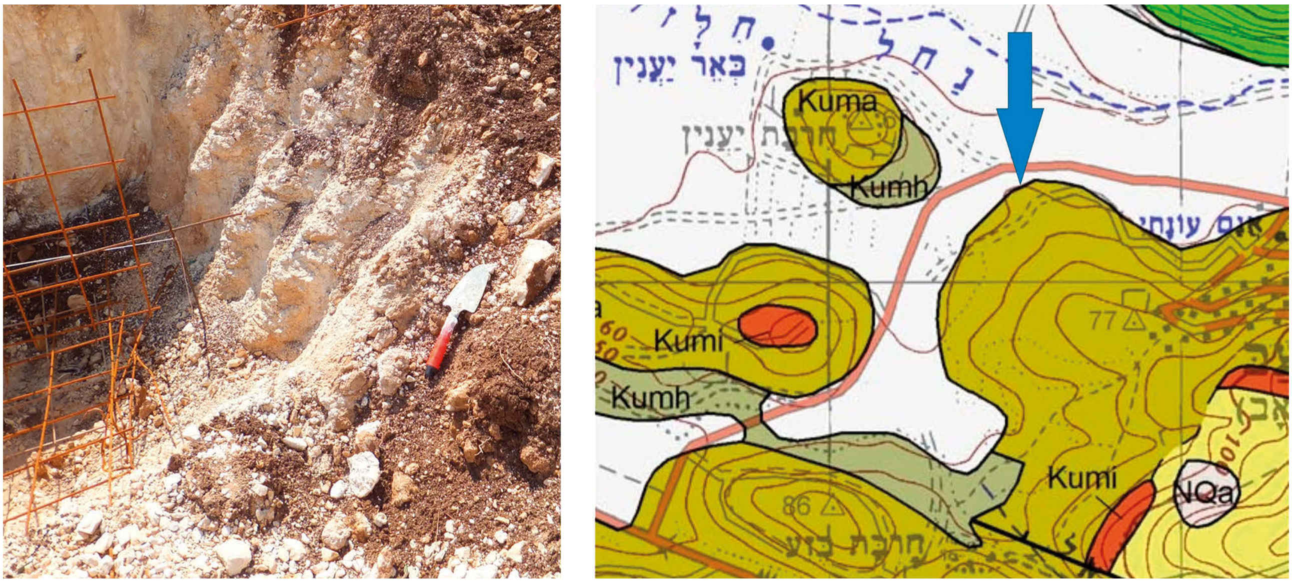


Fig. 202. One km west of Sa'ab village, the place of sampling specimens P.031 and P.032. On the right a fragment of a geological map (Sneh 2008).The arrow indicates the place of sampling the specimen. Symbols: Kumh-Senonian (Menuha Fm., Har Zefat Mbr); Kuma-Senonian (Menuha Fm. Ahihud Mbr.); Kumi-Senonian Mishash Formation (rich in chert); NQa – Pliocene (Ahuzam conglomerate)

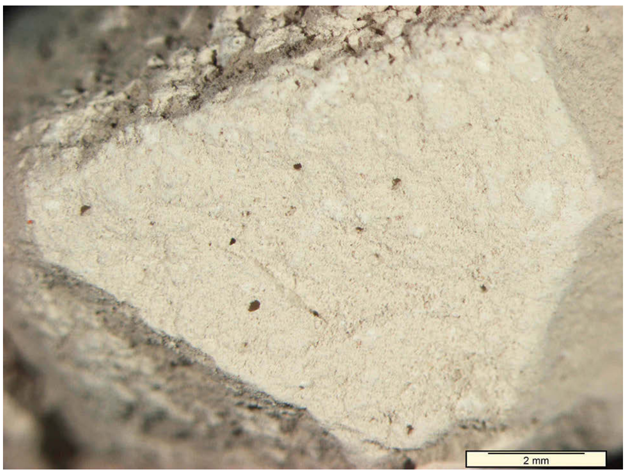


Fig. 203. Specimen P.033 after firing at 600°C

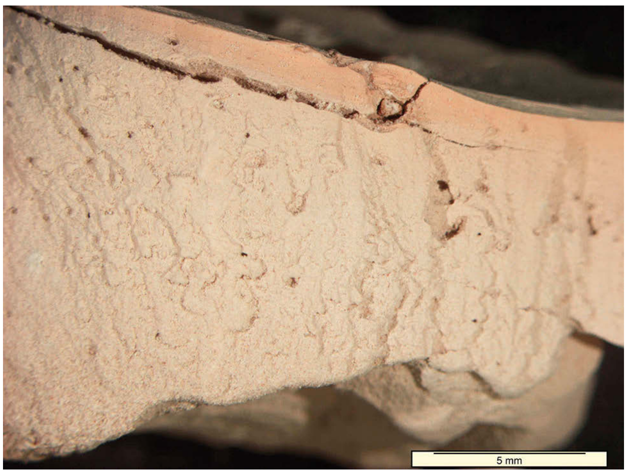


Fig. 204. Specimen P.029 after firing at 600°C

P.030

Microfossils: foraminifers (F): *Spiroplectamminella dentata* (Alth), *Tritaxia capitosa* (Cushman), *Dentalina* sp., *Neoflabellina* sp., *Gavelinella* cf. *monterelensis* (Marie), *Gyroidinoides nitidus* (Reuss), *Gyroidinoides globosus* (Hagenow), *Paralabamina toulmini* (Brotzen), *Lenticulina* div. sp., *Globotruncanita stuarti* (Lapparent), *Contusotruncana fornicata* (Plummer), *Abathomphalus mayaroensis* (Bolli), *Abathomphalus?* cf. *subornatus* (Gandolfi), *Heterohelix globulosa* (Ehrenberg), *Hedbergella* cf. *borhholmensis* Douglas & Rankin, *Hedbergella* cf. *holmdelensis* Olsson, *Hedbergella* cf. *planispira* (Tappan).

Other: single ostracods.

Age: Maastrichtian.

Note: mass occurrence (up to 100 specimens per square cm) of carbonate internal casts of planktonic forms from the genera *Hedbergella* and *Heterohelix* about 0.10 mm in diameter.

Calcareous nanoplankton: Late Campanian – Maastrichtian

P.033:

Microfossils: foraminifers: *Spiroplectinella dentata* (Alth), *Gaudryina rugosa* (d'Orbigny), *Verneuilina muensteri* Reuss, *Lenticulina* div. sp., *Eouvigerina* sp., *Globorotalites michelinianus* (d'Orbigny), *Abathomphalus* cf. *subornatus* (Gandolfi), *Globotruncanita stuartiformis* (Dalbiez), *Hedbergella holmdelensis* Olsson, *Hedbergella bornholmensis* Douglas & Rankin, *Heterohelix globulosa* (Ehrenberg).

Other: sea-urchin spines, ostracods, fragments of tubes (pipes?) of worms.

Age: Campanian – Maastrichtian.

Calcareous nanoplankton: Campanian – Maastrichtian.

Fig. 205. Specimen P.33H: a vessel made by mixing the P.033 marl with *hamra* soil and *terra rossa*

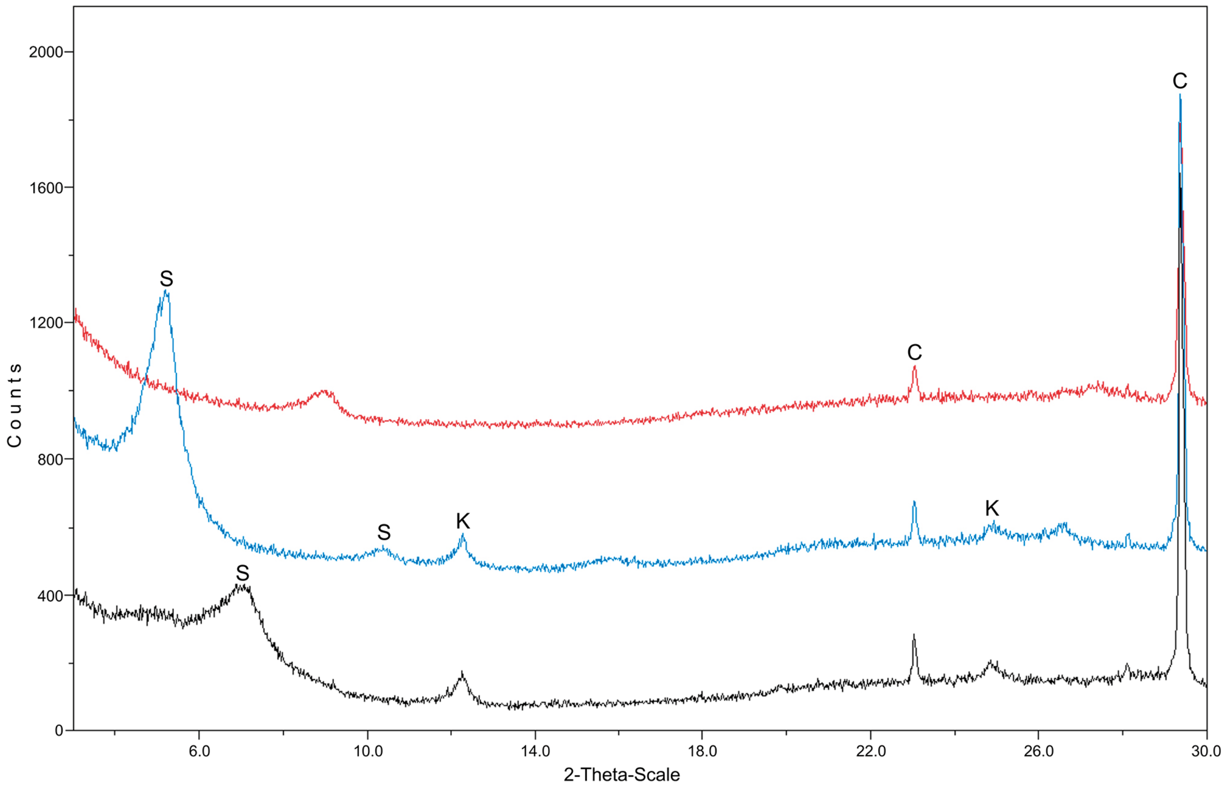


Fig. 206. XRD patterns of Ghareb Fm. marls (sample P.032/P.033) obtained as a result of oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). In spite of dissolving, carbonates (calcite) have been preserved. Symbols: smectite (S), kaolinite (K), calcite (C)

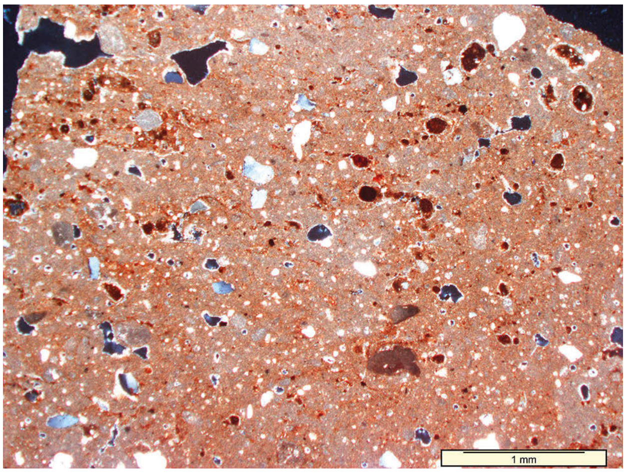


Fig. 207. Specimen P.33H after firing, photomicrograph of a thin section (CPL)

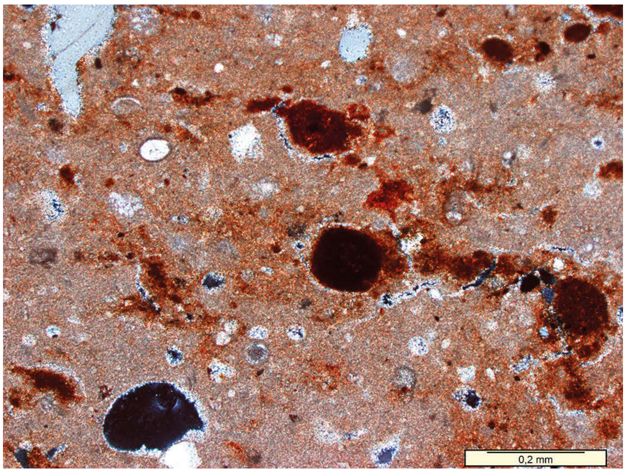


Fig. 208. Specimen P33H: an image obtained at higher magnification (CPL)

The determination of the age of the deposit as Maastrichtian differs from that of cartographic divisions, which indicate their age to be Santonian – Early Campanian[322] and on this basis were assigned to the Maastrichtian Ghareb Formation.

Taqiye Formation (P.253; P254), coord. 32.76731°N, 35.25178°E.

The Taqiye samples were taken along route no. 77 near the Eshkol Reservoir (Fig. 209).

The deposit is milk-white, highly calcareous. Its micro-paleontological composition:

Gaudryina sp., *Spiroplectinella dentata* (Alth), *Ramulina pseudoaculeata* (Olsson), *Bolivina incrassata* Reuss, *Quadrimorphina allomorphinoides* (Reuss), *Pullenia jarvisi* Cushman, *Charltonina florealis* (White), *Nuttallides truempyi* (Nuttall), *Guttulina trigonula* (Reuss), *Eponides umbonatus* (Reuss), *Bulimina midwayensis* (Cushman & Parker), *Gavelinella beccariiformis* (White), *Gyroidinoides globosus* (Hagenow), *Anomalinoides* cf. *welleri* (Plummer), *Subbotina triloculinoides* (Plummer), *Acarinina* cf. *soldadoensis* (Brönnimann), *Morozovella* cf. *subbotinae* (Morozova) is indicative of Middle – Late Paleocene.

The mineral composition of the sample: predominantly calcite, and among clay minerals, smectite (Fig. 210).

As in the case of Ghareb marls, the firing of pure Taqiye marl (specimen P.253) did not allow producing good-quality ceramics (Fig. 211, 212).

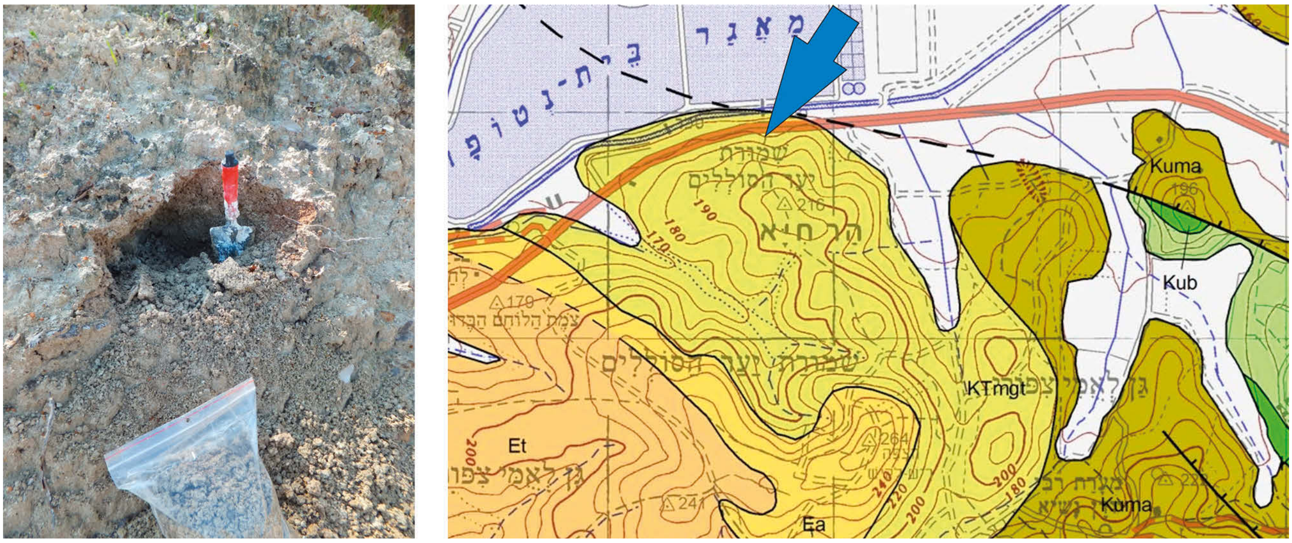


Fig. 209. Magav (near the road No 77), Taqiye marl (P.253, P.254). On the right a fragment of a geological map (Sneh 2008). The arrow indicates the place of sampling the specimen
Symbols: Kuma – Senonian (Ahihud Mbr.); KTmgt – Senonian & Paleocene (Ghareb & Taqiye Fm); Ea – Eocene (Adulam Fm.); Et – Eocene (Timrat Fm.)

[322] Cf. Levy 1983: 5.

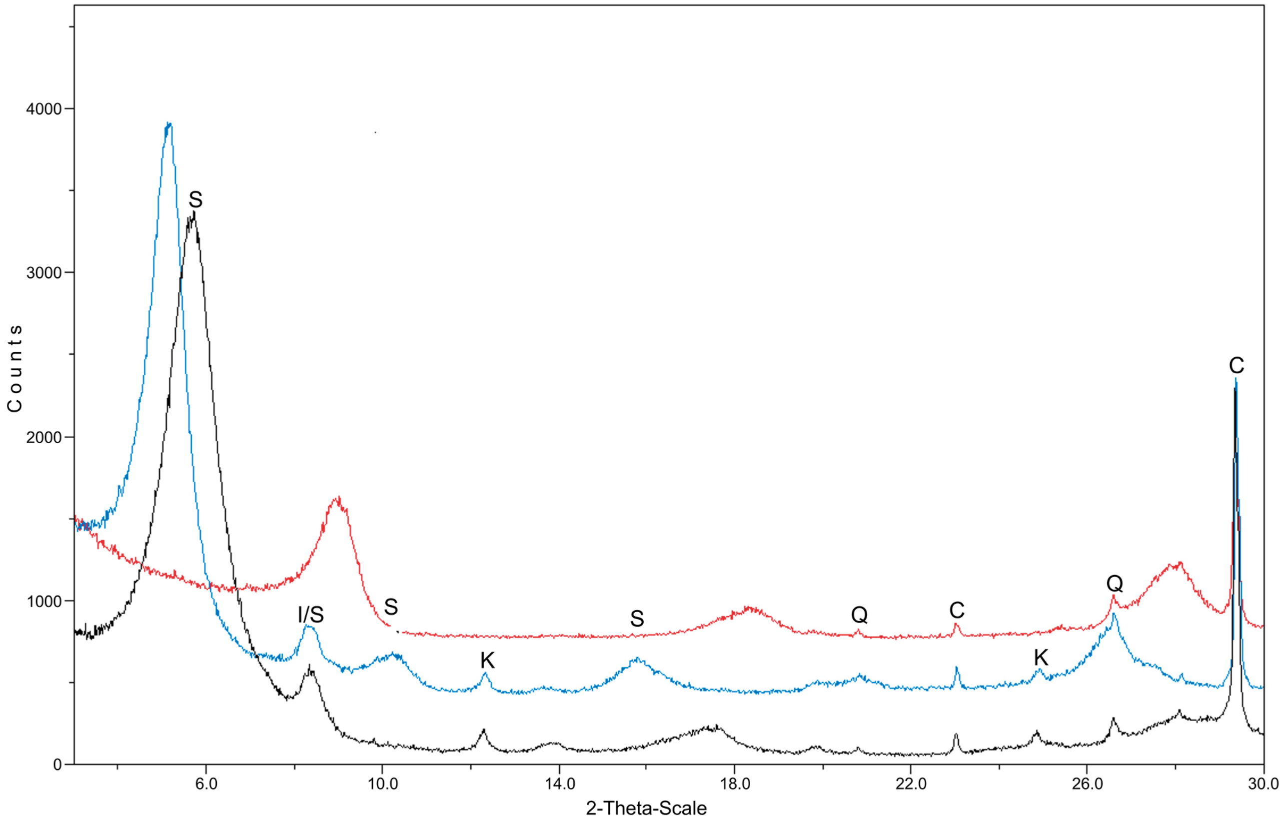


Fig. 210. XRD patterns of Paleocene Taqiye chalky marl (P.253) obtained as a result of oriented analysis (black line), after treatment with ethylene glycol (blue line) and roasting (red line). In spite of dissolving, calcite (C) has been preserved, the sample contains smectite (S), plus minor kaolinite (K)

The material obtained from the mixture of marl, *hamra* and *terra rossa* (specimen P.253H) allowed producing much better ceramics, but unsatisfactory as to physical parameters (cf. Fig. 213). On optical examination the dominant component of the matrix is decomposed carbonates, mixed with clayey balls of *terra rossa* and quartz grains (Fig. 214).

The grey colour of the carbonates is indicative of an unfinished process of their hydration and recrystallisation. The experimental sample obtained differs from the ceramics of the vessels examined.

Studies of the pyroclastic rocks in the Mount Carmel region were of a reconnaissance nature, they were carried out with a view to finding glass particles similar to the 'yellow fragments' found in the SG I.A3 and PG.V ceramics.

Fig. 211. Specimen P.253 – Taqiye marl after firing at 600°C

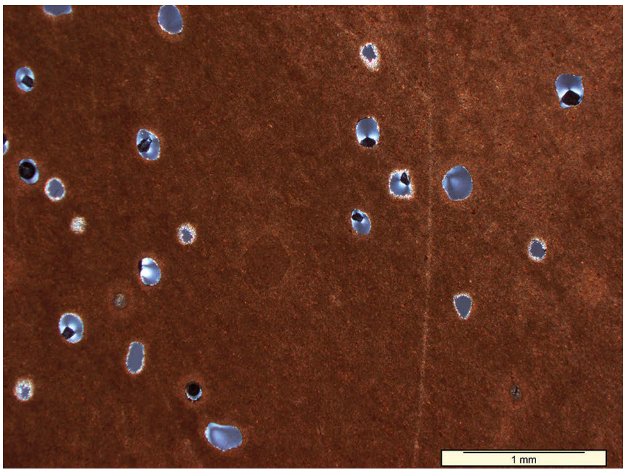


Fig. 212. Specimen P.253 after firing, photomicrograph of a thin section (CPL)

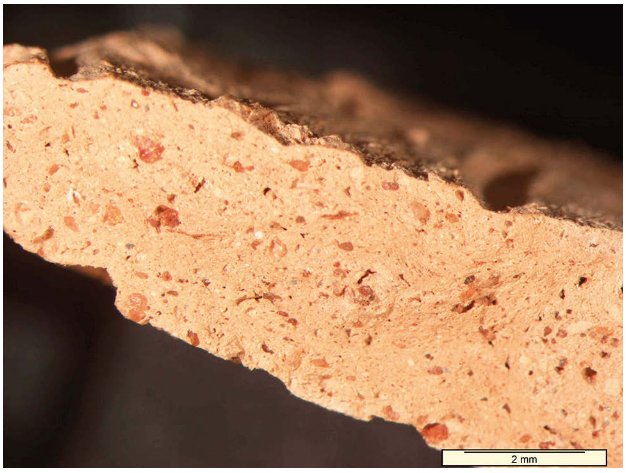


Fig. 213. Specimen P.253H, obtained experimentally from a mixture of Taqiye marl, *hamra* and *terra rossa*

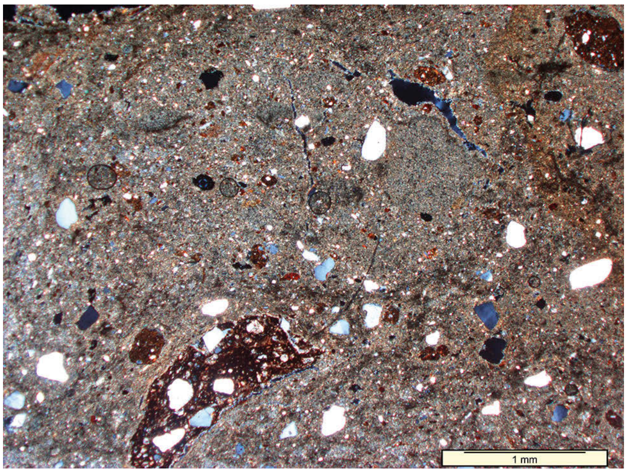


Fig. 214. Specimen P.253H, photomicrograph of a thin section (CPL)

Karem Maharal pyroclastics (coord. 32.6501°N, 34.9848°E).

Samples were taken from the level of yellow tuffs (Fig. 215, 'sample Maharal B', cf. Singer 1967: 104), those are angular, transparent, light-yellow clasts, fragmentarily argillitised, often surrounded by amor-

Fig. 216. Karem-Maharal: the sampling site

Table 14. Chemical composition of volcanic glass fragments sampled at Karem Maharal and Nahal Rakefet. Columns 1–4 give the chemical composition of 'yellow fragments' contained in samples SB35 and SD-68 (SG I.A3)

	SD-68, pt. 1	SD-68, pt. 2	SB-35 pt.1	SB-35 pt. 2	Raqefet Maharal pt. 3	Raqefet Maharal pt. 3-3	Karem Mharal	Karem Maharal	Karem Maharal	Karem Maharal	Karem Maharal	Raqefet Tavasim pt. 4	Raqefet Tavasim pt. 3	Raqefet Tavasim pt. 1	Raqefet clay Tavasim	Raqefet Tavasim	Karem Maharal analysis after Singer (1967)		
Formula	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	basalt	tuff A	bomb
Na_2O	0.39	0.63	0.37	0.62	0.50	1.13	0.30	0.41	0.00	0.31	0.36	0.00	0.36	0.00	0.00	0.36	2.65	0.55	0.00
MgO	7.05	8.52	9.44	9.63	7.82	15.73	12.45	13.88	10.06	11.74	7.96	8.58	11.05	8.80	8.58	11.05	7.16	11.70	12.40
Al_2O_3	14.15	11.42	10.74	11.71	8.58	14.13	10.64	12.86	13.47	11.58	13.83	13.66	11.34	11.73	13.66	11.34	13.16	11.62	11.37
SiO_2	52.53	45.32	43.79	39.56	30.43	52.38	35.97	44.09	61.76	35.75	50.04	50.17	44.43	50.16	50.17	44.43	46.19	39.03	37.90
P_2O_5	0.00	0.00	1.57	0.00	9.93	2.95	0.00	0.00	0.00	0.61	0.00	0.00	0.00	1.91	0.00	0.00	0.57	0.92	0.00
K_2O	0.60	1.09	1.57	3.72	0.00	0.00	2.29	0.54	0.60	2.96	0.61	4.11	0.00	3.38	4.11	0.00	0.83	1.00	0.20
CaO	7.03	6.94	6.24	4.48	17.77	13.69	7.96	7.68	5.49	6.54	8.46	2.35	6.27	5.49	2.35	6.27	9.40	5.29	11.20
TiO_2	0.00	0.99	0.95	1.45	0.92	0.00	1.21	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00	0.00	3.48	2.66	0.00
Fe_2O_3	18.26	25.09	25.33	28.83	21.62	0.00	28.61	20.54	8.61	29.44	17.66	21.13	26.55	18.53	1.13	26.55	12.00	13.00	13.00
SO_3	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Fig. 215. Tuffs in the Karem Maharal Reserve – the sampling site. On the right a fragment of a geological map (Segev, Sass 2009).The arrow indicates the place of sampling the specimen. Symbols: Klty – Albian (Talme Yafe Fm.); Klya – Albian (Yagur Fm.); Kuτm – Cenomanian (Maharal Tuff); Kui – Cenomanian (Isfye Fm.); Kuτt – Cenomanian (Tavasim Tuff); Kuar – Cenomanian (Argan Fm.); Kuvs – Cenomanian (Shefeya volcanics)

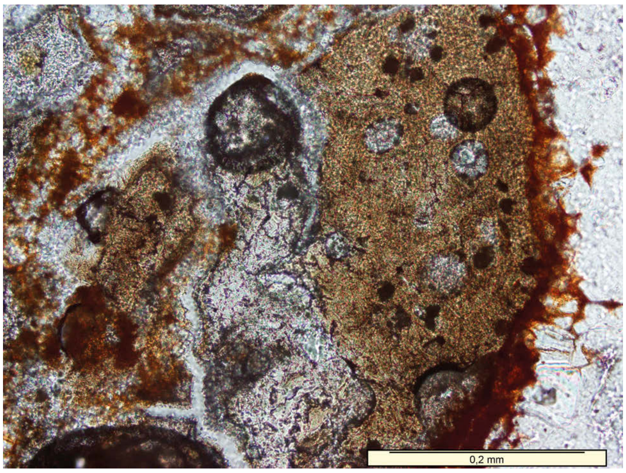


Fig. 217. Photomicrograph of volcanic glass, sampled from the stratum of yellow tuffs of Karem Maharal

phic reddish-coloured ferro-oxidised components. In the case of the analysed sample, those grains appear in the mass of sparite limestone (Figs. 216–217).

The results of a semi-quantitative analysis of the chemical composition of the volcanic glass are presented in Table 14.

Nahal Rakefet (coord. 32.6538°N, 35.0734°E).

Tavasim tuffs and Maharal outcrops on SW slopes of the valley (Fig. 218).

Symbols: Kuτm-Cenomanian (Maharal Tuff); Kui-Cenomanian (Isfye Fm.); Kuτt-Cenomanian (Tavasim Tuff); Kuzi-Cenomanian Arqon Fm.); Kuβr-Cenomanian (Raqefet Basalt); Kub(m)-Cenomanian/Turonian (Bina Fm., Muhraqa Mbr.); Kub(s)-Turonian (Bina Fm., Sumaq Mbr.)

Particles of the Tavasim tuffs were sampled from the south-eastern margin of the exposure, where they occur in dolomitic marl. They are honey-yellow in colour, relatively heavily argillitised, minute flakes of clay minerals have often completely replaced glass grains and turned yellow after the absorption of iron compounds; they are usually larger on the margins of clasts (Figs. 219–220).

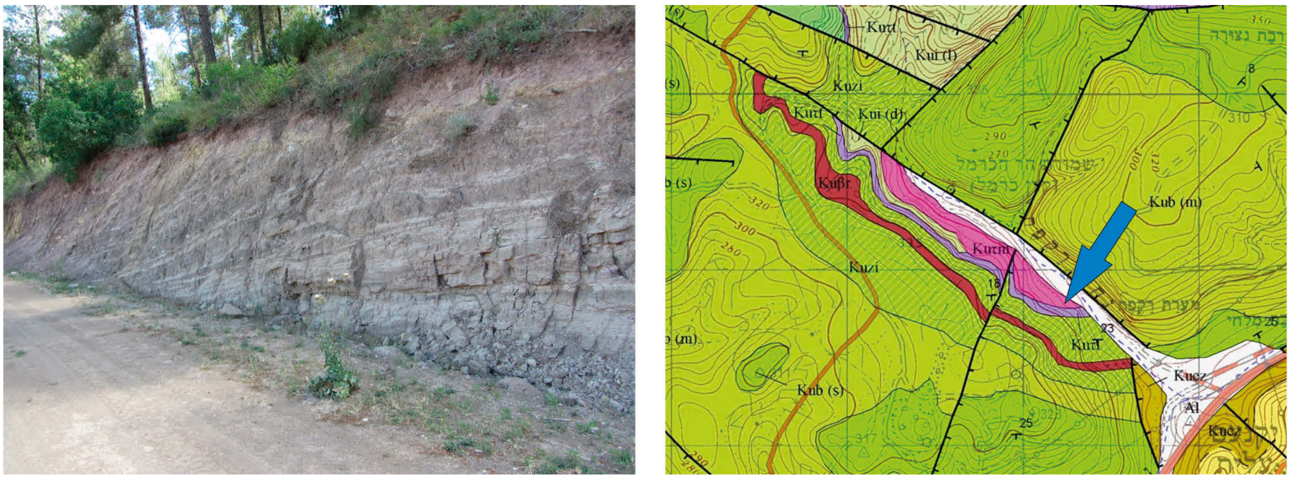


Fig. 218. Tavasim and Maharal tuffs, an outcrop on the south-western slopes of the **Nahal Rakefet** valley. On the right a fragment of a geological map (Segev, Sass 2009). The arrow indicates the place of sampling the specimen

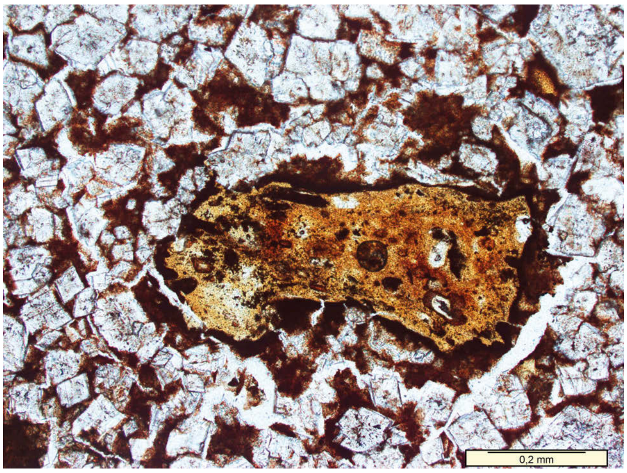


Fig. 219. Nahal Racefet, photomicrograph of volcanic glass fragment embedded in dolomite marl (PPL)

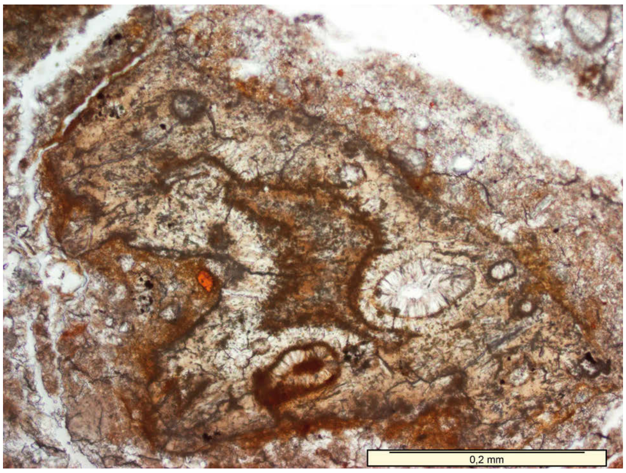


Fig. 220. Nahal Racefet, photomicrograph of a volcanic glass fragment of Tavasim tuff (PPL)

The glass of the Maharal tuffs is also altered in various degrees; compared with the Tavasim particles, they seem to contain fewer iron compounds (less advanced weathering), they have kept their hyaline structure more often, at least in the central parts.

It should be emphasised that the presented results of analyses of the chemical composition of particles of the Tavasim and Maharal glass cannot provide a basis for far-reaching conclusions because they are semi-quantitative in nature and they ignore the H_2O content. Besides, differences in the degree of weathering and argilitisation connected with it significantly change the chemical composition of the glass with time. Even so, it is worth noting that most analyses, especially of the Maharal tuffs and the glass in the ceramics, show a similar, relatively low content of SiO_2, but a high content of MgO and CaO, with a low content of alkalies.

Qishon River, (spec. P.QR) coord. 32.69767°N, 35.10294°E.

Samples of present-day Qishon River deposits were taken some 2 km above Sha'ar-Ha'Amakim near the Kiryat ha-Kahroshet bridge, below the mouth of its tributary, the Yokneam Stream, that can potentially transport Cretaceous volcanic debris eroded from Mount Carmel and the adjacent area of the Umm el Fahm Hills[323] (Figs. 221–222).

The experimentally obtained ceramics (specimen P.QR) are light-brown in colour (2.5 YR 6/6), compact, the visible fractures being an effect of the absence of a tempering admixture (Fig. 223).

On optical examination its matrix is light brown, rich in clay debris (Fig. 224).

The silt-sized minerals found in the sample (from <5% to over 10%) are mostly angular quartz (ca. 90%), as well as variously transformed feldspars (potassium and plagioclases), pleochroic amphiboles, and single automorphic crystals of carbonates. The SEM-EDS examination also revealed the presence of ilmenite, titanomagnetite, detritic calcium

Fig. 221. Qishon River near Kiryat ha-Kahroshet

Fig. 222. Kiryat ha-Kahroshet: dried modern sediments of the Qishon River

[323] Cf. Sneh et al. 1998, Cohen-Weinberger & Goren 2004: 78.

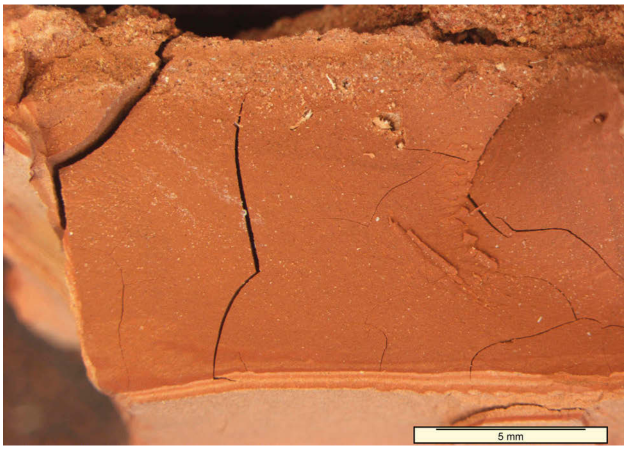


Fig. 223. Specimen P.QR: experimentally fired ceramics made of Qishon River alluvium

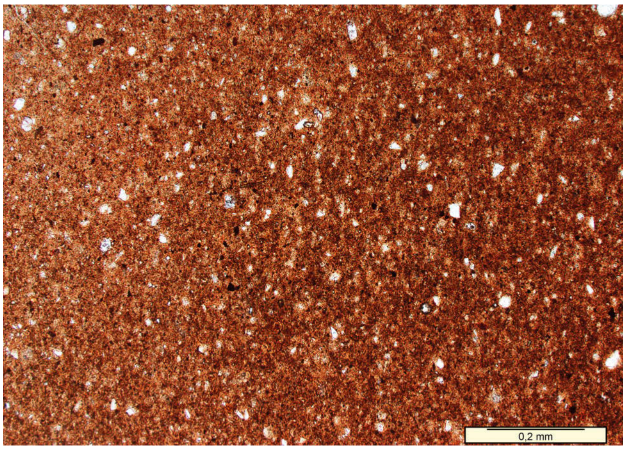


Fig. 224. Specimen P.QR, photomicrograph of a thin section (PPL)

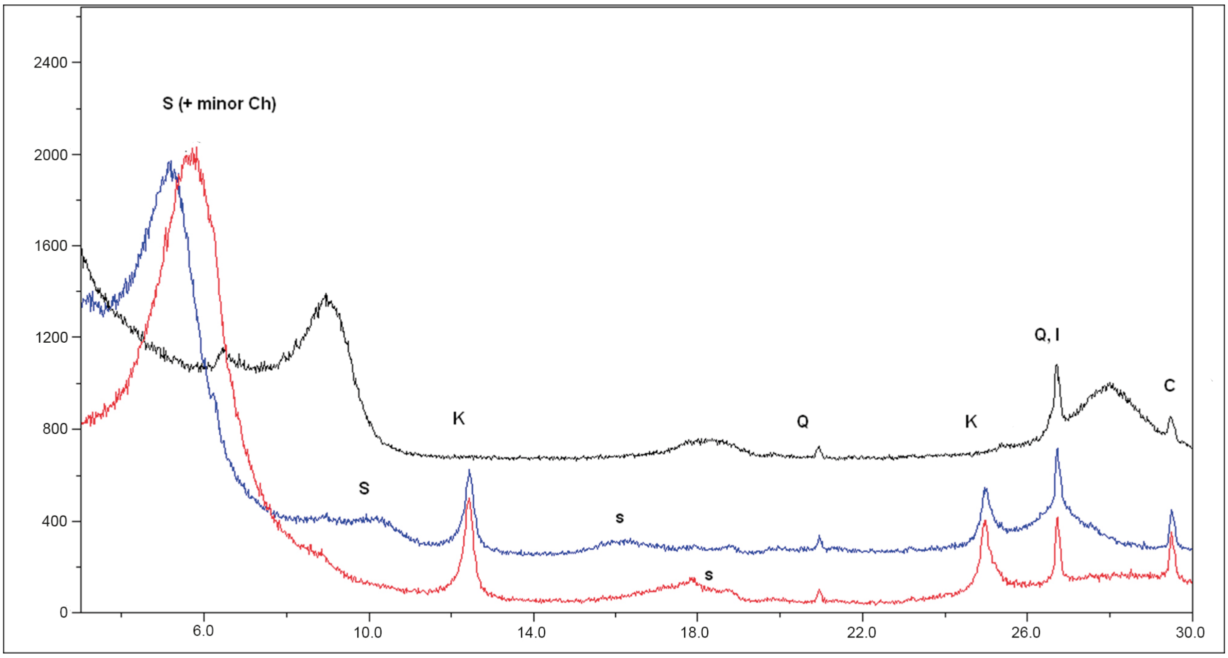


Fig. 225. XRD patterns of Qishon River alluvial deposits; quartz (Q), calcite (C) and smectite (S) predominate, there is also kaolinite (K)

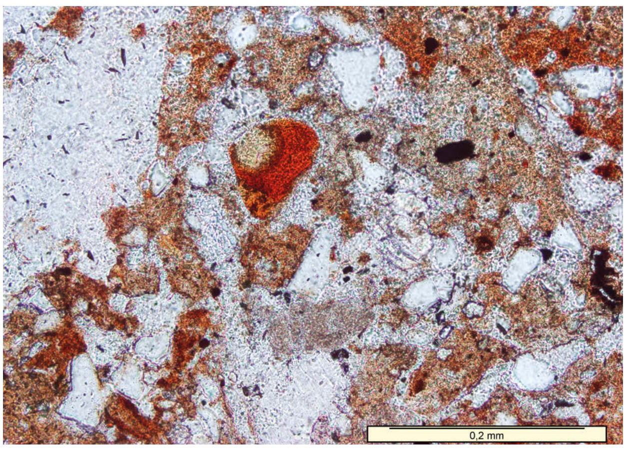


Fig. 226. Specimen P.QR, photomicrograph of a 'yellow volcanic (?) glass fragment' (PPL)

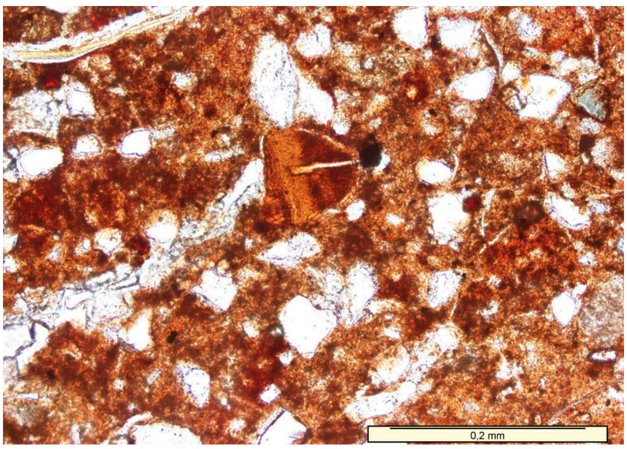
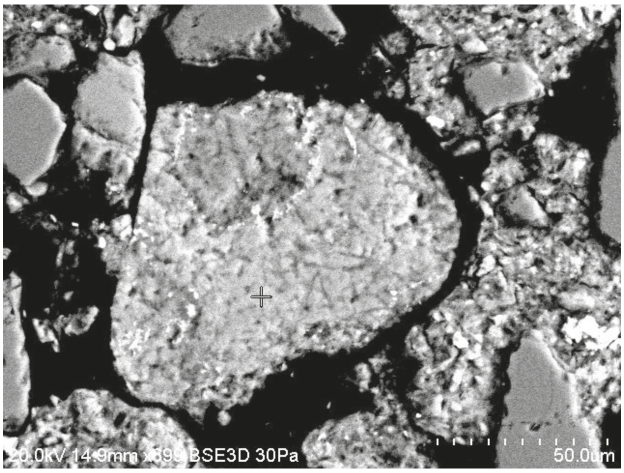
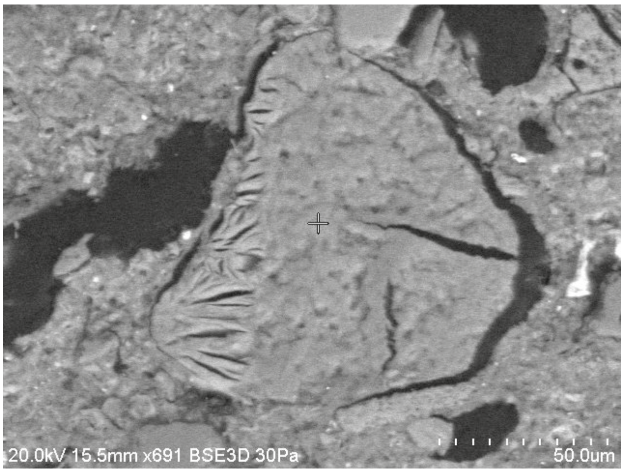


Fig. 227. Specimen P.QR, photomicrograph of another grain of the 'yellow fragment' (PPL)



Element line	Weight %	Formula	Compound %
O K	44.25S		—
Mg K	5.28	MgO	8.75
Al K	6.37	Al_2O_3	12.04
Si K	22.49	SiO_2	48.11
P K	0.20	P_2O_5	0.45
K K	0.46	K_2O	0.56
Ca K	2.42	CaO	3.38
Ti K	0.86	TiO_2	1.43
Fe K	17.68	Fe_2O_3	25.28
Total	100.00		100.00

Fig. 228. Specimen P.QR. Electron image of a yellowish volcanic glass fragment (cf. Fig. 226) and its chemical composition examined at the marked point



Element line	Weight %	Formula	Compound %
O K	46.44S		—
Na K	0.15	Na_2O	0.20
Mg K	7.38	MgO	12.25
Al K	7.57	Al_2O_3	14.30
Si K	25.75	SiO_2	55.08
S K	0.15	SO_3	0.37
K K	0.31	K_2O	0.38
Ca K	2.68	CaO	3.75
Fe K	9.57	Fe_2O_3	13.68
Total	100.00		100.00

Fig. 229. Specimen P.QR. Electron image of a glass grain (cf. Fig. 227, above) sampled at the site marked with a cross, with results of its chemical analysis

phosphates, and barite. An XRD analysis showed the presence of quartz and carbonates. The dominating clay component is smectites, there is also kaolinite, but in much smaller amounts (Fig. 225).

On optical examination especially notable is the presence of silt and fine sand-sized yellow volcanic glass, resembling the 'yellow fragments' found in the ceramics of groups SG I.A1 and PG V (Figs. 226–227).

'Yellow fragments' – discussion

The question of the derivation of the honey-yellow glass-fragments has already been discussed in the chapter on the SG I.A3 and PG V ceramics.

Similar particles in ceramics have also been found, e.g., by Cohen-Weinberger & Goren 2004, and Shapiro 2016: 66 (fig. 1). Those authors connect their presence with submarine Cretaceous volcanism, traces of which have been preserved on Mt Carmel and in the Um-Fahm hills.

Fragments similar to this glass were found in SG I.A3 and PG V jugs, and in the Nahal Qishon deposits. Moreover, the chemical composition of those particles, established with the use of a semi-quantitative SEM-EDS method, seems to be similar to that of a basalt glass, with low silica content. However, one should also take into account the various degrees of weathering of those grains, and the degree of their transformation, as proved in many cases by rosettes of secondarily formed clay minerals. It should also be kept in mind that the number of grains examined was small (especially of the Qishon sediments), hence the presented results are highly unsystematic in nature.

Still, it is worth emphasising that the chemical composition of the examined grains is similar to that of the glass particles of the Maharal tuffs, also those sampled in Nahal Raqefet.

7.3. Coastal sands

The observed variety of the mineral composition of coastal sands is used as a basic indicator of the provenance of ceramics produced in the coastal region of the Levant. This follows from the variable proportions of carbonate components in relation to quartz. This change can be noted especially north of Akko (cf. e.g. Landau & Goren 2004: 28), where the dominant components are carbonates, in contrast to the predominance of quartz observed towards the south, especially in Haifa Bay. This follows from the fact that "Haifa Bay is the north-eastern end of the Nile littoral cell, and constitutes the final depositional basin of the Nile-derived quartz sand, which is transported from the Nile Delta along the northern Sinai coast and the coast of Israel".[324]

According to Sanlaville,[325] in Lebanon quartz may appear only as a minor component in the sand of beach dunes, but near Tyre it is essentially carbonates, mostly from bioclasts.[326] According to Hamad et al. (1996), the composition of shore sands of Kasmiech (northward of Sidon) appears to be almost pure carbonates (75–85% of carbonates and only 5% of silica minerals), while near Beirut the sands from Ouzai turn out to be pure quartz, subrounded to subangular.

Somewhat different data are given by Bettles 2003b, according to whom along the shores north of Sidon the sands consist of ca. 60% of quartz and ca. 40% of carbonate grains (...). They derive probably from Late Cretaceous sandstone, which crops out in the region[327]. Bettles also reports that the sands south of Akko contain 80% of quartz, while 18 km southwards, close to Shiqmona, again 99% of biogenic grains[328]. In contrast, a study by Ownby & Griffiths (2009) showed a mostly calcareous composition of beach sands from Sidon.

The variations in the composition of coastal sands of the Levant discussed here generally agree with the studies carried out by the present author in the north of Israel between Atlit and Tel Haziv. Presented are petrographic images of those sands.

Predominant in the deposits of beaches in Akko and northward (specimen P6 – Achziv, P2 – Nahariya) are organo-detrital carbonates, while in the south in the sampled sands of Haifa Bay (P4 – Kiryat Yam) and on the northern beaches of the Carmel coastal plain (P3) the predominant component is quartz, the proportion of carbonates being small.

The next jump in the share of carbonates was recorded on beaches situated south of Nahal Megadim (the Ha Hoterim kibbutz), where quartz is still dominant, but organo-detrital calcium carbonate comes next; it includes relatively numerous fragments of *Corallinaceae* and *kurkar* fragments formed as a result of the abrasion of the nearby *kurkar* ridges. Micrite limestones and less numerous, but clearly present, are minerals of magmatic origin, especially amphiboles and single, automorphic pyroxenes. No particles of volcanic glass were observed in the Ha Hoterim sands (Figs. 230–233).

[324] Zvieley et al. 2006: 849.
[325] Sanlaville 1977: 162–164, fide Landau and Goren 2004.
[326] Cf. Cohen-Weinberger & Goren 2004; Landau & Goren 2004, Galili et al. 2007 – the authors quote Sivan 1996 and Sanlaville 1977: 162–164.
[327] Bettles does not report where exactly she sampled the sand for examination.
[328] Cf. Bettles 2003b: 297.

Fig. 230. Specimen P-2, Nahariya, central beach sands, photomicrograph of a thin section (PPL). The only component is organogenic detritus, including such microorganisms as *Ammonia* sp., *Astergerina* sp., *Miliolidae*, as well as numerous fragments of Corallinacea and snails – an association diagnostic for the Late Eocene

Fig. 231. Specimen P-6, Achziv National Park sands (Shikun Vatkim beach, coord. 33.0507°N, 35.06150°E), photomicrograph of a thin section. *Significant components of those sands are foraminifers: Textularia* sp., *Operculina?* sp., *Ammonia* sp., *Pararotalia ex gr. lithothamnica* (Uhlig), *Globigerina* sp., *Chiloguembelina* sp. Miliolidae; as well as sea-urchin spines, fragments of Corallinaceae thalli, and zoaria of bryozoans. Age: Late Eocene

What should be noted as significant is the presence in those deposits of numerous microorganisms, including foraminifers, the age of which, in the opinion of Barbara Olszewska, is the Middle – Late Eocene. The associations of foraminifers and other microfossils in those sands correspond well with the distribution of the biofacies of a shallow-water carbonate platform.[329]

[329] Cf. Arni 1965; Kulka 1985; Höntzsch et al. 2011.

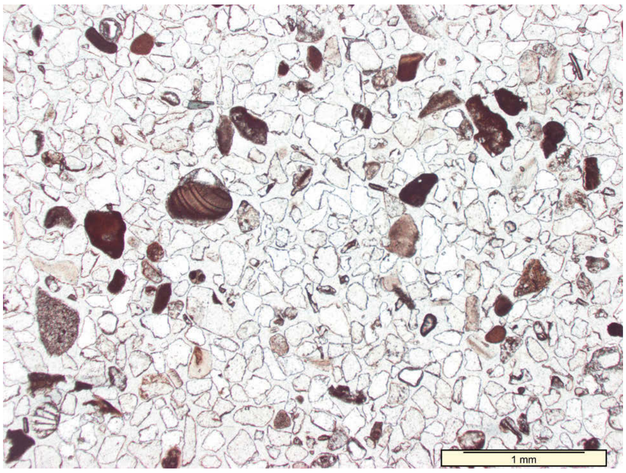


Fig. 232. Specimen P-4, Kiryat Yam (Hajfa bay) sands, photomicrograph of a thin section (PPL).Colourless quartz predominates, dark grains represent carbonates Foraminifers: *Rotalia* sp., *Lobatula lobatula* (Walker & Jacob), *Pseudohastigerina* (*Globanomalina*) cf. *wilcoxensis* (Cushman & Ponton) – one specimen, *Chiloguembelina* sp. – two specimens, Miliolidae. Other: numerous fragments of *Corallinaceae*. Age of the association: Middle Eocene

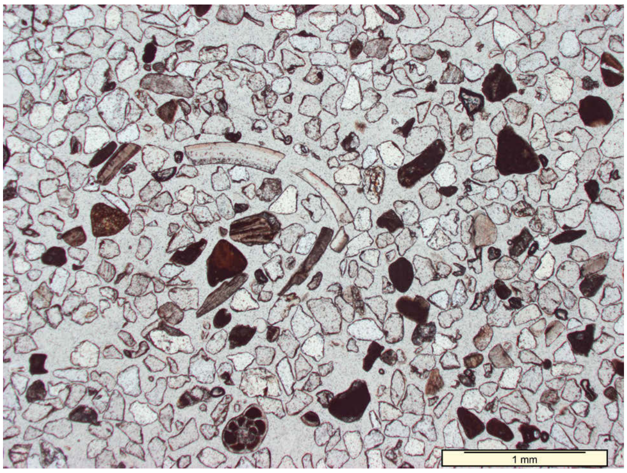


Fig. 233. Specimen P-3. Haifa, south (near Nahal Ahuza), Carmel coastal plain sands, photomicrograph of a thin section (PPL). Foraminifers: *Rotalia* sp., *Maslinella*? sp., *Ammonia* sp., *Operculina*? sp., *Nummulites* sp., Miliolidae. Other microfossils: numerous fragments of *Corallinaceae*, snails, sea-urchin spines. Age of the association: Middle (Upper) Eocene – Late Eocene

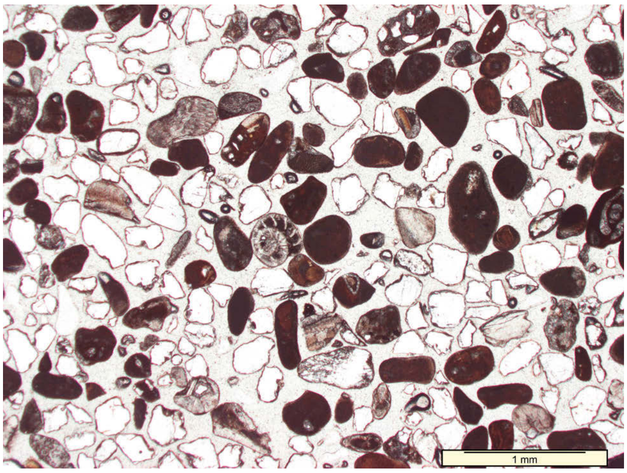


Fig. 234. Specimen P-7. Ha Hoterim, Carmel Coastal Plain sands, north of Atlit, photomicrograph of a thin section (PPL) Notable is the substantial proportion of carbonates (no micro-paleontological studies of them were conducted)

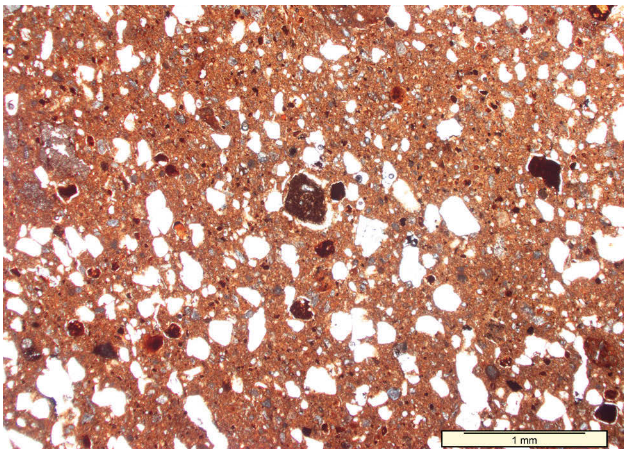


Fig. 235. Specimen Sb-35 (SG I.A3), photomicrograph of a thin section (PPL), included for comparison. Dark grains are *terra rossa* fragments. Notable is the absence of carbonates, predominant quartz grains of the size similar to that of sands from Haifa Bay (cf. specimen P-3)

7.4. Results of the examination of deposits sampled in the field – summing up

The presented results of examination of rocks sampled in the field do not provide an unequivocal answer as to the place of production of the jars and jugs examined.

In the course of the experiment no ceramics were obtained similar especially to Petrographic Subgroups I.A1/A2/A3, as well as to the cream-coloured ceramics, especially of Petrographic Group IV.

This holds especially for the marls occurring in the Tell Keisan area, probably representing the Ghareb Formation[330].

The low usefulness of the examined samples follows from the fact that their dominant component is expanding smectite, while in the case of samples of marls of the Taqiye and Ghareb Formations it is calcium carbonate, usually also co-occurring with smectite. This fact weakens, at least to some extent, the thesis about pottery workshops being located in the immediate vicinity of Tell Keisan as suggested by Glass 1980, and recently by Waiman-Barak & Gilboa 2016.

At the same time it should also be emphasised that the failure of the experiments conducted does not eliminate the entire Ghareb and Taqiye formations as a potential source of material. This is proved by, e.g., Arkin (1988: 7) or Illani et al. (1991), who demonstrate that the montmorillonite content ranges with the increased carbonate content, and in the case of Taqiye marls, kaolinite and illite gradually decrease towards the top of the formation.

Especially notable are numerous Eocene foraminifers present in the contemporary coastal sands.[331] This seems that their presence is an effect of the drainage of Eocene rocks by streams, including the Qishon River, flowing into the sea.[332]

Among the samples of sands taken from the beaches between Atlit and the border with Lebanon, the sands of Haifa Bay have the most monomineral, quartzitic composition.

Fragments of coralline algae *Amphiroa* can be found not only in the coastal sand deposits, but also in deposits from outside of the present-day coastline area, especially in the alluvial deposits of the Zevulun Plain connected with the exposure of the Kurdane Fm.[333]

The presence of fragments of orange glass fragments in the contemporary Qishon deposits seems to corroborate the thesis about the local (Mt Carmel) provenance of the SG I.A3 and PG V ceramics.

The results of laboratory experiments seem to corroborate that most ceramic workshops of those times, analogically to the practice of contemporary potters, employed the method of mixing at least two kinds of clay material. In the light of the present study, this was usually *terra rossa* (containing non-expanding clay minerals with an elevated Fe content facilitating sintering), mixed at various proportions with marly clay.

330 On the basis of micro-paleontological studies.

331 This fact has already been noted by Bettles (2003b).

332 Cf. Eliashiv et al. 2015: 3.

333 Cf. Levy 1983.

8. Tel Akko

8.1. Subject of study

Tel Akko (Tell el-Fukhar in Arabic) was a Phoenician site continuously inhabited till the mid-Hellenistic period (ca. 150 BC), by which date the main settlement shifted to the west.[334] The new series of archaeological works on the tell began in 2010 carried out by a joint mission directed by Ann Killebrew (University of Pennsylvania) and Michal Artzy (University of Haifa).[335] The sampled material submitted to the analyses was discovered during the field season of 2011 when mostly the Persian and Hellenistic levels were explored, beside some of the late Iron Age IIC.

The main criterion for the selection of the samples was their similarity to the sampled material from Tell Keisan in terms of both fabric and shape, with the aim to compare the petrographical and chemical profile of Tel Akko jars to those from Tell Keisan.

Of 24 samples (see list of samples below), just one belongs to group 4 ("control sample"), and it was selected on account of its visual similarity to one of the wares distinguished by means of macroscopic examination ("Light White ware"); the remaining 23 samples come from jars (22 specimens) and from a jug (one specimen). As many as probably 16 samples represented shape group 1a (carinated-shoulder jars), one sample pertained to shape group 1b (late Phoenician type of jar), one sample may have belonged either to shape group 1a or to 1b, two samples were of shape group 2a (bag-shaped jars), two samples (body sherds) either of group 1a or 2a, and one sample of shape group 3a (storage jug).

On the basis of macroscopic examination, it has become evident that two wares are strongly present at Tel Akko: the Phoenician Semi-fine ware and the Light White ware, accompanied by a few variants of the latter. According to M. Dothan, in the Late Persian and Early Hellenistic period strata the most common jars were those made of "white clay";[336] however, the renewed excavations show a rather even proportion of two main jar wares: ca. 50% of Persian and Early Hellenistic jars are in the Light White ware with its variants, and ca. 50% in the Phoenician Semi-fine ware (and variants?).

In the list of samples that follows, they are arranged according to the running number of the sample, marked AK – (for Akko), and followed by information on the excavation context (locus/basket/register number and estimated dating).

8.2. List of sampled pottery from Tel Akko with their context information, arranged by sample number

AK-225 (Loc. 2169, b. 20760/11, pottery from late IA IIC to Persian/Hellenistic) handle of jar, group 1a(?). Fabric brownish pink (5 YR 6/6 reddish yellow), with partial greyish core, many large white and pale grey grits, some tiny glistening particles, occ. small voids. Persian or Hellenistic period. **PG: ?**

AK-226 (Loc. 2163, b. 20585/4, pottery from late IA IIC to Persian/Hellenistic): rim of jar, group 1a. Fabric pale beige (10 YR 8/3 very pale brown) with many orange-brown grits, rare black grits, very rare voids(?) macroscopically identified as "Light White ware". Persian or Early Hellenistic period. **SG: IV.D.**

AK-227 (Loc. 2059, b. 20651/18, pottery from IA IIC/Persian to Hellenistic): jar handle, group 1a. Fabric pink/light red (near 2.5 YR 6/6 light red), many large deep irregular voids, rare small white

334 cf. Dothan 1976.

335 Killebrew & Olson 2014.

336 Dothan 1976:76.

grits, some dark red(?). Persian or Hellenistic period. S**G: I.A1.**

AK-228 (Loc. 2169, b. 20631/9, pottery from late IA IIC to Persian/Hellenistic): handle and body sherd of jar, gently ribbed; group 1b. Fabric pink (5 YR 7/6 reddish yellow), dense and clean, with some tiny glistening particles, macroscopically identified as Phoenician Semi-fine ware. Persian/ Hellenistic period. **SG: I.A1.**

AK-229 (Loc. 2204, b. 20837/149, pottery from late IA IIC to Persian/Hellenistic): jar handle, group 1a. Fabric dark pink, with some (occasional) white and "black" grits, and big piece of vitrified(?) dark green rock. Persian period. **SG: I.A1.**

AK-230 (Loc. 2170, b. 20800/2, pottery from late IA IIC to Persian/Hellenistic): rim of jar, group 1a. Fabric pink (7.5 YR 6/6 reddish yellow), dense, with occasional small white grits; macroscopically identified as "related to Phoenician Semi-fine ware". Persian or Early Hellenistic. **PG: ?**

AK-231 (Loc. 2169, b. 20654/14, pottery from late IA IIC to Persian/Hellenistic): rim of jar, group 1a. Fabric light red (2.5 YR 6/8 light red), dense, with some white grits (also filling shallow voids), occasional rather large red grits, some tiny glistening particles, macroscopically identified as "red fabric related to Phoenician Semi-fine ware". Persian period. **SG: I.A1**.

AK-232 (Loc. 2170, b. 20743/29, pottery from late IA IIC to Persian/Hellenistic): squared rim of jar, group 1a(?). Fabric pink (2.5 YR 6/6 light red) with greyish (yellow?) core, circular voids, some tiny glistening particles, macroscopically identified as "related to Phoenician Semi-fine ware". Late IA IIC period? **SG: I.A2.**

AK-233 (Loc. 2163, b. 20592/6, pottery: Persian): rim of jar, group 1a. Fabric pink (5 YR 7/6 reddish yellow), dense, with occasional irregular deep voids and rare very small white grits, macroscopically identified as "related to Phoenician Semi-fine ware". Persian period. **SG: IA1.**

AK-234 (Loc. 2204, b. 20837/18, pottery from late IA IIC to Persian/Hellenistic): handle of jug, group 3a. Fabric beige (7.5 YR 7/4 pink), with many small circular voids, occasional small white grits and large dark grey rock. Persian or Hellenistic period. **SG: I.A1.**

AK-235 (Loc. 2169, b. 20601/17, pottery from late IA IIC to Persian/Hellenistic): handle of jar, group 1a or 1b. Fabric pink (5 YR 7/6 reddish yellow), rather dense (shallow voids), rare white grits, macroscopically identified as "close to Phoenician Semi-fine ware". Persian or Hellenistic period. **SG: I.A1.**

AK-236 (Loc. 2059, b. 20664/13, pottery from IA IIC/Persian to Hellenistic): handle of jar, group 2a. Fabric pink (5 YR 7/4 pink) with many shallow voids, occasional white grits, some tiny glistening particles. Persian or Hellenistic period. **SG: IV.D.**

AK-237 (Loc. 2177, b. 20805/23, pottery: Persian): body sherd/handle of jar, group 1a. Fabric pink (5 YR 7/6 reddish yellow), rather dense (some shallow voids?), rare white and red grits; macroscopically identified as "Phoenician Semi-fine ware". Persian or Hellenistic period. **SG: I.A1.**

AK-238 (Loc. 2162, b. 20566/12, pottery from late IA IIC to Persian/Hellenistic): rim of jar, group 1a(?). Fabric pink (7.5 YR 7/6 reddish yellow) with partial greyish core, some voids, tiny white grits, occasional glistening particles. Late IA IIC period. **SG: I.A4.**

AK-239 (Loc. 2169, b. 20669/17: Persian-period context, with carinated-shoulder jars in a range of fabrics): body sherd/handle of jar, group 1a. Fabric pale pink (near 5 YR 8/3 pink), with shallow voids and rare white grits; white exterior surface, macroscopically identified as "Akko ware". Persian period. **SG: IV.D.**

AK-240 (Loc. 2162, b. 20566/20, pottery from IA IIC to Persian/Hellenistic): rim of jar, group 2a. Fabric very pale beige (10 YR 8/2 white), circular voids, some white/pale grey grits, black grits, occasional tiny glistening particles; macroscopically identified as "Light White ware". Persian/Hellenistic period. **SG: IV.D.**

AK-241 (Loc. 2059, b. 20651/21, pottery from IA IIC/Persian to Hellenistic): body sherd of jar, group 1a or 2a. Fabric pale beige (10 YR 8/2 white), with voids (circular/oblong) and white grits; white surface; macroscopically identified as "Light White ware". Persian or Early Hellenistic period. **SG: IV.D.**

AK-242 (Loc. 2163, b. 20575/26, pottery from IA IIC to Hellenistic): body sherd of jar, group 1a or 2a. Fabric pale pink (near 5 YR 8/4 pink), dense, with many small to medium-size red grits and some white ones (pale gritty pink). Persian or Early Hellenistic period. **SG: IV.H.**

AK-243 (Loc. 2163, b. 20585/1, pottery from late IA IIC to Persian/Hellenistic): jar rim, group 1a. Fabric beige (near 5 YR 8/2 pinkish white), with many voids (sponge-like look), occasional black(?) and white grits (abundant mineral admixture, prevailing dark grits). IA IIC/III(?) period. **SG: IV.B.**

AK-244 (Loc. 2177, b. 20805/25, pottery: Persian): body sherd/shoulder of jar, group 1a, Fabric pale pink (near 5 YR 8/4 pink) with many white grits, some red grits(?), some circular voids; macroscopically identified as "Akko ware"**.** Persian period. **SG: IV.D**.

AK-245 (Loc. 2170, b. 20743/6, pottery from late IA IIC to Persian/Hellenistic): fragment of jar, group 1a. Fabric pink (5 YR 7/6 reddish yellow), some deep irregular voids, some red grits (depositions?); macroscopically identified as "related to Phoenician Semi-fine ware". Persian/Hellenistic period. **SG: I.A1.**

AK-246 (Loc. 2095, b. 20622/3, pottery from late IA IIC to Hellenistic): rim of jar group 1a. Fabric pink (7.5 YR 7/6 reddish yellow), with voids (small to large, deep, irregular), some small white grits, some dark red up to large. Early Persian? **SG: I.A1.**

AK-247 (Loc. 2164, b. 20579/13, pottery from late IA IIC to Hellenistic): extended rim of a bowl, group 4. Fabric very pale beige (7.5 YR 8/2) with pinkish core, some tiny voids, occasional red grits, macroscopically identified as "Light White ware". Persian or Early Hellenistic period. **SG: IV.H.**

AK-248 (Loc. 2169, b. 20760/25, pottery from late IA IIC to Persian/Hellenistic): rim of jar, group 1a. Fabric pale beige-pink (7.5 YR 8/4 pink), dense, with many small white grits, medium- and large dark brown grits, tiny glistening particles; macroscopically identified as "Light White ware". Persian period. **SG: IV.D.**

8.3. Tel Akko petrographic database

24 samples from Tel Akko chosen for examination include fragments of 22 jars, one fragment of jug and one fragment of a bowl (control sample). Their descriptive information and the petrographic group assignment are presented in Table 15.

The basic and most notable distinction between the jars under examination is their colour (Fig. 236, 237):

(1) pale red, 12 specimens: (AK-227, AK-228, AK-229, AK-231, AK-233, AK-234, AK-235, AK-237, AK-245, AK-246, AK-232, AK-238); and

(2) beige (cream on the surface) – 10 specimens: (AK-225, AK-226, AK-230, AK-236, AK-239, AK-240, AK-241, AK-244, AK-247, AK-248, AK-243, AK-242).

Petrographic group I.A

Subgroup I.A1 (Figs. 236, 238–241)

Ten specimens: AK-227, AK-228, AK-229, AK-231, AK-233, AK-234, AK-235, AK-237, AK-245, and AK-246 are made of Eocene foraminiferous marl rich in sparse ferro-Globigerina concentrations, tempered by 5–8% of quartz sand.

The group includes vessels light-red in colour (2.5 YR 7/8), 'soft', especially on the surface.

In transmitted light the matrix of the samples is light-yellow, yellowish-grey or yellow-orange with scattered red iron-oxide mottles. It is optically active, which is indicative of a low temperature of firing, 650–700°C (apart from the more strongly fired sample AK-231), rich in numerous microfossils, especially foraminifers of *Chiloguembelina* sp., *Globige-*

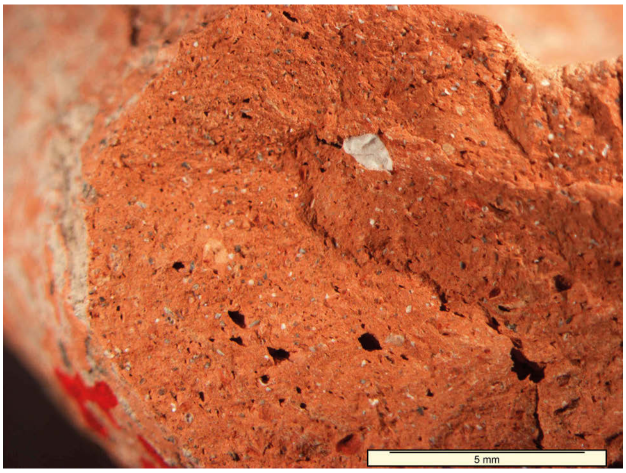


Fig. 236. Pale red ceramics, SG I.A1. Fragment of specimen AK-227

Fig. 237. Beige-cream ceramics, SG IV.D. Fragment of specimen AK-239

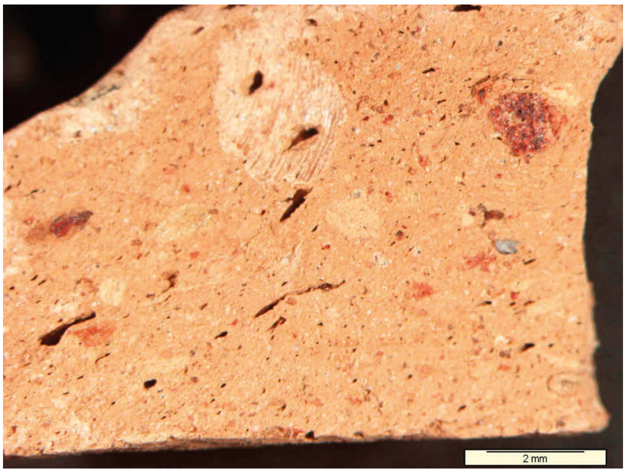


Fig. 238. SG I.A1. Fragment of specimen AK-246

Table 15. Descriptive information and petrographic group assignment of the ceramics from Akko

Sample symbol	Excavation inv.no.	Fragment identification	Dating	Vessel group	Petro group
AK-225	57/2011.2169 20760/11	handle of jar	Persian or Hellenistic	1a?	?
AK-226	57/2011.2163.20585/4	rim of jar	Persian or Early Hellenistic	1a	IV.D
AK-227	57/2011.2059.20651/18	handle of jar	Persian or Hellenistic	1a	I.A1
AK-228	57/2011.2169.20631/9	handle and body sherd of jar	Persian/Hellenistic	1b	I.A1
AK-229	57/2011.2204.20837/149	handle of jar	Persian	1a	I.A1
AK-230	57/2011.2170.20800/2	rim of jar	Persian or Early Hellenistic	1a	?
AK-231	57/2011.2169.20654/14	rim of jar	Persian	1a	I.A1
AK-232	57/2011.2170.20743/29	rim of jar	Late IA IIC(?)	1a	I.A2
AK-233	57/2011.2163.20592/6	rim of jar	Persian	1a	I.A1
AK-234	57/2011.2204.20837/18	handle of jug	Persian or Hellenistic	3a	I.A1
AK-235	57/2011.2/69.20601/17	handle of jar	Persian or Hellenistic	1a or 1b	I.A1
AK-236	57/2011.2059.20664/13	handle of jar	Persian or Hellenistic	2a	IV.D
AK-237	57/2011.2177.20805/23	body sherd/handle of jar	Persian or Hellenistic	1a	I.A1
AK-238	57/2011.2162.20566/12	rim of jar	Late IA IIC?	1a?	I.A4
AK-239	57/2011.2169.20669/17	body sherd/handle of jar	Persian	1a	IV.D
AK-240	57/2011.2162.20566/20	rim of jar	Persian/Hellenistic	2a	IV.D
AK-241	57/2011.2059.20651/21	body sherd of jar	Persian or Early Hellenistic	1a or 2a	IV.D
AK-242	57/2011.2163.20575/26	body sherd of jar	Persian or Early Hellenistic	1a or 2a	IV.H
AK-243	57/2011.2163.20585/1	rim of jar	IA IIC/III?	1a	IV.B
AK-244	57/2011.2/77.20805/25	body sherd/handle of jar	Persian	1a	IV.D
AK-245	57/2011.2170.20743/6	fragment of jar	Persian/Hellenistic	1a	I.A1
AK-246	57/2011.2095.20622/3	rim of jar	Early Persian?	1a	I.A1
AK-247	57/2011.2164.20579/13	rim of bowl	Persian	4	IV.H
AK-248	57/2011.2169.20760/25	rim of jar	Persian	1a	IV.D
P-252	P-33H	Kabri marl + terra rossa+ hamra			
P-253	TQ	Taqiye Fm			
P-254	TQ	Taqiye Fm			
P-255	P-D0y	Nazareth factory – ceramics			
P-256	P-D0r	Nazareth factory – ceramics			
P-257	NYC-1	Nazareth, yellow clay			
P-258	NYC-2	Nazareth, yellow clay			
P-259	P-030	Barlev Kabri marl + terra rossa + hamra			
P-260	P-10/11	Tell Keisan marl			
P-261	N-33	Nazareth terra rossa			
P-262	HP	Hajfa seaside (swampy soil)			
P-263	P-27'	Kefar Masaryk danuk, vertisol			
P-264	P-26	Afek – grumusol			
P-265	P-22	Afek – gray marl			
P-266	P-23	Afek – grumusol			
P-267	32H	P-10/11+hamra			
P-268	H2J	Hebron – Mozza			
P-269	H2C	Hebron – Mozza			
P-270	BLA 6940	Gaza LRA			
P-271	BLA 6281	Gaza LRA			

rina sp., *Globoturborotalita* sp., as well as radiolarians, putting the age of the material at the Eocene. Fragments of *Corallinacea* were detected in (AK-227; AK-228, AK-229, AK-231, AK-234). As in the other associations of Sha'ar-Ha'Amakim and Tell Keisan ceramics, Fe-coloured spots concentrate around accumulations of *Globigerina*.

The sand fraction (0.1–0.33 mm) mostly includes grains of monocrystalline quartz, unrounded or poorly rounded. Their share does not exceed 5–8% of the volume (apart from sample AK-229 – ca. 15% of the volume). Also present are single grains of unaltered plagioclases, unevenly scattered in the groundmass.

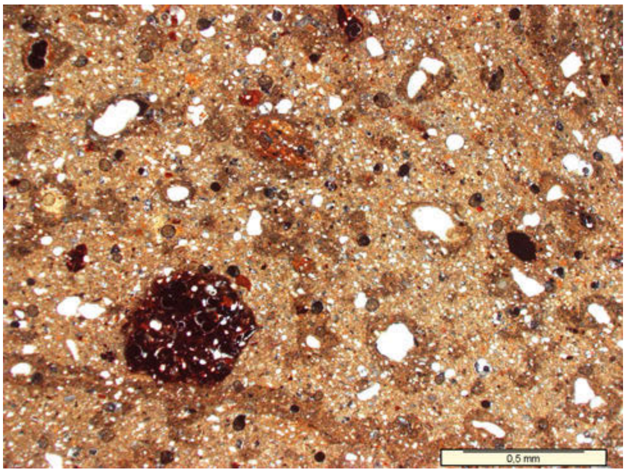


Fig. 239. SG I.A1. Specimen AK-246, photomicrograph of a thin section – note the dark ball of ferro-foraminifera ooze (PPL)

Subgroup I.A2.Eo (Figs. 242–243)

A distinct sample is **specimen** AK-232 as it is composed of Eocene foraminiferous 'light' marl enriched with red soil balls.

The vessel is light red, 2.5 YR 7/6. In transmitted light its groundmass is grey-orange, optically active, enriched with oval dark brown *terra rossa* balls, rich in quartz silt. The share of this admixture does not exceed 5% of the volume. Fragmentarily preserved are fragments of light-grey foraminiferous chalk. The material is rich in foraminifers of the *Chiloguembelina* sp., *Cibicides* sp. and *Corallinaceae*.

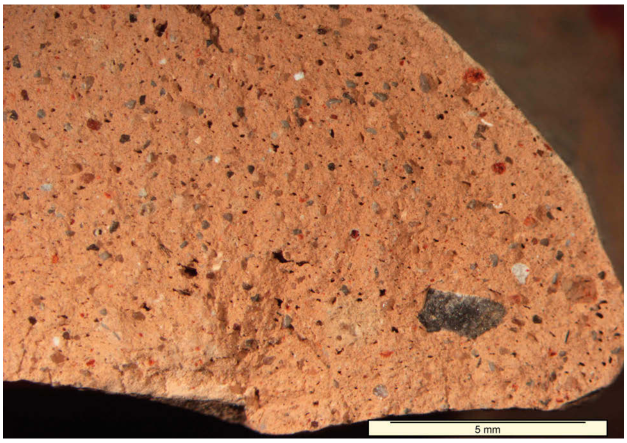


Fig. 240. SG I.A1. Fragment of specimen AK-234

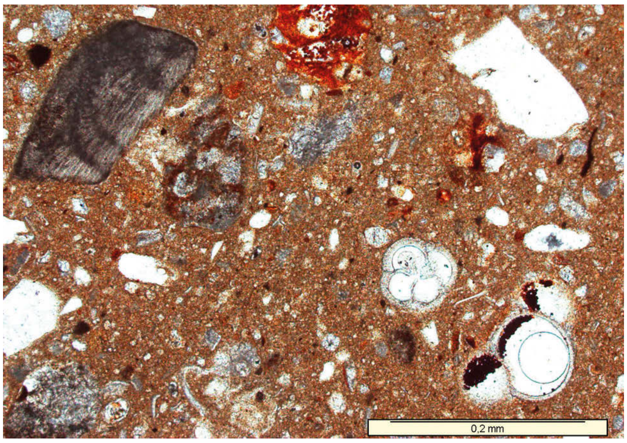


Fig. 241. SG I.A1. Specimen AK-234, photomicrograph of a thin section (PPL)

Fig. 242. SG I.A2.Eo. Fragment of specimen AK-232

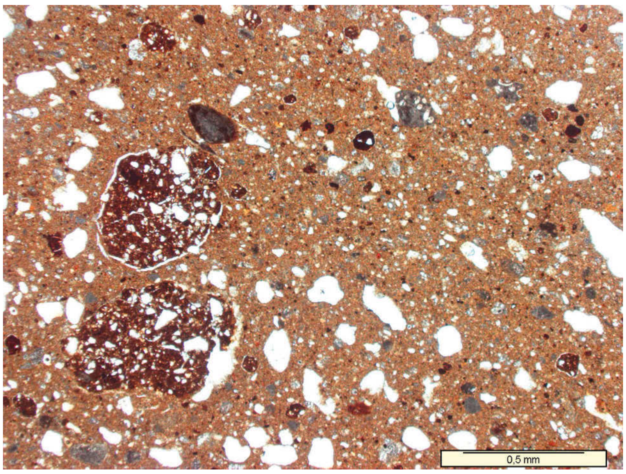


Fig. 243. SG I.A2.Eo. Specimen AK-232, photomicrograph of a thin section (PPL)

Fig. 244. SG I.A2. Fragment of specimen AK-238

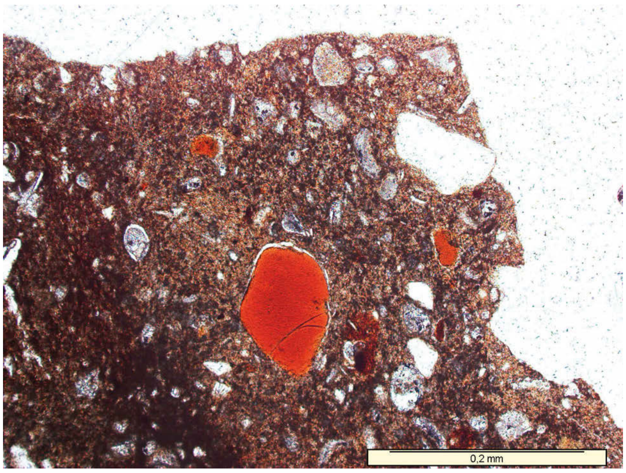


Fig. 245. SG I.A2. Specimen AK-238, photomicrograph of a thin section; note the presence of red fragments (PPL)

The content of quartz silt is smaller than 0.5% of the volume. The sand-fraction admixture, 0.1–0.42 mm in diameter, accounting for 10% of the volume, is primarily monocrystalline, variably rounded quartz; the proportion of feldspars does not exceed 5%. Some grains have rims of carbonates (*kurkar*). Also present are single coarse grains of micrite and biomicrite.

Subgroup I.A4 (Figs. 244–245)

Eocene foraminiferous 'light' marl + calcareous sand + "red fragments".

Sample AK-238 – a vessel light-brown in colour (5 YR 7/4), massive. In transmitted light its matrix is orange, mottled with iron diffusions, partly optically active.

As in the other samples in the group, its characteristic feature is the presence of Fe-coloured spots concentrating around numerous clusters of microfossils, including *Globigerina*. Microorganisms of a similar association, *Brizalina* sp., *Cibicides* sp., *Quinqueloculina* sp., *Globigerina* sp., are dispersed in the groundmass. They put the age of the material at the Eocene (Middle – Late).

The sand admixture accounts for ca. 15% of the volume. Those are mostly carbonate grains (85%) representing biomicritic limestones, numerous fragments of algae; there is less monocrystalline quartz (10%), and just a few flints.

What distinguishes the sample is the presence of red fragments that are either bits of pedogenic clay coatings or altered olivines.

The predominance of carbonates among grains of the sand fraction may suggest derivation from a more northerly part of the Mediterranean coast.

Petrographic group IV

Beige-coloured jars occur in Tel Akko as well as in Tell Keisan and Sha'ar-Ha'Amakim; they have been assigned to PG IV.

Subgroup IV.B (Figs. 246–247)

Specimen AK-243

Distinct in terms of petrography, it is made of Paleogene marl mixed with black reduced clayey soil. The vessel has a cream colour (10 YR 8/3), visible macroscopically are fine-sized dark grits of the temper.

In transmitted light the matrix is grey with a green hue, partly optically active, with a microgranular texture resulting from the decomposition of numerous carbonate microorganisms, the remains of which are oval micrite clusters.

It stands out for the presence of amorphous clasts of highly sintered ferric soil (?) or chamotte of the 0.2–1.5 mm fraction, accounting for ca. 20% of the volume. In transmitted light with parallel Nicol prisms their individual fragments are transparent in various degrees; some are reddish-grey, and with an increase in the Fe content they turn opaque. In reflected light with crossed Nicol prisms they are red. The presence of *Cibicides* sp. and *Bulimina* sp. puts the age of the material at the Paleogene.

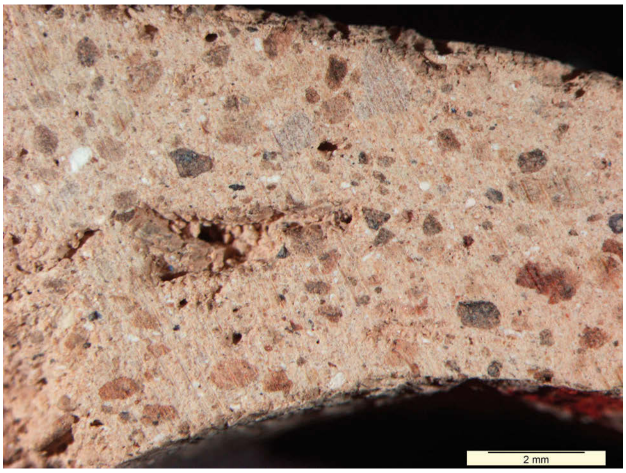


Fig. 246. SG IV.B. Fragment of specimen AK-243

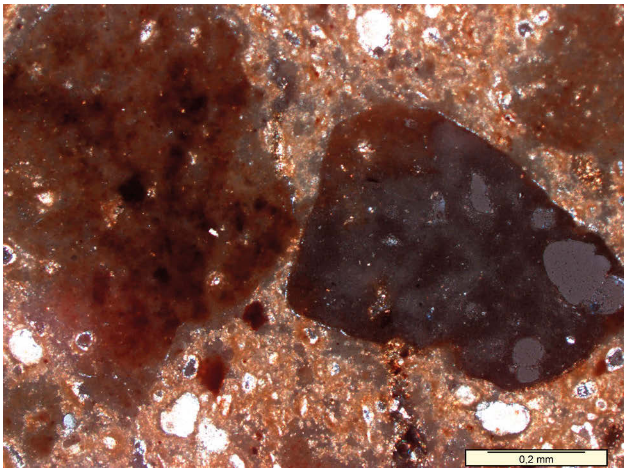


Fig. 247. SG IV.B. Specimen AK-243, photomicrograph of a thin section (PPL) – amorphous clasts of ferric soil or chamotte

Subgroup IV.D (Figs. 248–251)

Specimens: AK-226, AK-236, AK-239, AK-240, AK-241, AK-244, AK-248.

The jars are beige in colour (7.5 YR 8/4-7/4), made of pure, highly calcareous marl, partially of a shale texture enriched with quartz sand, some with red soil.

In transmitted light the matrix is grey with a green hue and scattered shales of chalk (specimens AK-226, AK-241,) or a red soil admixture (AK-236, AK-239, AK-244, AK-248), specimen AK-240 contains oval grains of *terra rossa* which turned black during the reducing firing.

The matrix is relatively massive, with fragmentarily preserved shales, almost devoid of quartz silt (less than 0.05% of the volume).

The aplastic admixture consists of grains of unevenly scattered fine quartz sand (0.1–0.3 mm), some fine red olivines(?), some pieces of volcanic glass. Their proportion does not exceed 5–8% of the volume.

Fig. 248. SG IV.D. Fragment of specimen AK-226

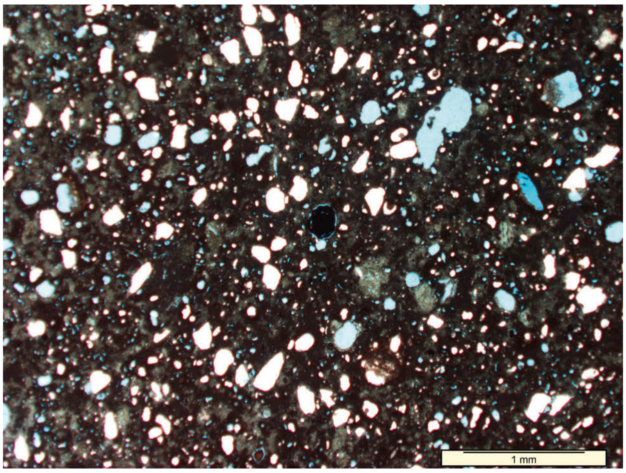


Fig. 249. SG IV.D. Specimen AK-226, photomicrograph of a thin section (PPL)

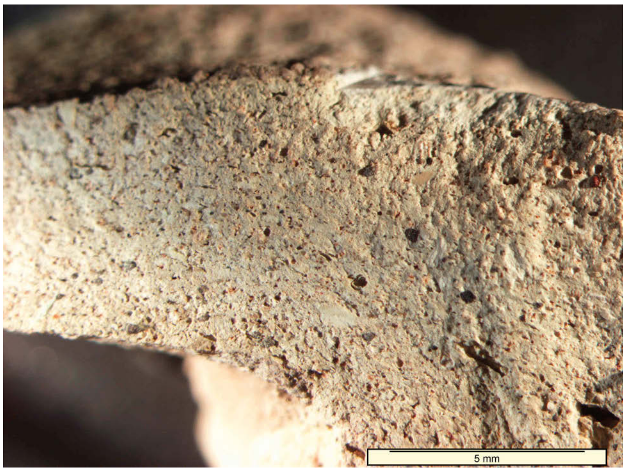


Fig. 250. SG IV.D. Fragment of specimen AK-240

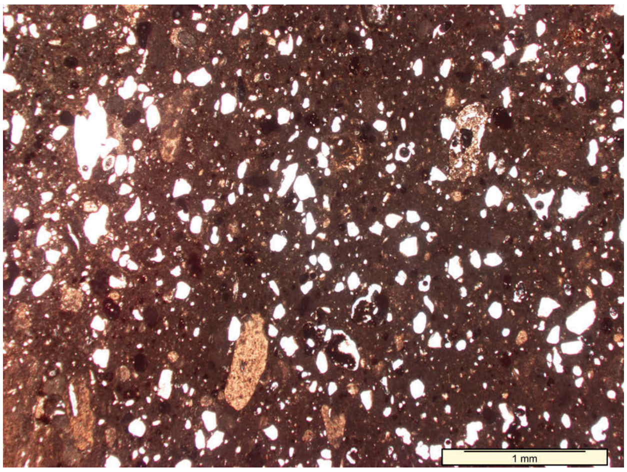


Fig. 251. SG IV.D. Specimen AK-240, photomicrograph of a thin section (PPL)

Subgroup IV.H (Figs. 252–255)

Specimens: AK-242, AK-247.

Especially different in PG IV is SG IV.H – pottery made of Eocene marl, rich in ferruginous chalk. These ceramics are white on the surface, and light-beige in the break (7.5 YR 8/3).

In transmitted light the colour of the matrix is reddish-grey. The red pigment comes from relatively evenly distributed iron compounds contained in fragments of ferruginous chalk rich in *Globigerina*.

The content of quartz silt is lower than 0.05%; also, the content of the sand admixture varies from negligible to 5–10% of the volume.

The Eocene age of the material is suggested by the *Globigerina* it contains, especially in the Fe-coloured spots.

Unassigned samples (Figs. 256–259)

Sample AK-225 – red ceramics (2.5 YR 7/8).

In transmitted light the matrix of the sample is grey-red, mottled with *terra rossa* fragments differing in size (0.15–2.2 mm in diameter). They display various degrees of oxidation, and hence different pigmentation, from bright-red through grey to opaque black. Their share is ca. 30% of the volume. They are uniformly embedded in an isotropic marly groundmass tempered by a fine-grained sand quartz fraction of 0.1–0.25 mm.

The few preserved pseudomorphoses from the family *Heterohelicidae* show the material to be not older than the Albian (Cretaceous).

AK-230 – a fragment of a vessel light-brown in colour (5 YR 7/4).

In transmitted light the matrix of the samples is light-brown, with sparse red Fe-coloured spots, optically active. It contains numerous foraminifers of *Guembelitaria* aff. *cretacea* Cushman, *Heterohelix*, and

Fig. 252. SG IV.H. Fragment of specimen AK-242

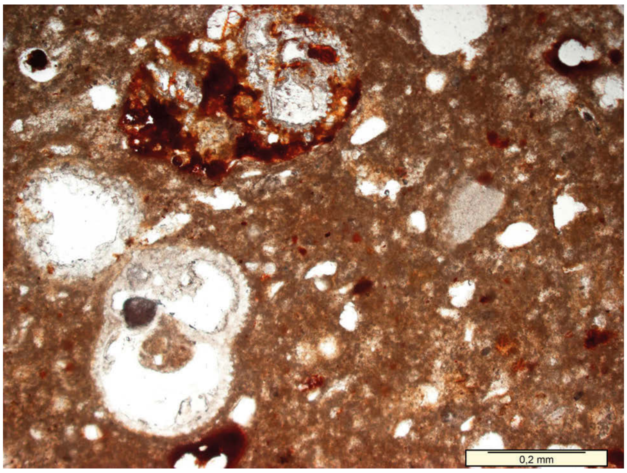


Fig. 253. SG IV.H. Specimen AK-242, photomicrograph of a thin section (PPL) – *Globigerina* sp.

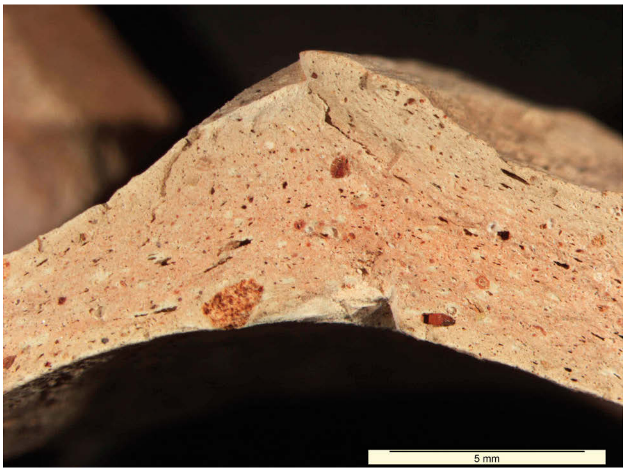


Fig. 254. SG IV.H. Fragment of specimen AK-247

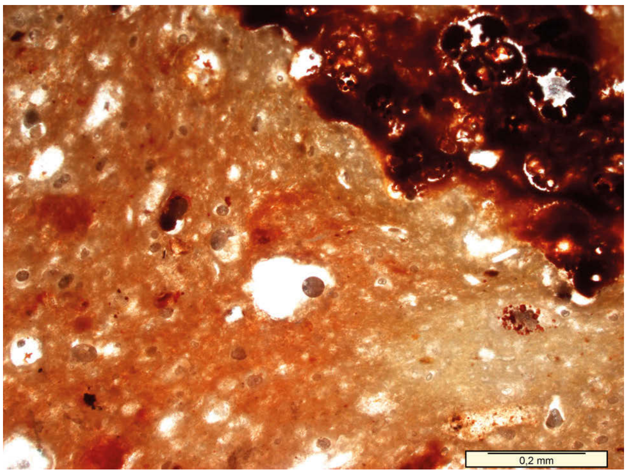


Fig. 255. SG IV.H. Specimen AK-247, photomicrograph of a thin section (PPL) – reddish ferro-foraminifera ooze

Fig. 256. Unassigned ceramics. Fragment of specimen AK-225

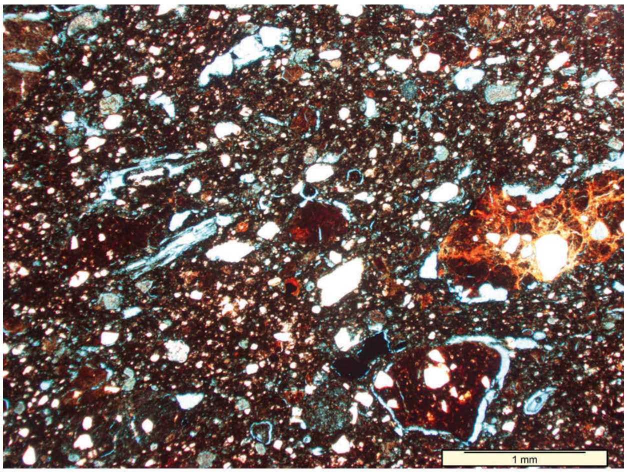


Fig. 257. Unassigned ceramics. Specimen AK-225, photomicrograph of a thin section (PPL)

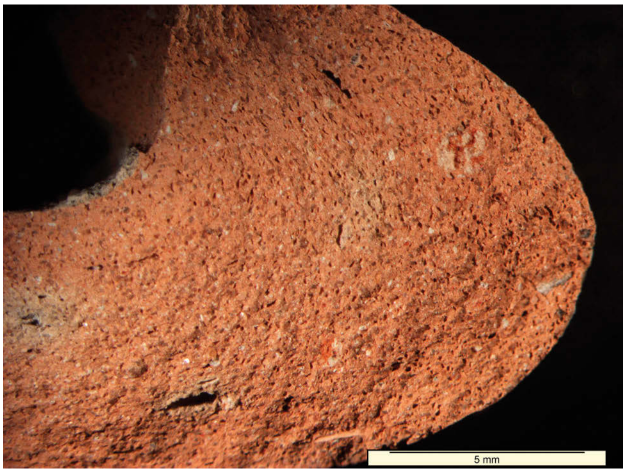


Fig. 258. Unassigned ceramics. Fragment of specimen AK-230

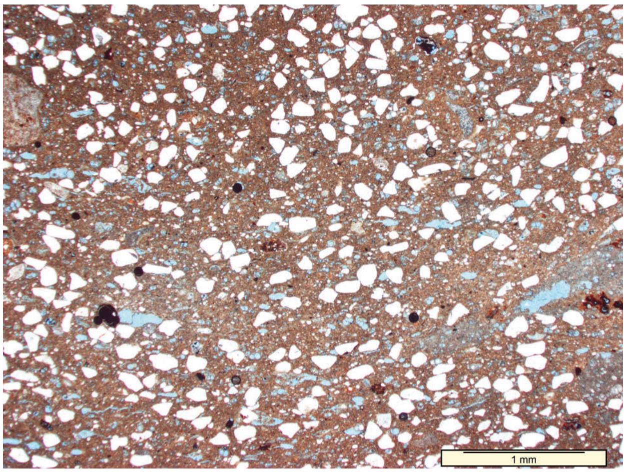


Fig. 259. Unassigned ceramics. Specimen AK-230, photomicrograph of a thin section (PPL)

Hedbergella, showing the age of the material to be Late Cretaceous.

The sample is almost completely devoid of quartz silt. The aplastic admixture accounts for about 30% of the volume. It mostly consists of grains of monocrystalline quartz, usually angular or subangular, 0.1–0.25 mm in diameter. One can also find single 'clear' plagioclases and flints.

9. Ceramics from Sha'ar-Ha'Amakim, Tell Keisan, Tel Akko: chemical comparison, reasons of differences

9.1. General comments

The notion of geological provenance is not identical with that of geographical provenance. While geological studies of the chemical composition serve primarily to identify the of rock forming processes, archeologists expect to have "chemical fingerprints" of each concrete place where a pottery workshop was situated (in the sense of a geographical location). In the geological perspective, the chemical composition of deposits is a source of information about their sedimentary environment understood as the distance from a landmasses (as a source of terrigenous sediment), the type (lithology) of rocks from which they have formed, the depth of the basin where they were deposited, water redox potential, the content of organic matter, the effect of volcanic activity, etc. Since the environment undergoes a transformation with time, the significance and contribution of factors controlling it changes too. And it is those changes that are recorded, especially in the vertical profile of deposits[337], by a change in its mineralogy and chemistry. That is why it is easier to distinguish deposits differing in age (especially when sedimentation conditions changed with time) than laterally find concrete places of their occurrence (in the sense of placing a point on a map), and this is the kind of information that archeologists seek most eagerly.

Hence, when adopting the 'geochemical fingerprints' method to identify the provenance of ceramics, we must be aware that we mainly identify the environment in which the clay was deposited rather than the place of its excavation. If collected in a uniform geochemical environment, samples of this clay will be similar whatever the distance, even tens or hundreds of kilometres, separating them. What allows differentiating among pottery workshops is the kind of tempering admixture used, its mineral composition, the grain size distribution of the temper.

In the geochemical interpretation of geological provenance especially valuable are those elements whose content, especially in argillaceous rocks, does not change under the influence of hypergenic factors (i.e. weathering processes). Therefore their content may reflect the chemistry of parent rock from which they have developed. This group includes primarily rare-earth elements (REE), Th, Sc, Co, and Cr. Also useful are the La/Sc, La/Co, Th/Sc, Th/Co, La/Th and TH/Yb ratios.[338] In the case of the presented research, chemical analyses served mainly to test the correctness of divisions made during petrographic observations, in accordance with the assumption that petrographically similar samples should also have a similar chemical composition. But even this assumption cannot be treated as absolute. The more polymineral a sample, the more aplastic the inclusions it contains, or if it is a product of a mixture of several clays, the greater mass of it can make the obtained result representative. For many reasons, including laboratory possibilities and especially the value of a subject this postulate cannot always be met. In the case of the presented analyses of the set discussed, this may be the cause of the revealed discrepancies between petrography and the chemistry of the samples.

9.2. Tel Akko jars – chemical database

The chemical data of the Akko ceramics and the clays sampled in the field are presented in Table 16.

[337] A vertical cross-section of sediments allows tracing the history of their deposition, assuming that younger deposits lie over the older ones.

[338] Taylor & McLennan 1985: 12–56; McLennan et al. 1980; McLenan 1989: 184–185; Rollinson 1993: 132–142; Condie et al. 1995.

Table 16. Chemical composition of the Akko ceramics and clays sampled in the field

Element	Au	Ag	Cu	Cd	Mo	Pb	Ni	Zn	S	Al	As	Ba	Be	Bi	Br	Ca	Co	Cr	Cs	Eu	Fe	Hf	Hg	Ir	K	Li
Unit	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	%	ppm
Detection limit	2	0.3	1	0.3	1	3	1	1	0.01	0.01	0.5	50	1	2	0.5	0.01	1	2	1	0.2	0.01	1	1	5	0.01	1
Analysis method	INAA	INAA / TD-ICP	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA / TD-ICP	INAA / TD-ICP	TD-ICP	TD-ICP	INAA	INAA	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	TD-ICP	TD-ICP
AC-225	<2	0.5	34	<0.3	<1	12	61	69	0.05	7.85	5.6	590	2	<2	4.8	8.55	16	127	9	1	4.36	8	<1	<5	1.82	28
AC-226	<2	0.4	43	<0.3	1	5	96	90	0.14	4.16	6.2	1810	1	<2	3.3	21.3	15	163	<1	1.1	2.48	3	<1	<5	0.54	21
AC-227	<2	0.3	46	1.1	4	13	69	127	0.08	7.45	6.9	690	2	<2	5.1	13.4	11	123	6	0.9	3.77	5	<1	<5	1.65	34
AC-228	<2	0.3	33	0.6	3	9	36	84	0.12	5.25	4.8	690	2	<2	6	18.4	9	92	<1	1.1	2.66	3	<1	<5	1.4	21
AC-229	<2	<0.3	49	<0.3	6	8	48	98	0.06	4.44	11.2	950	1	<2	5.9	12.4	10	141	<1	0.7	2.83	3	<1	<5	0.58	12
AC-230	<2	0.4	52	<0.3	3	7	77	120	0.07	4.3	17.7	1180	1	<2	4.3	13.8	10	167	<1	0.3	2.85	5	<1	<5	0.63	12
AC-231	<2	0.4	38	0.7	<1	11	48	102	0.12	6.53	7.4	1220	2	<2	<0.5	15.6	9	108	6	1.1	3.24	3	<1	<5	1.47	30
AC-232	<2	<0.3	28	<0.3	<1	7	29	48	0.12	4.32	5.6	840	1	<2	4.4	18	12	79	<1	0.9	2.46	5	<1	<5	0.92	12
AC-233	<2	<0.3	31	0.6	3	12	37	92	0.11	6.06	7.3	1070	2	<2	3.3	17.2	9	139	4	0.9	2.95	4	<1	<5	1.55	21
AC-234	<2	<0.3	27	<0.3	2	10	26	53	0.14	2.66	6.9	720	<1	<2	4.8	22.2	11	107	<1	0.6	2.19	4	<1	<5	0.6	10
AC-235	13	0.4	39	0.6	5	10	36	84	0.11	5.27	3.7	1040	2	<2	6.2	14.6	10	124	5	1.1	2.85	4	<1	<5	1.51	22
AC-236	<2	0.4	46	0.6	<1	7	92	117	0.18	3.79	6.3	1070	1	<2	7.5	19.6	7	180	<1	0.9	2.25	4	<1	<5	0.84	16
AC-237	<2	<0.3	61	0.6	3	13	45	97	0.09	6.86	5.4	730	2	<2	5.7	13.6	9	143	2	1.1	3.33	4	<1	<5	1.56	24
AC-238	<2	0.4	23	0.6	<1	11	43	102	0.13	7.56	5.4	820	2	<2	<0.5	16.1	11	187	6	1.4	3.49	4	<1	<5	1.5	34
AC-239	<2	<0.3	42	<0.3	<1	8	94	92	0.12	4.31	6.1	1070	1	<2	9	18.1	18	228	<1	1.4	2.97	5	<1	<5	0.84	19
AC-240	<2	0.9	60	0.6	<1	25	123	133	0.16	4.66	7.7	2580	1	<2	13	17.1	17	284	<1	1.4	3.12	5	<1	<5	0.85	22
AC-241	<2	<0.3	51	0.4	1	10	99	127	0.18	4.64	4.3	1730	1	<2	7.6	19.7	15	279	<1	1.4	2.8	4	<1	<5	0.68	20
AC-242	<2	0.5	46	0.8	1	12	66	119	0.18	6.71	10.5	680	2	<2	8.9	18.3	11	199	14	1.3	3.36	4	<1	<5	1.55	44
AC-243	<2	0.4	45	<0.3	1	7	61	82	0.14	7.13	18.4	700	2	<2	4.2	18.9	14	238	11	0.8	3.63	4	<1	<5	2.11	24
AC-244	<2	<0.3	47	0.7	1	14	105	102	0.18	4.43	8.5	1340	1	<2	9.5	17.7	17	197	<1	1.4	2.99	2	<1	<5	0.77	21
AC-245	<2	0.6	36	0.7	<1	15	50	111	0.13	6.98	4.6	760	2	<2	4.9	16.1	13	126	3	1.6	3.85	2	<1	<5	2.06	29
AC-246	<2	0.3	119	0.5	2	8	37	87	0.1	5.3	4.6	620	2	<2	4.4	16	10	119	3	1.1	3.28	2	<1	<5	1.55	22
AC-247	<2	0.7	28	0.4	2	8	61	110	0.15	8.68	5.8	640	2	2	9.3	13.3	13	193	3	2.1	5.06	3	<1	<5	1.87	40
AC-248	<2	0.4	31	0.4	2	4	77	91	0.2	3.82	5.1	1000	1	<2	11.6	21.7	13	181	<1	1.4	2.58	2	<1	<5	0.44	16
P-252	<2	3.1	20	<0.3	3	3	30	34	0.15	2.49	4.2	90	<1	<2	9.8	25.6	7	84	<1	0.7	1.71	2	<1	<5	0.26	9
P-253	<2	404	29	0.3	<1	7	70	86	0.1	5.41	2.8	520	1	<2	10.1	15.8	17	165	3	1.3	2.64	2	<1	<5	0.56	29
P-254	<2	0.6	37	0.5	<1	8	89	108	0.14	6.23	3.3	1000	1	<2	10.9	20.3	17	192	3	0.9	2.38	2	<1	<5	0.61	36
P-255	<2	0.4	38	<0.3	6	9	52	85	0.12	4.85	9.1	760	1	<2	5.4	20.9	13	162	2	1.2	3.34	3	<1	<5	0.53	19
P-256	<2	0.4	33	0.4	6	9	46	77	0.12	3.94	9.8	720	1	<2	6.3	18.8	13	160	<1	1.3	3.27	4	<1	<5	0.48	17
P-257	<2	<0.3	66	0.6	13	<3	116	126	0.18	3.27	30.1	<50	1	<2	6.6	29.8	10	238	<1	1.1	3.66	1	<1	<5	0.31	12
P-258	<2	<0.3	67	0.6	14	<3	117	130	0.19	3.24	28.1	<50	<1	<2	6.4	30.2	10	242	<1	1.2	3.63	<1	<1	<5	0.32	12
P-259	<2	5	23	0.5	5	<3	43	55	0.13	3.02	6.7	250	<1	<2	5.8	23.9	7	130	<1	0.9	1.97	2	<1	<5	0.29	13
P-260	<2	<0.3	47	0.6	2	12	56	106	0.18	3.14	6.6	330	<1	<2	14.6	28.8	11	161	<1	0.9	2.16	2	<1	<5	0.49	13
P-261	<2	0.5	97	<0.3	2	7	340	267	0.04	10.8	144	<50	4	<2	<0.5	5.86	46	289	13	1.4	9.17	4	<1	<5	1.85	53
P-262	<2	<0.3	29	<0.3	<1	14	66	76	0.09	7.81	7.3	540	2	<2	24.2	4.65	28	158	6	2.4	6.2	11	<1	<5	1.44	34
P-263	14	0.4	38	0.5	<1	873	63	92	0.07	6.86	9.4	280	2	<2	19.9	6.36	30	140	<1	2.1	5.26	9	<1	<5	1.36	29
P-264	<2	<0.3	38	0.3	<1	15	67	91	0.03	7.77	6.5	340	2	<2	14	3.48	30	155	3	2.2	5.92	10	<1	<5	1.19	32
P-265	<2	0.3	39	0.3	<1	16	69	100	0.05	7.83	8.1	370	2	<2	<0.5	5.96	34	151	4	2.8	6.32	11	<1	<5	1.3	32
P-266	<2	<0.3	13	0.7	3	5	33	41	0.13	7.87	9	370	2	<2	21.1	10.4	15	81	6	1	3.3	3	<1	<5	1.47	53
P-267	<2	<0.3	31	0.4	3	9	55	79	0.06	4.65	7.5	370	2	<2	10.5	6.86	14	95	<1	1.1	3.08	4	<1	<5	0.56	20
P-268	<2	0.4	14	<0.3	<1	11	44	90	0.01	10.1	41.7	<50	3	<2	<0.5	0.75	18	123	9	1.3	5.7	5	<1	<5	1.81	36
P-269	<2	<0.3	11	<0.3	3	<3	27	138	0.08	6.48	15.4	<50	1	<2	3.1	12.9	18	72	5	1.1	3.98	2	<1	<5	2.12	26
P-270	<2	0.7	27	<0.3	1	5	69	54	0.16	3.86	10.3	150	<1	<2	5.6	19	20	150	<1	1	3.42	3	<1	<5	0.76	15
P-271	<2	0.5	24	<0.3	2	5	68	51	0.18	3.8	12	270	<1	<2	4.2	20.3	19	140	<1	1.1	3.31	3	<1	<5	0.85	14

Table 16. cont.

Element	Mg	Mn	Na	P	Rb	Sb	Sc	Se	Sr	Ta	Ti	Th	U	V	W	Y	La	Ce	Nd	Sm	Sn	Tb	Yb	Lu	Mass
Unit	%	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	g
Detection limit	0.01	1	0.01	0.001	15	0.1	0.1	3	1	0.5	0.01	0.2	0.5	2	1	1	0.5	3	5	0.1	0.01	0.5	0.2	0.05	
Analysis method	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
AC-225	2.38	376	0.15	0.133	135	0.7	14.3	<3	202	<0.5	0.38	12.3	4.3	75	<1	20	31.9	63	21	4.8	<0.01	<0.5	2.6	0.24	1.26
AC-226	1.18	341	0.27	0.319	<15	0.9	11	<3	575	<0.5	0.11	6	6.9	85	<1	44	32	48	39	5.2	<0.01	2.1	3.7	0.13	1.13
AC-227	0.89	164	0.15	0.196	71	1.4	12.3	<3	381	<0.5	0.29	13.6	4.1	118	<1	27	40.8	85	21	6.2	<0.01	<0.5	2.9	0.1	1.12
AC-228	0.62	101	0.18	0.119	<15	0.8	9.3	<3	405	<0.5	0.27	9	3.3	70	<1	21	29.3	58	28	4.9	<0.01	<0.5	2.2	<0.05	0.903
AC-229	0.41	265	0.15	0.14	<15	0.9	9.4	<3	379	<0.5	0.17	6	4.9	76	<1	20	19.4	39	9	3.2	<0.01	0.7	2.3	0.07	1.29
AC-230	0.41	268	0.15	0.216	<15	1.1	9.5	<3	399	<0.5	0.12	6.9	5.6	75	<1	20	19.5	44	12	3.2	<0.01	<0.5	2.3	0.06	0.78
AC-231	0.94	117	0.16	0.122	68	0.9	11.2	<3	411	<0.5	0.32	12.1	3.6	81	<1	24	36.2	70	29	5.9	<0.01	<0.5	3	0.09	1.13
AC-232	0.71	351	0.24	0.059	<15	0.5	8.4	<3	442	<0.5	0.16	5.1	2.2	36	<1	13	18.3	43	12	3.2	<0.01	<0.5	1.7	<0.05	1.11
AC-233	0.78	123	0.18	0.119	98	0.7	10.4	<3	390	<0.5	0.32	10.2	5.1	73	<1	19	32	61	25	4.9	<0.01	<0.5	2.2	<0.05	1.1
AC-234	0.51	343	0.18	0.109	30	0.4	6.4	<3	475	<0.5	0.18	3.9	2	43	<1	15	19	35	13	3.4	<0.01	1.3	1.4	<0.05	1.01
AC-235	0.66	134	0.18	0.156	54	0.4	9.6	<3	386	<0.5	0.31	9.4	4.7	69	<1	19	32.7	57	16	5.1	<0.01	<0.5	2.6	0.08	1.06
AC-236	0.98	338	0.24	0.377	<15	0.8	10.6	<3	508	<0.5	0.05	4.7	5.2	71	<1	38	28.7	53	32	4.7	<0.01	<0.5	2.9	0.11	1.06
AC-237	0.72	145	0.19	0.152	91	0.7	11.6	<3	319	<0.5	0.34	11.5	4	85	<1	22	36	70	33	5.6	<0.01	<0.5	2.5	<0.05	1.23
AC-238	1.05	137	0.18	0.143	<15	0.7	13.1	<3	619	<0.5	0.35	13.9	3.3	93	<1	26	42.7	80	39	6.8	<0.01	<0.5	3	0.13	1.12
AC-239	1.08	553	0.28	0.226	<15	0.9	13.2	<3	443	<0.5	0.09	5.1	4.6	71	<1	47	36.7	47	19	6.1	<0.01	<0.5	4.3	0.2	1.2
AC-240	1.65	594	0.32	0.661	<15	0.8	12.9	<3	511	<0.5	0.06	5.7	8.3	84	<1	47	37.7	53	28	6	<0.01	1.1	4	0.3	0.999
AC-241	1.19	354	0.34	0.575	<15	1.2	12.3	<3	589	<0.5	0.05	6.4	5.8	69	<1	42	33	39	8	5.6	<0.01	<0.5	3.5	0.25	0.811
AC-242	1.45	190	0.23	0.262	35	1.5	12.1	<3	613	<0.5	0.15	11.8	7.3	82	<1	30	40.6	70	23	6.3	<0.01	<0.5	3.4	0.11	1.2
AC-243	1.43	222	0.41	0.153	74	1.3	12.8	<3	439	<0.5	0.36	11.7	6.4	76	<1	17	26.5	44	27	3.9	<0.01	<0.5	2.2	<0.05	1.09
AC-244	1.34	507	0.26	0.217	<15	0.7	11.4	<3	441	<0.5	0.14	4.9	5.6	86	<1	39	32.5	45	21	5.8	<0.01	<0.5	3.5	0.34	1.04
AC-245	0.95	145	0.33	0.133	76	0.6	12.2	<3	458	<0.5	0.3	10.1	3.3	79	<1	24	38.1	75	51	6.4	<0.01	1.8	2.5	0.18	1.02
AC-246	0.73	126	0.14	0.111	70	0.3	10	<3	390	<0.5	0.32	9.7	2.3	72	<1	19	32.8	56	26	5.4	<0.01	0.8	2.1	<0.05	1.02
AC-247	1.09	181	0.92	0.172	86	1	16.7	<3	535	<0.5	0.5	15.2	9.4	87	<1	26	51.6	97	36	8.7	<0.01	<0.5	4	0.47	0.454
AC-248	1.05	294	0.3	0.276	<15	0.6	10.2	<3	450	<0.5	0.06	5.4	4.6	56	<1	36	28.1	37	22	5.1	<0.01	<0.5	3.2	0.3	1.16
P-252	0.51	232	0.06	0.095	<15	0.3	5.2	<3	266	<0.5	0.19	2.8	2.5	47	<1	13	14.4	25	13	2.4	<0.01	<0.5	1.3	<0.05	1.26
P-253	1.54	299	0.15	0.13	<15	0.5	11.1	<3	309	<0.5	0.27	5.6	3.6	97	<1	25	25.8	36	33	4.1	<0.01	<0.5	2.3	<0.05	1.14
P-254	2.08	178	0.2	0.164	41	0.6	13	<3	418	1.3	0.22	5.5	4.5	112	<1	25	26.3	39	25	4	<0.01	<0.5	2.6	<0.05	1.09
P-255	0.71	339	0.12	0.196	32	0.9	10.7	<3	413	<0.5	0.27	5.5	7.6	106	<1	23	26.6	47	26	4.6	<0.01	<0.5	2.3	0.09	1.25
P-256	0.64	330	0.13	0.216	<15	0.8	10.1	<3	371	<0.5	0.31	5.7	7.5	98	<1	20	26.8	44	21	4.4	<0.01	1.1	2.2	0.09	1.47
P-257	0.38	61	0.07	0.364	<15	0.8	7.7	<3	768	<0.5	0.09	2.6	11.6	133	<1	23	21.5	26	14	3.3	<0.01	<0.5	1.9	<0.05	1.04
P-258	0.38	59	0.06	0.39	<15	0.6	7.6	<3	773	<0.5	0.12	3.2	11.6	132	<1	24	21.2	26	13	3.4	<0.01	<0.5	2.2	<0.05	1.12
P-259	0.57	169	0.07	0.087	36	0.4	6.4	<3	362	<0.5	0.22	3.2	4.7	69	<1	13	15.5	24	8	2.5	<0.01	<0.5	1.3	<0.05	1.13
P-260	1	256	0.1	0.231	<15	1.1	7.4	<3	616	<0.5	0.05	4.3	7	62	<1	22	20.4	39	22	3.4	<0.01	<0.5	2	<0.05	1.14
P-261	1.63	2140	0.07	0.218	150	6.4	14.5	<3	69	<0.5	0.39	14.7	11.9	335	<1	20	32.5	79	41	5.7	<0.01	<0.5	2.1	0.4	1.54
P-262	1.47	624	1.23	0.032	73	0.2	17	<3	148	<0.5	0.11	10.9	2.9	34	<1	31	42.5	96	32	8.3	<0.01	2	3.6	0.69	1.2
P-263	1.52	1460	0.35	0.105	56	0.6	15.2	<3	206	<0.5	0.13	10.1	3.8	43	<1	33	42.7	94	53	7.9	<0.01	<0.5	4	0.63	1.44
P-264	1.49	1060	0.3	0.046	134	0.4	17.3	<3	155	<0.5	0.17	10.7	1.8	47	<1	34	43.9	102	68	8.6	<0.01	1.4	4.3	0.73	1.32
P-265	1.94	1280	0.26	0.087	62	0.8	17.6	<3	137	<0.5	0.13	11.3	2.3	36	<1	32	45.8	107	74	9	<0.01	1.1	4.1	0.69	1.32
P-266	5.53	406	0.21	0.079	91	0.4	14.9	<3	205	<0.5	0.35	6.2	3.5	95	<1	18	23.1	36	21	4.2	<0.01	<0.5	2.3	0.3	1.09
P-267	0.7	496	0.12	0.089	30	0.4	9.3	<3	172	<0.5	0.35	5.8	2.9	76	3	26	28.4	45	28	4.7	<0.01	<0.5	2.4	0.46	1.13
P-268	1.48	84	0.08	0.08	85	0.6	18.8	<3	46	<0.5	0.33	8	1.6	154	<1	21	25.2	53	30	5.1	<0.01	<0.5	2.8	0.48	0.985
P-269	7.11	588	0.04	0.074	69	0.3	12.7	<3	75	<0.5	0.27	5.3	2.7	99	<1	16	21.2	40	30	3.9	<0.01	<0.5	1.8	0.07	0.987
P-270	1.05	643	0.25	0.093	87	0.2	9.3	<3	576	<0.5	0.38	4.5	3	62	<1	16	23.3	43	18	4	<0.01	<0.5	2.1	0.06	0.712
P-271	0.82	650	0.28	0.073	18	0.3	9	<3	535	<0.5	0.29	5.3	4.2	51	<1	17	23.4	48	14	3.8	<0.01	<0.5	1.9	<0.05	1.12

Table 17. Mean (M) and standard deviation (σ) values of the particular groups of Sha'ar-Ha'Amakim, Tell Keisam and Akko ceramics (without outliers)

Element	SG I.A1		SG I.A2.Eo		SG IA2.Cr		SG I.A3		PG II		PG III		PG IV(A.B.D.E)		IVC		IVH		PG V		PG VI		PG VII		PG VIII		PG IX		PG X		PG XI	
	n=43		n=6		n=2		n=8		n=57		n=11		n=38		n=3		n=8		n=15		n=11		n=2		n=3		n=2		n=2		n=6	
	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD	M	STD
Cu (ppm)	37.23	21.92	26.33	10.23	31.50	2.12	29.00	9.30	37.56	5.95	15.90	5.59	43.18	8.48	34.33	2.08	28.38	2.33	16.64	4.86	35.70	10.85	23.28	17.57	17.23	6.22	11.73	7.79	11.73	7.79	28.17	6.82
Pb (ppm)	9.60	2.73	7.17	3.19	7.00	5.66	6.75	1.91	11.50	2.33	3.60	0.70	6.79	4.19	9.00	2.65	10.00	1.60	4.57	1.60	12.20	2.35	7.27	6.97	5.53	2.76	4.14	1.96	4.14	1.96	15.00	4.47
Ni (ppm)	48.77	10.79	43.00	12.76	57.50	12.02	58.13	22.08	84.70	9.90	32.80	2.44	86.66	19.84	66.67	3.21	58.00	6.16	37.43	10.79	69.80	10.21	40.00	42.14	30.78	17.85	24.32	9.14	24.32	9.14	78.83	12.27
Zn (ppm)	97.40	18.50	68.50	24.85	78.50	21.92	69.63	16.95	98.91	13.69	47.70	4.97	109.05	20.46	78.67	8.96	113.50	10.42	49.93	12.28	84.30	13.74	49.02	49.90	37.55	20.63	29.09	11.97	29.09	11.97	120.17	29.83
As (ppm)	6.00	1.86	6.67	0.87	5.05	2.19	4.94	2.04	8.50	1.84	7.65	1.69	9.13	4.74	8.73	0.55	5.63	0.83	5.51	1.05	8.16	1.44	4.80	4.75	3.66	1.93	2.80	1.23	2.80	1.23	10.30	2.06
Ba (ppm)	879.77	462.42	958.33	504.24	1815.00	49.50	2142.50	866.81	894.26	379.52	1351.00	409.43	1194.74	535.68	546.67	55.08	603.75	152.50	617.86	339.91	597.00	175.31	386.16	298.18	286.55	105.90	196.23	127.74	196.23	127.74	326.67	148.95
Co (ppm)	9.88	2.10	13.00	2.97	14.50	7.78	16.13	5.87	30.26	4.36	8.60	1.26	12.63	2.68	18.00	1.00	13.25	1.28	11.93	3.08	24.70	4.50	14.60	14.28	11.13	5.74	8.44	3.81	8.44	3.81	26.17	5.04
Cr (ppm)	114.07	18.47	91.50	26.76	139.00	9.90	108.13	35.22	193.48	32.01	76.00	5.98	184.87	39.27	144.67	23.86	145.25	32.54	84.14	18.67	147.80	21.26	84.53	89.47	65.09	38.03	51.56	19.13	51.56	19.13	194.17	28.65
Eu (ppm)	1.30	0.36	0.98	0.29	1.00	0.28	1.00	0.34	2.03	0.40	0.53	0.20	1.37	0.40	2.03	0.55	2.15	0.48	1.08	0.55	1.68	0.45	1.07	0.87	0.80	0.31	0.55	0.34	0.55	0.34	2.15	0.49
Hf (ppm)	3.09	0.87	4.33	1.37	4.50	2.12	5.00	1.85	9.83	2.83	2.50	0.97	3.18	1.20	8.00	0.00	3.25	0.46	3.29	0.91	8.30	2.31	5.31	4.23	3.95	1.52	2.73	1.72	2.73	1.72	10.67	4.63
Li (ppm)	26.26	8.07	14.83	8.01	12.00	1.41	13.50	2.07	25.74	4.35	17.40	3.13	22.63	8.92	27.67	1.53	39.00	1.77	22.36	3.79	22.30	6.33	14.31	11.30	10.64	4.03	7.34	4.67	7.34	4.67	89.17	41.33
Mn (ppm)	169.81	76.03	417.33	196.31	409.00	243.24	467.50	136.22	1142.20	249.46	120.30	41.10	321.50	120.96	419.00	20.66	177.63	41.12	263.21	50.60	879.30	197.72	538.51	481.95	406.06	182.63	294.35	157.99	294.35	157.99	479.00	344.17
Sb (ppm)	0.85	0.44	0.52	0.27	0.75	0.35	0.59	0.19	0.82	0.21	0.37	0.11	0.93	0.32	0.80	0.26	0.74	0.29	0.35	0.16	0.83	0.20	0.52	0.45	0.39	0.17	0.28	0.16	0.28	0.16	0.48	0.30
Sc (ppm)	10.34	1.67	9.62	2.03	9.90	2.97	10.39	1.74	15.60	1.48	9.67	0.94	11.55	1.62	13.47	0.38	14.18	1.90	9.81	1.66	13.44	1.44	7.44	8.49	5.79	3.80	4.80	1.40	4.80	1.40	19.98	2.90
Sr (ppm)	419.63	76.32	421.00	89.69	493.50	4.95	312.25	61.76	259.89	56.33	170.40	18.44	500.84	81.72	269.00	7.55	531.25	27.93	301.93	37.33	215.00	63.99	139.49	106.78	103.42	37.86	70.64	46.36	70.64	46.36	268.50	29.08
Th (ppm)	9.52	2.43	5.68	1.74	6.60	2.55	6.19	1.58	10.06	1.66	3.89	0.83	5.74	2.40	13.10	0.61	13.06	2.55	5.41	1.52	8.39	1.76	5.07	4.69	3.84	1.81	2.83	1.43	2.83	1.43	13.05	2.59
U (ppm)	3.83	1.50	2.15	1.06	3.25	2.33	2.15	1.19	3.90	1.68	3.17	1.19	6.05	1.89	5.97	1.82	5.31	2.59	2.39	0.74	2.83	0.93	1.88	1.34	1.39	0.48	0.93	0.64	0.93	0.64	4.35	0.92
V (ppm)	82.16	20.34	65.50	18.71	85.50	16.26	50.50	12.25	70.22	31.62	68.00	14.20	81.61	12.71	95.67	7.64	84.75	12.89	55.86	14.64	55.40	25.40	40.40	21.21	29.01	10.09	19.55	13.38	19.55	13.38	78.00	40.25
Y (ppm)	21.88	3.03	18.50	6.86	22.50	4.95	19.38	6.52	31.48	3.39	7.10	1.20	36.29	9.45	24.00	1.73	25.75	2.55	11.86	2.98	30.00	3.46	16.73	18.76	12.99	8.31	10.65	3.31	10.65	3.31	29.83	3.49
La (ppm)	32.94	6.23	24.85	9.00	27.25	7.42	24.63	5.74	43.16	4.84	12.62	2.03	32.09	4.87	33.03	1.91	46.63	5.06	19.45	5.88	38.26	5.04	21.65	23.49	16.73	10.16	13.44	4.64	13.44	4.64	56.05	12.31
Ce (ppm)	63.91	12.54	48.67	16.37	50.50	21.92	50.50	11.16	102.00	12.88	24.70	3.80	46.39	11.60	76.67	9.87	88.63	8.09	42.71	12.27	85.30	17.28	51.29	48.10	38.89	18.78	28.84	14.22	28.84	14.22	112.17	24.30
Nd (ppm)	34.26	12.99	22.67	4.08	47.00	19.80	33.88	15.72	50.52	14.58	14.30	6.07	29.42	12.51	36.00	7.81	46.88	14.70	25.36	9.00	35.00	7.39	21.20	19.52	16.04	7.53	11.78	6.01	11.78	6.01	48.33	19.19
Sm (ppm)	5.20	0.93	4.17	1.42	4.30	1.41	4.24	1.16	7.64	0.81	2.10	0.35	5.14	0.87	5.00	0.10	7.24	1.18	3.20	0.85	6.82	0.92	3.87	4.17	2.99	1.80	2.39	0.84	2.39	0.84	8.68	1.16
Yb (ppm)	2.32	0.34	1.98	0.74	2.10	0.71	1.98	0.61	3.79	0.48	0.94	0.22	3.19	0.60	2.80	0.20	2.96	0.70	1.55	0.32	3.24	0.45	1.84	1.97	1.42	0.85	1.13	0.41	1.13	0.41	3.90	0.82
S (wt %)	0.11	0.02	0.14	0.03	0.13	0.04	0.11	0.02	0.08	0.02	0.13	0.02	0.15	0.04	0.09	0.03	0.15	0.03	0.10	0.02	0.05	0.03	0.04	0.02	0.03	0.01	0.02	0.01	0.02	0.01	0.06	0.03
Al (wt %)	6.04	1.20	4.84	1.31	4.56	1.24	5.04	0.63	7.06	0.85	5.17	0.29	4.82	1.26	7.21	0.28	8.05	0.76	5.13	0.72	6.37	0.67	3.52	4.03	2.74	1.81	2.28	0.66	2.28	0.66	10.30	2.95
Ca (wt %)	15.38	2.66	16.68	2.85	18.20	4.67	13.88	1.97	9.46	2.29	15.63	1.29	18.51	2.65	12.03	1.17	14.83	1.42	14.29	2.15	5.86	2.49	4.17	2.39	3.01	1.00	2.01	1.42	2.01	1.42	6.48	1.54
Fe (wt %)	3.03	0.44	2.87	0.55	3.05	1.26	3.31	0.74	5.19	0.50	2.80	0.26	2.86	0.53	4.06	0.23	4.11	0.69	3.03	0.62	4.42	0.55	2.48	2.73	1.92	1.19	1.56	0.52	1.56	0.52	4.74	0.37
K (wt %)	1.54	0.32	1.25	0.40	0.70	0.22	0.70	0.17	1.11	0.14	0.84	0.14	0.96	0.39	1.73	0.13	1.66	0.40	1.00	0.24	1.10	0.28	0.69	0.58	0.52	0.21	0.37	0.22	0.37	0.22	1.45	0.38
Mg (wt %)	0.78	0.20	0.67	0.21	0.47	0.08	0.78	0.12	0.97	0.22	3.03	0.53	1.29	0.45	2.02	0.10	1.13	0.09	1.08	0.29	0.87	0.42	0.64	0.32	0.46	0.17	0.31	0.21	0.31	0.21	0.89	0.42
Na (wt %)	0.19	0.05	0.27	0.10	0.22	0.04	0.27	0.09	0.31	0.06	0.12	0.02	0.28	0.09	0.18	0.01	0.58	0.31	0.24	0.07	0.42	0.20	0.31	0.15	0.22	0.08	0.15	0.10	0.15	0.10	0.26	0.16
P (wt %)	0.15	0.04	0.12	0.06	0.16	0.03	0.09	0.03	0.13	0.05	0.06	0.02	0.37	0.16	0.24	0.08	0.18	0.03	0.08	0.03	0.11	0.05	0.08	0.04	0.06	0.02	0.04	0.03	0.04	0.03	0.16	0.05
Ti (wt %)	0.30	0.07	0.29	0.08	0.28	0.23	0.25	0.08	0.28	0.18	0.24	0.06	0.12	0.10	0.35	0.09	0.41	0.08	0.26	0.08	0.23	0.15	0.19	0.06	0.13	0.07	0.10	0.04	0.10	0.04	0.42	0.19

9.3. Sha'ar-Ha'Amakim, Tell Keisan, Tel Akko – a chemical comparison

Mean element concentration in the individual petrographic groups, treated jointly (Sha'ar-Ha'Amakim, Tell Keisan, Tel Akko), are presented in Table 17.

For a comparative analysis of the chemical composition, also examined were two specimens of Moza Formation marls sampled in the Hebron region[339] and two specimens of Late Roman amphorae discovered in Gaza[340]. They were chosen because of petrographic similarities with SG I.A1 (cf. Appendix 1, especially as to the presence of *Corallinacea* fragments).

The results of the principal components analysis of the whole analysed set of ceramics and clays sampled in the field are presented in Fig. 260.

The geometrical relations between the specimens analysed in 32-dimensional space after projection onto the plane of the first two principal components PC1 and PC2 were preserved in 51.8%. Together with the third dimension, PC3, it explains 60.6% of the actual variability of the chemical composition of the Sha'ar-Ha'Amakim, Tell Keisan and Tel Akko ceramics (cf. Table 18).

The first principal component PC1 is mostly determined by variations of Fe, Sc, Co, rare earths, Hf, Th, Ca and Al, thus distinguishing ceramics produced on the basis of iron-rich *terra rossa* from those made of marl; the second, PC2, is determined by three elements: P, U and Sr, the presence of which is an indicator of organic-rich sediments; whereas the third, PC3, by K as an indicator of clay minerals, commonly illite (cf. Table 19).

Details of the relations of the chemical similarity between the Sha'ar-Ha'Amakim and Tell Keisan ceramics seen against samples taken in the field and reference samples of jars from Tel Akko are presented in the form of a dendrite (spanning tree, Fig. 261).

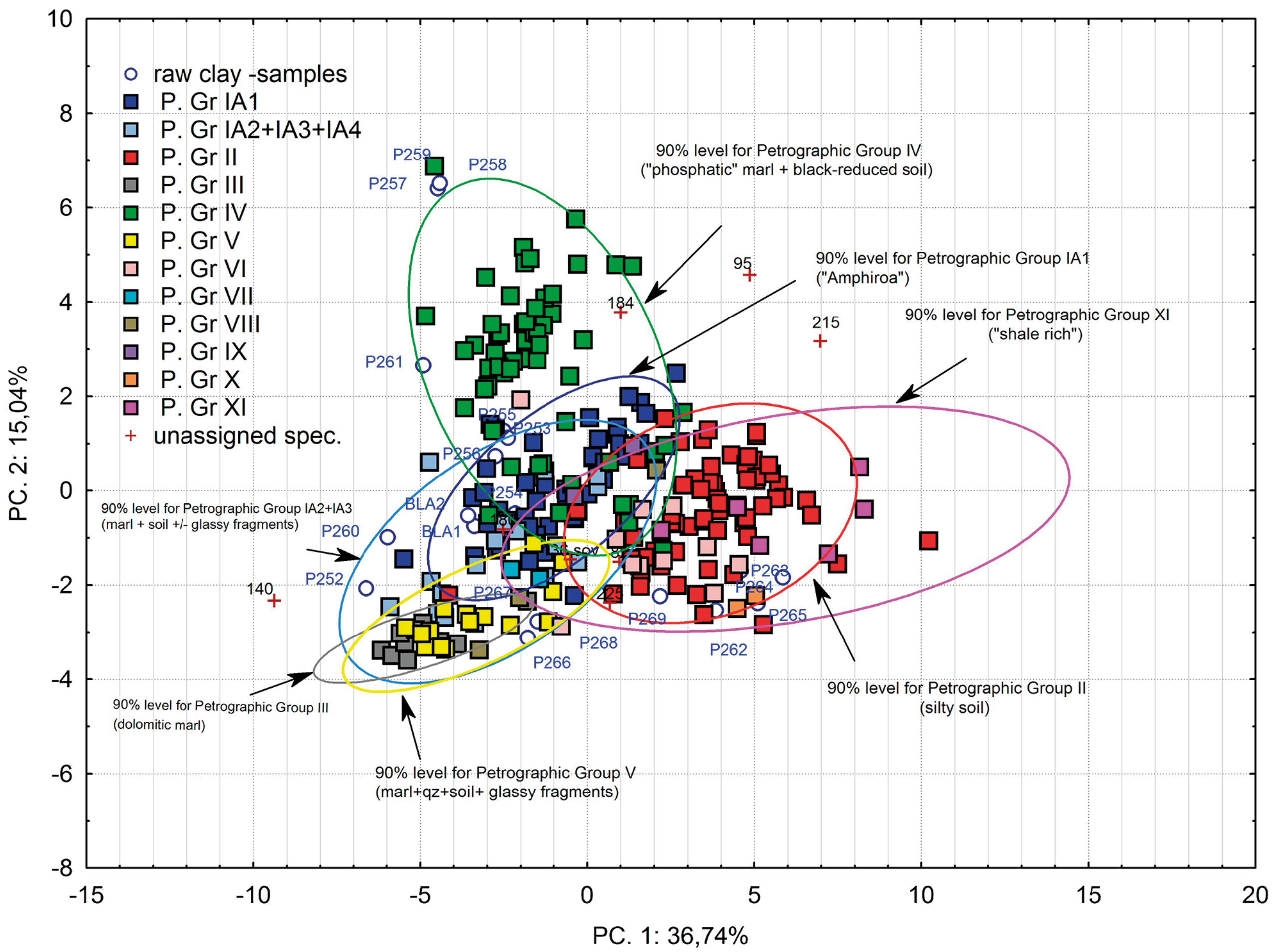


Fig. 260. Principal components analysis of the complete set of ceramics from Sha'ar-Ha'Amakim, Tell Keisan, and Tel Akko in the PC1-PC2 coordinate system

[339] Cf. Michniewicz 2009.
[340] They were made available by the courtesy of the EBAF.

The values of distances (D) between the jar specimens are presented in Table 20. Assuming a distance equal to $M+2\sigma = 6.08$ as well $M+\sigma = 4.4$ to be the criterion of the statistical separateness of specimens, standing out are mainly samples of clays taken in the field (also raw "yellow clay" from Nazareth), most ceramics of petrographic group XI, and most vessels of an untypical petrography, not forming any petrographic group.

Table 18. Results of principal components analysis based on the correlation matrix of the complete data set

Principal component number	Eigenvalue	Percentage of variance explained	Cumulative % of total variance
1	11.71	36.74	36.74
2	4.79	15.04	51.78
3	2.81	8.83	60.61
4	1.79	5.61	66.22
5	1.33	4.18	70.40
6	1.15	3.60	74.00
7	1.01	3.17	77.17
8	0.97	3.04	80.21
9	0.92	2.90	83.11
10	0.84	2.63	85.74

Table 19. PCA of the complete data set. Determination coefficient $R^2 \times 100\%$ for the first two principal components PC1 and PC2

Element	PC1	PC2
Cu	3.4	14.0
Pb	1.8	0.3
Ni	25.1	38.0
Zn	24.6	49.1
As	1.5	8.1
Ba	3.9	1.0
Co	**70.7**	1.2
Cr	1.5	4.6
Eu	**61.3**	2.0
Hf	**60.8**	6.5
Li	26.6	0.0
Mn	**51.1**	0.9
Sb	9.9	20.1
Sc	**73.6**	0.1
Sr	15.5	**52.1**
Th	**58.4**	2.1
U	0.0	**58.8**
V	0.4	20.1
Y	31.2	44.9
La	**84.2**	4.0
Ce	**90.2**	0.9
Nd	47.3	0.1
Sm	89.9	1.8
Yb	70.3	13.7
S	46.6	21.2
Al	**61.4**	3.7
Ca	**60.3**	21.6
Fe	**80.8**	2.6
K	10.1	1.0
Mg	2.7	3.6
P	1.1	77.3
Ti	9.4	5.7

Table 20. Values of the shortest Euclidean distances as a measure of similarity among all the specimens studied

Pairs	Distance	Pairs	Distance	Pairs	Distance	Pairs	Distance	Pairs	Distance
1 –9	2.51	113–150	1.66	89–106	2.10	106–118	1.83	191–238	2.08
9 –3	2.95	150–97	2.14	106–44	1.76	118–52	1.74	238–126	2.94
3–37	2.55	97–94	2.24	44–43	1.92	52–55	2.02	172–175	2.44
37–164	2.10	94–266	5.11*	44–174	1.70	52–141	2.03	175–203	2.18
164–181	2.31	266–269	5.67*	174–76	1.92	141–144	1.78	203–160	1.96
181–26	2.18	150–105	1.68	76–77	1.93	144–92	1.78	160–165	1.98
26–61	2.24	105–102	1.20	77–145	1.17	144–93	1.66	165–185	2.07
61–261	3.79	102–117	1.30	145–151	2.57	93–91	2.16	165–212	2.15
26–120	2.28	105–114	1.72	77–147	1.85	93–96	2.03	212–220	2.17
120–59	3.01	105–149	1.98	147–73	1.73	96–148	2.17	220–221	1.77
26–183	2.69	150–157	2.29	73–75	4.39*	148–79	4.54*	221–242	3.55
183–25	3.35	38–29	1.80	77–189	3.19	93–201	7.11**	212–227	1.82
25–13	3.55	38–249	1.89	189–121	5.27*	201–206	3.49	160–209	2.58
25–33	2.42	32–60	1.80	76–80	1.76	206–192	3.49	209–162	2.90
33–24	2.06	60–133	2.17	174–98	1.68	206–204	2.97	209–208	2.48
33–257	6.07**	133–125	1.78	98–22	2.87	204–163	4.43*	172–245	1.95
257–258	0.94	125–66	0.90	22–85	2.81	93–215	4.22	245– 5	2.91
258–259	0.00	133–127	2.81	85–137	2.82	215–95	4.45**	173–176	1.78
25–255	3.24	133–232	2.10	137–138	0.00	93–250	2.00	173–237	1.90
255–169	3.29	232–51	3.08	98–81	1.75	250–87	2.06	233–235	1.71
169–171	2.57	51–124	2.85	81–152	3.53	52–223	2.50	235–30	2.70
171–130	3.35	124–134	3.31	98–104	1.14	223–219	2.71	30–246	2.25
171–187	2.39	134–72	4.16	104–107	2.14	70–110	2.54	246–214	3.49
187–197	2.47	134–101	2.67	104–109	2.29	202–122	3.10	214–47	9.64**
197–270	3.29	101–108	3.42	104–194	2.18	202–188	3.15	255–256	1.18
270–271	1.38	101–179	3.81	194–196	2.67	188–88	3.74	256–229	3.33
169–228	1.92	179–178	5.03*	194–205	2.70	188–207	2.73	229–230	2.51
228–41	1.60	134–112	3.10	194–213	2.49	207–99	2.95	230–156	3.17
41–71	1.28	112–128	2.90	98–142	1.75	99 42	2.99	183–34	2.52
71–115	1.67	112–136	3.57	142–53	2.11	99–69	2.91	26–244	2.26
115–67	1.79	232–132	2.28	53–54	1.34	217–173	1.96	244–158	2.71
67–39	1.62	232–234	2.00	54–46	1.23	173–172	2.01	244–184	16.99**
39–86	2.34	234–260	2.54	46–45	1.92	172–129	1.85	244–239	2.52
71–143	1.47	260–252	2.10	45–56	1.82	172–153	1.89	181–167	2.14
71–146	1.48	252–140	3.27	56–49	3.29	153–2	2.45	167–168	3.21
146–11	2.48	27–68	3.11	46–50	1.52	06.lut	2.19	168–74	5.34*
228–62	1.29	68–63	1.51	50–111	2.56	08.cze	2.44	167–177	2.76
62–119	1.45	68–78	2.51	50–131	1.99	20.cze	4.14	177–251	2.75
228–233	1.67	68–90	2.92	54–57	1.37	153–186	1.91	167–198	2.20
233–217	1.69	90–200	3.13	57–116	2.13	186–135	2.01	181–190	1.89
217–31	2.14	200–195	2.83	142–103	2.42	135–100	3.24	190–222	2.57
31–27	2.90	195–28	2.53	142–123	2.88	135–231	2.03	181–226	1.99
27–35	2.79	195–243	2.18	174–166	2.21	186–191	1.72	181–241	2.75
35–18	1.71	68–253	2.87	166–155	2.83	191–161	3.01	241–218	2.69
18–4	1.60	253–180	3.39	166–216	5.18*	161– 7	3.51	218–139	5.66*
4–58	1.93	180–82	10.55**	216–210	3.58	161–154	1.31	241–240	3.29
18–14	2.52	253–254	2.64	210–268	8.31**	161–247	3.37	240–182	3.67
14–17	1.77	31–159	2.87	166–263	16.46**	191–193	1.83	37–236	2.22
18–19	2.45	159–48	3.01	166–264	2.83	193–16	3.45	236–211	2.30
35–32	1.68	159–267	2.58	264–262	3.10	16–65	3.11	211–40	3.17
32–38	1.79	31–199	2.86	264–265	2.19	paź.65	2.73	40–23	3.30
38–12.	1.77	199–202	1.49	106–84	1.89	65–64	2.71	211–248	2.22
12–15	2.31	202–70	3.07	84–36	1.97	65–225	3.00	248–170	2.12
12–113	2.84	70–89	2.52	36–83	2.89	193–224	4.13	9 –21	3.21

MEAN (M) = 2.71; Standard deviation (σ) = 1.69; M+σ = 4.4*; M+2σ = 6.08**

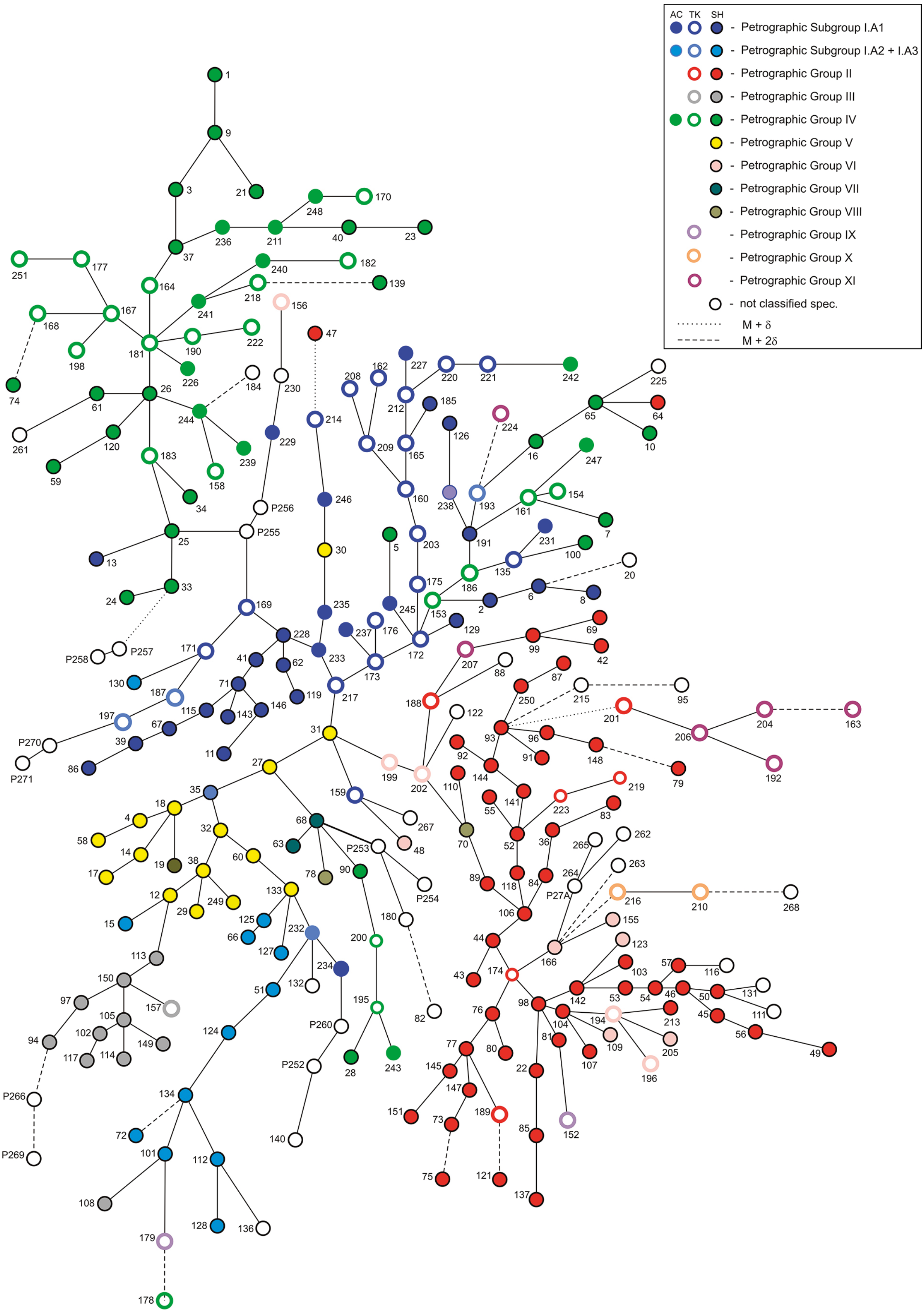


Fig. 261. Spanning tree of the complete data set, presenting the similarity between the jars and jugs from Sha'ar-Ha'Amakim, Tell Keisan, Tel Akko, and the clays sampled in the field

10. Archaeometric interpretation

10.1. Chemical data

As a map of similarities among specimens of the analysed set, the obtained spanning tree generally corroborates the distinctness of most of the petrographic groups established, while making it possible to trace the degree of their internal uniformity (cf. Fig. 261).

Petrographic s**ubgroup I.A1**, by its central location, separates most samples of petrographic group IV situated at the top of the diagram (green dots) from those of lower-lying PG II (red dots) and PG V (yellow dots). PG I.A consists of jars from Sha'ar-Ha'Amakim_(dark-blue dots with a black ring in the diagram), jars and jugs from Tell Keisan (dark-blue ring) and jars from Akko (blue dots without a black ring).

Outside the main body of subgroup I.A1 are samples of quartz-rich sand[341]: SA-13 (shape 1a) and AK-229 (shape 1a), which shows a chemical affinity with the ceramics of group IV; TK-159 (shape 2b or 2c) chemically close to the quartz-rich group V, and AK-234 (shape 3a), chemically close to the IA2+IA3 ceramics.

Subgroup I.A1 is generally[342] distinct because of a high level of Ca, Sr (as in group IV) and K. The high content of **Ca** is understandable given the marly character of the material, **strontium** is strongly associated with calcium[343], it occurs especially in aragonite, thus reflecting the presence of microfossils in the matrix.

The high level of **potassium,** 1.5% (+/–0.3)%, is closely correlated with the **Al** content (6.0%), a marker of the presence of clay minerals, mostly illite and/or kaolinite, which are products of the terrestrial weathering of the continent, and a small admixture of *terra rossa*. Thus, it can be assumed that the material of SG I.A1 is associated with shallow-sea, coastal sedimentation[344].

The level of thorium and rare-earth elements (REE) is high, which makes SG I.A1 significantly different from I.A2 and I.A3 (Fig. 265). In the case of SG I.A1, also notable is the absence of a correlation between the level of manganese (constantly low) and the variable content of iron (Fig. 262).

Petrographic subgroup I.A2 was discovered in Sha'ar-Ha'Amakim, Tell Keisan and Akko. Together with the entire set of petrographic subgroup I.A3 (not found in Tell Keisan) they form a separate uniform cluster. This supports the assumption of their petrographically established distinctness from subgroup I.A1.

It should be stressed that subgroups I.A2 and I.A3 are not identical in petrographic terms. Besides, they differ chemically in the content of potassium (Fig. 264). In SG I.A2 it is relatively high (1.25 +/– 0.4% of weight), i.e. at a level similat to I.A1, while in SG I.A3 it is lower (0.7% of weight). At the same time the two subgroups differ from SG I.A1 due to an elevated level of manganese (Fig. 262).

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341 This is hard to explain because an elevated content of quartz sand generally lowers the concentration of most elements, which we have not found in the case of the discussed samples.

342 Not all single samples fulfil this suggestion in an equal way, which is reflected in high standard deviation values.

343 Aragonite is the basic ingredient of skeletons. With time, it is transformed into calcite and then Sr is removed, enriching sea water. The high content of this element, i.e. 400 ppm, probably corresponds to the presence of numerous microfossils in the matrix, and it can also suggest a relatively young age of the raw material: its content in sea water increases with time. Consequently, the Sr content increases in skeletons, cf. Abdel-Rahman & Nadar (2002: 83).

344 Shallow-water sedimentation is also confirmed by micro-paleontological studies, as Barbara Olszewska states: we notice the constant presence of the *Chiloguembelina* species in PG IA1 (it generally tends to disappear on the border of the Early and Late Oligocene (Berggren & Pearson 2005), as well as the presence of *Radiolaria* (the Middle Eocene being one of its optimum periods of occurrence) and the *Korobkovella* and *Victoriellidae* characteristic of the Middle and lower parts of the Late Eocene, originating from shallow-water carbonate sedimentation (Höntzsch et al. 2011).

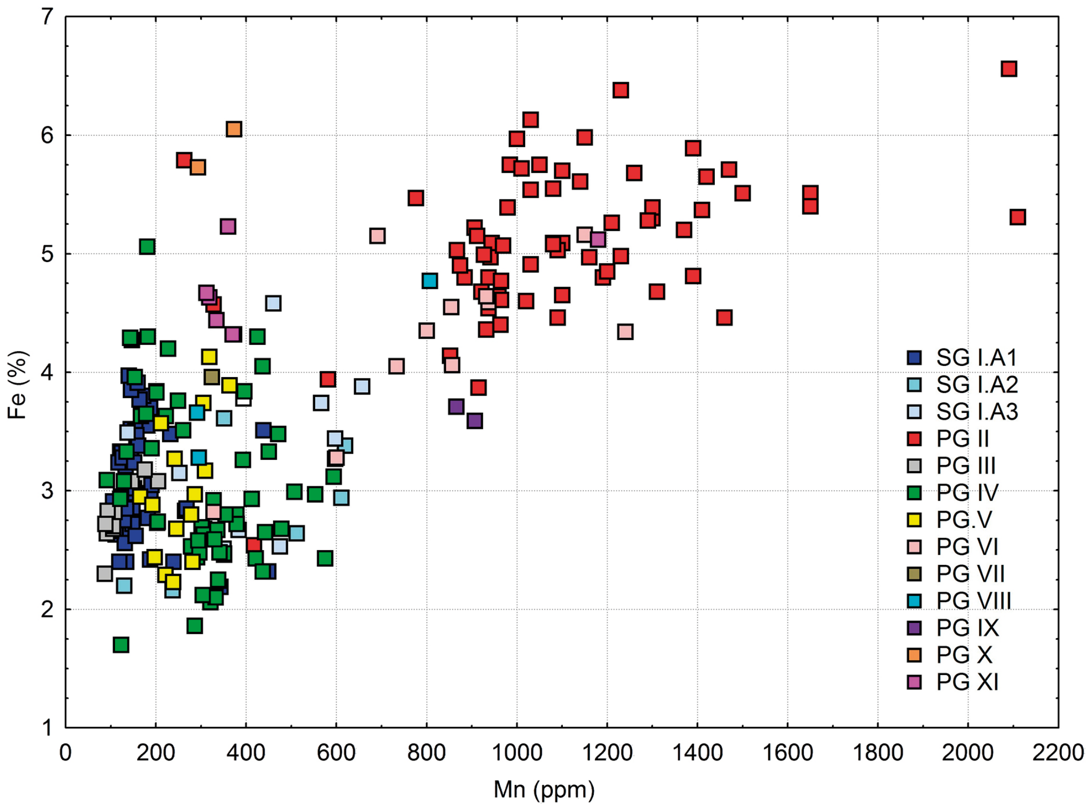

Fig. 262. Bivariate plot of the Mn/Fe ratio in the Sha'ar-Ha'Amakim, Tell Keisan and Akko jars and jugs. Notable is the separateness of petrographic group II and most specimens of PG IV caused by different Fe/Mn proportions

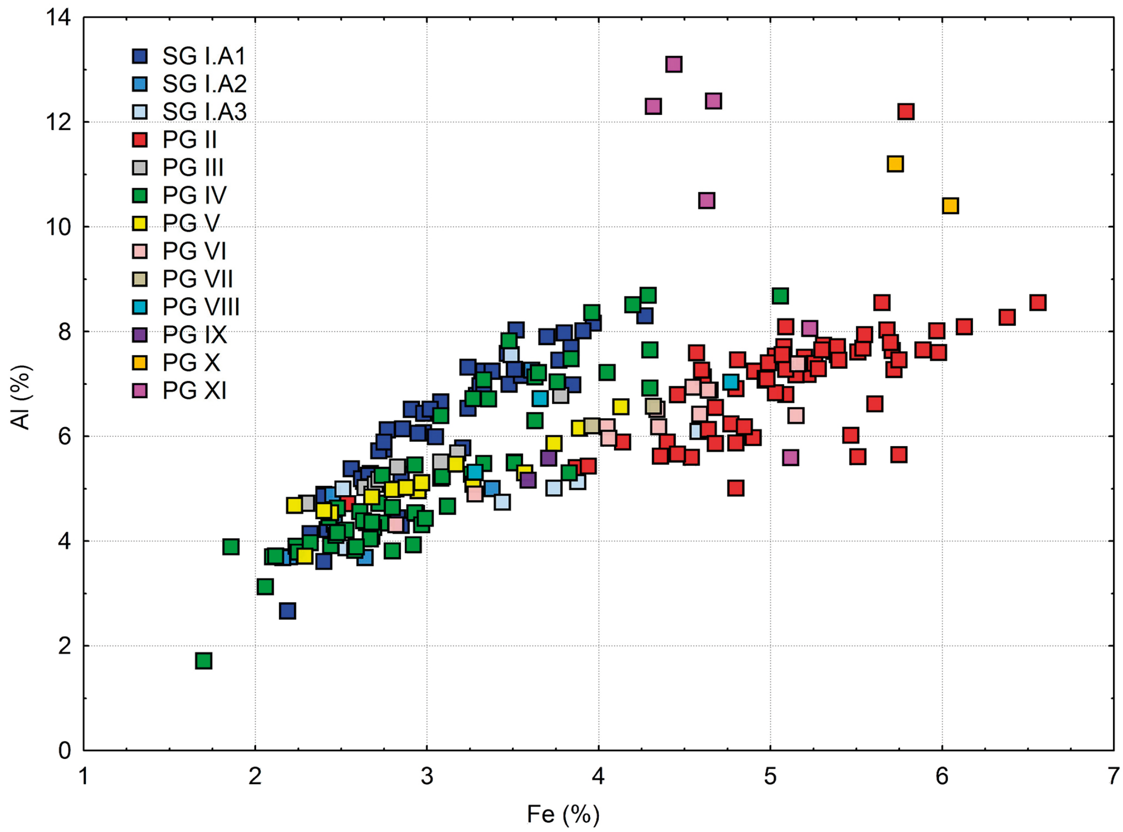

Fig. 263. Bivariate plot of the Fe/Al ratio in the Sha'ar-Ha'Amakim, Tell Keisan and Akko jars and jugs. Notable is the separateness of petrographic groups: IA1, II, and XI caused by different Fe/Al proportions

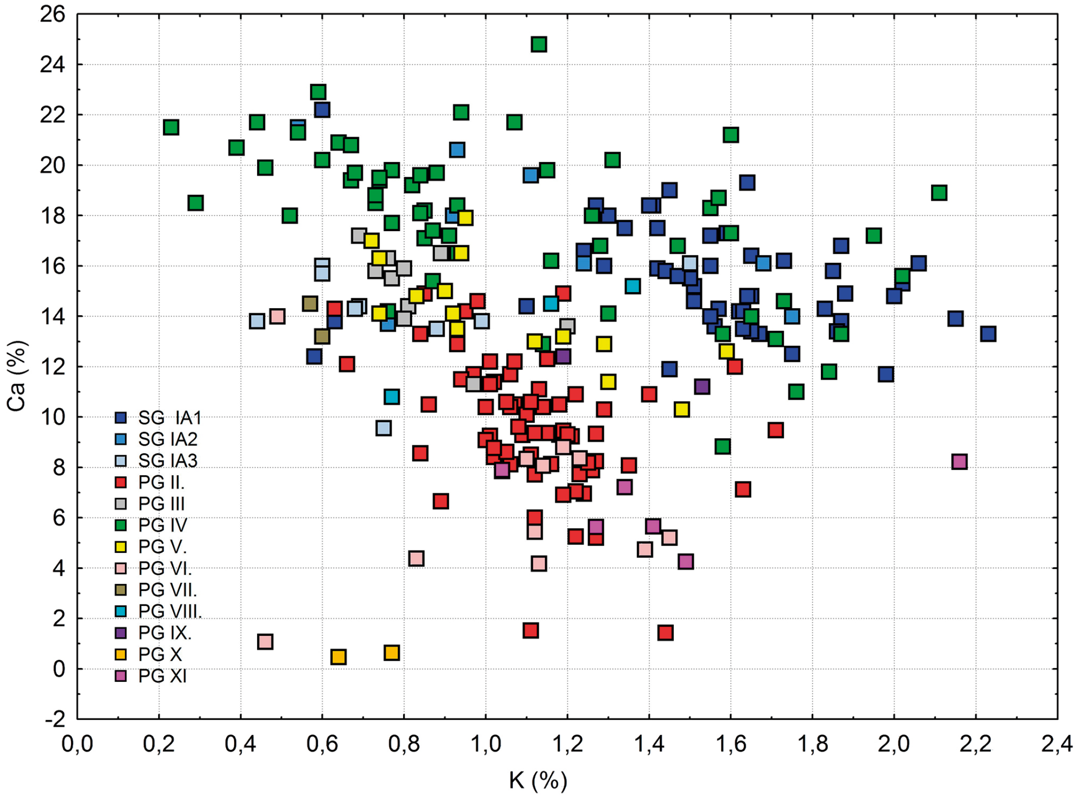

Fig. 264. Bivariate plot of K/Ca ratio in the Sha'ar-Ha'Amakim, Tell Keisan and Akko jars and jugs. Notable is the separateness of petrographic subgroup I.A1, the separation and division of PG IV into two parts, and the separateness of PG II caused by different levels of potassium and calcium

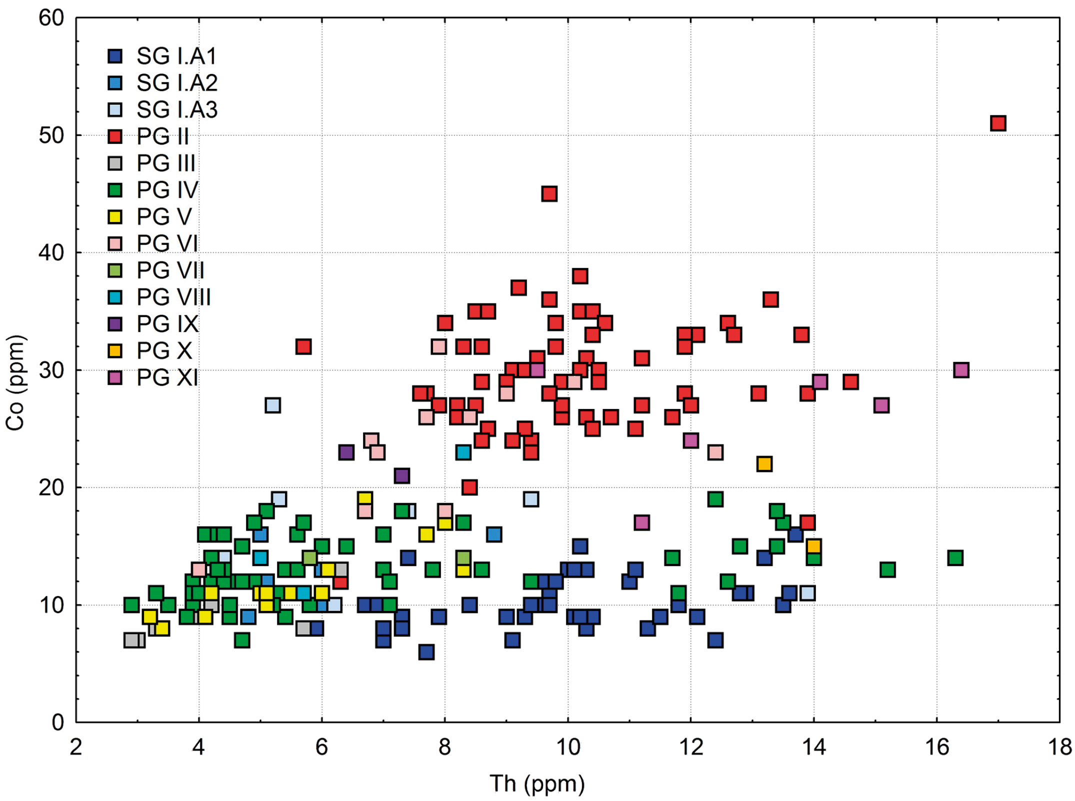

Fig. 265. Bivariate Th/Co plot. Note the high level of thorium in SG I.A1, PG II, SG IV.C, and SG IV.H, PG V and the relatively low cobalt content in SG I.A1*

*Projection points PG IV co-occurring with SG I.A (see right-hand side of diagram), represent samples of petrographic subgroup IV.C: (SA-10, SBc-16, SD1-65); subgroup IV.H: (SA-7, TK-154, TK-161, AK-247), some outliers of petrographic subgroup IV.D (SA-5, SBc-20; AK-242) and a single sample – AK-242 – of petrographic subgroup IV.B.

Standing out among the SG I.A2 samples are those from Tell Keisan: [TK-187 (shape 2a/4), TK-193(4), and TK-197(3a)]; they are chemically closer to jars of petrographic subgroup I.A1. Chemically distinct is also jar SA-130 (early 1a) made of Cretaceous (Senonian) marl. The sample of of petrographic subgroup I.A3, SBc-35 (2a) is especially close to PG V, while SD2-72 (shape 2b) is different in a statistically significant way, although close to SG I.A2 and SG I.A3.

The ceramics of **petrographic group II** made of ferruginous silty soil (rendzina, *terra rossa*) prevails among Roman jars of group shape 2b. This holds especially for Sha'ar-Ha'Amakim. Similar to this group are PG VI jars. This is a relatively uniform set, clearly distinct in all discriminating diagrams. What separates it from the remaining petro-groups are elevated levels of Fe, Mn, Sc, Cr, Ni, Co, and REE. In contrast to I.A1, the correlation between Fe and Mn and the other elements that make this group distinct is linear (Figs. 262, 268–270). The elevated level of Fe is typical of lateritic, pedogenic processes,[345] whereas the higher content of Hf can be interpreted as an effect of the presence of heavy minerals. This group also has a proportionately lower Ca content.

Petrographic group III (grey dots – the lower left side of the spannig tree), embraces Roman vessels of shape groups 1c and 2b. This group, composed of Late Cretaceous dolomitic marl, is exceptionally uniform[346], located on the peripheries of diagrams. As expected, the group stands out for its high magnesium level as well as the lowest content of rare-earth elements, thorium, Mn, and Sr (Figs. 267–268).

The two samples of the Cenomanian Moza Formation clay taken in the Hebron region (P-267, P-268) are different in a statistically significant way, although they lie close to PG III on the spanning tree[347].

Petrographic group IV is a large set of ceramics made of chalky marl, mixed with ferruginous *terra rossa* soil (presently highly sintered), the common feature of which is the cream color of the sherd. They were discovered in Sha'ar-Ha'Amakim, Tell Keisan and Akko. This is not a set uniform in petrographic and micro-paleontological terms, hence eight subgroups have been distinguished in it.

Most samples belong to subgroups IV.A (Late Paleocene – Eocene), IV.B (Eocene)[348], and IV.D (Senonian?). They stand out in the multivariate space of elemental variables as well as on the scatter diagrams, where they form common clusters.

Clearly distinct in chemical terms are three jars forming subgroup IV.C (unknown age): [SA-10 (shape group 2a), SBc-16 (shape group 2a), SD1-65 (shape group 2a)] and six samples belonging to subgroup IV.H (Eocene marl): [SA-5 (shape group 1a), SA-7 (shape 1a), TK-153 (shape group 1a/2a), TK-154 (shape group 1a/2a), TK-161 (shape group 1a/2a), TK-186 (shape group?); AK-242(?); and AK-247(shape group 4)]. On the spanning tree they are located peripherally with respect to subgroup I.A1 on the right-hand side of the diagram, with only two SG IV.H specimens, specifically TK-153 (shape group 1a/2a) and TK-186 (shape group 2a?), situated more centrally. They also clearly stand out from the rest of the PG IV set on the SG IV.C and SG IV.H bivariate diagrams, and co-occur with SG I.A1 projection points (cf. Figs. 265–266).

Two SG IV.E samples are chemically similar to subgroups IV.A, IV.B, and IV.D. The remaining three jars of this subgroup: [SBc-28 (shape group 2a), TK-195 (shape group 2a), and TK-200 (shape group 3a)][349] are located in the lower part of the diagram. Chemically similar to them are two samples: AK-243 (SG IV.B, shape group 1a, Paleogene) and SE-90 (SG IV.D, shape group 2b, Eocene + Cretaceous); they should be treated as outliers.

The kiln sample SOV-139 and specimen SD2-74 (SG IV.D, shape group 2b) are statistically different, while samples SA-5 (SG IV.D, shape group 1a) and AK-242 (SG IV.D, shape group 1a/2a) are close to subgroup I.A1.

The elements that differentiate most specimens assigned to PG IV (especially SG IV.A and IV.D) are primarily phosphorus (P), yttrium (Y), uranium (U), nickel (Ni), chromium (Cr), strontium (Sr) and calcium (Ca). Their levels are the highest in the examined set of pottery (Fig. 266–267). Worth noting is a slightly elevated proportion of scandium in relation to iron, as well as the disproportionately large share of Y in relation to the rare earths (Fig. 268).

The elevated P and Y levels are explained by the results of SEM-EDS analyses. They showed phosphorus to be clustered in numerous irregular grains of high porosity resembling a cellular texture, possibly bone fragments. Calcium phosphate is often also present in the form of automorphic apatite[350].

Yttrium is a lithophile metallic element that forms several minerals, e.g. xenotime, YPO_4 could be associated with *terra rossa* soil and phosphorite mineralisation.[351]

345 Cf. Singer 2007: 96–122.

346 Standing out in this set is specimen SF-108 (2b).

347 The trace-element composition of the Moza formation in the Hebron region (cf. Michniewicz 2009:132).

348 Petrographic subgroup IV.B differs from SG IV.C and SG IV.D in micropaleontological terms because of the admixture of Late Eocene chalk rich in foraminifers.

349 Whereas the two other samples in this subgroup, SBc-24 and SBc-33, are similar to the main body of this set.

350 The composition of apatite given by manuals is: $Ca_5(PO_4)_3$ (OH, F, Cl).

351 De Vos et al. 2006: 407–408.

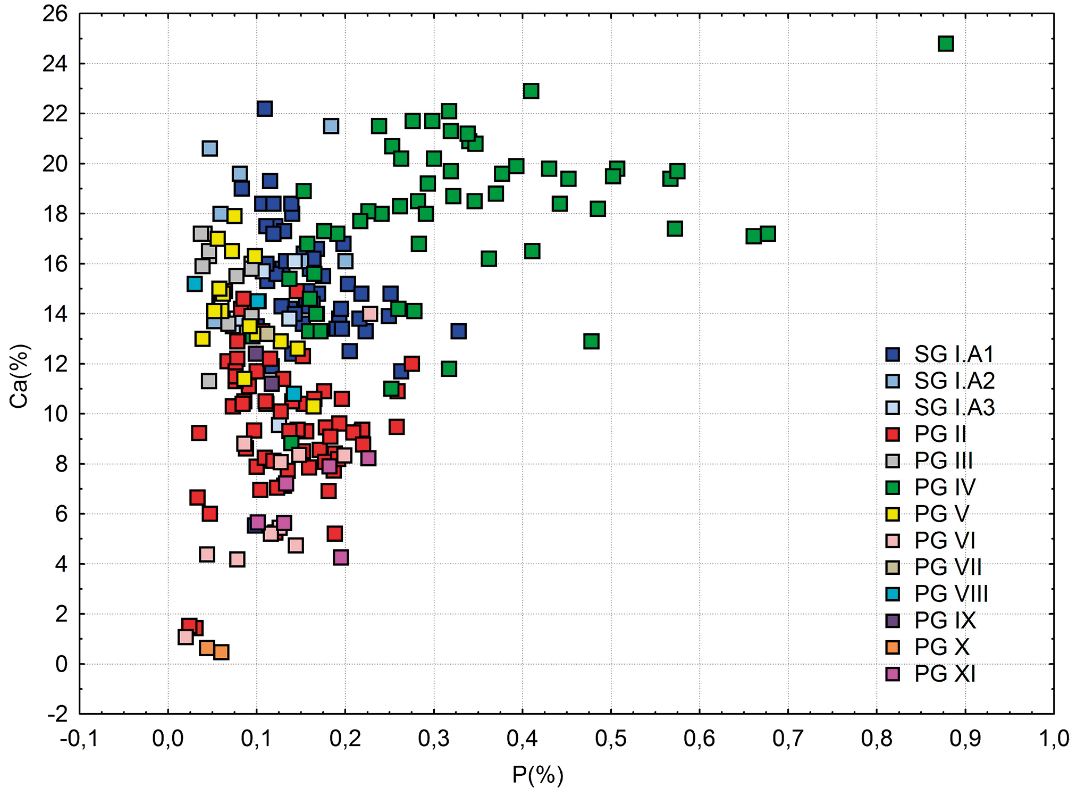

Fig. 266. Bivariate plot of the P/Ca ratio in the Sha'ar-Ha'Amakim, Tell Keisan and Tel Akko jars and jugs
Notable is the separateness of petrographic subgroups IV caused by a higher level of P. Analogically to Fig. 265 we can observe a chemical affinity of samples in SG IV.C (SA-10, SBc-16, SD1-65); SG IV.H (SA-7, TK-153, TK-154, TK-161, AK-247) as well as outliers of SG IV: TK-156, TK-162, and SG IVB: AK-243.

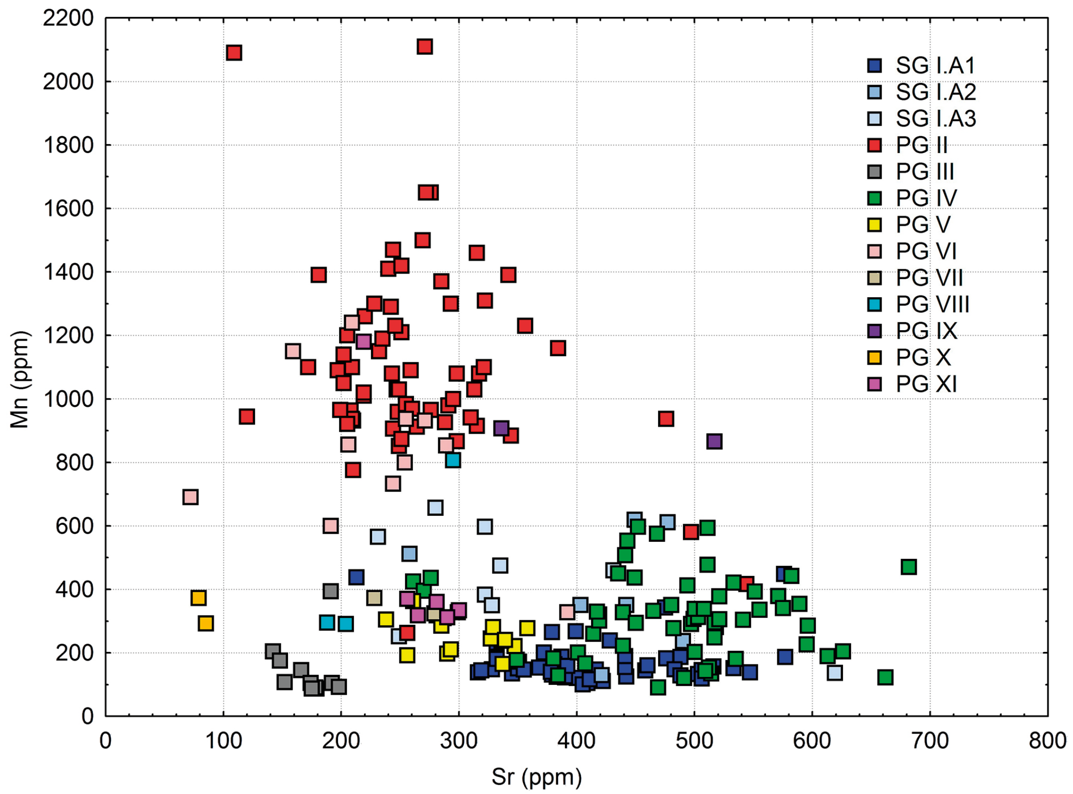

Fig. 267. Bivariate Sr/Mn plot. Note the high Mn content in PG II and PG VI, and the separateness of PG III because of the low level of both those elements. Subgroup I.A3 clearly differs from I.A1

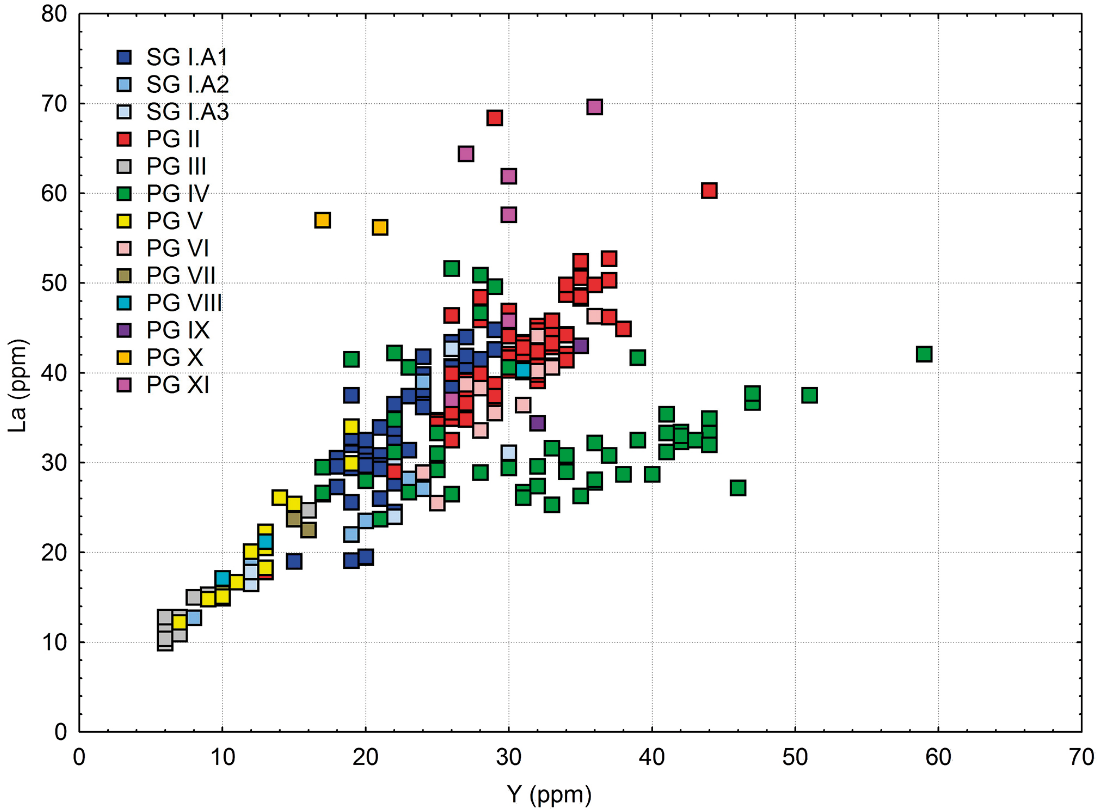

Fig. 268. Bivariate Y/La plot. Note the separate Y/La proportion of most specimens of subgroups IV vs. the remaining groups of the analyzed set (an exception being specimens representing subgroups IV.C and IV.H)

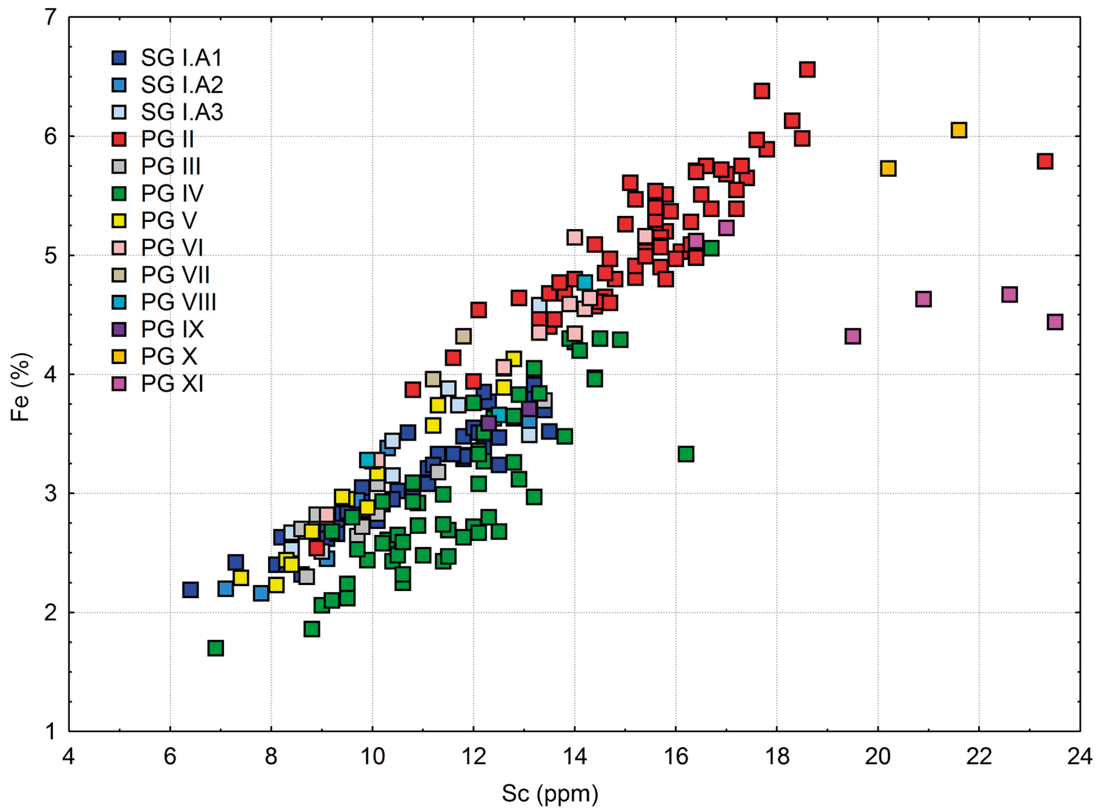

Fig. 269. Bivariate Sc/Fe plot. Note the separate Sc/Fe proportion observed in PG IV (with the exception of subgroups IV.C and IV.H)

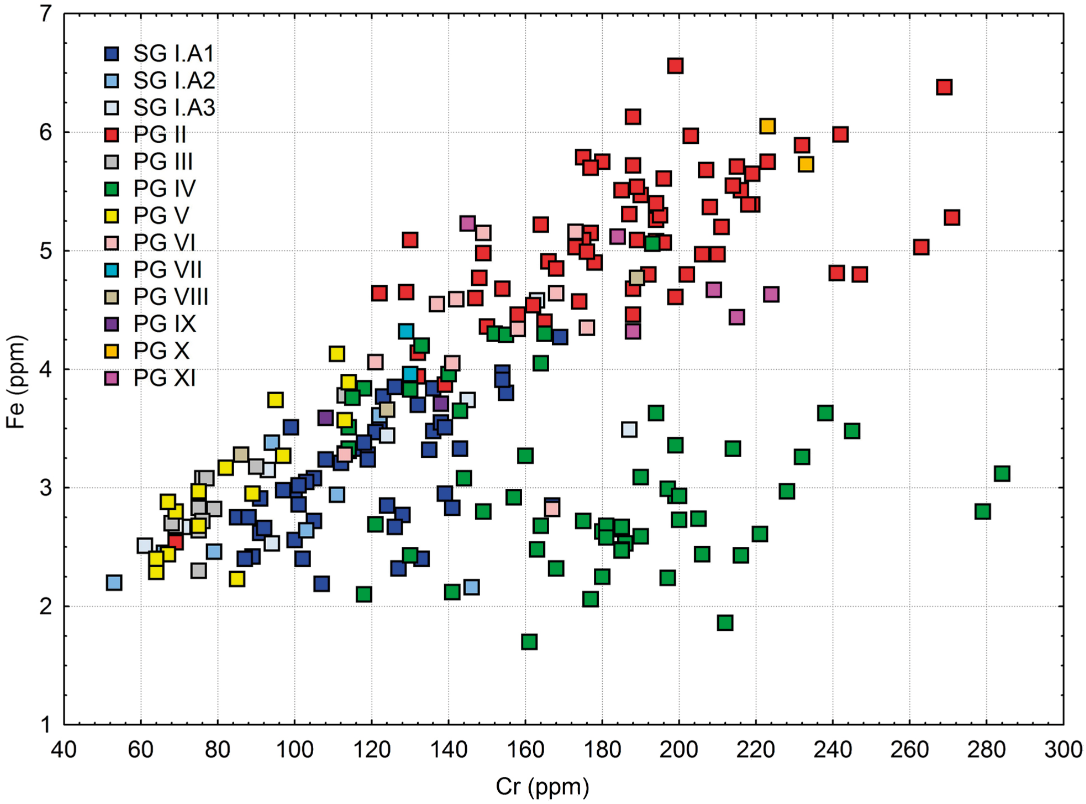

Fig. 270. Bivariate Cr/Fe plot. Notable is the strong correlation between the two elements in most groups, except PG IV (with the exception of SG IV.C and SG IV.H)

When reflecting on the identification of the raw material it is worth noting that in the Levant region higher levels of P, Cr, V, Ni, U and Co are especially recorded in marls deposited at the Upper Cretaceous/Paleogene boundary and belonging to the Mt Scopus Group: the Maastrichtian Ghareb Fm. and upper parts of the Chekka Fm. as well as in the Paleocene: the Taqiye Fm.[352] Those facts may be an indirect proof of a relationship of the examined vessels with the Maastrichtian and Paleocene formations. But what partly contradicts this thesis is the presence of *Chilogumbelina* sp. and *Pseudohastigerina* sp. indicative of an age not later than the early Eocene[353]. This issue is hard to settle unequivocally because there are no microorganisms preserved in most samples of SG IV.D, while shells of the *Chilogumbelina* and *Pseudohastigerina* Eocene foraminifers are also found in the contemporary coastal sands of the Levant. Hence it cannot be ruled out that they may be components of a sandy tempering admixture added to Late Cretaceous or Paleocene marls.

Petrographic group V (shape groups 2a and 3a) on the spanning tree (the lower part of the diagram, yellow dots) is similar to PG III (shape groups 1c and 2b), as well as to SG I.A2 and I.A3 (shape groups 2a and 2b). Only sample SBc-30 (shape group 3a) is similar to the ceramics of SG I.A1. In turn, the location of one sample, SBc-35 (shape group 2a), representing SG I.A3 among the ceramics of PG V, corroborates the mutual affinity of the two groups. As to the chemical composition, those are ceramics high in calcium, low in phosphorus, Fe and siderophile elements, and with a moderate strontium content. The similarity of PG V to PG III is only apparent, connected with the dilution effect caused by a high quartz content in the PG V.

Macroscopic similarities of the ceramics of PG V to PG IV and often also a similar vessel shape (group 2a) may suggest a common provenance of those vessels, while differences in the levels of Ni, Zn, Cu, and P seem to indicate different sedimentation environments of the material of the two groups.

Petrographic group VI is made of sandy *hamra* soil. Jars made of this material were found in both Sha'ar-Ha'Amakim and Tell Keisan. Its projection points are scattered on the margins of PG II. Only sample TK-156 has a different chemical composition.

The affinity of PG VI to PG II follows from elevated levels of iron and siderophilic elements, while their scattering on the margins of PG II is a dilution effect caused by a high quartz content. Not insig-

352 Especially considering the dilution effect caused by the presence of a tempering admixture, the Sr content would be even higher, cf. Ilani et al. 1991, Abdel-Rahman & Nader 2002: 84

353 This concerns samples SBc-34, SE-90, TK-168, TK-190, TK-198.

nificant is also an elevated share of heavy minerals, which, through the 'erratic' concentration of trace elements typical of them, may greatly distort the results of comparative chemical analyses.

Petrographic group VII comprises two specimens: SD1-63 (shape group 2b) and SD1-68 (shape group 2b). They are made of dolomitic marl, rich in 'red fragments' (possibly representing red fired glauconite?). They are akin (rather seemingly) to the ceramics of PG V, but different in terms of the magnesium content, which make them closer to that of the ceramics of petrographic group III (dolomitic marl).

Petrographic group VIII (SDc-19 (shape group 2a/3a), SD1-70 (shape group 2c), SD2-78 (shape group 2a) is not internally similar in terms of the chemical composition; on the spanning tree specimen SD2-78 is close to two samples of PG VII, specimen SBc-19 occurs in PG V, whereas specimen SD1-70 is observed on the margins of PG II.

Samples belonging to **petrographic group IX** (TK-152 and TK-179) also do not occur together on the spanning tree, mainly because of their different barium content.

Petrographic group X are two cooking pots (TK-210, TK-216) made of silty soil with an admixture of chamotte are chemically similar, but statistically different from the remaining ceramics, e.g. because of their highest Al and Fe content.

Petrographic group XI is clearly distinct petrographically, and because of the presence of ferruginous clayey shales not chemically uniform. Similarity is the greatest among samples TK-192 (shape group 2a), TK-204 (shape group 2c), and TK-206 (shape group 2c), the projections of which occur at the margin of PG II, near them is sample TK-163 (shape group 2c), different in a statistically significant way. The other two samples of this group, TK-207 (shape group 2c) and TK-224 (shape group 2b), are different and dispersed. PG XI also stands out for its highest content of Al, a high content of Pb, Cr, Sc, Th, and Hf, and light rare earths (LREE).

Most samples taken in the field (P) are on the margins of the diagram. This also holds for two samples of Late Roman amphorae (P-270, P-271) discovered in Gaza, rich in *Coralllinacea*. On the spanning tree, as expected, they oscillate around the margins of SG I.A1.

Notable is the central location of two samples of ceramics made today in the Nazareth Musmar factory, P-255 and P-256. In chemical terms, they are similar to both, SG I.A1 and SG IV.A, B, D. Their petrographic assignment to one of the groups distinguished is hard because they are products made mechanically in which marl, rich in foraminifers, was mechanically homogenised with an admixture of *terra rossa* and marine-beach quartz[354].

10.2. Suggested provenance for each petrographic group

The presented results do not give an unequivocal answer as to the place of production of the vessels examined, but they narrow down the geological age of the material used, thus also narrowing down the likely area from which it came.

Some suggestions as to the potential import of some vessels can be derived from a map of trade routes existing from the Iron Age until the Roman times (Fig. 271), especially when compared against the geological maps of this area (Fig. 9).

The petrography of SG I.A1 closely corresponds to the Fabric Class 1A of carinated-shoulder amphorae defined by Bettles (2003b). What distinguish those ceramics are a characteristic light-red colour of the sherd, an orange matrix, the presence of coralline algae *Amphiroa* sp., numerous *Globigerina*, and well-sorted quartz sand of the <0.25 mm fraction making up ca. 5% of the volume,[355] the grains of which are mostly angular or subangular.

The set of microfossils identified during the research, especially foraminifers, puts the age of the material of SG I.A1 at the Middle-Late Eocene. What distinguish those vessels chemically are their relatively high content of potassium, probably associated with the high content of clay minerals, and a particularly low level of Mn, not correlated with the iron content. The Middle Eocene age of the foraminifers precludes the connection of this group with the Early-Paleogene Taqiye formation. What should be checked in further studies is the potential connection of the ceramics of this petrogroup with Eocene chalks of the Adulam or Maresha Formations.[356]

When discussing the provenance of carinated-shoulder amphorae (in our case shape group 1a), it is worth quoting the opinion of E. Bettles, who argues that it is logical to assume, because of the amphorae being intended for marine transport, that they were produced near the coast. If this was so, outcrops of Middle-Late Eocene rocks lying close to the sea occur northward of Nahariya, in Lebanon between Mannsouri and Tyre, and between Sarepta and Sidon. More distant outcrops, at a distance of 15 km from the sea, can be found within the synclinal Qiry-

354 This marine genesis is corroborated by the presence of kurkar fragments.

355 Bettles established the age of the raw material micropaleontologically at Paleogenic; she believes that it was used between Akko and Sarepta because of those rocks being close to the coast. The sand serving as the tempering admixture would come from beaches located south of Akko.

356 Cf. Sneh 2004.

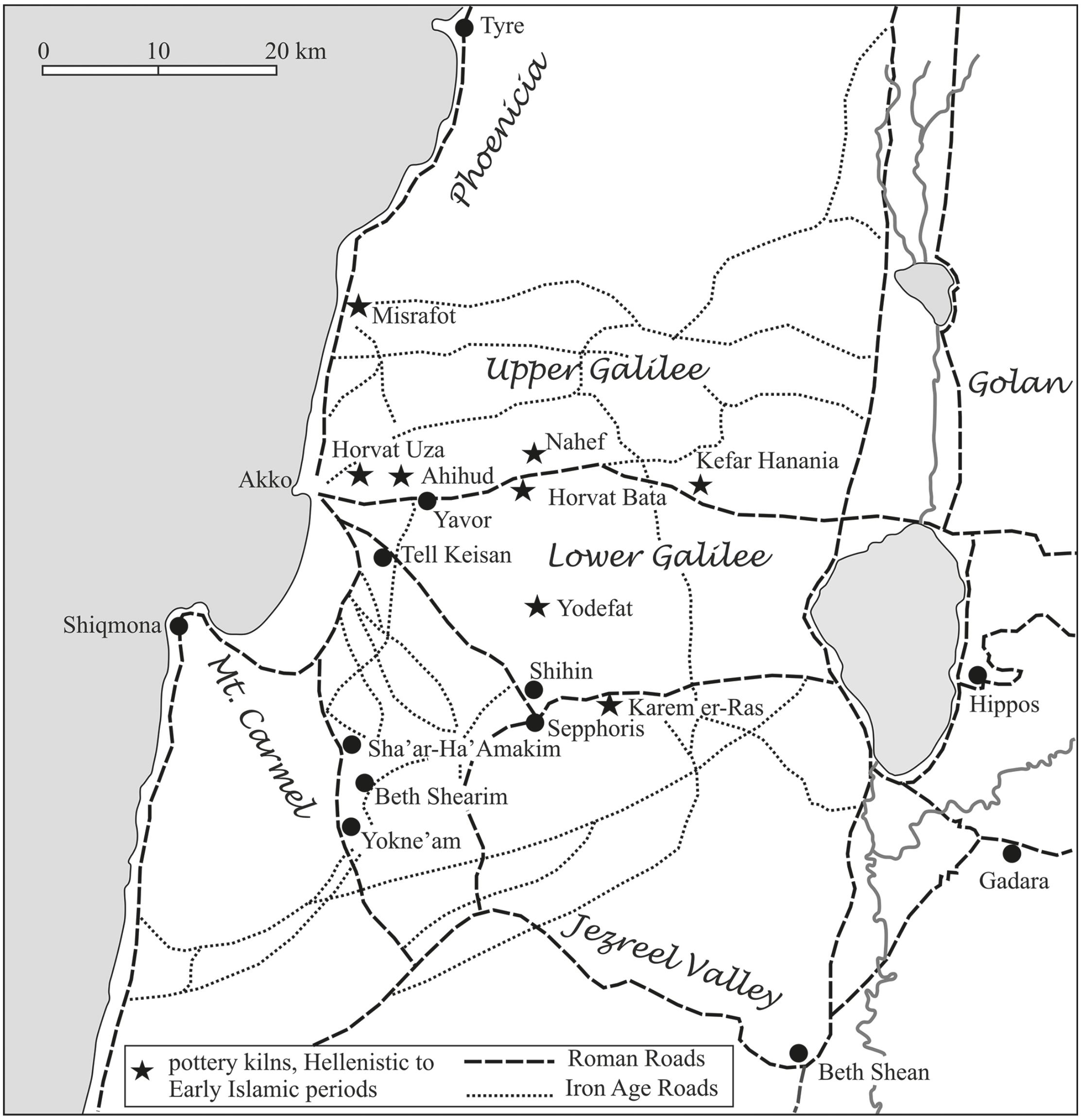

Fig. 271. Map of trade routes from the Iron Age till the Roman Period (based on: Aviam 2014, fig. 6)

at Tiv'on Eocene block and in the Menashe syncline, where they are relatively readily accessible from the Sharon Plain.

So far no attention was given to the question of the potential use of the Late Eocene Bet Guvrin Formation, at places rich in *Globigerina* ooze.[357] Those rocks are generally inaccessible because they appear offshore; they have not been found in Lebanon, inland in Israel they crop out near Nahariya Horst[358] and east of Hadera.[359]

Late Eocene sediments commonly accompany Oligocene outcrops[360]. They include *Turborotalia cerroazulensis* zones commonly missing in Israel – species detected in specimen AK-227. The accessibility of those rocks and their usefulness for pottery making could account for the low content of quartz sand diagnostic for SG I.A1 and only single Corallinacea fragments, which in this case would come from the Neogene rocks covering them.

Subgroup I.A2 includes ceramics also made of Middle-Late Eocene marl, usually slightly more silty than in SG I.A1, mixed with ferruginous *terra rossa*. In spite of the shared petrographic group, the jars from Sha'ar-Ha'Amakim differ chemically from those of Tell Keisan. Those are ceramics clearly different chemically from PG I.A1. It seems that here we deal with a technology based on the enrichment of marl by silty *terra rossa*, practised in many workshops of the region. This group has no equivalent among the FC defined by Elizabeth Bettles (2003b).

As to SG I.A3, the basic material here is marls of the Middle or Late Eocene. In transmitted light the matrix has a characteristic orange colour, as in SG I.A1 and SG I.A2. The group is characterised by

357 Cf. Gvirtzman & Buchbinder 1978: 1201.
358 Sneh 2004, cf. Hofstetter et al. 2010.
359 Cf. Sneh et al. 1996.
360 Buchbinder et al. 2005.

the presence of fragments of honey-yellow volcanic glass, similar to that found in the Nahal Qishon deposits. This strongly supports the thesis about the connection of SG I.A3 with areas adjacent to Mt Carmel (cf. chapter 7.2). It cannot be ruled out that those vessels were produced inland, importing sand from the sea region (Haifa Bay?). Also this type of fabric has not been described by E. Bettles (2003).

PG II includes ceramics markedly distinct petrographically and chemically. They were made of ferruginous silty soil. Their characteristic is the absence of a sand admixture. Predominant in this group are thin-walled jars with features of the Kefar Hananya and Shikhin ceramics. Since this material is so widespread, it is impossible to indicate the place of production or to determine in how many workshops those vessels were made. What can be stated is that a similar technology was employed for the whole group. It includes primarily ceramics produced in the Roman period, and among the vessels examined this is the dominant time. This gives the impression of a marked breakthrough in the production technology or of the commercial domination of the site that produced them. In the case of Sha'ar-Ha'Amakim, it can be treated as a marker of the period of the creation of the product.[361]

PG III is made of Late Cretaceous dolomitic marl; in the case of the analysed set it represents the Roman period. Dolomitic rocks are widespread in the Mt Carmel region, hence it is possible that the material comes from an unidentified local source. One cannot forget about the occurrence of a similar raw material in Samaria (via Megiddo?) and even in Judea (where dolomitic marls belong to the Moza Formation) – the question of a potential import requires further studies and an archeological interpretation.

PG IV – this group is clearly distinct (like PG II). The jars were made of calcareous marl mixed with *terra rossa* and fired in reducing conditions. Macroscopically they are similar, but petrographically and chemically they turn out to be diversified.

Chemically distinct is especially subgroup IV.C (SA-10; SBc-16, SD1-65). This is not surprising because of the admixture of fragments of ferruginous shales. It should be emphasised, however, that those are vessels distinct from the shale-rich ceramics assigned to PG XI, established for Tell Keisan jars, dated mostly to the Byzantine period.

Also subgroup IV.H is chemically distinct, perhaps similar to PG I.A1. It is possible that the vessels of this group were made of a geologically similar material, here fired in reducing conditions, which gave the sherds a white hue.

Petrographic subgroups IV.A and IV.D seem to be close to FC 1D described by Bettles (2003: 169), which this author associates with the Haifa Bay area. Both subgroups have the highest content of phosphorus as well as high concentrations of uranium, nickel and chromium. This fact (on the assumption that the single Eocene foraminifers found in the ceramics are only an addition together with the tempering admixture) at least partly corroborates the thesis about the connection of those jars with Maastrichtian Ghareb and Paleocene Taqiye marls[362]. What makes it even more probable is that the Taqiye Formation outcrops occur a short distance to the north-east of Akko (Ahihud Ridge), where they could be used together with local sand.

PG V is a petrographically uniform set, characterised by a high content of a quartz admixture of the size less than 0.25 mm and by frequently found particles of volcanic glassn The presence of *Globigerina* sp., *Chiloguembelina* sp. and *Angulogerina* sp., making the Eocene the probable age of the material. It can be made oeAdulam chalky marls. The presence of glass particles described here as "yellow fragments", as in the case of SG I.A3, makes probable the local character of those jars (the Zevulun Plain/Lower Galilee).

In this context we cannot rule out a connection of PG V with kilns of Tel Yokne'am, located near the Nahal Raqefet, the waters of which dissect the hyalloclastite-bearing Cretaceous volcanic tuffs of Maharal, Tavasim and Bat Shelomo. The Nahal Raqefet sediments are taken over by the Nahal Yokne'am, and then the Nahal Qishon flowing at the foot of Tel Yokne'am. But this is only a hypothesis.

PG VI is a set of six dark reddish-brown jars made of higly ferruginous sand clay resembling *hamra* – soil levels, intercalated coastal kurkar ridges[363]. Deposits of this type occur along the Israeli coastal plain up to the boundary with Lebanon, where they disappear. Chemically, those ceramics are similar to PG II, associated with the coastal region (e.g. Tel Dor).[364] This group corresponds to Bettles' FC. 2A.

PG VII – two jars distinguished as a separate group because of the unusual oval "red fragments" they contain – partly amorphic aluminosilicates of iron, formed either as an effect of the oxidation of glauconite, or representing thermally oxidised pedogenous forms. Because of the high content of silt-sized dolomite, the vessels are similar petrographically to PG III, but chemically different. Even so, like PG III, they can be associated the Mt Carmel, Samaria or Judea regions.

PG VIII – two light-brown jars rich in sand-sized dolomite; they could be produced anywhere from a

361 Cf. Michniewicz & Młynarczyk 2017.

362 The high concentrations of those elements in Senonian and Paleocene rocks are stressed by Ilani et al.(1991) and Abdel Rahman & Nader (2002).

363 Cf. Singer. 2007.

364 Cf. Eliyahu-Behar et al. 2008: 2901.

material developed on the substratum of dolomite rocks, e.g. in the Mt Carmel area[365].

PG IX – the two specimens of this group are different on the spanning tree, which may only be apparent. The basic difference results from a difference in the content of barium, which is absent from one of the samples because of its very small mass. More probable is the affinity of the two jars to PG II.[366]

PG X – two fragments of cooking pots (?) – chemically clearly distinct, could be produced anywhere.

PG XI – includes ceramics relatively easy to identify in petrographic terms. The matrix of this groups contains minute pieces of argillaceous clayey shales, the presence of which is regarded as diagnostic for Lower Cretaceous formations. This raw material has been known since the Bronze Age.[367]

The colour of the sherds varies from red and dark red to yellow, grey or black. They are usually oblong and scattered in the clay groundmass in various numbers. Their presence can be an effect of non-uniform hydration and mixing of the ceramic paste, or of its intentional addition to improve a material of poor/unsatisfactory quality. They vary in their content of quartz silt, which is often absent. Because of their high content of kaolinite and an elevated iron content which lowers the temperature of firing, the deposits of those rocks are the highest-quality ceramic raw material. The sherds, scattered in the matrix, usually display a different anisotropy than the groundmass, or none at all. They are usually accompanied by grains of monocrystalline quartz, sandstones, quartzose mudstones, as well as characteristic ferruginous ooliths.[368]

Undoubtedly the ceramics of PG XI were made using Lower Cretaceous shales. Thus, it could have been imported both, from the eastern or north-eastern boundaries of today's Israel, or from the north of today's Lebanon. Because of the situation of Tell Keisan on the trade route connecting Akko and Capernaum, the easterly direction (Kefar Hananya) seems highly probable.

10.3. Typology of petrographic groups

The relationship of the particular petrographic groups with vessel forms is presented in Table 21.

When analysing the raw material used in relation to the typology of the vessels it can be demonstrated that:

- jars of the Phoenician type (shape group 1a) are dominated by SG I.A1 and SG IV.D;
- jars of the Late Phoenician type (shape group 1b) represent SG I.A1 (with one possible exception (specimen SC-40);
- jars of the post-Phoenician shape (group 1c) are made of various paste types, and their small number does not allow any generalisations; notable is the appearance of PG III;
- the Persian and Hellenistic bag-shaped forms (shape group 2a) are made of various types of pottery clay; notable is the domination of PG V (only in Sha'ar-Ha'Amakim, only this type of jar) as well as a high proportion of SG IV.D – also used in the production of shape group 1a;
- the bag-shaped jars of the Roman-period (shape group 2b) were mostly made in the Shikhin technology using silty soil; relatively frequent is also PG III, as well as *hamra* soil (PG VI);
- the Roman-Byzantine jars of shape group 2c were made primarily from *hamra* soil or Lower Cretaceous clays.
- large bag-shaped jugs of group 3a are made of a similar material as forms 2a;
- Roman dipper jugs of group 3b are mostly made from silty soil (PG II); there also appears dolomitic marl (PG III), or the raw materials used for the Roman-period 2b forms.

Table 21. Petrographic groups and subgroups according to vessel forms

Petro group/ vessel form	1a	1b	1c	2a	2b	2c	3a	3b
I.A1	26–32(?)	8–10(?)	1	–	–	–	1	–
I.A2	–	–	–	2	1	–	1(?)	–
I.A3	–	–	1	2–3(?)	4	–	–	–
II	–	–	1	2	54	–	1	3
III	–	–	3	–	7	–	–	1(?)
IV.A	–	–	–	4	–	–	1	–
IV.B	1	–	–	–	–	–	2	–
IV.C	–	–	–	3	–	–	–	–
IV.D	8–9(?)	–	–	8	2	–	2–3(?)	–
IV.E	–	–	–	4	–	–	1	–
IV.F	–	–	–	–	–	–	–	1(?)
IV.G	1	–	–	–	–	–	–	–
IV.H	1	–	–	–	–	–	–	–
V	–	–	–	10–11(?)	–	–	1	–
VI	2	–	1(?)	–	4	3	–	–
VII	–	–	–	–	2	–	–	–
VIII	–	–	–	1	1	–	–	–
IX	–	–	–	1–2(?)	–	–	–	–
X	–	–	–	–	1(?)	–	–	–
XI	–	–	–	1	1	4	–	–

365 E.g. the author found clays rich in sand-sized dolomite crystals along the Nahal Rakefet river, in the Isfye Fm.
366 Cf. Adan-Bayewitz & Wieder 1992: 199, fig. 12.
367 Greenberg & Porat 1996.
368 Cf. Goren 1995, Greenberg Porat 1999, Michniewicz 2009, Choen-Winberger & Goren 2011.

10.4. Conclusions

As a whole, the examined set of vessels from Sha'ar-Ha'Amakim, Tell Keisan, and Akko were made according to a fairly wide range of formulae, among which those petrographically most distinct and most numerous are SG I.A1, SG I.A3, PG II, PG III, PG IV, PG V, PG VI and PG XI.

The petrographic diversity of the basic groups is generally reflected in significant differences in their chemical composition, but there are exceptions to this rule. At the same time there are many petrographic subgroups that do not differ in chemical terms.

An important exception here, however, is the chemically proved distinctness of petrographic subgroups I.A2, I.A3; as well as distinctness of subgroups IV.C, IV.H from IV.A, IV.B, IV.D, IV.E.

Micropaleontological studies served to identify the age of the material used, allowed distinguishing petrographically similar material of Late Cretaceous (Senonian) clays/marls from Paleogene rocks and Eocene marls. It should be emphasised that owing to the high temperature of firing, in many samples the state of preservation of foraminifers made it impossible to determine their systematics, especially their species, more closely, thus making it impossible to establish the age of the raw material employed.

Petrographic subgroup I.A1 is clearly different; it corresponds to the "Phoenician fabric" known from the research conducted so far. The composition of microfossils present in those vessels narrows down the age of its raw material to the Middle-Late Eocene. Outcrops of Eocene marls can be found northeast of Nahariya, especially in Lebanon between Mannsouri and Sidon (i.e. northern Israeli/southern Lebanon coast).

SG I.A2 is made of Eocene marls with a large admixture of *terra rossa* soil. Production may have been carried out near the outcrops of those rocks (Israeli -Lebanon coastal plain?/Lower Galilee?).

SG I.A3, made of Eocene marls, also has features of the "Phoenician fabric", and the presence of hyaloclastites may be indicative of its origin in the nearby Mt Carmel (Zevulun or the Sharon Plain?). Eocene in this area outcrops both locally with Sha'ar-Ha'Amakim on the Qirat Tiv'on Block but primarily forms the core of the Ramot Menashe syncline.

PG II represents ceramics composed of rendzina and/or *terra rossa* soil. The vessels in this group could have been made elsewhere, this material seems to have been especially popular in the Roman period.

PG III (dolomitic marl) in the set examined is the raw material used in the Roman period; it is not commonly available in the vicinity of the sites discussed, it may come from Mt Carmel, but equally probable is its import especially from Samaria.

PG IV is a set of vessels fired white with a green of creamy hue, made of highly calcareous chalky marl, not uniform in petrographic and chemical terms. Unlike SG I.A, the ceramics in this group contain much fewer microfossils, primarily *Globigerina*; it stands out for its high content of phosphorus. Perhaps for the ceramics of SG IV.A and IV.D top parts of the Taqiye Formation (the Lower Eocene) were used.

Subgroup IV.E probably comprises the Cretaceous (Maastrichtian) Ghareb Formation.

Those three groups: IV.A; IV.D; IV.E could be locally produced in Lower Galilee or on the Zevulun Plain, at Akko, but their material could also come from more distant areas.

Subgroups IV.B and IV.H comprise Eocene chalky marls, which makes them similar to SG I.A1 Especially the numerous ferruginous Globigerina ooze concentrations in the matrix of SG IV.H indicates the connection of this subgroup with SG I.A1.

Subgroup IV.C is made of marls of unknown age, especially distinct because of the small fragments of clayey shales clustered in the marly groundmass; those jars may come from both, Lebanon and Samaria.

PG V – because of the presence of brown-yellow hyaloclasts it was probably made locally, in the vicinity of Mt Carmel.

PG VI – with features of sandy *hamra* soil, connected probably with the coastal region, especially south of Akko (the Israeli coast).

PG VII and PG VIII comprise marls rich in dolomitic sand of Late Cretaceous age; it could be local to Mt Carmel/ the Sharon Plain (?).

PG IX – beige in colour, made of some soil rich in chalk of Late Eocene age and pedogenic ferruginous ooliths; it could have been made elsewhere.

PG XI, because of its diagnostic content of ferruginous sherds, is an import either from Samaria or Mt Hermon, or from the Lebanese Mountains; its relation with Kefar Hananya kilns is highly probable.

Abstracting from the typology, the examined set of ceramics from Sha'ar-Ha'Amakim seems to be more diversified petrographically than the Tell Keisan vessels. However, it cannot be ruled out that products showing the petrography of, e.g., PG V and PG XI found in Sha'ar-Ha'Amakim, can also be found in Tell Keisan, but were not chosen for study in the random selection. The predominance of amphorae with features of SG I.A1 and SG IV.D among carinated Tell Keisan vessels corroborates the results of Bettles (2003b).

The above analogies notwithstanding, there are still some scholarly doubts about the places where the raw material for SG I.A1 was obtained, especially the natural or anthropogenic character of the presence in it of remnants of coralline algae of the *Amphiroa* sp.

The study of the rocks sampled in the field did not provide an unequivocal answer about the place of production of the examined jars. What makes conclusions difficult is the technological necessity for potters to enrich the marly material predominant in Galilee with an admixture of *terra rossa* or *hamra*.

It is worth noting that the dolomitic marls belonging to the Moza Formation sampled in the Hebron area are not chemically similar to samples of PG III jars, hence it is hard to assume their potential import from Judea without more comprehensive studies. Also the two samples of LRA jars from Gaza used as a comparative material, rich in fragments of algae, and therefore partly similar to SG I.A1, show only a limited chemical similarity to the vessels of this subgroup.

A promising element of the presented results is the presence of fragments of honey-yellow volcanic glass among the contemporary Nahal Qishon deposits, which reinforces the thesis about the local – Mt Carmel – derivation of the SG I.A3 and PG V ceramics.

A micropaleontological analysis seems to be an especially effective method for examining the Levant ceramics; an equally efficient one is a complementary use of petrography and chemical analyses.

11. Concluding remarks (archaeological point of view)

A most important achievement of the present research project from the archaeological point of view has been demonstrating the existence of a multitude of "workshops" (pot-making technologies) in the area of western Lower Galilee and a part of southern Phoenicia, as reflected by the very number of petrographic groups and subgroups. Combined with the chemical analyses and the geography of that part of Palestine (especially considering the network of regional and interregional roads, see the map (Fig. 271), this allows for suggesting the provenance of at least some of the ceramic products and reconstructing the pattern of trade contacts. Another interesting aspect of the obtained results is the period-specific and shape-specific variability of jar/storage jugs fabrics.

In two important cases, the macroscopic examination of vessels fabrics by an archaeologist agrees fairly well with the divisions obtained by means of petrography analyses. Specifically, Phoenician Semi-fine ware, noted in field descriptions of some jars of groups 1a and 1b at all three sites (Sha'ar-Ha'Amakim, Tell Keisan and Tel Akko), consistently equals petrographic subgroup I.A1, while the Light White ware corresponds to petrographic subgroup IV.D. Certainly, meaningful is the fact that the proportion of those wares among sampled jars as well as their distribution throughout the chronological periods is different at each of the three sites.

At Sha'ar-Ha'Amakim, among the jars of shape group 1a (Phoenician carinated-shoulder type) and 1b (late Phoenician barrel-shape type), the Phoenician Semi-fine ware (SG I.A1) greatly prevails, while the Light White ware (SG IV.D) is poorly represented among jars of shape group 1a and absent from shape group 1b. One should note that in the jars of shape group 2a (Hellenistic baggy jars) at that site the Phoenician Semi-fine ware is not present at all unlike the Light White ware which is represented by a few examples; moreover, two of the sampled jars of shape group 2b (Roman baggy jar) from Sha'ar-Ha'Amakim are also made in the Light White ware (SG IV.D). As to Tell Keisan, it is possible to state on the basis of both the publication of the material uncovered in 1971–1976[369] and the acquaintance with that found in 1979–1980 that among the carinated-shoulder jars (group 1a) the Light White ware was definitely more common than the Phoenician Semi-fine ware, even if the sampled material does not reflect that proportion. At the same site, Light White ware was also the standard fabric of the vessels of the shape groups 2a and 3a (baggy jars and jugs respectively). At Tel Akko, an important harbour town, which was taking advantage of both the maritime connections and its agricultural hinterland, the proportions of Semi-fine ware and Light White ware among the carinated-shoulder jars (group 1a) of the Persian and Early Hellenistic periods seem to be more or less equal.

The two wares in question are no doubt derived from the coastal region of southern Phoenicia, but each of them comes from a different jars manufacturing area, as confirmed not only by the results of the physico-chemical analyses, but also by slight differences in the details (rim, shoulder, handles) of their respective shape. The Phoenician Semi-fine ware (identified as our SG I.A1) corresponds to FC 1A of Bettles, connected with the workshops of Sarepta and its vicinity, Tyre included.[370] The Light White ware (identified as our SG IV.D) is close (corresponds?) to FC 1D of Bettles, attributed by her to the region of Haifa Bay, probably Akko.[371] This seems most probable indeed, given the mass occurrence of this ware both in Akko and Tell Keisan, while its examples become less frequent in Shiqmona and especially in Sha'ar-Ha'Amakim. It is worthy of note that in Tell Keisan the Light White ware has been represented by a wide range of vessels, including jars of our shape groups 1a and 2a, as well as jugs

[369] Briend & Humbert 1980.
[370] Bettles 2003a, 2003b. Berlin & Frankel 2012: 61 speak about the origin of Phoenician Semi-fine ware in "the region around the cities of Tyre and 'Akko-Ptolemais'.
[371] Bettles 2003b: 164–169.

of shape group 3a. Also from Akko there come examples of the Hellenistic-period baggy jars (group 2a) and storage jugs (group 3a) made in the Light White ware. In general, the Tel Akko samples cover the time range from the 7th/6th c. BC till 3rd/2nd c. BC, therefore it comes as no surprise that they include a limited number of fabrics/petrographic groups: SG I.A1 (the most common one), I.A2, I.A4, IV.D (second in frequency among the Akko samples) and IV.H; petrographic groups of two carinated-shoulder jar fragments (samples AK-225 and AK-230) remain unknown. Also the number of the shape groups among the sampled material is strictly limited to the carinated-shoulder jars (group 1a), and single examples of groups 1b, 2a and 3a (plus one fragment of bowl AK-247 of SG IV.H).

The site of Sha'ar-Ha'Amakim received Phoenician carinated-shoulder jars (group 1a) already at the close of IA IIC and into IA III (later 7th into 6th century BC) as attested by samples SA-6 and SA-126 of fabric SG I.A1 (**Fig. 1:1**); the same petro group and the same date is represented by samples TK-191 (**Fig. 11:1**) and TK-209. However, the carinated-shoulder type of jar was being manufactured during that period also by the workshops represented by SG IV.H (Sha'ar-Ha'Amakim samples SA-7, perhaps also SA-5), PG VI (Sha'ar-Ha'Amakim sample SA-123, **Fig. 2:1**) and SG VI.C (Tell Keisan sample TK-202). The origin of all those fabrics should be connected with the coastal area of the southern Phoenicia, broadly understood. Standing in contrast is sample SA-4, a handle probably of a baggy jar (group 2a) equally early in date; it pertains to PG V, which in the light of the present archaeometric research appears to have originated in an inland area relatively close to Sha'ar-Ha'Amakim.

In the Persian and early Hellenistic periods the carinated-shoulder jars (group 1a) sampled at Sha'ar-Ha'Amakim represent, beside SG I.A1 (seven samples), also SG IV.B (one sample) and SG IV.D (two samples). In Tell Keisan, the same shape group 1a is represented by SG I.A1 (15 or 16 samples), SG IV.D (three samples), SG IV.G (one sample) and SG IV.H (one sample). Among the samples from Tel Akko there prevail examples of SG I.A1 (seven or eight samples) and SG IV.D (four or five samples); other fabrics are SG I.A2, I.A4, IV.B and IV.H, each represented by a single sample. One should note that Tel Akko and Tell Keisan have similar range of petro groups which at both sites is broader than in Sha'ar-Ha'Amakim. The repertoire of petro groups is especially diversified in Tel Akko, probably owing to the importance of the town as a maritime harbour and a regional centre.

As regards the bag-shaped form of jars (group 2a) and jugs (group 3a) in the period between the Late Iron/Persian and Hellenistic, those found at Sha'ar-Ha'Amakim must have come from a number of workshops to judge by the diversity of petrographic groups they represent. Worthy of note is the clear prevalence of PG V (14 samples, present only in Sha'ar-Ha'Amakim and only in this particular shape variant of jars/jugs), as well as the presence of SG IV.D (three samples). Other petro groups are SG I.A2Eo (two samples), I.A2.Cr (two samples), I.A3 (three samples), IV.A (four samples, including one jug), IV.B (two samples: jugs), IV.C (three samples), IV.E (three samples) and PG VIII (two samples). As mentioned above, PG V can be tentatively identified as local to Sha'ar-Ha'Amakim and/or its vicinity (Zevulun plain/Lower Galilee), perhaps Yokne'am, distant from Sha'ar-Ha'Amakim only by ca. 8 km.

The range of petro groups in the same category of shapes (groups 2a and 3a) sampled in Tell Keisan is slightly different. Both sites share the presence of SG I.A2Eo (one sample from Keisan), SG IV.A (one sample from Keisan), SG IV.D (nine samples from Keisan, both jars and jugs) and SG IV.E (two samples from Keisan). However, the set of Keisan samples in shape groups 2a/3a lacks the representation of SG I.A3, IV.B, IV.C and of PG VIII. On the other hand, some fabrics present in shape groups 2a/3a at Tell Keisan are absent from Sha'ar-Ha'Amakim: specifically, SG I.A1, SG IV.H, PG IX and PG XI, suggesting different pattern of supply sources and trade contacts.

Most interesting is the transition in the shapes and pot-making technologies between the Hellenistic and Roman periods as reflected by our samples, especially those from Sha'ar-Ha'Amakim. Thus, the change from shape group 2a (bag-shaped jar of the Persian and Hellenistic periods) to group 2b (bag-shaped jar of the Roman period) is illustrated by Sha'ar-Ha'Amakim jar SD1-70 (**Fig. 9:6**) in fabric PG VIII from unspecified source. Another example of the late production of shape group 2a (Hellenistic baggy jar) is Sha'ar-Ha'Amakim sample SD1-64 identified as representing SG II.B, a petro group most typical of the Roman-period jars both in Sha'ar-Ha'Amakim and Tell Keisan (see below). And, on the other hand, two samples from Sha'ar-Ha'Amakim, pertaining to the jars of shape group 2b (SD2-74 and SE-90 identified as one of the earliest Roman-period jar forms: Fernandez T 1.3, with its *floruit* between 50 BC and 50 AD), represent SG IV.D typical of the Persian and earlier Hellenistic period jars and storage jugs (shape groups 1a, 2a, 3a) attested at all the three sites (Sha'ar-Ha'Amakim, Tell Keisan and Tel Akko)

During the Roman period, 1st to 2nd century AD, the late Phoenician type of jar survives in our shape group 1c (**Fig. 4:3–6**), perhaps a missing link between the Phoenician hole-mouth baggy jars of the late 2nd -1st centuries BC (our shape group 1b) and the Tyrian hole-mouth amphora of the 2nd /3rd century AD of which jars **Fig. 4:5–6** seem to be imitation. Sampled material of this group represents as many as four fabrics (in Sha'ar-Ha'Amakim: SG I.A3, PG III, PG VI(?) and one unidentified; in Keisan: one example of PG III). The limited number of the items pertaining to this shape group, however, does not allow for any broader conclusions, except for the fact that PG III must have come from some regional (unidentified) manufacturing source, perhaps Mt Carmel area. This petrographic group occurs in two samples from Sha'ar-Ha'Amakim (SFx-113 and 114, **Fig. 4:5–6**) and in one from Tell Keisan (TK-157) and, moreover, it is rather well represented among the bag-shaped Roman-period jars (shape group 2b) from Sha'ar-Ha'Amakim (nine samples).

It is interesting to note that a rather dramatic change in pot-making technologies occurred around the turn of the era. PG V, common in Persian and Hellenistic period baggy jars/jugs sampled at Sha'ar-Ha'Amakim, has not survived the 1st century BC. It still occurs in jars of shape group 2a in Sha'ar-Ha'Amakim chronological Phase D1 ("Herodian", second half of the 1st century AD), but not later. Instead, with a couple of exceptions listed above, in the manufacturing of a modified shape of the bag-shaped jar (group 2b) new petrographic groups came into use. Apart from the introduction of PG III (mainly to Sha'ar-Ha'Amakim, because at Tell Keisan it is represented by just a single sample), striking is an enormous popularity of PG II with its many subgroups, among which the most common one appears to be SG II.B amounting to at least 17 samples at Sha'ar-Ha'Amakim and six samples at Tell Keisan. The PG II technology was based on ferruginous silty soil used in a wide area of the western Galilee, including the Shikhin workshop and probably that of Yodefat. This rather sudden breakthrough in the technology of the manufacturing of wine jars and doubtlessly also of other domestic vessels which occurred around the turn of the 1st century BC must have been connected to increasing density of the Jewish population in Galilee who preferred to use the pottery made by their own potters and not the gentile ones. If we are right in interpreting the smaller variety of baggy jars (shape group 2b) from Sha'ar-Ha'Amakim marked with a white band on the body as containers of olive oil offerings, then they prove the maintaining of Jewish religious customs at that site during the 2nd-3rd centuries AD. The three samples of such jars we have from Sha'ar-Ha'Amakim (SDc-44, SDc-47 and SDc-50) all represent subgroups of PG II (SG II.B, II.C and II.A respectively).

Another fabric of the Roman-period jars is PG VI with its subgroups. Based on *hamra* soil, it is present mainly at Tell Keisan (four samples),[372] while in Sha'ar-Ha'Amakim it is represented by just one sample of shape group 2b (SDc-48) and possibly another one of shape group 1c (SF-109). Beside these three petro groups (PG II, PG III, PG VI) present in Sha'ar-Ha'Amakim of the Roman-period, two samples from that site represent PG VII and one sample is of PG VIII. As to the Tell Keisan material, PG VII and VIII are absent, but instead PG XI makes its appearance there, while it is not found in Sha'ar-Ha'Amakim thus far.

As we have said, the Byzantine-period jars, which have been marked as our shape group 2c and would date from the 4th/5th century AD to the 7th century AD (and beyond?), are not present in Sha'ar-Ha'Amakim at all. In Tell Keisan only six to perhaps ten samples (bearing in mind that some body sherds may be either of shape group 2b or of 2c) have been gathered. However, if one is allowed to draw any conclusions from such small collection of samples, it seems that there was no major breakthrough from the Roman to Byzantine period in terms of the sources of supply in jars. While no sample represents PG II anymore (which may be accidental, of course), PG VI (three or four examples) and PG XI (three or four examples, again) do continue beyond the 4th/5th century AD.

Finally, two samples from Tell Keisan (TK-210 and TK-216) of a Roman or perhaps Byzantine date, which are the only ones to represent PG X belong, in fact, to cooking pots the fabric of which must have been suitable to endure the thermal shock, hence its specific composition.

To conclude on the archaeological profits from the present project: the archaeometric investigation combined with archaeological data, both published and unpublished, has to some degree reconstructed the pattern of presumed manufacturing sources of wine (and olive?) jars throughout the region of western Galilee and southern Phoenicia between the 7th/6th centuries BC and 3rd/4th (Sha'ar-Ha'Amakim) and 6th(?) century AD (Tell Keisan).

[372] Plus one sample (TK-202) representing SG VI.C, but assigned to shape group 1a and dated to 7th/6th century BC.

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Appendices

Appendix 1 – Petrographic dataset of the ceramics

		Groundmass									Temper																			
											textural features							sand & silt mineral composition												
Lab. No.	Petro Group	coulor (PPL)	anisotrophy	raw clay type	microfossils	terra rossa admxt.	argillaceous shale	foraminiferous oze	opaque iron oxides	opaque ferruginous ooliths	coralinacea	silt frequency	Qz silt%	Ca silt%	sand frequency	sand ø (mm)	roundness	quartz	sparitic carbonates	micritic carbonates	k feldspars	plagioclase	amphibole	piroxene	chert	basalt	hyaloclastics	dolomite	Qz sandstone	chalk clasts
SA-1	IV.A	yellowish gray	0		0	1	0	0	0	0	0	<2	-	-	0	-	varied	0	0	0	0	0	0	0	0	0	0	0	0	0
SA-2	I.A1	grayish-orange	0.5	marl	2	0.2	0	1	0	0	0	5-7	100	0	~5		ang-subang	2	0	0	0	0.2	?	0	0	0	0	0	0	2
SA-3	IV.A	yellowish-gray	0		0.5	0.5	1	0	0	0	0	0	-	-	<5		subangular	2	0	0	0	0	0	0	0	0	0	0	0	0
SA-4	V	reddish-gray	0.5		2	0.2	0.2	0	0	1	0	<2	-	-	20	0.1-0.55	angular-subangular	2	0	1	0.5	0.5	0.5	0	0	0	0.2	0	1	-
SA-5	IV.H	yellowish-gray	0		1	1	1	1	0.2	0	0	<2	-	-	5		angular	2	0	0	0	0	0	0	0	0	0.2	0	0	0
SA-6	I.A1	orange	1	marl	2	0	0	2	0.2	0	1	<5	100	0	5-8	0.1-0.35	ang-subang	2	0	0	0.2	0.2	0	0	0	0	0	0	0	0
SA-7	IV.H	greenish-gray	0		0.5	0	0	1	0.2	0	0	<2	-	-	<5		subangular	2	0	0	0	0	0	0	0	0	0	0	0	0
SA-8	I.A1	orange	1	marl	2	0	0	2	0	0	1	<5	100	0	5-8	0.1-0.35	ang-subang	2	0	0	0.2	0.2	0	0	0	0	0	0	0	0
SA-9	IV.D	yellowish-gray	0		0	0.2	0.2	?	0	0	0	<2	-	-	15-20		varied	2	0	0	0	0	0	0	0	0	0	0	0	0
SA-10	IV.C	brownish gray	0		0	1	0.5	0	1	0	0	<5	100	?	10		varied	2	0	1	0.2	0.2	0.2	0.2	0	0	0	0	1	0
SA-11	I.A1	orange	1	marl	2	0	0	1	0	0	1	<5	100	0	<5		ang-subang	2	0	0.2	0	0.2	0.2	0	0	0	0	0	0	0.5
SA-12	V	reddish-gray	0.5		0	1	1	0	1	0	1	<2	-	-	20	0.1-0.55	angular-subangular	2	0.5	0.2	0.2	0.5	0.5	0.2	0	0	1	1	1	-
SA-13	I.A1	orange	1	marl	2	1	0	1	0	0	0	<5	100	0	20	coarse	subangular	2	0	1	0	0	0.2	0	0.5	0	0	0	0.2	0
SBc-14	V	reddish-gray	0		0	1	0	0	2	0	0	0	-	-	30	0.1-0.55	angular-subangular	2	0	0	0.5	0.5	0	1	0	0	1	0	0	-
SBc-15	I.A2Eo	yellow	1	marl	2	1	0	0	0	0	1	<5	100	0	10-15	coarse	subangular	2	0.2	1	0.2	0.5	0.2	0	0.2	0	0	0	0.2	0.2
SBc-16	IV.C	yellowish-gray	0		0	1	0	0.2	1	0	0	30	20	80	<5		varied	2	0	0	0	0	0	0	0	0	0	0	0	0
SBc-17	V	reddish-gray	0		2	0.5	1	0	1	0	0	<2	-	-	15	0.1-0.55	angular-subangular	2	0	1	0.2	0.2	0.5	0	0	0	1	0	1	-
SBc-18	V	gray	0		0.2	1	0	0	1	0	-	<2	-	-	<20			2	0	1	0.5	0.2	0.2	0.5	0	0	1	0	0.2	0
SBc-19	VIII	brown/orange	0.5		0.2	1	0	0	0	0	0	15	0	100	20		angular	0	1	2	0.5	-	-	-	-	-	-	2	-	-
SBc-20	?	light gray	0		0	0.2	0.5	0	0.2	0	0	<5	100	?	10			2	0	0.2	0.2	0.2	0	0	0	0	?	0	0.5	0.2
SBc-21	IV.A	yellowish-gray	0		0	0.5	0	0	0	0	0	<2	-	-	<2	-	-	2	0	0	0	0	0	0	0	0	0	0	0	0
SBc-22	II.A	light red	1	soil	1	0.5	0	0	0	0.5	0	50	80	20	0	-		-	-	-	-	-	-	-	-	-	-	-	-	-
SBc-23	IV.B	yellowish-gray	0		1	1	0.5	0	0	0	0	0	-	-	0	-	varied	0	0	0	0	0	0	0	0	0	0	0	0	0
SBc-24	IV.E	yellowish-gray	0		1	1	1	1	1	0	0	<2	-	-	0	-	varied	0	0	0	0	0	0	0	0	0	0	0	0	-
SBc-25	IV.B	reddish-gray	0		2	1	1	0	0	0	0	0	-	-	0	-	varied	0	0	0	0	0	0	0	0	0	0	0	0	0
SBc-26	IV.D	greenish-gray	0		0	1	0	0	0	0	0	<2	-	-	5		angular	2	0	0	0	0	0	0	0	0	0	0	0	0
SBc-27	V	light red	0.2		0.2	0.5	0	0.5	0.5	0	-	?	-	-	<20		varied	2	0.5	0	0	1	0.2	1	0	0	1?	0	0.2	0
SBc-28	IV.E	yellowish-gray	0		0	1	0	0	0	0	0	?	-	-	0	-	varied	0	0	0	0	0	0	0	0	0	0	0	0	0
SBc-29	V	pale-yellow/ light gray	0		0	1	0	0	1	0	2	<2	-	-	30	0.1-0.55	angular-subangular	2	0.2	0.5	0.5	1	0.5	0	0.2	0	0.2	0	0	-
SBc-30	V	brownish-gray	0.5		2	1	0	0	1	0	0	5	100	-	20	0.1-0.55	angular-subangular	2	0	0.5	0.2	0.2	0	0	0.2	0	0.2	0	0	-
SBc-31	V	reddish-gray	0.5		0.2	0.5	0	0.2	0	0	-	<5	100	0	30		subangular	2	0	0.2	0.5	0.5	0	0	0.2	0	0	0	0.2	0
SBc-32	V	reddish-gray	0		0	0.5	1	0	1	0	0	<2	-	-	20	0.1-0.55	angular-subangular	2	0.5	0.2	0.2	0.5	0.2	0.2	0	0	0.5	0	1	-
SBc-33	IV.E	yellowish-gray	0		1	1	0	1	1	0	0	0	-	-	0	-	varied	0	0	0	0	0	0	0	0	0	0	0	0	0
SBc-34	IV.D	greenish-gray	0		1	1	0	0	0	0	0	<2	-	-	0	-	angular	2	0	0	0	0	0	0	0	0	0	0	0	0
SBc-35	I.A3	yellowish-orange	1	marl	2	1	1	0	0	0	0	<5	100	0	10-15	coarse	subangular	2	0.2	0	0.2	0.2	0.5	?	0	0	1	0	0	0
SC-36	II.B	red/brown/black	0		0.5	0	0	0	0	1	0	50	20	80	5		varied	0.2	1	1	0	0	0.2	0	0	0	0	0	0	0
SC-37	IV.D	yellowish-gray	0		0.2	0.2	0.5	?	0.5	0	0	5	100	0	15-20		varied	2	0	0	0	0	0	0	0	0	0	0	0	0
SC-38	V	greenish-gray	0		0	0.5	0	0	1	0	0	<2	-	-	20	0.1-0.55	angular-subangular	2	0	1	0.2	0.2	0.2	0	0.2	0	1	0	0	-
SC-39	I.A1	yellowish-orange	1	marl	2	0	0	1	0	0	1	<2	-	-	5-8		ang-subang	2	0	0	0.2	0.2	0	0	0	0	0	0.2?	0	2
SC-40	IV.B	reddish-gray	0		2	0	0.5	0	0	0	0	0	-	-	0	-	varied	0	0	0	0	0	0	0	0	0	0	0	0	0
SC-41	I.A1	orange	1	marl	2	0	0	1	0	0	0	<5	100	0	~5	-	ang-subang	2	0	0	0.2	0.2	0	0	0.2	0	0	0	0.2	0
SDc-42	II.D2	dark red-brown	0	soil	0	0.5	0	0	0.5	0.5	0	40	30	70	5-8		well	0.2	0	1	0	0	0	0	0	0	0	0	0	0
SDc-43	II.D4	black	0	soil	0	0	0	0	0	1	0	30	10	90	2	-	well	0	0	1	0	0	0	0	0	0	0	0	0	0
SDc-44	II.B	brown/black	0		0.5	0.5	0	0	0	1	0	50	10	90	<5		varied	0	0	2	0	0.2	0.2	?	0	0	0	0	0	0.5
SDc-45	II.D3	pale brown	0.2	soil	0	0.5	0	0	1	0.2	0	~50	80	20	<5		varied	0.5	0	1	0.2	0.2	0.2	0	0.2	0	0	0	0	0
SDc-46	II.C	red/brown	0		0.5	0.5	0	0	0	1	0	30	80	20	<5		varied	1	0	1	1	0.5	0.5	?	0.2	0	0	0	0	0
SDc-47	II.C	dark red	0.5		1	0	0	0	0	1	0	20	10	90	10		varied	0.2	0	2	0	0.2	0.2	?	0	0	0	0	0	0
SDc-48	VI	red	0.5		0.2	0	0	0	0	0.2	-	<15	100	0	40		varied	2	0	0.2	0.5	0.5	0.2	0.5	0.5	0	0	0	0	0
SDc-49	II.D2	orange-red	0.5		0	0	0	0	0.5	0.5	-	30	100	0	15		rounded	2	0	0	0.5	1	0.2	0.2	0.5	0.2	?	0	0	0
SDc-50	II.A	reddish-gray	0	soil	1	1	0	0	0	0.5	0	40	100	0	<2	-	-	0	0.5	1	0	0	0	0	0	0	0	0	0	0
SDc-51	I.A2.Eo	grayish-brown	0.2	marl	2	1	0	0	1	0	0	<5	100	0	~5	coarse	subangular	2	0	1	0.2	0	0.2	0.2	0.2	0	0	0	0.2	0
SDc-52	II.D1	brownish-black	0	soil	0	0	0	0	1	1	0	30	50	50?	5-10		varied	1	0	1	0.5	0.5	0.5	0	0	0	0	0	0.2	0.2
SDc-53	II.D2	light red	0	soil	0	0.5	0	0	0.5	0.2	0	40	50	50	~5		varied	1	0	1	0.2	0.2	0.5	0	0.2	0	0	0	0	-
SDc-54	II.A	red/brown	0	soil	1	1	0	0	0	0.5	0	30	100	0	0	-		-	-	-	-	-	-	-	-	-	-	-	-	-
SDc-55	II.D4	black	0	soil	1	0	0	0	0.2	0	0	40	60	40	2	-	well	1	0	0	0	0.2	0	0	0	0	0	0	0.2	0
SDc-56	II.D2	yellowish brown	0	soil	0	0.5	0	0	1	1	0	30	20	80	2	-	rounded	0	0	1	0	0	0	0	0.2	0	0	0	0	0
SDc-57	II.A	reddish-brown	0	soil	0.5	1	0	0	0	0.5	0	30	100	0	<2	-	-	0.2	0	1	0	0	0	0	0	0	0	0	0	0
SD1-58	V	gray	0.5		0	0.5	1	0	1	0	0	<2	-	-	20-30	0.1-0.55	angular-subangular	2	0	1	0.5	0.5	0.5	0	0	0	1	0	1	-
SD1-59	IV.A	yellowish gray	0		0	0.2	0.2	0	0	0	0	<2	-	-	<2	-	-	2	0	0	0	0	0	0	0	0	0	0	0	0
SD1-60	V	greenish-gray	0		0	1	1	0	1	0	0	<2	-	-	30	0.1-0.55	angular-subangular	2	0	1	0.5	0.5	0.5	0	0.5	0	1	0	0	-
SD1-61	IV.A	yellowish gray	0		0	0.5	0.2	0	0	0	0	?	-	-	<2	-	-	1	0	0	0	1	0	0	0	0	0	0	0	0
SD1-62	I.A1	orange	1	marl	2	0	0	2	0	0	1	<5	100	0	5-8	0.1-0.35	ang-subang	2	0.2	0.2	0.2	0.2	0	0	0	0	?	0	0	0
SD1-63	VII	dark red	0		1	0	0	0	0	0	0	40	0	100	<5		varied	0	-	1	0.2	0.2	0	0	0	0	?	1	0	0
SD1-64	II.B	gray	0		1	0	0	0	0	1	0	40	40	40	<5		varied	1	0	1	0	0	0	0	0	0	0.2	0	0	0
SD1-65	IV.C	reddish gray	0		0	1	1	0	1	0	0	<5	100	?	10		varied	2	0	1	0	0	0	0.2	0	0	0	0	0	0.2
SD1-66	I.A3	yellowish-orange	1	marl	2	1	0.2	0	0	0	1	~5	100	0	10-15	coarse	ang-subang	2	0	1	0.5	0.5	?	?	0.2	0	1	0	0	0
SD1-67	I.A1	orange	1	marl	2	0	0	1	0	0	0	<5	100	0	-	-	ang-subang	2	0.2	0.5	0.2	0.2	0	0	0.2	0	0	0	0.2	0
SD1-68	VII	dark red	0.2		0.2	0	0	0	0	0	0	60	0	100	<5		rounded	0	0.2	1	0	0	0	0	0	0	?	1	0	0
SD1-69	II.B	brownish-black	0		1	0	0	0	0	1	0	20	20	80	<5		varied	0.2	0.2	1	0	0	0	0	0	0	0	0	0	0
SD1-70	VIII? CR	brown	0	soil	1	1	0	0	0	1	0	30	10	90	<15		angular	0	1	1	0	0	0	0	0	0	0	0	0	0
SD2-71	I.A1	orange	1	marl	2	0	1	1	0	0	2	<5	100	0	~5	0.1-0.35	ang-subang	2	0	0	0.2	0.2	0	0	0	0	0	0	0	2
SD2-72	I.A3	pale reddish-brown	0.5	marl	2	1	0	0.2	0.2	0	1	<5	100	0	~5	coarse	subangular-angular	2	0	0	0.2	0.5	0.5	0.5	0	0.2	0.2	0	0	0
SD2-73	II.C	reddish-brown	0		1	73	0	0	0	1	0	40	10	90	2	-	varied	0	0	1	0	0	0	0	0	0	0	0	0	0
SD2-74	IV.D	greenish-gray	0		0	0	0	0	0	0	0	<2	-	-	<10		subangular	2	0	0	0	0	0	0	0	0	0	0	0	0
SD2-75	II.C	yellowish-brown	0.2		1	0	0	0	0	1	0	50	20	80	<5		varied	0.2	1	1	0	0.2	0.2	0	0	0	0	0	0	0
SD2-76	II.B	gray	0		1	0	0	0	0	1	0	40	60	40	<2	-	-	1	0	1	0	0.2	0.2	0	0	0	0	0	0	0.5
SD2-77	II.B	dark brown	0		0.5	0	0	0	0	1	0	50	30	70	5		varied	0	0	1	0	0	0	0	0	0	0	0	0	0
SD2-78	VIII	dull brown, partialy gray	0		0	2	1	0	1	0	0	?	-	-	40		angular	0	0	2	0	0	0	0	0	0	0	0	0	0
SD2-79	II.B	blackish-gray	0		1	0	1	0	0	1	0	20	20	80	<5		varied	0.2	0.5	2	0	0	0	0	0	0	0	0	0	1
SD2-80	II.B	brown/red/gray	0.5		1	0	0	0	0	1	0	40	60	40	<2	-	-	0	1	1	0	0.2	0.2	?	0	0	0	0	0	0.5
SD2-81	II.C	red/black	0.2		1	0	0	0	0	0	0	40	70	30	<2	-	varied	1	0	1	0	0.2	0.2	0	0	0	0	0	0	0
SD2-82	?	reddish-gray	0.2		0	0	0	0	0	0	-	0	-	-	30		rounded-subrd.	0	0	0	0	1	1	1	0	?	1	0	0	0

Lab. No.	Petro Group	Groundmass								Temper																				
										textural features						sand & silt mineral composition														
		coulor (PPL)	anisotrophy	raw clay type	microfossils	terra rossa admxt.	argillaceous shale	foraminiferous oze	opaque iron oxides	opaque ferruginous ooliths	coralinacea	silt frequency	Qz silt%	Ca silt%	sand frequency	sand ø (mm)	roundness	quartz	sparitic carbonates	micritic carbonates	k feldspars	plagioclase	amphibole	piroxene	chert	basalt	hyaloclastics	dolomite	Qz sandstone	chalk clasts
SD2-83	II.C	brown	0.5		1	1	0	0	0	1	0	30	30	70	<5		varied	0	1	2	0	0.2	0.2	0	0.2	0	0	0	0	0
SD2-84	II.D3	dark gray	0	soil	0	0	0	0	0	1	0	50	20	80	<2	-	-	0	0	1	0	0	0	0	0.2	0	0	0	0	0
SD2-85	II.D2	light red	0	soil	0	1	0	0	0.2	0.5	0	85	30	100	0	-		-	-	-	-	-	-	-	0	-	-	-	-	-
SE-86	I.A1	orange	1	marl	2	0	0	1	0	0	1	<5	100	0	-	-	ang-subang	2	0	0.5	0.2	0.2	0	0	0	0	0	0	0	0
SE-87	II.B	black/reddish-black	0		1	0	0	0	0	1	0	10-15	50	50	<5		varied	1	0	1	0	0.2	0.2	0	0	0.2	0	0	0	0
SE-88	?	darkish-brown	0		0	0	0	0	0.5	0.2	-	10	100	0	10			0	0.2	2	0.2	0.5	0	1	0	0.5	0	0	0	0
SE-89	II.D2	dark red	0	soil	0	0	0	0	0.2	0.5	0	30	10	90	2	-	varied	0	0	1	0	0	0	0	0	0	0	0	0	0
SE-90	IV.D	yellowish-gray	0		0.2	1	1	0	0	0	0	0	-	-	5		subangular	2	0	0	0	0	0	0	0	0	0	0	0	0
SE-91	II.D1	nlack	0	soil	0	0	0	0	1	1	0	30	50	50?	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SE-92	II.B	brownish-black	0		1	0	0	0	0	1	0	40	20	80	2	-	varied	0	0	1	0	0.2	0.2	0	0	0	0	0	0	0
SE-93	II.D4	black	0	soil	0	0	0	0	0	0.2	0	30	20	80	2	-	varied	0	0	1	0	0	0	0	0	0	0	0	0	0
SE-94	III	gray/orange	0.5		0.2	0.2	0	0	1	0	0	50	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
SE-96	II.C	brownish-black	0		1	0	0	0	0	1	0	50	30	70	<5		varied	0.5	1	1	0	0.2	0.2	0	0	0	0	0	0	0
SE-97	III	red	0.5		0.2	1	0.2	0	1	0	0	50	0	100	0	-	-	-	0.2	-	-	-	0.2	-	-	-	-	2	-	-
SE-98	II.B	red/brown	0.5		1	0	0	0	0	1	0	40	30	70	<2	-	-	0	1	1	0	0.2	0.2	0	0	0	0	0	0	0.5
SE-99	II.B	red-black	0.2		1	0	0	0	0	1	0	50	20	80	<5		varied	0.2	1	1	0	0.5	0.5	0	0	0	0	0	0	0
SE-100	IVF	yellowish gray	0		1	0	0	0	0	0	0	<2	-	-	<2	-	-	1	0	0	0	0	0	0	0	0	0	0	0	0
SE-101	I.A3	grey	1	marl	1	2	0	0	1	0	1	~5	80	20	<2	-	subangular	2	0.2	1	0	0.2	0.5	?	0	0	1	0	0	0
SF-102	III	light red	0.5		0.2	0.2	0.5	0	1	0	0	30	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
SF-103	II.D2	dark red	0.2	soil	0	0	0	0	0.2	1	0	40	30	70	10			0.2	0	1	0	0.2	0.2	-	1	0	0	0	0	0
SF-104	II.D2	brown/black	0	soil	0	0	0	0	0	1	0	50	10	90	5		well	0	0	1	0	0	0	0	0	0	0	0	0	0
SF-105	III	red	0.5		0.2	0.2	0.5	0	0	0	0	70	0	100	0	-	rounded	-	-	-	-	-	-	-	-	-	-	2	-	-
SF-106	II.B	reddish-brown	0		1	0	0	0	0	1	0	40	40	60	<2	-	-	0.2	1	1	0	0.5	0.5	0	0	0	0	0	0	0
SF-107	II.B	reddish-brown	0.5		1	0.5	1	0	0	0.5	0	40	60	40	<5		varied	0	0.5	2	0	0.2	0.2	0	0	0	0	0	0	0
SF-108	III	gray/orange	0.5		0	0	?	0	0	0	0	50	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
SF-109	VI?	dark red	0		0	1	0	0	0	0	0	<10	100	?	10		varied	1	-	0.5	0.2	0.5	0.2	0.5	0	0	0	0.5	0	0
SF-110	II.C	red	0		1	0.5 (tcf)	0	0	0	1	0	30-40	20	80	<5		varied	0.5	0	2	0	0.2	0.2	?	0	0	0	0	0	0
SFx-111	?	pale reddish gray	0	marl	1	2	1	0	0.2	0	0	<5	100	?	0		-	0	-	-	-	-	-	-	-	-	-	-	-	-
SFx-112	I.A3	pale yellow	1	marl	1	0.2	0	0	0	0	1	~2			5-8	coarse	ang-subang	2	0	1	0.2	0.5	0.5	?	0.2	0.2	0.5	0	0	0
SFx-113	III	orange	0.5		0.2	1	0.5	0	0	0	0	50	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
SFx-114	III	orange	0.5		0.2	0.2	0.5	0	0	0	0	50	0	100	0	-	-	-	-	-	-	-	-	-	0.2	-	-	2	-	-
SFx- 115	I.A1	orange	1	marl	2	0.2	0	1	0	0	1	<5	100	0	-	-	ang-subang	2	0.2	0.2	0.2	0.2	0	0.2	0	0	0	0	0	0
SFx-116	?	reddish-gray	0		0	0.5	0	0	0.5	0.2	-	n	<5	?	15-20		angular-subang.	2	0	1	0.2	0.5	0.2	0.2	0	0.5	?	0	0	0
SFx-117	III	orange	0.5		0.2	0	1	0	0	0	0	50	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
SFx-118	II.C	red	0		1	0	0	0	0	1	0	50	20	80	<5		varied	0.2	1	1	0	0	0	0	0	0	0.2	0	0	0
SX-119	I.A1	orange	1	marl	2	0	0.2	1	0	0	1	<5	100	0	3-5		ang-subang	2	0.2	0.5	0	0	0	0.2	0.2	0	0	0	0	0.5
SA-120	IV.D	greenish-gray	0		0	0.2	0	?	0	0	0	<2	-	-	<5		subangular	2	0	0	0	0	0	0	0	0	0	0	0	0
SD1-121	II.D2	red/black	0	soil	0	0	0	0	0.2	1	0	60	80	20	<2	-	-	0	0	1	0	0	0	0	0	0	0	0	0	0
SBc-122	?	red/black	0.5		0	0.5	0	0	1	0	-	5-7	100	0	15		varied	0	0.2	2	0.5	0.5	0	1	0	1	0.5	0	0	0
SA-123	VI	red	0.5		0	0	0	0	0	0	-	<5	50	50	30		varied	2	0	0	0.5	1	0	0.2	0.5	0	0	0	0	0
SF-124	I.A3	yellowish-gray	0.5	marl	1	0.5	0	0	0.2	0	0	10	100	5-8	coarse	coarse	subangular	2	0.2	0.2	0	0.2	0.5	?	0.2	0	1	0	0	0
SD1-125	I.A3	orange-red	1	marl	1	1	1	0	0	0	1	~2			10-15	coarse	subangular-angular	2	0.2	0	0	0.5	0.2	0.2	0	0	1	0	0	0
SA-126	I.A1	reddish-gray	0	marl	1	0	0	1	0	0	0	<2	-	-	5-8		ang-subang	2	0	1	0.2	0.2	0	0	0	0	0	0	0	0
SA-127	I.A2.Eo	graysh-orange	0.2	marl	2	0.2	0	0.2	0.2	0	0	~5	100	?	15-20	coarse	subangular - angular	2	0.2	1	0.2	0.5	0.2	0	0.2	0	0	0	0	0
SA-128	I.A2.Cr	orange, light red	1	soil	1	1	0	0	0	0	0	<5	100	0	0	-		-	-	-	-	-	-	-	-	-	-	-	-	1
SX-129	I.A1	grayish-orange	0	marl	2	0	0	1	0.2	0	1	<2	-	-	5-8		ang-subang	2	0	0.2	0.2	0.2	?	3	0.2	0	0	0	1	1
SA-130	I.A2.Cr	light orange	1?		2	1	0	0	0	0	0	<2	-	-	<2	-	-	2	0	0	0	0	0	0	0	0	0	0	0	0
SDc-131	?	light brown	0	marl+soil	0	1	0	0	0	0	0	20	100	0	10			0	0	1	0	0	1	0	0	0	0	0	0	0
SBc-132	?	orange-gray	0.5		0.2	0.2	0	0	0	0	-	40	0	0	30		subangular	1	0	1	0.2	0.5	0.2	0.2	0.2	0	0	0	0	0
SD1-133	V	reddish-gray	0		1	1	0.5	0	1	0	0	<2	-	-	30	0.1-0.55	angular-subangular	2	0.2	0.2	0.2	0.5	0.2	0	0	0	0?	0	0	-
SE-134	I.A3	reddish-orange	0.5		1	1	0	0	0	0	0	<2	-	-	10			0	-	1	0	0	0.2	0	0	0	0	0.5	0	0
SX-135	I.A1	dark orange	0.5	marl	2	0	0	1	0.2	0	1	<2	-	-	<3		ang-subang	2	0	0.5	0	0.2	0	0	0.2	0	0	0	0	0.5
SOV-136	?	reddish-gray	1	hamra	1	0.2	0	0	0.2	0	1	<5	100	-	40	0.1-0.55	angular-subangular	2	0.5	0.2	0.5	0.5	0.2	0.2	0.2	0	0	0	0	-
SOV-137	II.A	light red	1	soil	1	0	0	0	0	1	0	30	60	40	10			0	0	1	0	0	0	0	0	0	0	0	0	0
SOV-139	IV.E?	pale orange	0		1	0	0	0.5	0.5	0	0	0	-	-	<2	-	-	1	1	0	0	0	0	0	0	0	0	0	0	0
SX-141	II.D2	reddish-black	0	soil	0	0	0	0	0	1	0	50	70	30	5		varied	0.2	0	1	0	0	0	0	0	0	0	0	0	0
SX-142	II.B	gray	0	soil	1	0	0	0	0	1	0	30	10	90	2	-	varied	0.2	0	1	0	0	0	0	0.2	0.	0	0	0	0
SX-143	I.A1	orange	1	marl	2	0	0	1	0	0	1	<5	100	0	~5	0.1-0.35	ang-subang	2	0.2	0.2	0.2	0.2	0	0	0	0	?	0	0	0
SX-144	II.C	graysh-black	0		1	0	0	0	0	1	0	50	20	80	<5		varied	0.2	0	1	0	0	0	0	0	0	0	0	0	0
SX-145	II.D3	grayish-black	0	soil	0	0	0	0	0	1	0	40	50	50	2	-	varied	0.5	0	1	0	0	0	0	0.2	0	0	0	0	0
SX-146	I.A1	orange	1	marl	2	0	0	1	0	0	1	<5	100	0	<5		ang-subang	2	0	0.2	0	0.2	0	0	0	0	0	0	0	1
SX-147	II.C	graysh-black	0		1	0	0	0	0	1	0	40-50	60	40	<5		varied	0.2	0	2	0	0	0	0	0	0	0.2	0	0	0
SX-148	II.B	brownish-red	0		1	0	0	0	0	1	0	20	60	40	<5		varied	1	0	1	0	0.2	0.2	0	0	0	0.2	0	0	0
SFx-149	III	red	0.5		0	0	1	0	0	0	0	50	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
SX-150	III	orange	0.5		0.2	0.2	0.5	0	0.5	0	0	50	0	100	0	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
SX-151	II.B	dark red	0		1	0	0	0	0	1	0	30	60	40	<5		varied	0.2	0.5	2	0	0.2	0.2	0	0	0	0	0	0	2
SOV-249	V	gray	0.5		0	1	0	0	1	0	0	<2	-	-	20	0.1-0.55	angular-subangular	2	0	1	0.2	0.2	0.2	0	0.2	0	0.2	0	0	-
SOV-250	II.B	brownish-black	0		1	0	0	0	0	1	0	50	20	20	2	-	varied	0	0	1	0	0.2	0.2	0	0	0	0	0	0	0
TK-152	IX	reddish - brown	0		1	1	0	0	0	0	0	<2	100	?	5-10	f	angular	1	0	0	0	0	0	0	0	0	0	0	0	2
TK-153	IV.H	gray with red mottles	0		1	0	0	1	1	0	0	0	0	?	5-7	f	varied	1	0	0	0	0.2	0	0	0	0	0	0	0	0
TK-154	IV.H	greenish-gray	0		1	0	0	1	1	0	0	0	0	?	<5	f	varied	1	0	0	0.2	0	0	0	0	0	0	0	0	?
TK-155	VId	dark red	0		0	0	0	0	0	1	0	5	100	0	30	m	subangular	2	0	0	0.5	0.5	0	0	0.5	0	0	0	0	0
TK-156	VI.A	dark red	1		0?	0	0	0	1	0	0	<2	100	?	15	m	varied	2	0	1	0.5	0.5	0.2	0	0.5	0	0	0	0	0.5
TK-157	III	orange	1		?	1	0.5	0	0	0	0	20	0	100	0	-	-	-	-	0	0	0	0	0	0	0	0.2	2	0	0
TK-158	IV.D	yellowish gray, red mottles	0.5		0.5	1	0.5	0	0	0.2	0	<2	100	?	<5	f	varied	1	0.5	0	0.5	0.2	0.2	0	0	0	0	0	Siltst	0.5
TK-159	I.A1 ?	light brown	1		1	? tcf?	0	0.5	0.2	0	0.5	<2	-	-	30>	m	varied	2	0.2	0.5	0.2	0.2	0.2	0	0.5	0	0	0	0	0
TK-160	I.A1	orange	1		2	0	0	1	0.5	0	0.5	<2	-	-	5	f	varied	1	0	1	0	0.5	0	0	0.5	0	0	0	0	0
TK-161	IV.H	gray with red mottles	0		1	0	0	1	0.2	0	0	0	0	?	5-7	f	varied	1	0	1	?	0	0	0	0	0	0	0	0	0
TK-162	I.A1?	grayey-black/red	0		2	0	0.2	1	0.2	0	1	<2	-	-	15			1	0.2	1	0	0.5	0	0	0.5	0	0	0	1	2
TK-163	XI	reddish-black	0		0	0	2	0	1	0	0	30	100	0	10	m	varied	1	0	0	0	0	0	0	0	0	1	0	0.2	0.2
TK-164	IV.D	pale gray with red mott	0.5		?	1	0	0	0.5	0	0	<2	100	?	20	m	varied	1	2	0	?	1	0	0	0	0	0	0	0	0
TK-165	I.A1	dark orange	1		2	?	0	0.2	0.5	0	1	<2	-	-	<5	m	varied	2	0	0.2	0	0	0	0	0	0	0	0	0	1
TK-166	VI.B	reddish black	0		0.2	0	0	0	1	0	0	15	100	?	20-30	m	varied	2	0	0	0.5	0.5	0.2	?	0.5	0	0	0	0	1
TK-167	IV.D	pale gray	0		0	0.5	0	0	0	0.5	0	<2	100	-	<10	f	varied	2	0	0	0.5	0.5	0.2	0	0	0	0	0	Siltst	0.5
TK-168	IV.D	pale gray	0		0	0.5	0	0	0	0.5	0	0	-	-	<10	f	varied	2	0	0	0.5	0.5	0.2	0	0	0	0	0	0	0
TK-169	I.A1	pale brown	1		2	0	0	1	0.5	0	1	<2	-	-	5		varied	2	0.2	0.5	0	0.5	0	0	0	0	0	0	0	1

Lab. No.	Petro Group	Groundmass									Temper																			
											textural features						sand & silt mineral composition													
		coulor (PPL)	anisotrophy	raw clay type	microfossils	terra rossa admxt.	argillaceous shale	foraminiferous oze	opaque iron oxides	opaque ferruginous ooliths	coralinacea	silt frequency	Qz silt%	Ca silt%	sand frequency	sand ø (mm)	roundness	quartz	sparitic carbonates	micritic carbonates	k feldspars	plagioclase	amphibole	piroxene	chert	basalt	hyaloclastics	dolomite	Qz sandstone	chalk clasts
TK-170	IV.D	pale gray	1		1	0.2	0	0	0.5	0.2	0	<2	100	-	10	m	varied	2	0	1	?	1	0	0	0.2	0	0	0	0	1
TK-171	I.A1	light brown	1		2	0	0	0	0	0	2	5-7	10	90	10	c	varied	0.5	0	2	0	0	0.2	0	0.2	0	1	0	0	0
TK-172	I.A1?	brownish gray	0		2	0.2	0	1	0.5	1	0	<2	0	?	10	f	varied	0	0	0	0	0	0	0	0	0	0	0	0	1
TK-173	I.A1	light orange	1		2	0	0	1	0.5	0	0	<2	-	-	10	m	varied	2	0	0	0	0.2	0	0	0.2	0	0	0	0	1
TK-174	II.B	brownish black	0		1	0	0	0	1	1	0	30-40	50	50	<2	-	-	0	0.2	-	0.2	0.2	0.2	?	0.2	0	0	0	0	0
TK-175	I.A1	orange, red mottles	1		2	0	0	1	0.5	0	0.5	<2	-	-	5	f	varied	1	0	0	0	0	0	0	0.5	0	0	0	0	0
TK-176	I.A1	orange	1		2	0	0	1	0.5	0	0	<2	-	-	5-10	f	varied	2	0	0	0.2	0	0	0	0	0	0	0	0	1
TK-177	IV.D	pale gray	0		1	0.5	0	0	0	0	0	0	-	-	<10		varied	2	0	0.5	0	0.2	0	0	0	0	0	0	0	0
TK-178	IV.A	graysh-brown	1		1	1?/tcf?	0	0	0	0	0	5	100	?	<10	c	varied	-	0.2	1	0	0	0	0	0	0	2	0	0	1
TK-179	IX	greenish-gray	0		0	1	0	0	0	0	0	<2	100	?	5-10	f	angular	1	0	0	0	0	0	0	0.2	0	0	0	0	1
TK-180	?	reddish-brown	0		1	0	0	1	0	0	0	<2	-	-	15	f	angular	1	1	1	1	1	0	2	2	1	0	0	0	1
TK-181	IV.D	pale gray	0		?	0.5	0	0	0.5	0	0	<2	100	?	10	m	varied	2	0	0.5	?	1	0	0	0	0	gl	0	Siltst	0
TK-182	IV.D	reddish gray	0		?	0.5	0	0	0.5	0	0	<2	100	?	<10	f	varied	2	0	0	?	1	0	0	0	0	0	0	0	0
TK-183	IV.G	greenish-gray	0		0.5	0.2	0	0.2?	0.2	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TK-184	?	greenish-gray	0		0	0	0	0.2	0	0	0	0	-	-	15	f	angular	0	0	0	0.5	0.5	?	0.5	2	0.2	0	0	0.2	0
TK-185	I.A1	orange	1		2	0	0	1	0.5	0	1	<2	-	-	5-7	m	varied	1	0.2	1	0	0	0	0	0.2	0	0	0	0	1
TK-186	IV.H	yellowish gray	0		1	0	0.5	1	0.5	0	1	5	?	?	5	c	ang-subang	1	0	2	0	0	0	0	0.2	0	0	0	K	1
TK-187	I.A2?	light brown	1		2	1	0	0	0	1	1	5	100	?	15	c	subangular	2	0	0.5	0.2	0.5	0	0	0	0	0	0	0	2
TK-188	II.B	red	0		1	tcf	0	0	0.5	1	0	20	100	0	0	-	-	0	0	0.5	0.2	0.2	0.2	0	0	0	0	0	0	0.2
TK-189	II.B	brownish black	0		0?	0	0	0	0.5	0	0	20-30	100	0	<2	c	-	0	0	1	0.2	0.2	0.2	0	0	0	0	0	0.2	0.5
TK-190	IV.D	pale gray	0		?	0.5	0	0	0.5	0	0	0	-	-	<10		varied	2	0	0.5	0.2	1	0	0	0	0	0	0	0	0
TK-191	I.A1	graysh-brown	0		?	0	0	1	0.5	0	0	<2	-	-	<10		varied	0.5	0	2	0	0.2	0	0	0.2	0	0	0	0	0
TK-192	XI	black	0		0	0	1	0	1	0	0	30	100	0	<2	f	-	1	0	0	0	0	0	0	0	0	0	0	Siltst	0
TK-193	I.A2	light brown	1		1	1	0	0.5	0	0	1	5	50	50?	5	f	varied	1	0	0	0.2	0.2	0.2	0	0	0	0	0	0	0
TK-194	VI.B	reddish black	0		0?	0	0	0	1	0	0	<2	100	?	15	f	varied	2	0	1	0.5	0.5	0.2	0	0.5	0.2	0	0	0	0.5
TK-195	IV.E	graysh-red	0		?	1?/tcf?	0	0	1	0	0	<2	100	?	-	-	-	-	-	0.5	0	0	0	0	0	0	1	0	0	0.5
TK-196	VI.A	dark red	0.2		0	0	0	0	1	0	1	30-40	100	0	10	m	varied	2	0.5	0	0.5	0.5	0.2	0	0.5	0	0	0	0	0
TK197	I.A2 ?	light brown	1		2	1	0	0	0	0	1	5	100	?	<5	f	varied	1	0	1	0	0.5	0	0	0	0	0	0	0	2
TK-198	IV.D	yellowish gray	0		0	0.5	0	0	0	0.5	0	0	-	-	<2		-	-	-	-	-	-	-	-	-	-	-	-	-	-
TK-199	VI.A	brownish red	0.5		0.5	0tcf	0	0	0	1	0	<5	-	?	20-30	f	varied	2	0	0	0.5	0.5	0.5	?	0.5	0	0	0	0	1
TK-200	IV.E	graysh-green	0		?	1	0	0	1	0	0	<2	100	?	-	-	-	-	-	1	0	0	0	0	0	0	0	0	0	?
TK-201	II.B	dark red/black	0		0	0	0	0	0.5	0.5	0	20	100	0	<2	-	-	0	0	1	0.2	0.2	0.2	0	0.2	0	0	0	0.2	1
TK-202	VI.C	red	1		1	0	0	0	0	0	0.2	5	100	?	30	m	varied	2	0	0	0.5	0.5	0.5	?	0	0	0	0	0	0
TK-203	I.A1	orange	1		2	1	0.2	1	0.5	0	1	<2	-	-	2	f	varied	1	0	0.2	0	0	0	0	0.5	0	0	0	Siltst	1
TK-204	XI	dark red	0		0	0	1	0	1	0	0	30	100	0	<2	m	-	1	0	0	0	0	0	0	0	0	0	0	Siltst	0
TK-205	VI.A	brownish red	1		1	0	0	0	1	0.5	0	15	100	0	20	f	varied	2	0	0	0.5	0.5	0.5	0	0.5	0	0	0	0	1
TK-206	XI	reddish - brown	0		0	0	1	0	1	0	0	30	100	0	5	m	varied	1	0	0	0	0	0	0	0	0	0	0	0	0
TK-207	XI	reddish - brown	0		0	0	1	0	1	0	0	30	100	0	5	m	varied	1	0	0	0	0	0	0	0	0	0	0	0	0
TK-208	I.A1?	red/dark brown	1		2	0	0.5	0.2	0.2	0	1	5-7	100	-	15-20			2	0	2	0	0.2	0	0	0.5	0	0	0	0	0
TK-209	I.A1	dark red	0		2	0	0.5	0.2	0.2	0	0	<2	-	-	10-15			1	0.2	1	0	0	0	0	0.5	0	0	0	0	1
TK-210	X.	light red	1		0	2cham	0	0	1	0	0	5-10	100	0	10-15	m	varied	2	0	0	0.5	0.5	0.2	0	0.5	0	0	0	0	0
TK-211	IV.D	pale gray	1		0.2	1	0	0	0.5	0.2	0	<2	100	?	>15	m	varied	2	0	0.5	0.2	1	0.2	0	0.2	0	0	0	0.2	0
TK-212	I.A1	orange	1		1	0	0.5	0.5	0.2	0	1	<2	-	-	2-5	f	angular	1	0	1	0	0	0	0	0.2	0	0	0	0	1
TK-213	II.C	graysh-brown	1		1	1?tcf?	0.5	0	0	0	0	5	100	?	5	c	varied	-	0.2	1	0	0	0	0	0	0	0	0	0	1
TK-214	I.A1	graysh-red	0		1	0	0.5	0.5	0	0	0	10-15	-	100	15	m	varied	1	0	2	0	0	0	0	0.2	0	0	0	0	0
TK-215	?	black	0	soil	0	tdp?	0	0	1	0	0	5	100	0	<20	f	varied	2	0	0	0.5	0.5	0	0	0.2	0	0	0	0	?
TK-216	X.	light red	0.2		0	1cham	0	0	2	0	0	5	100	0	10-15	m	varied	2	0	0	0.5	0.5	0.2	0	0.5	0	0	0	0	0.5
TK-217	I.A1	light brown	1		1	0.2	0	0.2	0.5	0	0	<2	-	-	15	m	varied	2	0	0	0.5	0	0.2	0	0.5	0	0	0	0	0.5
TK-218	IV.D	pale gray	0		0	0.5	0	0	0	0	0	0	-	-	10	f	varied	2	0	0.5	0.2	0.5	0.2	0	0	0	0	0	0	0
TK-219	II.B	dark red	0		0?	0	0	0	0	0.2	0	30-40	100	0	0	-	-	0	0	1	0	0.2	0.5	0	0	0	0	0	0	0.5
TK-220	I.A1	yellow	1		2	0	0	1	0.5	0	1	<2	-	-	<5	f	varied	2	0	0.5	0	0	0.2	0	0.5	0	0	0	0	0
TK-221	I.A3/I.A1	reddish-brown	0		2	1	0.2	1	0.2	0	0	<2	-	-	5	f	varied	2	0	2	0	0	1	?	0.5	0	?	0	0	2
Tk-222	IV.D	yellowish gray	0		1	0.5	0	0	0	0	0	0	-	-	<2	-	-	2	0	0	0	0	0	0	0	0	0	0	2	0
TK-223	II.B	dark brown	00		0	0	0	0	1	0	0	20	100	0	0	-	-	-	-	-	0.2	0.2	0.2	0	0	0	0	0	0	1
TK-224	XI	reddysh-black	0		0	0	0.5	0	0	0	0	30	100	0	10	m	varied	2	0	0.5	0	0	0.2	0	0.2	0	0	0	Siltst	1
TK-251	IV.D	yellowsh gray	0		0	0.5	0	0	0	0.5	0	0	-	-	<10	f	varied	2	0	0	0.5	0.5	0.2	0	0	0	0	0	0	0
AK-225	?	reddish-brown	0		0.5	2	0	0	1	0	0	10	50	50	5	m	varied	2	0.5	0.2	0	0.2	0.2	0	0	0	0	0	0	0
AK-226	IV.D	greenish-gray	0		0	0.5	0	0	0	0.2	0	<2	-	-	10	f	varied	2	0	0	0	0.5	0	0	0	0	0	0	0	0
AK-227	I.A1	orange	1		2	0	0	1	0.5	0	1	<2	-	-	<10	f	varied	2	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0
AK-228	I.A1	orange	1		2	0	0	1	0.5	0	1	<2	-	-	<10	f	varied	2	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0
AK-229	I.A1	yellowish-gray	1		2	0	0	1	0.5	0	0	5	100	0	15	m	varied	2	0	0.5	0.5	0.5	0.5	0	0	0	0	0	0	0
AK-230	?	pale-browh	1	marl	2	0	0	0.2	0.2	0	0	<2			30-40	f	varied	2	0	0.2	0.2	0.2	0	0	0.2	0	0	0	0	0.5
AK-231	I.A1	reddish-gray	0.2		2	0	0	1	0.5	0	1	<2	-	-	5-10	f	varied	2	0	0	0.5	0.5	0.2	0	0.5	0	0	0	0.2	0.5
AK-232	I.A2	pale gray, black grits	1		2	2	0	0	0	0	1	<5	100	0	10	f	varied	2	0	1	0	0.5	0	0	0	0	0	0	0	0
AK-233	I.A1	orange	1		2	0	0	1	0.5	0	0	<2	-	-	5	f	varied	2	0	0	0.2	0.2	0	0	0	0	0	0	0.2	0
AK-234	I.A1	orange	1		2	0	0	1	0.5	0	2	<2	-	-	10	m	varied	1	0	1	0.5	0.5	0	0	0	0	?	0	0	0
AK-235	I.A1	yellow	1		2	0	0	1	0.5	0	0	5	100	0	15	f	varied	2	0	0	1	1	0.2	0	0	0	0	0	0	0
AK-236	IV.D	yellowish-gray	0		0	1	0	0	0	0	0	0	-	-	10	f	varied	2	0	1	0	0.5	0.2	0	0.2	0	0	0	Siltst	0
AK-237	I.A1	pale orange	1		2	0	0	1	0.5	0	0	<2	-	-	<10	f	varied	2	0	0	0.2	0.2	0.2	0	0.2	0	0	0	0	0
AK-238	I.A.4	orange	1		2	0	0	2	0	0	1	<2	-	-	15	m	varied	1	0	2	0	0	0	0	0.5	0	0	0	0	0
AK-239	IV.D	greenish-gray	0		0	1	0	0	0	0	0	0	-	-	10	f	varied	2	0	0	0	1	0	0	0	0	0	0	0	0
AK-240	IV.D	yellowis-gray	0		0	0.5	0	0	0	0	0	<2	-	-	10	f	varied	2	0	0	0.2	0.2	0	0	0.2	0	0	0	0	0
AK-241	IV.D	greenish-gray	0		0.5	0	0	0.2	0	0	0	<2	-	-	<5	f	varied	2	0	0	0	0.5	0	0	0	0	0	0	0	0
AK-242	IV.H	greenish-gray	0		1	0	0	1	0	0	0	<2	-	-	<10	f	varied	2	0	0	0	0.5	0	0	0	0	0	0	0	0
AK-243	IV.B	yellowish-gray, red mottles	0		0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
AK-244	IV.D	yellowish-gray	0		0	0.5	0	0	0	0	0	0	-	-	15	f	varied	2	0	0	0	0.5	0	0	0	0	0.5?	0	0	0
AK-245	I.A1	reddish-gray	1		2	0	0	1	0.5	0	1	<2	-	-	5	f	varied	2	0	0	0.5	0.5	0.2	0	0	0	0	0	0	0
AK-246	I.A1	yellowish-gray	1		2	0	0	1	0.5	0	1	5	100	0	10	f	varied	2	0	0	1	1	0	0	0	0	0	0	0	0
AK-247	IV.H	yellowish-gray	0		0	0	0	2	0	0	0	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AK-248	IV.D	yellow	0		0	0.2	0	0	0	0.2	0	<2	-	-	10	f	varied	2	0	0	0.2	0.2	0	0	0	0	0	0	0	0
P-270	P270	yellowish-brown	1		2	0	0	0	0	0.5	2	0			15	m	angular	0.5	0.5	1	0.2	0	0.2	0	0	0	0.2?	0	0	0
P-271	P271	brown	1		2	0	0	0	0	0.5	2	0			15	m	angular	0.2	0	2	0.2	0	0	0	0	0	0.2	0	0	0

Appendix 2 – Microfossil analysis (*by Barbara Olszewska*)

Petro Group	Specimen	Microfossils identified	*Acarinina* cf. *alticonica* Fleisher	*Acarinina* ? sp.	*Angulogerina* sp.	*Anomalina*? sp.	*Arenobulimina* sp. ?	*Bolivina* sp.	*Brizalina* aff. *mississippiensis* (Cushman)	*Brizalina* sp.	*Bulimina* sp.	*Cassigerinella* sp.	*Catapsydrax* sp.	*Chiloguembelina* aff. *gracillima* (Andreae)	*Chiloguembelina cubensis* Howe	*Chiloguembelina* sp.	*Cibicides* aff. *amphisylensis* (Andreae)	*Cibicides* sp.	*Dentalina* sp.	*Dripsidripella* cf. *danvillensis* (Howe & Wallace)	*Fursenkoina* sp.	*Gaudryina* sp.	*Globanomalina* aff. *luxorensis* (Nakkady)	*Globanomalina* sp.	*Globigerina* aff. *eocaena* (Gümbel)	*Globigerina* ex gr. *praebulloides-officinalis*	*Globigerina* cf. *praebulloides* Blow	*Globigerina* cf.. *officinalis* Subbotina	*Globigerina* sp	*Globigerinatheka* ? sp.	*Globigerinoides* sp.	*Globoturborotalita ouachitaensis*	*Guembelitria* (Jenkinsina) ex gr *columbiana* Howe	*Guembelitria* sp.	*Gyroidina*	*Heterolepa* sp.	*Igorina* sp.	*Korobkovella* sp.	*Lenticulina* sp.	*Lingulina* sp.	*Marssonella* sp.	*Morozovella* sp.	*Osangularia* sp.	*Paragloborotali* aff. *nana* (Bolli)	*Pararotalia* cf. *lithothamnica* (Uhlig)	*Pararotalia* sp.	*Planorotalites* sp.	*Podolia* sp.	*Pseudohastigerina* aff. *naguewichiensis* (Myatliuk).	*Pseudohastigerina* sp.	*Pseudohastigerina* aff. *micra* (Cole)	*Pullenia bulloides* Reuss	*Pullenia* sp.	*Quinqueloculina* sp.	*Reussella* sp.	*Rotalia*	*Spiroplectinella* sp.	*Streptochilus martini* (Pijpers)	*Subbotina* cf. *linaperta* (Finlay)	*Subbotina* sp.	*Tenuitella* sp.	*Tenuitellinata* cf. *angustiumbilicata* (Bolli)	*Textularia* sp.	*Tritaxia* ? sp.	*Truncorotaloides* sp.	*Turborotalia* cf. *cerroazulensis* (Cole)	*Turborotalita* aff. *carcoselleenis* (Toumarkine & Bolli)	*Turborotallia* aff. *frontosa* (Subbotina)	*Turborotalia* sp.	*Uvigerina* sp.	*Verneuilina* sp.	*Victoriella* sp.	*Corallinaceae* sp.	*Frustula* (diatoms)	*Spumellaria* (radiolaria)	*Dentalina* sp.	*Dorothia* cf. *oxycona* (Reuss)	*Dorothia* sp.	*Gavelinella* sp.	*Gllobigerinelloides* sp.	*Globigerinelloides* aff. *bolli* Pessagno	*Globigerinelloides* aff. *asperus* (Ehrenberg)	*Globigerinelloides bolli* Pessagno.	*Globigerinelloides* cf. *bentonenis* (Cushman)	*Globigerinelloides* cf. *bentonensis* (Morrow)	*Globorotalia* sp.	*Globotruncana* sp.	*Guembelitria* cf. *cretacea* Cushman	*Guembelitria* aff. *cretacea* Cushman	*Haplophragmium* sp.	*Hedbergella* aff. *delrioensis* Carsey	*Hedbergella* ex gr. *flandrini* Porthault	*Hedbergella* sp.	Hedbergellidae	Heterohelicidae	*Heterohelix* cf. *reussi* (Cushman)	*Heterohelix* sp.	*Marginotruncana* sp.	*Marginulina* sp.	*Praebulimina* aff. *reussi* (Morrow)	*Praebulimina* sp.	*Praebulimina* sp.	*Planomalina* sp.	*Praeglobotruncana* sp.	*Pyramidina* sp.	*Stensioeina* sp.
		Range	Early Eocene	Late Paleocene-Late Eocene	Eocene-Recent	Cretaceous- recent	Maastrichtian-Late Eocene	Cretaceous- Recent	Late Eocene-Oligocene	Mesosoic -Recent	Paleocene-Recent	?	Middle Eocene - Miocene	Late Eocene- Oligocene	Middle Eocene-Oligocene	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Cretaceous-Recent,	Permian-Recent	Middle Eocene	Cretaceous-Recent,	Mesozoic-Recent	Early Eocene	Late Paleocene-Late Eocene	Paleogene	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Mesozoic-recent	Middle Eocene-Late Eocene	Late Eocene-Recent	Middle Eocene-Oligocene	Early Paleocene-Middle Eocene	Cenomanian-Early Paleocene	Valanginian-Recent	Maastrichtian-Recent	Paleocene-Early Eocene	Middle Eocene-Late Eocene	Mesozoic-Recent	Permian-Recent	Maastrichtian-Early Paleocene	Late Paleocene-Middle Eocene	Valanginian-Recent	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Carboniferous-Recent	Paleocene-Eocene	Paleogene-Neogene	Late Eocene-Oligocenee	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Eocene-Recent	Cretaceous-Recent,	Jurassic-Recent	Cretaceous-Recent	Late Cretaceous-Recent	Carboniferous-Recent	Middle Eocene-Oligocene	Early Paleocene-Late Eocene	Late Paleocene-Late Eocene	Late Eocene-Late Oligocene	Late Eocene-Oligocene	Mesozoic-Recent	Berias-Recent	Early Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene	Middle Eocene-Early Oligocene	Early Eocene-Recent	Triassic-Recent	Late Eocene-Miocene				Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Valanginian-Recent	Valanginian-Maastrichtian	Coniacian-Campanian	Cenomanian-Maastrichtian	Coniacian-Campanian	Albian-Turonianian	Albianianian-Turonianian	Albian-Maastrichtian	Coniacian-Maastrichtian	Santonian-Maastrichtian	Santonian-Maastrichtian	Middle Jurassic-Cretaceous	Albian-Coniacian	Late Cretaceous	Valanginian-Maastrichtian	?	Albian-Maastrichtian	Turonian- Campanian	Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Late Cretaceous	Jurassic- Mastrichtian	Middle Jurassic-Cretaceous	Cretaceous	Albian - Cenomanian	Santonian-Maastrichtian	Turonianian - Maastrichtian
Afek P-22/23		Early Paleogene + Late Cretaceous																x						x											x																																																						x					x													
Kef Masaryk P-27		Early Paleocene		x														x											x																																																																																				
"yellow clay" Nazareth		Mastrichtian																																			x																		x																							x													x				x				x			x	
Ahihud P-13		Late Cretaceous + Early Eocene																											x												x								x																																x	x						x	x						x				x							x		
Menuha/Ghareb P-30		Mastrichtian																																			x																																							x			x														x				x									
Sa'ab P-032/33		Kampanian-Mastrichtian																															x				x																		x														x																								x				x									
Keisan P-10/11		Kampanian-Mastrichtian		x																																				x															x														x								x																x				x									
Shaar Ha'Amakim P-015		Middle Eocene		x		x?																					x!															x?											x							x								x!						x																																		
Taqiye -P.253		Late Paleocene		x				x			x											x																		x											x				x			x																						x																											
I.A1	SA-2	Middle-Late Eocene								x								x								x																																	x										x																																						
	SA-6	Middle-Late Eocene								x						x													x			x						x									x														x										x					x																																			
	SA-8	Middle-Late Eocene								x						x													x																																																	x																																								
	SA-11	Middle Eocene														x										x							x						x																			x					x							x								x		x																																			
	SA-13	Middle Eocene?														x													x																																															x																																								
	SC-39	Middle Eocene								x						x	x												x										x																																																																										
	SC-41	Middle Eocene														x													x																																																																																					
	SD-62	Middle Eocene								x						x	x												x					x																																												x		x																																					
	SD-67	Middle Eocene														x													x																	x																																																																				
	SD2-71	Middle Eocene														x													x																	x				x																										x		x																																					
	SE-86	Middle Eocene			x	x(?)																				x									x											x																												x																																											
	SFx-115	Middle Eocene			x					x						x													x																																																x		x																																					
	SX-119	Middle-Late Eocene														x													x		x			x																																									x				x																																						
	SA-126	?																																																																																																														
	SX-129	Middle-Late Eocene								x								x											x	x(?)																																		x												x																																									
	SX-135	Middle-Late Eocene																								x																							x												x												x																																									
	SX-143	Late Eocene														x													x																	x							x		x																				x																																									
	SX-146	Late Eocene -Oligocene ?										x				x													x																																														x		x											x																						
	TK-159	Late Eocene								x			x			x		x											x																																								x																																																			
	TK-160	Late Eocene -Oligocene ?								x						x					x			x					x			x																													x											x		x																																					
	TK-162	Middle-Late Eocene								x						x		x									x																																																		x		x																																					
	TK-165	Late Eocene -Oligocene ?										x		x		x					x								x		x	x		x																						x					x											x		x																																					
	TK-169	Late Eocene -Oligocene ?								x						x													x																																		x											x		x																																					
	TK-171	Late Eocene -Oligocene ?																								x																														x		x					x										x																																										
	TK-172?	Eocene?																											x																																													x																																								
	TK-173	Late Eocene -Oligocene ?								x						x													x			x														x															x											x		x																																					
	TK-175	Late Eocene -Oligocene ?								x																x						x														x															x											x		x																																					
	TK-176	Late Eocene -Oligocene ?								x						x													x					x																											x											x		x																																					
	TK-185	Late Eocene -Oligocene ?																x											x			x																													x											x																																							
	TK-191	Late Eocene -Oligocene ?																								x																																																																																							
	TK-203	Late Eocene -Oligocene ?								x						x					x								x					x																											x											x		x																																					
	TK-208	Late Eocene -Oligocene ?									x					x										x			x			x		x					x									x													x											x		x																																					
	TK-209	Middle-Late Eocene								x							x?	x	x										x										x																																			x	x																																						
	TK-212	Late Eocene -Oligocene ?			x					x						x		x											x					x																																									x		x																																					
	TK-214	Paleogene																											x										x															x																																																												
	TK-217	Late Eocene -Oligocene ?			x											x													x			x							x							x							x																																																												
	TK-220	Late Eocene -Oligocene ?								x						x													x					x																											x											x		x																																					
	TK-221	Paleogene																											x						x																																																																																
	AK-227	Middle-Late Eocene																						x					x																									x													x						x																																											
	AK-228	Middle-Late Eocene								x						x			x					x					x													x																																			x																																						
	AL-229	Eocene (Middle ?)														x													x						x															x																										x																																						
	AK-231	Middle-Late Eocene								x	x					x													x																																x											x																																						
	AK-233	Middle-Late Eocene								x						x					x			x					x																																										x																																								
	AK-234	Middle-Late Eocene														x																x														x																															x																																						
	AK-235	Middle-Late Eocene														x													x			x														x															x																																																		
	AK-237	Middle-Late Eocene														x													x										x																						x													x																																					
	AK-245	Middle-Late Eocene								x						x													x						x																										x													x																																					
	AK-246	Middle-Late Eocene								x						x																																													x													x																																					
I.A2.Eo	SBc-15	Middle Eocene														x													x									x								x																															x																																									
	SDc-51	Middle Eocene																																				x								x																	x																																																				
	SA-127	Paleogene		x(?)												x						x																																												x(?)																																														
	TK-187	Eocene?														x		x			x								x									x																							x											x																																							
	TK-193	Middle-Late Eocene														x										x																				x																															x																																									
	TK-197	Paleogene (Eocene?)													x														x																	x																															x																																									
	AK-232	Middle-Late Eocene														x		x																																																											x																	x																
I.A2.Cr	SA-128	Late Creteaceous																																										x?																																							x								x					x												x	
	SA-130	Late Creteaceous																																																																																						x				x					x				x									

Petro Group	Specimen	Microfossils identified	*Acarinina* cf. *alticonica* Fleisher	*Acarinina* ? sp.	*Angulogerina* sp.	*Anomalina*? sp.	*Arenobulimina* sp. ?	*Bolivina* sp.	*Brizalina* aff. *mississippiensis* (Cushman)	*Brizalina* sp.	*Bulimina* sp.	*Cassigerinella* sp.	*Catapsydrax* sp.	*Chiloguembelina* aff. *gracillima* (Andreae)	*Chiloguembelina cubensis* Howe	*Chiloguembelina* sp.	*Cibicides* aff. *amphisylensis* (Andreae)	*Cibicides* sp.	*Dentalina* sp.	*Dripsidripella* cf. *danvillensis* (Howe & Wallace)	*Fursenkoina* sp.	*Gaudryina* sp.	*Globanomalina* aff. *luxorensis* (Nakkady)	*Globanomalina* sp.	*Globigerina* aff. *eocaena* (Gümbel)	*Globigerina* ex gr. *praebulloides-officinalis*	*Globigerina* cf. *praebulloides* Blow	*Globigerina* cf.. *officinalis* Subbotina	*Globigerina* sp	*Globigerinatheka* ? sp.	*Globigerinoides* sp.	*Globoturborotalita ouachitaensis*	*Guembelitria* (Jenkinsina) ex gr *columbiana* Howe	*Guembelitria* sp.	*Gyroidina*	*Heterolepa* sp.	*Igorina* sp.
		Range	Early Eocene	Late Paleocene-Late Eocene	Eocene-Recent	Cretaceous- recent	Maastrichtian-Late Eocene	Cretaceous- Recent	Late Eocene-Oligocene	Mesosoic -Recent	Paleocene-Recent	?	Middle Eocene - Miocene	Late Eocene- Oligocene	Middle Eocene-Oligocene	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Cretaceous-Recent,	Permian-Recent	Middle Eocene	Cretaceous-Recent,	Mesozoic-Recent	Early Eocene	Late Paleocene-Late Eocene	Paleogene	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Mesozoic-recent	Middle Eocene-Late Eocene	Late Eocene-Recent	Middle Eocene-Oligocene	Early Paleocene-Middle Eocene	Cenomanian-Early Paleocene	Valanginian-Recent	Maastrichtian-Recent	Paleocene-Early Eocene
I.A3	SB-35	Middle-Late Eocene								x								x											x								
	SD1-66	Middle Eocene														x													x								
	SD2-72	Middle-Late Eocene							x	x								x								x			x								
	SE-101	Paleogene														x																					
	SFx-112	Paleogen(Eocene?)														x													x								
	SF-124	Middle-Late Eocene													x			x	x									x		x(?)							
	SX-125	Middle-Late Eocene												x				x			x																
	SE-134	Paleogene (Eocene?)														x		x											x								
I.A4	AK-238	Middle Late Eocene								x								x											x								
II.A	SBc-22	Eocene?		x																																	
	SDc-50	Middle Eocene?						x								x													x								
	SDc-54	Paleogene, Eocene?														x													x								
	SDc-57	Paleogene																											x								
	SOV-137	Eocene	x																											x(?)							
II.B	SC-36	Late Cretaceous									x							x																			
	SDc-44	?																																			
	SD1-64	Late Cretaceous																																			
	SD1-69	Late Cretaceous																																			
	SD2-76	Late Cretaceous																																			
	SD2-77	Late Cretaceous																																			
	SD2-79	Cretaceous <Coniacian																																			
	SD2-80	Late Cretaceous																																			
	SE-87	?																																			
	SE-92	?																																			
	SE-98	?																																			
	SE-99	?																																			
	SF-106	?																																			
	SF-107	?																																			
	SX-142	?																																			
	SX-148	?																																			
	SX-151	?																																			
	SOV-250	?																																			
	TK-174	Cretaceous <turon																																			
	TK-188	?																																			
	TK-189	?																																			
	TK-201	?																																			
	TK-219	?																																			
	TK-223	?																																			
II.C	SDc-46	Late Cretaceous?																																			
	SDc-47	Late Cretaceous?																																			
	SD2-73	Late Cretaceous																																			
	SD2-75	Late Cretaceous									x																										
	SD2-81																																				
	SD2-83																																				
	SE-96																	x																			
	SF-110																																				
	SFx-118																																	x			
	SX-144																																				
	SX-147																																				
	TK-213																																				
II.D	SDc-42	?																																			
	SDc-43	?																																			
	SDc-45	Late Cretaceous?																																			
	SDc-49	Paleogene?																																			
	SDc-52	?																																			
	SDc-53	?																																			
	SDc-55	?																																			
	SDc-56	?																																			
	SD2-84	?																																			
	SD2-85	?																																			
	SE-89	?																																			
	SE-91	?																																			
	SE-93	?																																			
	SF-103	?																																			
	SF-104	?																																			
	SD1-121	?																																			
	SX-141	?																																			
	SX-145	?																																			

Specimen	*Korobkovella* sp.	*Lenticulina* sp.	*Lingulina* sp.	*Marssonella* sp.	*Morozovella* sp.	*Osangularia* sp.	*Paragloborotali* aff. *nana* (Bolli)	*Pararotalia* cf. *lithothamnica* (Uhlig)	*Pararotalia* sp.	*Planorotalites* sp.	*Podolia* sp.	*Pseudohastigerina* aff. *naguewichiensis* (Myatliuk).	*Pseudohastigerina* sp.	*Pseudohastigerina* aff. *micra* (Cole)	*Pullenia bulloides* Reuss	*Pullenia* sp.	*Quinqueloculina* sp.	*Reussella* sp.	*Rotalia*	*Spiroplectinella* sp.	*Streptochilus martini* (Pijpers)	*Subbotina* cf. *linaperta* (Finlay)	*Subottina* sp.	*Tenuitella* sp.	*Tenuitellinata* cf. *angustiumbilicata* (Bolli)	*Textularia* sp.	*Tritaxia* ? sp.	*Truncorotaloides* sp.	*Turborotalia* cf. *cerroazulensis* (Cole)	*Turborotalita* aff. *carcoselleensis* (Toumarkine & Bolli)	*Turborotallia* aff. *frontosa* (Subbotina)	*Turborotalia* sp.	*Uvigerina* sp.	*Verneuilina* sp.	*Victoriella* sp.
Range	Middle Eocene-Late Eocene	Mesozoic-Recent	Permian-Recent	Maastrichtian-Early Paleocene	Late Paleocene-Middle Eocene	Valanginian-Recent	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Carboniferous-Recent	Paleocene-Eocene	Paleogene-Neogene	Late Eocene-Oligocenee	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Eocene-Recent	Cretaceous-Recent,	Jurassic-Recent	Cretaceous-Recent	Late Cretaceous-Recent	Carboniferous-Recent	Middle Eocene-Oligocene	Early Paleocene-Late Eocene	Late Paleocene-Late Eocene	Late Eocene-Late Oligocene	Late Eocene-Oligocene	Mesozoic-Recent	Berias-Recent	Early Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene	Middle Eocene-Early Oligocene	Early Eocene-Recent	Triassic-Recent	Late Eocene-Miocene
SB-35																								x											
SD1-66																																			
SD2-72													x											x									x		
SE-101																																			
SFx-112	x																																		
SF-124				x(?)				x																											
SX-125																																			
SE-134																																			
AK-238																	x																		
SBc-22																																			
SDc-50		x(?)																																	
SDc-54																																			
SDc-57																																			
SOV-137							x																												
SC-36																																			
SDc-44																																			
SD1-64																																			
SD1-69																																			
SD2-76																																			
SD2-77																																			
SD2-79																																			
SD2-80																																			
SE-87																																			
SE-92																																			
SE-98																																			
SE-99																																			
SF-106																																			
SF-107																																			
SX-142																																			
SX-148																																			
SX-151																																			
SOV-250																																			
TK-174																																			
TK-188																																			
TK-189																																			
TK-201		x																																	
TK-219																																			
TK-223																																			
SDc-46																																			
SDc-47																																			
SD2-73																																			
SD2-75																																			
SD2-81																																			
SD2-83																																			
SE-96																																			
SF-110																																			
SFx-118																																			
SX-144																																			
SX-147																																			
TK-213																																			
SDc-42																																			
SDc-43																																			
SDc-45																																			
SDc-49																																			
SDc-52																																			
SDc-53																																			
SDc-55																																			
SDc-56																																			
SD2-84																																			
SD2-85																																			
SE-89																																			
SE-91																																			
SE-93																																			
SF-103																																			
SF-104																																			
SD1-121																																			
SX-141																																			
SX-145																																			

Specimen	*Corallinaceae* sp.	*Frustula* (diatoms)	*Spumellaria* (radiolaria)	*Dentalina* sp.	*Dorothia* cf. *oxycona* (Reuss)	*Dorothia* sp.	*Gavelinella* sp.	*Gllobigerinelloides* sp.	*Globigerinelloides* aff. *bolli* Pessagno	*Globigerinelloides* aff. *asperus* (Ehrenberg)	*Globigerinelloides bolli* Pessagno.	*Globigerinelloides* cf. *bentonenis* (Cushman)	*Globigerinelloides* cf. *bentonensis* (Morrow)	*Globorotalia* sp.	*Globotruncana* sp.	*Guembelitria* cf. *cretacea* Cushman	*Guembelitria* aff. *cretacea* Cushman	*Haplophragmium* sp.	*Hedbergella* aff. *delrioensis* Carsey	*Hedbergella* ex gr. *flandrini* Porthault	*Hedbergella* sp.	Hedbergellidae	Heterohelicidae	*Heterohelix* cf. *reussi* (Cushman)	*Heterohelix* sp.	*Marginotruncana* sp.	*Marginulina* sp.	*Praebulimina* aff. *reussi* (Morrow)	*Praebulimina* sp.	*Praebulimina* sp.	*Planomalina* sp.	*Praeglobotruncana* sp.	*Pyramidina* sp.	*Stensioeina* sp.
Range				Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Valanginian-Recent	Valanginian-Maastrichtian	Coniacian-Campanian	Cenomanian-Maastrichtian	Coniacian-Campanian	Albian-Turonianian	Albianianian-Turonianian	Albian-Maastrichtian	Coniacian-Maastrichtian	Santonian-Maastrichtian	Santonian-Maastrichtian	Middle Jurassic-Cretaceous	Albian-Coniacian	Late Cretaceous	Valanginian-Maastrichtian	?	Albian-Maastrichtian	Turonian- Campanian	Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Late Cretaceous	Jurassic- Mastrichtian	Middle Jurassic-Cretaceous	Cretaceous	Albian - Cenomanian	Santonian-Maastrichtian	Turonianian - Maastrichtian
SB-35																																		
SD1-66	x																																	
SD2-72																																		
SE-101	x																																	
SFx-112	x																																	
SF-124																																		
SX-125																																		
SE-134																																		
AK-238	x		x																															
SBc-22																																		
SDc-50			x																															
SDc-54																																		
SDc-57																																		
SOV-137																																		
SC-36								x													x				x									
SDc-44																																		
SD1-64								x													x				x									
SD1-69								x													x				x									
SD2-76								x													x				x									
SD2-77					x																x													
SD2-79									x										x						x			x						
SD2-80							x						x						x							x(?)		x						
SE-87								x													x				x									
SE-92								x													x				x									
SE-98								x													x				x				x					
SE-99								x	x												x			x					x					
SF-106								x													x													
SF-107								x													x				x									
SX-142																					x				x									
SX-148								x													x			x										
SX-151				x				x													x						x(?)							
SOV-250								x													x								x					
TK-174									x						x(?)						x				x				x					
TK-188								x													x				x									
TK-189																																		
TK-201								x																										
TK-219																					x				x									
TK-223																					x													
SDc-46			x					x																										
SDc-47																					x				x									
SD2-73								x																										
SD2-75																				x	x				x									
SD2-81																					x				x									
SD2-83							x(?)		x				x								x				x									
SE-96						x				x											x				x									
SF-110																			x						x									
SFx-118									x										x					x					x					
SX-144								x													x								x					
SX-147																					x				x									
TK-213							x	x		x											x								x		x(?)			
SDc-42																																		
SDc-43																																		
SDc-45																																		
SDc-49																																		
SDc-52																																		
SDc-53																																		
SDc-55																																		
SDc-56																																		
SD2-84																																		
SD2-85																																		
SE-89																																		
SE-91																																		
SE-93																																		
SF-103																																		
SF-104																																		
SD1-121																																		
SX-141																																		
SX-145																																		

Petro Group	Specimen	Microfossils identified	*Acarinina* cf. *alticonica* Fleisher	*Acarinina* ? sp.	*Angulogerina* sp.	*Anomalina*? sp.	*Arenobulimina* sp. ?	*Bolivina* sp.	*Brizalina* aff. *mississippiensis* (Cushman)	*Brizalina* sp.	*Bulimina* sp.	*Cassigerinella* sp.	*Catapsydrax* sp.	*Chiloguembelina* aff. *gracillima* (Andreae)	*Chiloguembelina cubensis* Howe	*Chiloguembelina* sp.	*Cibicides* aff. *amphisylensis* (Andreae)	*Cibicides* sp.	*Dentalina* sp.	*Dripsidripella* cf. *danvillensis* (Howe & Wallace)	*Fursenkoina* sp.	*Gaudryina* sp.	*Globanomalina* aff. *luxorensis* (Nakkady)	*Globanomalina* sp.	*Globigerina* aff. *eocaena* (Gümbel)	*Globigerina* ex gr. *praebulloides-officinalis*	*Globigerina* cf. *praebulloides* Blow	*Globigerina* cf.. *officinalis* Subbotina
		Range	Early Eocene	Late Paleocene-Late Eocene	Eocene-Recent	Cretaceous- recent	Maastrichtian-Late Eocene	Cretaceous- Recent	Late Eocene-Oligocene	Mesosoic-Recent	Paleocene-Recent	?	Middle Eocene - Miocene	Late Eocene- Oligocene	Middle Eocene-Oligocene	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Cretaceous-Recent,	Permian-Recent	Middle Eocene	Cretaceous-Recent,	Mesozoic-Recent	Early Eocene	Late Paleocene-Late Eocene	Paleogene	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Middle Eocene-Oligocene
III	SE-94	Cretaceous, Albian<																										
	SE-97	Cretaceous, Albian<																										
	SF-102	Cretaceous, Coniacian																										
	SF-105	Cretaceous, Albian<																										
	SF-108	Cretaceous, Albian<																										
	SFx-113	Cretaceous, Albian<																										
	SFx-114	Cretaceous, Albian<																										
	SFx-117	Cretaceous, Albian<																										
	SFx-149	Cretaceous, Albian<															x											
	SX-150	Cretaceous, Albian<																										
	TK-157	Cretaceous, Albian<																										
IV.A	SA-1	?																										
	SA-3	Paleogene																										
	SBc-21	?																										
	SD1-59	?																										
	SD1-61	?																										
	TK-178	Late Paleocene-Eocene														x												
IV.B	SBc-23	Late Eocene														x		x		x							x	
	SBc-25	Late Eocene									x					x		x		x		x					x	
	SC-40	Eocene														x									x		x	
	AK-243	?									x(?)							x										
IV.C	SA-10	Paleogene?																										
	SBc-16	?																										
	SD1-65	?																										
IV.D	SA-9	Paleogene?																										
	SBc-26	?																										
	SBc-34	Paleogene?																										
	SBc-37	Paleogene																										
	SD2-74	?																										
	SE-90	Paleogene (Eocene)? +_Cretaceous														x												
	SA-120	?																										
	TK-158	Paleogene																										
	TK-164	?																										
	TK-167	?																										
	TK-168	Paleogene (Eocene?)														x												
	TK-170	Paleogene?																										
	TK-177	?																										
	TK-181	?																										
	TK-182	?																										
	TK-190	Paleogene (Eocene?)														x												
	TK-198	Early Eocene														x							x					
	TK-211	?																										
	TK-218	?																										
	TK-222	?																										
	TK-251	?																										
	AK-226	?																										
	AK-236	?																										
	AK-239	?																										
	AK-240	?																										
	AK-241	?																										
	AK-244	?																										
	AK-248	?																										
IV.E (Cr)	SBc-24	Late Cretaceous																										
	SBc-28	?																										
	SBc-33	Late Cretaceous																										
	SOV-139	Late Cretaceous																										
	TK-195	?																										
	TK-200	Late Cretaceous																										
	TK-222	?																										
IV.F	SE-100	Late Eocene			x					x	x							x										
IV.G	TK-183	Late Cretaceous ?																										
IV.H	SA-5	Paleogene?																										
	SA-7	Late Paleocene-Eocene		x																								
	TK-153	Eocene?																										
	TK-154	Paleogene																										
	TK-161																											
	TK-186	Eocene-Oligocene														x												
	AK-242	Eocene					x(?)			x	x					x		x										
	AK-247	Eocene-Oligocene																									x	

Specimen	*Globigerina* sp	*Globigerinatheka* ? sp.	*Globigerinoides* sp.	*Globoturborotalita ouachitaensis*	*Guembelitria* (Jenkinsina) ex gr *columbiana* Howe	*Guembelitria* sp.	*Gyroidina*	*Heterolepa* sp.	*Igorina* sp.	*Korobkovella* sp.	*Lenticulina* sp.	*Lingulina* sp.	*Marssonella* sp.	*Morozovella* sp.	*Osangularia* sp.	*Paragloborotali* aff. *nana* (Bolli)	*Pararotalia* cf. *lithothamnica* (Uhlig)	*Pararotalia* sp.	*Planorotalites* sp.	*Podolia* sp.	*Pseudohastigerina* aff. *naguewichiensis* (Myatliuk).	*Pseudohastigerina* sp.	*Pseudohastigerina* aff. *micra* (Cole)	*Pullenia bulloides* Reuss	*Pullenia* sp.	*Quinqueloculina* sp.
Range	Mesozoic-recent	Middle Eocene-Late Eocene	Late Eocene-Recent	Middle Eocene-Oligocene	Early Paleocene-Middle Eocene	Cenomanian-Early Paleocene	Valanginian-Recent	Maastrichtian-Recent	Paleocene-Early Eocene	Middle Eocene-Late Eocene	Mesozoic-Recent	Permian-Recent	Maastrichtian-Early Paleocene	Late Paleocene-Middle Eocene	Valanginian-Recent	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Carboniferous-Recent	Paleocene-Eocene	Paleogene-Neogene	Late Eocene-Oligocenee	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Eocene-Recent	Cretaceous-Recent,	Jurassic-Recent
SE-94																										
SE-97																										
SF-102																										
SF-105																										
SF-108																										
SFx-113																										
SFx-114																										
SFx-117																										
SFx-149																										
SX-150																										
TK-157																										
SA-1																										
SA-3	x																		x							
SBc-21																										
SD1-59																										
SD1-61																										
TK-178	x								x									x	x							
SBc-23								x																		
SBc-25																					x					
SC-40															x											
AK-243																										
SA-10	x(?)																									
SBc-16																										
SD1-65																										
SA-9	x																									
SBc-26																										
SBc-34	x																					x				
SBc-37																						x(?)				
SD2-74																										
SE-90	x																									
SA-120																										
TK-158	x																									
TK-164																										
TK-167																										
TK-168	x																					x				x
TK-170	x																									
TK-177																										
TK-181																										
TK-182																										
TK-190	x																									
TK-198																										
TK-211																										
TK-218																										
TK-222																										
TK-251																										
AK-226																										
AK-236																										
AK-239																										
AK-240																										
AK-241																										
AK-244																										
AK-248																										
SBc-24																										
SBc-28																										
SBc-33																										
SOV-139																										
TK-195																										
TK-200																										
TK-222																										
SE-100	x		x									x												x		
TK-183																										
SA-5	x																									
SA-7	x																									
TK-153	x																						x			
TK-154	x																									
TK-161																										
TK-186																										
AK-242	x																									
AK-247																										

Specimen	*Reussella* sp.	*Rotalia*	*Spiroplectinella* sp.	*Streptochilus martini* (Pijpers)	*Subbotina* cf. *linaperta* (Finlay)	*Subbotina* sp.	*Tenuitella* sp.	*Tenuitellinata* cf. *angustiumbilicata* (Bolli)	*Textularia* sp.	*Tritaxia* ? sp.	*Truncorotaloides* sp.	*Turborotalia* cf. *cerroazulensis* (Cole)	*Turborotalita* aff. *carcoselleensis* (Toumarkine & Bolli)	*Turborotallia* aff. *frontosa* (Subbotina)	*Turborotalia* sp.	*Uvigerina* sp.	*Verneuilina* sp.	*Victoriella* sp.	*Corallinaceae* sp.	*Frustula* (diatoms)	*Spumellaria* (radiolaria)	*Dentalina* sp.	*Dorothia* cf. *oxycona* (Reuss)	*Dorothia* sp.	*Gavelinella* sp.	*Gllobigerinelloides* sp.
Range	Cretaceous-Recent	Late Cretaceous-Recent	Carboniferous-Recent	Middle Eocene-Oligocene	Early Paleocene-Late Eocene	Late Paleocene-Late Eocene	Late Eocene-Late Oligocene	Late Eocene-Oligocene	Mesozoic-Recent	Berias-Recent	Early Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene	Middle Eocene-Early Oligocene	Early Eocene-Recent	Triassic-Recent	Late Eocene-Miocene				Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Valanginian-Recent	Valanginian-Maastrichtian
SE-94																										
SE-97																										
SF-102																										
SF-105																										
SF-108																										
SFx-113																										x
SFx-114																										
SFx-117																										
SFx-149																										
SX-150																										x
TK-157																										
SA-1																										
SA-3																					x					
SBc-21																										
SD1-59																										
SD1-61																										
TK-178						x									x											
SBc-23								x																		
SBc-25																										
SC-40							x		x																	
AK-243																										
SA-10																										
SBc-16																										
SD1-65																										
SA-9																										
SBc-26																										
SBc-34																										
SBc-37																										
SD2-74																										
SE-90																										x
SA-120																										
TK-158																										
TK-164																										
TK-167																										
TK-168																										
TK-170																										
TK-177																										
TK-181																										
TK-182																										
TK-190																										
TK-198																										
TK-211																										
TK-218																				x						
TK-222																										
TK-251																										
AK-226																										
AK-236																										
AK-239																										
AK-240																										
AK-241																										
AK-244																										
AK-248																										
SBc-24																										x
SBc-28																										
SBc-33																										
SOV-139																										
TK-195																										
TK-200																										
TK-222																										
SE-100							x									x										
TK-183																										x
SA-5																										
SA-7																										
TK-153																			x		x					
TK-154																										
TK-161																										
TK-186																										
AK-242																										
AK-247																										

Specimen	*Globigerinelloides* aff. *bolli* Pessagno	*Globigerinelloides* aff. *asperus* (Ehrenberg)	*Globigerinelloides bolli* Pessagno.	*Globigerinelloides* cf. *bentonenis* (Cushman)	*Globigerinelloides* cf. *bentonensis* (Morrow)	*Globorotalia* sp.	*Globotruncana* sp.	*Guembelitria* cf. *cretacea* Cushman	*Guembelitria* aff. *cretacea* Cushman	*Haplophragmium* sp.	*Hedbergella* aff. *delrioensis* Carsey	*Hedbergella* ex gr. *flandrini* Porthault	*Hedbergella* sp.	Hedbergellidae	Heterohelicidae	*Heterohelix* cf. *reussi* (Cushman)	*Heterohelix* sp.	*Marginotruncana* sp.	*Marginulina* sp.	*Praebulimina* aff. *reussi* (Morrow)	*Praebulimina* sp.	*Praebulimina* sp.	*Planomalina* sp.	*Praeglobotruncana* sp.	*Pyramidina* sp.	*Stensioeina* sp.
Range	Coniacian-Campanian	Cenomanian-Maastrichtian	Coniacian-Campanian	Albian-Turonianian	Albianianian-Turonianian	Albian-Maastrichtian	Coniacian-Maastrichtian	Santonian-Maastrichtian	Santonian-Maastrichtian	Middle Jurassic-Cretaceous	Albian-Coniacian	Late Cretaceous	Valanginian-Maastrichtian	?	Albian-Maastrichtian	Turonian- Campanian	Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Late Cretaceous	Jurassic- Mastrichtian	Middle Jurassic-Cretaceous	Cretaceous	Albian - Cenomanian	Santonian-Maastrichtian	Turonianian - Maastrichtian
SE-94														x	x											
SE-97														x	x											
SF-102									x				x				x									
SF-105													x				x									
SF-108													x				x									
SFx-113													x				x									
SFx-114													x				x									
SFx-117													x													
SFx-149																										
SX-150													x				x								x	
TK-157				x									x			x										
SA-1																										
SA-3																										
SBc-21																										
SD1-59																										
SD1-61																										
TK-178																										
SBc-23																										
SBc-25																										
SC-40																						x				
AK-243																										
SA-10																										
SBc-16																										
SD1-65																										
SA-9																										
SBc-26																										
SBc-34																										
SBc-37																										
SD2-74																										
SE-90													x													
SA-120																										
TK-158																										
TK-164																										
TK-167																										
TK-168																										
TK-170																										
TK-177																										
TK-181																										
TK-182																										
TK-190																										
TK-198																										
TK-211																										
TK-218																										
TK-222													?				?									
TK-251																										
AK-226																										
AK-236																										
AK-239																										
AK-240																										
AK-241																										
AK-244																										
AK-248																										
SBc-24													x				x(?)									
SBc-28																										
SBc-33														x	x											
SOV-139					x								x				x	x								
TK-195																										
TK-200													x?				x(?)									
TK-222													x?				x?									
SE-100																										
TK-183													x													
SA-5																										
SA-7																										
TK-153																										
TK-154																										
TK-161																										
TK-186																										
AK-242																										
AK-247																										

Petro Group	Specimen	Microfossils identified	*Acarinina* cf. *alticonica* Fleisher	*Acarinina* ? sp.	*Angulogerina* sp.	*Anomalina*? sp.	*Arenobulimina* sp. ?	*Bolivina* sp.	*Brizalina* aff. *mississippiensis* (Cushman)	*Brizalina* sp.	*Bulimina* sp.	*Cassigerinella* sp.	*Catapsydrax* sp.	*Chiloguembelina* aff. *gracillima* (Andreae)	*Chiloguembelina cubensis* Howe	*Chiloguembelina* sp.	*Cibicides* aff. *amphisylensis* (Andreae)	*Cibicides* sp.	*Dentalina* sp.	*Dripsidripella* cf. *danvillensis* (Howe & Wallace)	*Fursenkoina* sp.	*Gaudryina* sp.	*Globanomalina* aff. *luxorensis* (Nakkady)	*Globanomalina* sp.	*Globigerina* aff. *eocaena* (Gümbel)	*Globigerina* ex gr. *praebulloides-officinalis*	*Globigerina* cf. *praebulloides* Blow	*Globigerina* cf.. *officinalis* Subbotina
		Range	Early Eocene	Late Paleocene-Late Eocene	Eocene-Recent	Cretaceous- recent	Maastrichtian-Late Eocene	Cretaceous- Recent	Late Eocene-Oligocene	Mesosoic -Recent	Paleocene-Recent	?	Middle Eocene - Miocene	Late Eocene- Oligocene	Middle Eocene-Oligocene	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Cretaceous-Recent,	Permian-Recent	Middle Eocene	Cretaceous-Recent,	Mesozoic-Recent	Early Eocene	Late Paleocene-Late Eocene	Paleogene	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Middle Eocene-Oligocene
V	SA-4	Cretaceous?																										
	SA-12	?																										
	SBc-14	?																										
	SBc-17	?																										
	SBc-18	Eocene?														x												
	SBc-27	Paleogene? / + Cretaceous?				x																						
	SBc-29	?																										
	SBc-30	Middle Eocene			x					x						x		x										
	SBc-31	Paleogene									x																	
	SBc-32	?																										
	SB-38	?																										
	SD1-58	?																										
	SD1-60	?																										
	SD1-133	Eocene?								x						x												
	SOV-249	?																										
VI	SDc-48	Paleogene (redeposited)																										
	SA-123	?																										
VI.A	TK-156	Late Cretaceous																										
	TK-196	Late Cretaceous																										
	TK-199	Late Cretaceous																										
	TK-205	Late Cretaceous																										
VI.B	TK-166	?																										
	TK-194	?														x											x		
VI.C	TK-202	Dasycladacea ?																										
VI.D	TK-155	?																										
VII	SD1-63	Late Cretaceous																										
	SD1-68	Late Cretaceous				x																						
VIII	SBc-19	Paleogene			x																							
	SD1-70	Late Cretaceous																										
	SD2-78	Eocene - Recent			x																							
IX	TK-152			x																								
	TK-179																											
X	TK-210	?																										
	TK-216	?																										
XI	TK-163	?																										
	TK-192	?																										
	TK-204	?																										
	TK-206	?																										
	TK-207	?																										
	TK-224	?																										
unassigned ceramics	SBc-20	Middle Eocene																										
	SD2-82	?																										
	SE-88	?																										
	SF-109	?																										
	SFx-111	?																										
	SFx-116	?																										
	SBc-122	?																										
	SD-131	?																										
	SBc-132	Middle-Late Eocene																										
	SOV-136	Eocene														x												
	TK-180	?																										
	TK-184	Paleogene?																										
	TK-215	?																										

Petro Group	Specimen	Microfossils identified	*Globigerina* sp	*Globigerinatheka* ? sp.	*Globigerinoides* sp.	*Globoturborotalita ouachitaensis*	*Guembelitria* (Jenkinsina) ex gr *columbiana* Howe	*Guembelitria* sp.	*Gyroidina*	*Heterolepa* sp.	*Igorina* sp.	*Korobkovella* sp.	*Lenticulina* sp.	*Lingulina* sp.	*Marssonella* sp.	*Morozovella* sp.	*Osangularia* sp.	*Paragloborotali* aff. *nana* (Bolli)	*Pararotalia* cf. *lithothamnica* (Uhlig)	*Pararotalia* sp.	*Planorotalites* sp.	*Podolia* sp.	*Pseudohastigerina* aff. *naguewichiensis* (Myatliuk).	*Pseudohastigerina* sp.	*Pseudohastigerina* aff. *micra* (Cole)	*Pullenia bulloides* Reuss	*Pullenia* sp.	*Quinqueloculina* sp.
		Range	Mesozoic-recent	Middle Eocene-Late Eocene	Late Eocene-Recent	Middle Eocene-Oligocene	Early Paleocene-Middle Eocene	Cenomanian-Early Paleocene	Valanginian-Recent	Maastrichtian-Recent	Paleocene-Early Eocene	Middle Eocene-Late Eocene	Mesozoic-Recent	Permian-Recent	Maastrichtian-Early Paleocene	Late Paleocene-Middle Eocene	Valanginian-Recent	Middle Eocene-Oligocene	Middle Eocene-Oligocene	Carboniferous-Recent	Paleocene-Eocene	Paleogene-Neogene	Late Eocene-Oligocenee	Early Eocene-Early Oligocene	Middle Eocene-Oligocene	Eocene-Recent	Cretaceous-Recent,	Jurassic-Recent
V	SA-4	Cretaceous?																										
	SA-12	?																										
	SBc-14	?																										
	SBc-17	?																										
	SBc-18	Eocene?	x																									
	SBc-27	Paleogene? / + Cretaceous?	x																									
	SBc-29	?																										
	SBc-30	Middle Eocene	x										x															
	SBc-31	Paleogene	x(?)																									
	SBc-32	?																										
	SB-38	?																										
	SD1-58	?																										
	SD1-60	?																										
	SD1-133	Eocene?	x																									
	SOV-249	?																										
VI	SDc-48	Paleogene (redeposited)	x																									
	SA-123	?																										
VI.A	TK-156	Late Cretaceous																										
	TK-196	Late Cretaceous																										
	TK-199	Late Cretaceous																										
	TK-205	Late Cretaceous																										
VI.B	TK-166	?	x(?)																									
	TK-194	?																						x				
VI.C	TK-202	Dasycladacea ?																										
VI.D	TK-155	?																										
VII	SD1-63	Late Cretaceous																										
	SD1-68	Late Cretaceous																										
VIII	SBc-19	Paleogene																										
	SD1-70	Late Cretaceous																										
	SD2-78	Eocene - Recent																										
IX	TK-152															x												
	TK-179		x																									
X	TK-210	?																										
	TK-216	?																										
XI	TK-163	?																										
	TK-192	?																										
	TK-204	?																										
	TK-206	?																										
	TK-207	?																										
	TK-224	?																										
unassigned ceramics	SBc-20	Middle Eocene																										
	SD2-82	?																										
	SE-88	?																										
	SF-109	?																										
	SFx-111	?																										
	SFx-116	?																										
	SBc-122	?																										
	SD-131	?																										
	SBc-132	Middle-Late Eocene														x					x							
	SOV-136	Eocene	x										x							x								
	TK-180	?																										
	TK-184	Paleogene?																										
	TK-215	?																										

Petro Group	Specimen	Microfossils identified	*Reussella* sp.	*Rotalia*	*Spiroplectinella* sp.	*Streptochilus martini* (Pijpers)	*Subbotina* cf. *linaperta* (Finlay)	*Subbottina* sp.	*Tenuitella* sp.	*Tenuitellinata* cf. *angustiumbilicata* (Bolli)	*Textularia* sp.	*Tritaxia* ? sp.	*Truncorotaloides* sp.	*Turborotalia* cf. *cerroazulensis* (Cole)	*Turborotalita* aff. *carcoselleenis* (Toumarkine & Bolli)	*Turborotallia* aff. *frontosa* (Subbotina)	*Turborotalia* sp.	*Uvigerina* sp.	*Verneuilina* sp.	*Victoriella* sp.	*Corallinaceae* sp.	*Frustula* (diatoms)	*Spumellaria* (radiolaria)	*Dentalina* sp.	*Dorothia* cf. *oxycona* (Reuss)	*Dorothia* sp.	*Gavelinella* sp.	*Gllobigerinelloides* sp.
		Range	Cretaceous-Recent	Late Cretaceous-Recent	Carboniferous-Recent	Middle Eocene-Oligocene	Early Paleocene-Late Eocene	Late Paleocene-Late Eocene	Late Eocene-Late Oligocene	Late Eocene-Oligocene	Mesozoic-Recent	Berias-Recent	Early Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene-Late Eocene	Middle Eocene	Middle Eocene-Early Oligocene	Early Eocene-Recent	Triassic-Recent	Late Eocene-Miocene				Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Valanginian-Recent	Valanginian-Maastrichtian
V	SA-4	Cretaceous?																										
	SA-12	?																										
	SBc-14	?																										
	SBc-17	?																										
	SBc-18	Eocene?																										
	SBc-27	Paleogene? / + Cretaceous?																										
	SBc-29	?																										
	SBc-30	Middle Eocene			x				x																			
	SBc-31	Paleogene																										
	SBc-32	?																										
	SB-38	?																					x					
	SD1-58	?																										
	SD1-60	?																										
	SD1-133	Eocene?																		x								
	SOV-249	?																										
VI	SDc-48	Paleogene (redeposited)																										
	SA-123	?																										
VI.A	TK-156	Late Cretaceous																										
	TK-196	Late Cretaceous																										x
	TK-199	Late Cretaceous																										
	TK-205	Late Cretaceous																										x
VI.B	TK-166	?																										
	TK-194	?							x																			
VI.C	TK-202	Dasycladacea ?		x																								x
VI.D	TK-155	?																										
VII	SD1-63	Late Cretaceous																										
	SD1-68	Late Cretaceous																										
VIII	SBc-19	Paleogene							x																			
	SD1-70	Late Cretaceous																									x	
	SD2-78	Eocene - Recent																										
IX	TK-152												x															
	TK-179													x														
X	TK-210	?																										
	TK-216	?																										
XI	TK-163	?																										
	TK-192	?																										
	TK-204	?																										
	TK-206	?																										
	TK-207	?																										
	TK-224	?																										
unassigned ceramics	SBc-20	Middle Eocene															x											
	SD2-82	?																										
	SE-88	?																										
	SF-109	?																										
	SFx-111	?																										
	SFx-116	?																										
	SBc-122	?																										
	SD-131	?																										
	SBc-132	Middle-Late Eocene																				x						
	SOV-136	Eocene									x											x						
	TK-180	?																										
	TK-184	Paleogene?																					x					
	TK-215	?																										

Petro Group	Specimen	Microfossils identified	*Globigerinelloides* aff. *bolli* Pessagno	*Globigerinelloides* aff. *asperus* (Ehrenberg)	*Globigerinelloides bolli* Pessagno.	*Globigerinelloides* cf. *bentonenis* (Cushman)	*Globigerinelloides* cf. *bentonensis* (Morrow)	*Globorotalia* sp.	*Globotruncana* sp.	*Guembelitria* cf. *cretacea* Cushman	*Guembelitria* aff. *cretacea* Cushman	*Haplophragmium* sp.	*Hedbergella* aff. *delrioensis* Carsey	*Hedbergella* ex gr. *flandrini* Porthault	*Hedbergella* sp.	Hedbergellidae	Heterohelicidae	*Heterohelix* cf. *reussi* (Cushman)	*Heterohelix* sp.	*Marginotruncana* sp.	*Marginulina* sp.	*Praebulimina* aff. *reussi* (Morrow)	*Praebulimina* sp.	*Praebulimina* sp.	*Planomalina* sp.	*Praeglobotruncana* sp.	*Pyramidina* sp.	*Stensioeina* sp.
		Range	Coniacian-Campanian	Cenomanian-Maastrichtian	Coniacian-Campanian	Albian-Turonianian	Albianianian-Turonianian	Albian-Maastrichtian	Coniacian-Maastrichtian	Santonian-Maastrichtian	Santonian-Maastrichtian	Middle Jurassic-Cretaceous	Albian-Coniacian	Late Cretaceous	Valanginian-Maastrichtian	?	Albian-Maastrichtian	Turonian- Campanian	Albian-Maastrichtian	Late Cretaceous	Albian-Maastrichtian	Late Cretaceous	Jurassic- Mastrichtian	Middle Jurassic-Cretaceous	Cretaceous	Albian - Cenomanian	Santonian-Maastrichtian	Turonianian - Maastrichtian
V	SA-4	Cretaceous?															x											
	SA-12	?																										
	SBc-14	?																										
	SBc-17	?																										
	SBc-18	Eocene?																										
	SBc-27	Paleogene? / + Cretaceous?													x													
	SBc-29	?																										
	SBc-30	Middle Eocene																										
	SBc-31	Paleogene																										
	SBc-32	?																										
	SB-38	?																										
	SD1-58	?																										
	SD1-60	?																										
	SD1-133	Eocene?																										
	SOV-249	?																										
VI	SDc-48	Paleogene (redeposited)																										
	SA-123	?																										
VI.A	TK-156	Late Cretaceous														x	x											
	TK-196	Late Cretaceous													x				x									
	TK-199	Late Cretaceous														x	x											
	TK-205	Late Cretaceous								x					x				x					x				
VI.B	TK-166	?																										
	TK-194	?																										
VI.C	TK-202	Dasycladacea ?													x				x									
VI.D	TK-155	?																										
VII	SD1-63	Late Cretaceous													x				x									
	SD1-68	Late Cretaceous													x				x									
VIII	SBc-19	Paleogene															x											
	SD1-70	Late Cretaceous					x								x			x					x					
	SD2-78	Eocene - Recent																										
IX	TK-152																											
	TK-179																											
X	TK-210	?																										
	TK-216	?																										
XI	TK-163	?																										
	TK-192	?																										
	TK-204	?																										
	TK-206	?																										
	TK-207	?																										
	TK-224	?																										
unassigned ceramics	SBc-20	Middle Eocene																										
	SD2-82	?																										
	SE-88	?																										
	SF-109	?																										
	SFx-111	?																										
	SFx-116	?																										
	SBc-122	?																										
	SD-131	?																										
	SBc-132	Middle-Late Eocene																										
	SOV-136	Eocene																										
	TK-180	?																										
	TK-184	Paleogene?																										
	TK-215	?																										

Notes about the authors

Jacek Michniewicz is a geologist-petrographer and a professor at the Institute of Geology in the Adam Mickiewicz University, Poznań. He specializes in petrographical and chemical studies of pottery, mortars and raw materials. In 1996 he began cooperation with École biblique et archéologique française de Jérusalem and the Israel Antiquities Authority undertaking physico-chemical study of Qumran and Jericho pottery. After that, he was investigating the provenance of Roman amphorae discovered in the Herodian palaces in Jericho, Cypros, Masada, Herodium as well as in the city of Caesarea. He also conducted studies on the pottery from Hippos (Susita) in the Golan Heights, and recently he has got involved in the Pennsylvania State University project regarding the provenance of cermics from Tel Akko.

Jolanta Młynarczyk is a professor in the Institute of Archaeology, University of Warsaw, lecturing in various aspects of archaeology of the Near East during the1st millenium BC – 1st millenium AD. One of the fields of her interest is the research into different kinds of pottery of the southern Levant, Egypt and Cyprus such as store jars, oil lamps, table wares and cooking vessels. She worked on several sites of Greco-Roman and Byzantine/early Islamic periods in Egypt, Cyprus, Israel and Jordan. She is responsible for the archaeological part of the present book, including the samples descriptions, their chronology and the typology of the ceramics under discussion.

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