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Pottery from Arslantepe (Malatya, Turkey): petrographic features and archaeological data

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ABSTRACT. — In the high Euphrates Valley, near the Arslantepe site (Malatya, south-central Turkey), many systematic excavations have revealed an almost continuous stratified sequence of settlements dating from the Chalcolithic (IV mill. BC) to neo-Hittite (1200-700 BC) periods.

More than 200 ceramic objects, of different class, function and chronology, have been characterised from both archaeometric and archaeological points of view.

Using as discriminating factors mineralogical components and, subordinately, the lithic nature of rock fragments occurring within the samples, the sherds were divided into five groups: a) group I (Pl ± Qz ± Kf ± Px ± Bt ± Amph ± Cc ± reddish Ol); b) group II (Pl ± Qz ± Px ± Amph ± Bt + Ep); c) group III (Pl ± Qz ± Kf ± Px ± Bt ± Amph ± rare garnet, zircon, tourmaline, olivine, gypsum, dolomite, chlorite crystals, and frequent basic volcanic rock fragments; d) group IV (Pl ± Qz ± Px ± Bt). Group V, micro-crystalline, distinct from the others by the presence of very sporadic sub-microscopic grains in the matrix.

Semi-quantitative petrographic data-sets showed that the most of the pastes used to make these ancient pots were very homogeneous in composition, confirming previous results from chemical analyses carried out on the same samples.

As shown by the numerous carbonate rock fragments and calcite phenocrysts, maximum firing temperatures did not exceed 600°C.

More than one factor indicated that, in the Arslantepe site, well established production technology for functional ceramic objects existed for specific pot classes and periods.

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RIASSUNTO. — Nell'Alta Valle dell'Eufrate, presso Arslantepe (Malatya, Turchia), scavi sistematici hanno portato alla luce una sequenza quasi ininterrotta, dal periodo Calcolitico (IV millennio a.C.) fino all'età Neo-Ittita (1200-1700 a.C.), di insediamenti stratificati.

Questo lavoro tratta della caratterizzazione archeometrica ed archeologica di oltre 200 oggetti ceramici, diversi per tipologia, funzione e cronologia, reperiti nel sito di Arslantepe.

Le indagini petrografiche hanno permesso di suddividere i reperti ceramici in gruppi tra loro differenti usando quale elemento discriminante la tipologia delle fasi cristalline e, subordinatamente litiche, presenti negli impasti argillosi. Tale metodo ha permesso di creare i seguenti gruppi:a) gruppo I (Pl ± Qz ± Ol rossastra ± Kf ± Px ± Bt ± Amph ± Cc); b) gruppo II (Pl ± Qz ± Px ± Amph ± Bt ± Ep); c) gruppo III (Pl ± Qz ± Kf ± Px ± Bt ± Amph ± presenza, seppur rara, di cristalli di granato, zircone, tormalina, olivina, gesso, dolomite, clorite e grandi e frequenti frammenti di rocce vulcaniche di natura basica); d) gruppo IV (Pl ± Qz ± Px ± Bt); e) gruppo V ceramiche a componenti microcristalline.

I dati semiquantitativi ottenuti dall'analisi petrografica confrontati, mediante analisi multivariate, con i risultati raggiunti su base archeologica (cronologia dei reperti e tipo di utilizzazione) hanno evidenziato l'esistenza di interessanti corrispondenze. In particolare, le indagini petrografiche dei manufatti hanno permesso di rilevare che, per quelli più antichi, la composizione degli impasti utilizzati è del tutto omogenea confermando precedenti risultati ottenuti per via chimica.

Dalle indagini petrografiche è emersa un'ampia diffusione di frammenti di rocce carbonatiche e di cristalli di calcite; ciò implica che le temperature massime di cottura dei manufatti non hanno superato i 600°C.

L'insieme dei dati acquisiti ha permesso di ipotizzare l'esistenza di conoscenze tecnologiche artigiane che per alcuni periodi e/o tipologie prescindevano dalla qualità della materia prima.

KEY WORDS: *Pottery, Arslantepe, petrography, archaeological data, multivariate analyses.*

INTRODUCTION AND ARCHAEOLOGICAL HISTORY OF SITE

An Italian team investigated the archaeological site of Arslantepe, in the high Euphrates Valley (Eastern Anatolia; Fig. 1) since 1961. The excavations, covering about 5 hectares, have brought to light an almost uninterrupted sequence of settlements from the Chalcolithic (IV mill. BC) to neo-Hittite periods (1200-700 BC). Some remains from the Roman-Byzantine and Islamic periods have also been found in the same site.

The large number of settlements is clearly related to favourable conditions for agriculture, in an alluvial plain rich in springs and watercourses. Excavations revealed that the Arslantepe site played a central political and economic role in the region, controlling surrounding territories and relationships with other Near East regions.

The production of ceramic objects involves several processes, from obtaining raw materials to completing finished objects subjected to the action of heat. These operations, which make up one aspect of the production technology, have been transformed in many ways over time and have changed from area to area. From the archaeological point of view, to better define the historical and social-economic contexts to which all production belongs, it is important to reconstruct the various periods of the production process. Petrographic analyses elucidate some of these problems, e.g., nature and provenance of clay paste; some variations related to archaeological classes and various periods.

The aims of the present work were: 1) to characterise and classify the nature of the pastes used, on mineralogical and petrographic bases; 2) to verify whether changes in pastes were related to periods, varying production methods, technological transformations aimed at optimising mechanical characteristics, and/or the impossibility of using the same raw materials during different periods. In particular, concerning production methods, mineralogical and petrographic studies aimed at ascertaining firing temperatures and identifying the nature of any surface treatments.

During the first historical period, the Arslantepe settlement was closely linked with Mesopotamian culture and events. The Late Chalcolithic (period VII) currently represents the oldest documented period, during which the formation of a local *élite* and the organisation of «mass-produced pottery» both developed (*chaff*: TGC; Tab. 1, Photo 1). These processes reached their peak during the following period (VI A; Fig. 2) when Arslantepe played a very important role in the birth and development of the first state organisation (end of IV mill.).

During this period (VI A), the emerging picture is that of a stratified society, with monumental buildings and public institutions, with centralised activities and resources in relation to the evolution of the Mesopotamian state (Late Uruk period) but with specific and autonomous features. Close relationships with southern communities were probably managed by the *élite,* resulting in the diffusion of the same models of power organisation. The pottery of this period was mainly produced by wheel (*wheel-made*: TG; Tab. 1, Photo 2), gradually becoming more standardised and refined with respect to that of the previous period and also showing signs of centralised production. This hypothesis is supported by the great development and extensive use of «mass-produced» wheel-thrown bowls (Photo 2). This phenomenon is found in all proto-state Late

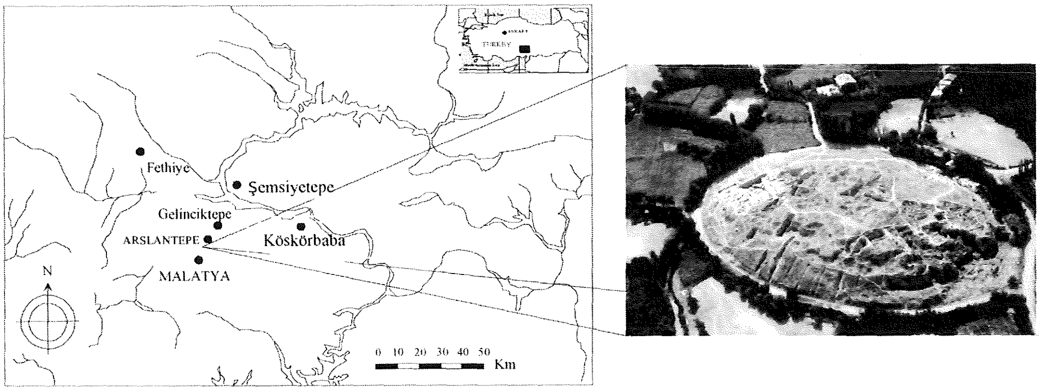

Fig. 1 – a) Location of studied archaeological settlements along Euphrates Valley in Malatya Plain (south-central Anatolia); b) Overview of Arslantepe archaeological site (Malatya, Turkey).

Photo 1 – Arslantepe site. «*Chaff*» production (CHA; for more detail, see Tab. 1) of period VII. Small glass pieces.

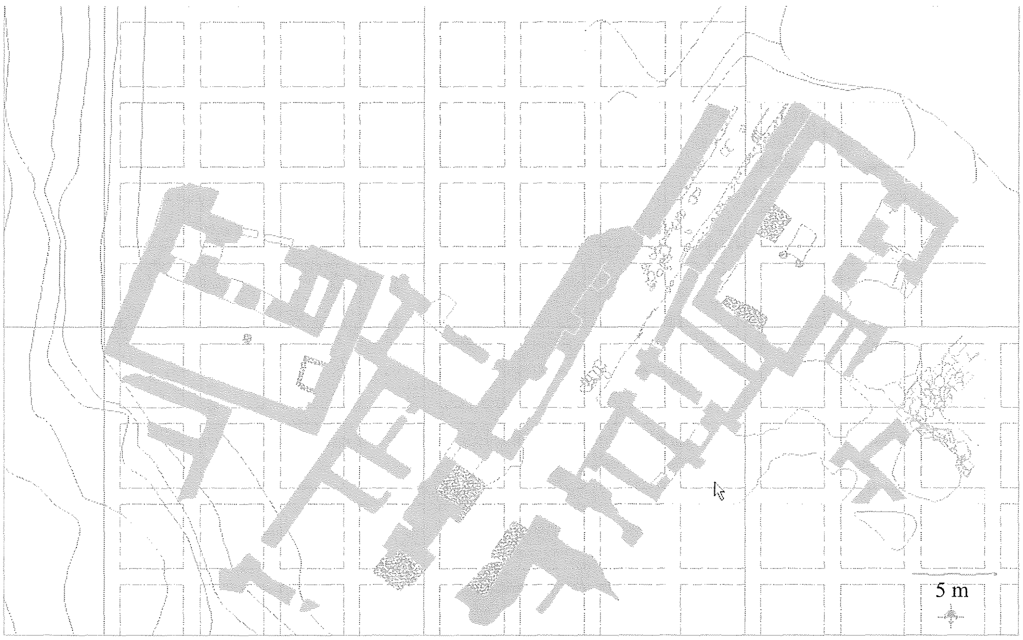

Fig. 2 – Arslantepe site. Map of buildings in level of period VI A.

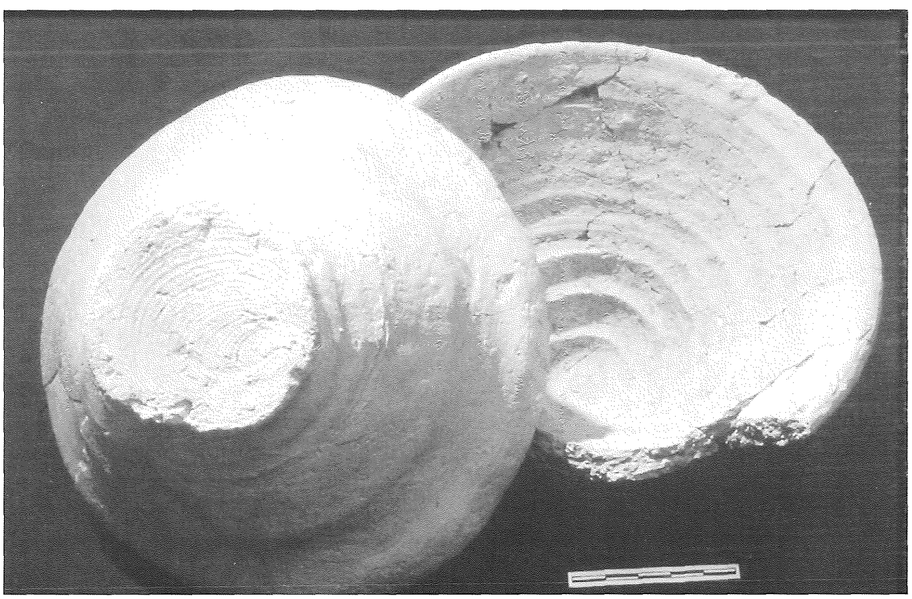

Photo 2 – Arslantepe site. *Wheel-made* production (WHM), period VI A. Bowls (TG; for more detail, see Tab. 1) for food rations («mass-production»).

Uruk contexts and was probably connected with food distribution.

At the end of the Late Uruk period, at Arslantepe all public buildings were destroyed and/or abandoned, relationships with surrounding Mesopotamian areas ended, and the advent of peoples with East-Anatolian/Transcaucasian traditions is noted. All traces of the centralisation typical of the previous social-economic structure disappeared, and profound economic and cultural transformations took place. Both building structures and pottery production radically changed. The latter was hand-made and was only related to the *red-black* production (RN; Photo 3, Tab. 1) typical of Eastern Anatolia and the Transcausus. Later (period VI B2; Fig. 3), Transcaucasian groups retired from the area and the local people repossessed it, but without succeeding in organising themselves politically in a complex way.

Although the characteristic elements (public buildings and «mass production») of the proto-state period definitively disappeared, pottery re-established the tradition of period VI A, retracing both shapes and hand-made methods (*wheel-made*: SFG, TFG, TRG, TFF; see Tab. 1). During period VI C, as a result of local preparation, the Eastern-Anatolian/Transcaucasian tradition re-established itself at Arslantepe, and continued until the end of period VI D, giving rise to small-scale regional aspects.

During this period, the Arslantepe site became a centre of local culture, and its social-economic organisation was inspired by Anatolian models. The re-establishment of

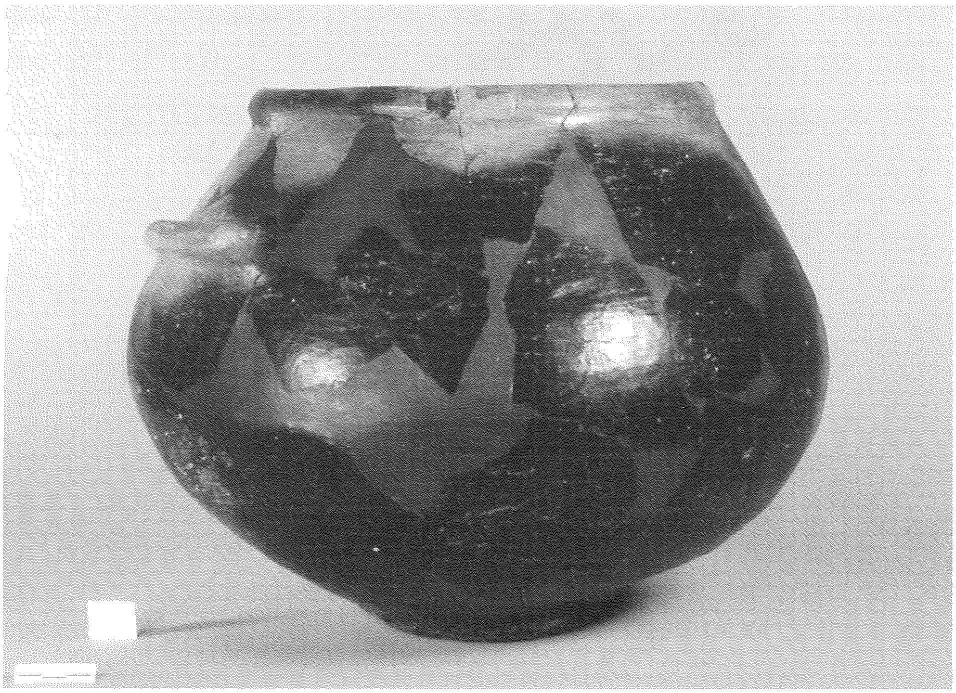

Photo 3 – Arslantepe site. *Red-black* production (RN; for more detail, see Tab. 1) period VI D. Jar with square handle for storing food.

limited forms of urbanisation is totally disconnected from the more ancient Mesopotamian matrix.

Within this scenario, pots, always hand-made, are of two types: i) *red-black* domestic production (RN; Tab. 1) and ii) *painted* pots (DIP; Photo 4, Tab. 1). The latter seem to have been made by specialised potters and circulated throughout the Malatya and Elažig regions (Frangipane & Palmieri, 1987; Conti & Persiani 1993; Frangipane, 1993, 1997).

ARCHAEOLOGICAL DATA AND SAMPLE TYPES

Selected samples (Table 1) are representative of archaeological classes (defining several features such as paste type and surface treatment) belonging to different chronological periods. The various functions of both ceramic classes (serving vessels, kitchenware, etc.) and of the buildings from which they come (food stores, place of worship, houses, etc.) were also examined.

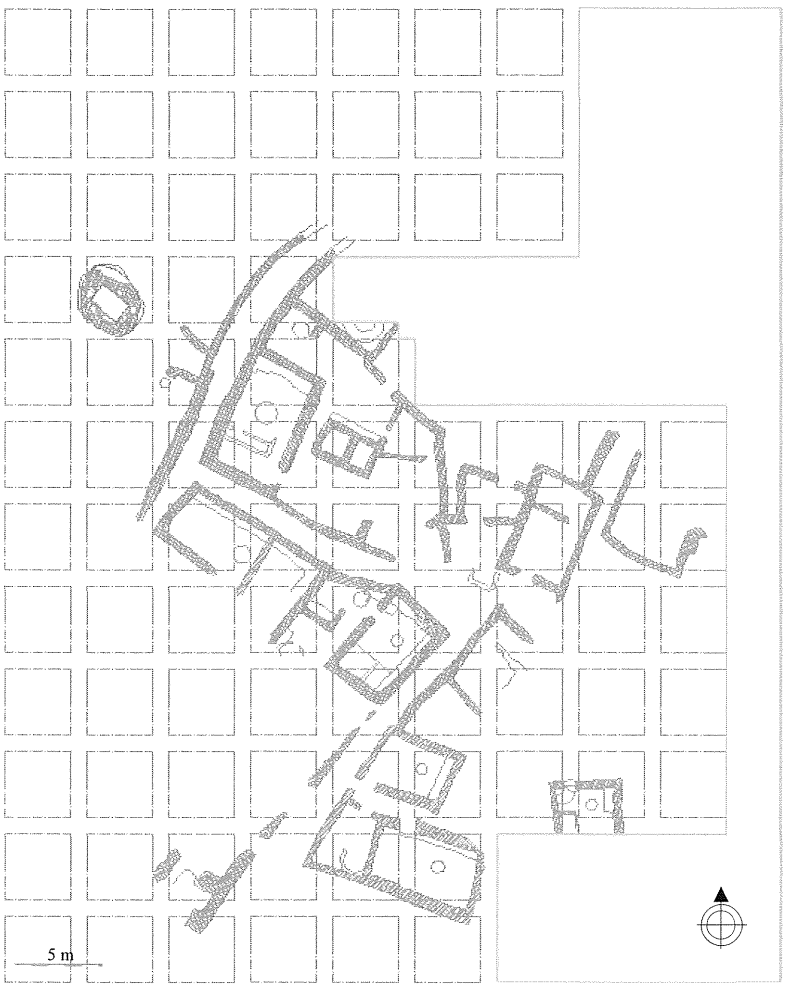

Fig. 3 – Arslantepe site. Map of buildings in level of period VI B2.

Photo 4 – Arslantepe site. *Painted* production (DIP; for more detail, see Tab. 1), period VI D. Jar with spout for serving liquids.

Various classes of pastes were sampled for all identified pots. Characterising factors, like painted surfaces or surface treatments (burnishing, slip), distinguishable by optical examination, were also taken into account during sampling.

Each category contains various samples. A few ceramic materials from other contemporary sites located in the Malatya Plain were also examined for the sake of comparison (Fig. 1, Table 1).

Morphological analyses were carried out macroscopically to attribute samples to the various archaeological classes. Clearly, this traditional method of classification is not sufficient to characterise pots showing similar (i.e., functional) and sometimes persisting shapes (even in different production areas; Tampellini & Mazzeo Saracino, 1999). The sampled ceramic objects were attributed to 16 different classes (Table 1) from five sites (Tab. 1; Arslantepe = ARS, Köskörbaba = KOS, Gelinciktepe = GEL, Fethyie = FET, Şemsiyetepe = SM) and cover six chronological periods (Table 2).

Experimental methods and data processing

A total of 205 samples were selected from more than 900 ceramic objects coming from structures and levels belonging to the various chronological periods of the Malatya Plain sites. Pottery fragments mainly come from Arslantepe, because this site has been systematically investigated since 1961. Forty-six samples were also taken from other sites along the high Euphrates Valley, in order to highlight any differences in paste compositions.

Sample analyses started with petrographic and mineralogical studies on thin sections oriented perpendicularly to outer surfaces.

TABLE 1

Malatya Plain archaeological settlements. Semi-quantitative petrographic features of selected samples related to provenance, archaeological ceramic type and chronology. Surface treatments also indicated. PG = petrographic group; Prov = provenance: ARS = Arslantepe; KOS = Köskörbaba; SM = Şemsiyetepe; GEL = Gelinciktepe; FET = Fethiye. Relchr = relative chronology (see Tab. 2); Typ = archaeological type of ceramic: SFG = semi-fine grit; TG = wheel-made grit; SF = semi-fine; TFG = fine wheel-made grit; M. ware = metalware; DIP = painted; RN = red-black; TRG = red wheel-made grit; T IM = foreign wheel-made ceramic; RIB = polished red slip; CT = wheel-made kitchen vessel; TGC = wheel-made grit bowl; CI = slipped kitchen vessel; TFF = very fine wheel-made ware from period VI B2; TFS= very fine wheel-made ware from period VI C; TF = fine wheel-made ware; Typ red = reduced archaeological type: CHA = "chaff"; WHM = wheel-made; OTH = other classes. Sort = sorting: L = low; M = medium; H = high; vL = very low; vH = very high; ML = medium-low; MH = medium-high; Mc = micro-crystalline. Max dim = maximum dimension.

Sample	PG	Prov	Relchr	Typ	Sort	Max dim (mm)	Pl	Qz	Px	Kf	Bt	Ms	Amph	Redd-Ol	Cc	Ep	Ox	Zrn	Grt	Chl	Tur
3	II	ARS	VI B2	TFG	L	0.4	xx	xx	x	x	xxx	x	–	–	xx	x	–	–	–	–	–
8	IV	ARS	VI B2	TFG	H	0.6	–	xx	–	xx	xx	–	x	–	–	–	xx	–	–	–	–
14	IV	ARS	VI B2	TFG	L	0.5	–	xx	–	–	xxx	x	–	–	–	–	–	–	–	–	–
17	III	ARS	VI B2	TFG	v L	0.3	–	–	xx	–	xxx	–	xx	–	–	–	–	x	–	–	–
18	I	ARS	VI B2	TFG	L	0.4	–	xx	xx	–	xxx	–	–	x	–	–	–	x	x	–	–
22	I	ARS	VI B2	SFG	L	0.6	xx	xx	xx	–	xxx	xx	–	x	–	–	–	x	–	–	–
23	I	ARS	VI B2	SFG	v L	2.2	xx	–	–	xxx	xx	–	xx	x	–	–	–	–	–	–	–
24	I	ARS	VI B2	SFG	v L	0.8	xx	xx	x	–	–	x	x	xxxx	xx	–	–	–	–	–	–
26	I	ARS	VI B2	SFG	L	0.8	xxx	xxx	–	–	xx	x	x	xxx	–	–	–	–	–	–	–
30	I	ARS	VI B2	SFG	H	0.7	xx	–	xx	–	–	–	xx	–	–	x	–	–	–	–	–
37	I	ARS	VI B2	SFG	ML	0.3	xxx	xx	xxxx	–	xx	–	x	xx	–	–	x	–	–	–	–
38	I	ARS	VI B2	SFG	ML	0.3	xxx	xxx	xx	xx	x	xx	xx	xx	–	–	–	–	–	–	–
44	IV	ARS	VI B2	TFF	M	0.4	x	xxx	–	–	–	–	–	–	–	–	–	–	–	–	–
46	IV	ARS	VI B2	TFF	H	0.2	–	xx	–	–	–	–	x	–	xx	–	–	–	–	–	–
47	V	ARS	VI B2	TFF	Mc	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48	IV	ARS	VI B2	TFF	L	0.2	x	xx	–	–	–	–	–	–	xxx	–	–	–	–	–	–
50	V	ARS	VI B2	TFF	Mc	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
58	I	ARS	VI B2	TRG	v H	0.8	xxx	xx	xx	xx	x	x	–	xx	–	–	–	–	–	–	–
62	III	ARS	VI B2	TRG	v L	0.6	xxx	–	xx	–	x	x	x	–	x	–	–	–	x	–	–
63	I	ARS	VI B2	TRG	L	0.3	xx	xxx	x	–	x	x	x	x	–	–	–	–	–	–	–
67	IV	ARS	VI B2	TRG	M	0.7	x	xx	xx	–	xxx	xx	x	–	xx	–	–	–	x	x	–
68	IV	ARS	VI B2	RN	v H	4	xx	xxx	–	–	x	x	x	–	–	–	–	–	–	–	–
69	II	ARS	VI B2	RN	H	1.5	xx	–	x	xx	–	x	x	–	x	x	–	–	–	–	–
70	II	ARS	VI B2	RN	H	8	xx	xx	xx	–	–	xx	x	–	x	x	–	–	–	–	–
77	IV	ARS	VI B2	RN	v H	3	xxx	xxx	–	–	–	–	–	–	–	–	–	–	–	–	–
78	II	ARS	VI B2	RN	M	5.5	–	xxx	–	–	x	xx	–	–	x	x	–	–	–	–	–
80	II	ARS	VI B1	RN	L	3.5	–	xx	–	–	x	x	xx	–	–	x	–	–	–	–	x
84	II	ARS	VI B1	RN	M	2	xx	xxx	–	–	xx	xx	xx	–	–	x	–	–	–	–	–
86	II	ARS	VI B1	RN	v L	9	xx	xxx	–	–	xxx	xxx	–	–	x	x	–	–	–	–	–
92	II	ARS	VI B2	RN	M	2.2	–	xxx	–	–	xxx	xx	–	–	x	x	x	–	–	–	–
93	II	ARS	VI B2	RN	M	2.8	xxx	–	–	–	x	xx	xxx	–	x	x	–	–	–	–	–
97	II	ARS	VI B2	RN	v H	2.8	xx	xxx	–	–	xx	xx	xx	–	x	x	–	–	–	–	–
102	II	ARS	VI B2	RN	L	1	x	xx	–	–	x	x	–	–	x	x	–	–	–	–	–
103	IV	ARS	VI B2	RN	v H	2.5	xxxx	xx	xx	–	–	–	–	–	–	–	–	–	–	–	–
105	II	ARS	VI B2	RN	L	1.9	xx	–	–	–	xx	xx	xx	–	x	x	–	–	–	–	–
108	IV	ARS	VI B2	RN	v H	2.2	xxx	xxx	–	–	x	–	–	–	–	–	–	x	–	–	–
111	III	ARS	VI B2	RN	L	0.7	–	xxx	–	–	xxxx	–	–	–	–	–	–	–	–	xxx	–
114	II	ARS	VI B2	RN	L	1.1	xx	xx	–	–	x	x	x	–	x	x	–	–	–	–	–
119	II	ARS	VI B2	RN	H	10	xx	–	–	–	xx	–	–	–	–	x	–	–	–	–	–
120	II	ARS	VI B2	RN	M	6.5	x	x	–	–	xx	x	xx	–	–	–	x	–	–	–	–
121	II	ARS	VI B2	RN	M	5	x	xx	x	–	x	x	–	–	–	x	–	–	–	–	–
123	IV	ARS	VI B2	RN	L	4	xx	xx	–	–	xx	x	xx	–	x	–	x	–	–	–	–
125	IV	ARS	VI B2	RN	v H	1.2	xxxx	xx	xx	–	x	–	–	–	–	–	–	–	–	–	–
126	IV	ARS	VI A	TF	L	0.8	xx	xx	–	–	xx	x	xx	–	–	–	–	–	–	–	–
127	II	ARS	VI A	TF	L	0.6	xxx	xx	x	–	–	x	–	–	x	x	–	–	–	–	–
128	IV	ARS	VI A	TF	M	0.8	xxx	xx	x	–	–	x	xx	–	x	–	–	–	–	–	–
132	IV	ARS	VI A	TF	M	1.3	x	xx	xx	xx	x	x	x	–	–	–	–	–	–	–	–
136	IV	ARS	VI A	TF	M	0.7	xxx	xx	xx	–	xx	x	xx	–	–	–	–	–	–	–	–
144	I	ARS	VI A	TG	ML	0.2	x	x	–	–	–	–	–	x	xxx	–	–	–	–	–	–
145	IV	ARS	VI A	TG	M	1.6	xx	x	–	–	–	xx	–	–	x	–	–	–	–	–	–

Symbols for rock-forming minerals from Kretz (1983): Pl = plagioclase; Qz = quartz; Px = pyroxene; Kf = K-feldspar; Bt = biotite; Ms = muscovite; Amph = amphibole; Redd Ol = reddish olivine; Cc = calcite; Ep = epidote; Ox = Fe-Ti oxides; Zrn = zircon; Grt = garnet; Chl = chlorite; Tor = tormaline; Srp = serpentine; Dol = dolomite; Gp = gypsum. Vf = vegetable fibres; Foss = fossils; volc = volcanic rock fragments; met = metamorphic rock fragments; carb = carbonatic rock fragments; Cham = chamotte.
T before each abbreviation: mineral or rock fragments occurring as temper. - = under detection limit; X = scarce; XX = frequent; XXX = abundant; XXXX = very abundant. Surf treat = surface treatment: IP = inner polishing; IS = inner slip; EP = outer polishing; ES = outer slip; IPS = inner polishing and slip; EDIP = outer painting; IDIP = inner painting; ESDIP = outer slip and painting; ISDIP = inner slip and painting; IPDIP = inner polishing and painting.

Ol	Srp	Dol	Gp	VF	Foss	Surf treat	TMax dim (mm)	Tvolc	Tmet	Tcarb	Cham	TPl	TQz	TPx	TKf	TBt	TMs	TAmph	Tredd Ol	TCc	TChl
–	–	–	–	–	x	ES+IPS	0.4	–	–	x	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	x	IP+IS	0.6	–	x	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.5	–	–	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.3	x	x	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.4	x	–	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	x	–	0.6	x	–	x	–	x	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	2.2	x	x	–	–	–	–	–	x	–	–	–	x	–	–
–	–	–	–	–	–	–	0.8	–	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.8	x	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.7	x	x	x	–	–	–	–	–	x	–	–	x	–	–
–	–	–	–	–	–	–	0.3	–	–	x	–	x	x	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.3	x	–	x	–	x	x	–	–	–	–	–	x	–	–
–	–	–	–	–	x	IP+EP	0.4	–	x	–	–	–	–	x	–	–	–	–	x	–	–
–	–	–	–	–	x	IS	0.2	–	–	–	–	–	x	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	IS	0.2	–	x	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	EDIP	0.8	–	–	x	–	x	x	–	x	x	–	–	x	–	–
–	–	–	–	–	–	IS+ES	0.6	x	x	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	IS+ES	0.3	–	–	–	–	x	–	–	–	–	x	–	x	–	–
–	–	–	–	–	x	EDIP	0.7	–	x	–	x	–	–	–	–	–	–	x	–	x	–
–	–	–	–	x	x	ES	4.0	x	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	1.5	x	–	–	–	–	–	x	x	–	–	x	–	–	–
–	–	–	–	x	–	–	8.0	x	x	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	ES	3.0	x	x	–	–	–	x	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	5.5	x	x	x	–	–	–	–	–	x	–	–	–	–	–
–	–	–	–	x	–	–	3.5	–	x	–	–	–	–	–	–	–	–	x	–	–	–
–	–	–	–	x	–	–	2.0	–	x	–	–	–	x	–	–	–	–	–	–	–	–
–	–	–	–	x	–	ES+EDIP	9.0	x	x	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	2.2	–	x	–	–	–	–	–	–	–	–	x	–	–	–
–	–	–	–	x	–	IS	2.8	x	x	–	–	–	–	–	–	–	x	–	–	–	–
–	–	–	–	x	–	ES	2.8	–	x	–	–	–	–	–	–	x	–	–	–	–	–
–	–	–	–	x	–	ES	1.0	x	–	–	–	x	–	–	x	–	–	–	–	–	–
–	–	–	–	x	–	–	2.5	x	–	–	–	x	–	x	–	–	–	–	–	–	–
–	–	–	–	x	–	IS	1.9	x	x	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	2.2	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.7	–	x	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	1.1	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	10.0	x	x	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	6.5	x	x	–	–	–	–	–	x	–	–	–	–	–	–
–	–	–	–	x	–	–	5.0	–	x	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	ES	4.0	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	ES+IP	1.2	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	x	–	0.8	x	–	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	EP	0.6	x	–	–	–	x	x	–	–	x	–	–	–	–	–
–	–	–	–	–	–	IP+ES	0.8	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	1.3	x	–	–	x	x	–	–	xx	–	–	–	–	–	–
–	–	–	–	–	–	IP	0.7	x	–	–	–	x	x	–	–	–	x	–	–	–	–
–	–	–	–	x	–	–	0.2	x	–	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	x	–	1.6	–	x	–	–	–	–	–	–	x	–	–	–	x	–

TABLE 1: *Continued*

Sample	PG	Prov	Relchr	Typ	Sort	Max dim (mm)	Pl	Qz	Px	Kf	Bt	Ms	Amph	Redd Ol	Cc	Ep	Ox	Zrn	Grt	Chl	Tur
146	II	ARS	VI A	TG	H	2.2	xx	xx	–	–	x	x	xx	–	–	x	–		–	–	–
151	IV	ARS	VI A	TG	v L	0.2	–	x	–	–	–	–	–	–	xx	–	–	–	–	–	–
156		ARS	VI A	TG	H	1.1	xx	xx	–	–	–	x	–	–	–	–	–	–	–	–	–
163	I	ARS	VI A	TG	H	.8	xx	xx	–	–	x	–	x	x	–	–	x	–	–	–	–
173	IV	ARS	VI A	SF	H	1.9	xxx	xx	x	–	x	x	x	–	–	–	–	–	–	–	–
175	IV	ARS	VI A	SF	ML	1	x	xx	–	–	–	–	xx	–	–	–	x	–	–	–	–
177	IV	ARS	VI A	SF	v H	1.7	x	x	–	–	x	x	x	–	x	–	–	–	–	–	–
180	IV	ARS	VI A	SF	L	2.7	xxx	xx	x	–	xxx	xx	x	–	–	–	–	–	–	–	–
181	I	ARS	VI A	SF	ML	0.8	xxx	xxx	–	–	xx	–	xxx	x	–	–	–	–	–	–	–
187	II	ARS	VI A	RN	v H	2.4	xx	xxxx	–	–	xxx	–	x	–	–	x	–	–	–	–	–
191	II	ARS	VI A	RN	v H	2.2	xxxx	xx	x	x	–	–	x	–	–	x	–	–	–	–	–
192	III	ARS	VI A	RN	H	2.5	xx	xx	xx	–	xx	x	x	–	xx	–	–	–	–	–	–
199	IV	ARS	VI A	RN	M	0.7	–	xx	–	–	x	xx	–	–	–	–	–	–	–	–	–
209	IV	ARS	VI A	RN	v H	0.8	xxxx	xx	–	–	xx	–	x	–	x	–	–	–	–	–	–
211	I	ARS	VI A	RN	v H	9	xx	xx	–	–	xx	xx	–	x	–	x	–	–	–	xxx	–
212	II	ARS	VI A	RN	L	1.5	xx	xx	x	–	x	–	x	–	x	x	x	–	–	xxx	–
229	IV	ARS	VI A	SF	ML	1.2	xx	xx	x	–	–	–	–	–	–	–	–	–	–	–	–
230	IV	ARS	VI A	SF	H	1	xx	xx	x	xx	–	–	–	–	–	–	–	–	–	–	–
232	IV	ARS	VI A	TF	H	2	xxx	x	x	xx	–	–	–	–	–	–	–	–	–	–	–
234	IV	ARS	VI A	SF	H	3	xxx	x	xx	–	–	–	–	–	x	–	–	–	–	–	–
235	I	ARS	VI A	TF	ML	0.3	xx	xxxx	–	–	–	–	x	x	–	–	–	–	–	–	–
250	I	ARS	VI A	TF	ML	0.3	xx	xxx	–	–	xx	–	xx	xx	x	–	–	–	–	–	–
250	I	ARS	VI A	TFG	L	0.6	xx	xx	xx	–	xx	xx	x	xxx	x	x	–	–	–	–	–
251	I	ARS	VI A	TF	ML	0.4	x	x	–	–	x	–	x	x	–	–	–	–	–	–	–
251	I	ARS	VI A	TFG	H	0.9	xx	x	–	–	x	x	–	x	xx	x	–	–	–	–	–
271	IV	ARS	VI A	SF	ML	1	xx	xx	xx	–	–	–	xx	–	–	–	x	–	–	–	–
275	I	ARS	VI A	SF	ML	0.3	xx	xx	–	–	–	–	x	x	–	–	–	–	–	–	–
291	I	GEL	VI C	DEP	M	0.8	xxx	xx	xxx	–	xx	xx	xxx	xxxx	–	–	–	–	x	–	–
292	I	ARS	VI C	DEP	L	0.9	x	–	–	xx	x	x	–	x	–	–	–	–	–	–	–
293	II	ARS	VI C	DEP	v H	0.8	x	xxx	–	x	xx	x	–	–	x	x	x	–	–	–	–
294	IV	ARS	VI C	DEP	L	0.9	xx	xxx	–	–	xx	x	x	–	x	–	–	–	–	–	–
305	II	GEL	VI C	RN	v H	1.2	–	xxx	xx	–	xx	xx	–	–	xx	x	–	–	–	–	–
306	IV	ARS	VI C	RN	L	1.5	xx	xxx	x	–	x	x	–	–	xx	–	–	–	–	–	–
307	II	ARS	VI C	RN	H	1.7	xx	xx	xx	x	xx	x	x	–	x	x	–	–	–	–	–
310	IV	ARS	VI D1A	DEP	L	1.5	xxxx	xxx	x	–	xx	–	xx	–	–	–	–	–	–	–	–
319	I	KOS	VI D1A	DEP	H	0.6	–	xx	xx	xx	xx	x	x	xx	–	x	–	–	–	–	–
320	I	KOS	VI D1A	DEP	H	0.8	x	xx	xx	xx	xx	x	x	xx	xx	x	–	–	–	–	–
321	I	SM	VI D1A	DEP	L	0.8	x	xx	xx	–	x	x	–	xx	–	x	x	x	–	–	–
323	I	SM	VI D1A	DEP	v H	0.8	xx	x	xx	–	x	x	x	x	xx	–	–	–	–	–	–
325	I	SM	VI D1A	DEP	L	0.6	x	x	x	–	x	–	–	xx	x	–	–	–	–	–	–
334	IV	SM	VI D1	RN	H	1.5	xxxx	xx	xxx	–	–	–	xx	–	–	–	–	–	–	–	–
344	IV	KOS	VI D1	RN	v H	2.1	xx	x	–	–	–	–	–	–	–	–	–	–	–	–	–
348	II	KOS	VI D1	RN	v H	2.2	x	xx	–	–	–	–	x	–	x	x	–	–	–	–	–
349	I	ARS	VI D1	DEP	v L	0.7	xx	xxx	–	xx	xx	xx	x	xxx	–	–	–	–	–	–	–
350	I	ARS	VI D1b	DEP	M	0.7	xx	xx	xx	xx	xx	–	x	xxxx	–	–	–	–	–	–	–
352	I	KOS	VI D1A	DEP	H	0.7	–	xx	x	xx	x	–	x	xx	xxx	x	–	–	–	–	–
354	I	KOS	VI D1b	DEP	H	0.7	x	–	xx	xx	xx	–	xx	xx	x	x	–	–	–	–	–
355	I	KOS	VI D1b	DEP	L	0.8	x	x	xx	xxx	x	x	xx	xxx	xxx	x	–	–	–	–	–
361	I	KOS	VI D1b	DEP	M	2.5	x	x	–	xxx	xx	x	–	–	–	–	–	–	–	–	–
362	I	KOS	VI D2	DEP	M	0.5	x	x	xx	xx	xx	x	x	xxx	xx	–	–	–	–	–	–
364	I	SM	VI D2	DEP	v H	1.3	xx	x	xx	xxx	xx	xx	x	xx	xx	x	–	–	–	–	–
365	I	ARS	VI D3	DEP	M	1.5	xxx	xxx	x	x	xxx	–	x	xx	–	–	–	–	–	–	–
370	I	KOS	VI D3a	DEP	M	0.6	–	xx	x	xx	xxx	xx	x	xx	xxx	–	–	–	–	–	–
371	I	KOS	VI D2	DEP	M	0.6	–	–	xx	xx	x	–	x	xx	xx	–	–	–	–	–	–
373	I	SM	VI D2	DEP	H	1	x	xx	x	–	xx	x	x	xx	xx	–	x	–	–	–	–
377	I	KOS	VI D2	DEP	M	0.5	xx	xx	–	–	xx	x	x	xx	–	x	–	–	–	–	–
381	I	FET	VI D3	DEP	H	0.8	x	x	xx	xx	xx	–	x	x	xx	–	–	–	–	–	–
383	II	ARS	VI D3	DEP	v H	0.5	xx	xx	xx	–	xx	xx	xx	–	xx	x	–	–	–	–	–
384	I	ARS	VI D3a	DEP	L	2	xxx	xxx	–	–	xx	x	x	x	–	–	–	–	x	–	–
388	I	SM	VI D2	DEP	L	0.8	x	x	xx	–	x	–	–	x	xx	–	–	x	–	–	–
392	I	KOS	VI D2	DEP	v H	0.9	xx	xx	x	–	x	x	x	x	x	x	–	–	–	–	–
393	I	KOS	VI D2	DEP	L	0.7	x	x	x	–	–	x	x	x	x	–	–	–	–	–	–
394	I	KOS	VI D3a	DEP	H	0.7	x	–	x	xxx	x	x	x	x	xx	x	–	–	–	–	–
395	I	KOS	VI D2	DEP	L	0.5	x	xxx	xx	–	x	x	x	xx	x	x	–	–	–	–	–
396	I	KOS	VI D3	DEP	H	0.7	xx	x	x	–	x	–	x	x	xxxx	–	–	–	–	–	–
397	II	ARS	VI D2	RN	v H	1.5	xxx	xxxx	–	–	x	–	x	–	x	x	–	–	x	–	–

Ol	Srp	Dol	Gp	VF	Foss	Surf treat	TMax dim (mm)	Tvolc	Tmet	Tcarb	Cham	TPl	TQz	TPx	TKf	TBt	TMs	TAmph	Tredd Ol	TCc	TChl
–	–			x	–	–	2.2	x	–	x	–	x	–	–	x	–	–	–	–	–	–
–	–	–	–	x	–	–	0.2	–	–	–	–	–	–	–	–	–	–	–	–	x	–
–	–	–	–	x	x	–	1.1	–	–	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	IS	0.0	x	–	–	–	x	–	–	–	–	–	–	x	–	–
–	–	–	–	–	x	EP	1.9	x	–	–	–	x	–	–	x	–	–	–	–	–	–
–	–	–	–	x	–	–	0.1	x	–	–	–	x	–	–	–	x	–	–	–	–	–
–	–	–	–	x	x	EP	1.7	x	–	–	–	–	x	–	–	–	–	–	–	x	–
–	–	–	–	–	–	IP+ES	2.7	–	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.8	x	–	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	–	ES	2.4	–	x	–	–	–	–	–	–	–	–	x	–	–	–
–	–	–	–	x	–	ES	2.2	–	–	x	–	x	–	–	–	–	–	–	–	–	–
x	–	–	–	–	x	–	2.5	x	–	x	–	–	–	–	x	–	–	–	–	–	–
–	–	–	–	x	x	IP	0.7	–	–	–	–	–	x	–	–	–	x	–	–	–	–
–	–	–	–	x	–	ES	0.8	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	9.0	–	–	–	x	–	x	–	–	–	–	–	x	–	x
–	–	–	–	x	–	–	1.5	–	x	–	–	–	–	–	–	–	–	–	–	x	x
–	–	–	–	–	–	–	1.2	x	–	x	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	1.0	x	–	–	–	x	x	–	–	–	–	–	–	–	–
–	–	–	–	x	x	–	2.0	x	x	–	–	x	–	–	x	–	–	–	–	–	–
–	–	–	–	x	–	–	0.0	x	–	–	–	x	x	–	–	–	–	–	–	–	–
–	–	–	–	–	x	–	0.3	–	–	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.3	–	–	x	–	x	–	–	–	–	–	–	x	–	–
x	–	–	–	–	x	–	0.6	–	x	x	–	–	x	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.4	–	x	x	–	–	–	x	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.9	x	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	–	–	1.0	x	x	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.3	x	–	–	–	x	x	–	–	–	–	–	x	–	–
–	–	–	–	–	–	EDIP	0.8	x	–	x	–	x	–	–	–	–	–	–	x	–	–
–	–	–	–	x	–	IS+ESDIP	0.9	–	x	x	–	–	–	–	–	x	–	–	x	–	–
–	–	–	–	x	x	–	0.8	–	x	x	–	–	–	–	–	–	–	–	–	x	–
–	–	–	–	–	–	IP	0.9	x	x	x	–	–	–	–	x	–	–	x	–	–	–
–	–	–	–	x	–	–	1.2	–	x	–	–	–	x	–	–	–	–	x	–	x	–
–	–	–	–	x	x	–	1.5	–	–	x	x	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	1.7	–	x	–	x	–	x	x	–	–	–	–	–	–	–
–	–	–	–	x	–	–	1.5	–	–	–	–	x	–	–	x	–	–	–	–	–	–
–	–	–	–	–	–	EDIP	0.6	x	x	x	–	x	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	ESDIP	0.8	x	x	x	–	x	–	–	–	–	–	x	x	–	–
x	–	–	–	–	–	EDIP	0.8	x	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	x	EPDIP	0.8	–	x	x	–	x	–	–	–	–	–	x	x	x	–
x	–	–	–	–	–	IPDIP	0.6	–	x	x	–	–	–	–	–	x	–	–	x	–	–
x	–	–	–	x	–	–	1.5	x	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	EP	2.1	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	2.2	–	–	x	x	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	x	–	0.7	x	x	x	–	–	–	–	–	–	–	x	x	–	–
–	–	–	–	–	–	ESDIP	0.7	–	x	x	–	–	–	x	–	–	–	–	x	–	–
–	–	–	–	–	–	EDIP	0.7	–	–	x	–	x	–	–	–	–	–	–	x	–	–
x	–	–	–	–	–	EPDIP	0.7	–	–	x	–	–	x	–	–	–	–	x	x	–	–
x	–	–	–	–	–	IDIP	0.8	x	–	x	–	–	x	–	x	–	–	x	x	–	–
–	–	–	–	x	–	IDIP	1.8	–	x	–	x	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	–	ISDIP	0.8	–	x	x	–	x	–	–	–	x	–	x	x	–	–
x	–	–	–	–	–	ISDIP	0.7	x	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	EDIP	1.5	–	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	–	ESDIP	0.6	x	–	x	–	x	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	EDIP	0.6	–	–	x	–	–	x	–	x	–	–	x	x	–	–
x	–	–	–	–	x	EDIP	1.0	–	x	x	–	x	x	–	–	–	–	x	x	–	–
–	–	–	–	–	–	ESDIP+IP	0.5	x	–	x	–	x	x	x	–	–	–	x	x	–	–
x	–	–	–	–	x	–	0.8	x	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	x	IS+IPDIP	0.5	–	x	–	–	–	–	–	–	–	–	–	–	x	–
–	xx	–	–	x	–	ESDIP	2.0	–	x	–	–	x	x	–	–	–	–	–	x	–	–
x	–	–	–	–	–	ESDIP	0.8	x	x	–	–	–	–	–	–	–	–	x	x	–	–
–	–	–	–	x	–	ESDIP	0.9	x	–	–	–	x	x	–	x	–	–	–	x	–	–
–	–	–	–	x	–	ESDIP	0.7	x	x	–	–	x	x	–	–	–	–	–	x	–	–
–	–	–	–	x	–	–	0.7	x	–	x	–	x	x	–	–	–	–	–	x	–	–
x	–	–	–	x	–	–	0.5	–	–	–	–	x	x	–	–	–	–	x	x	–	–
–	–	–	–	–	x	–	0.7	–	–	x	–	x	x	–	x	–	–	x	x	–	–
–	–	–	–	x	–	–	1.5	x	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE 1: *Continued*

Sample	PG	Prov	Relchr	Typ	Sort	Max dim (mm)	Pl	Qz	Px	Kf	Bt	Ms	Amph	Redd Ol	Cc	Ep	Ox	Zrn	Grt	Chl	Tur
399	III	KOS	VI D2	RN	H	1.6	–	xx	–	x	–	–	–	–	–	x	x	x	–	xxx	x
400	IV	KOS	VI D2-3	RN	L	3.5	xxxx	xxx	x	–	xx	–	x	–	–	–	–	–	–	–	–
404	IV	FET	VI D2-3	RN	H	2.8	xxxx	xxxx	xx	x	xxx	x	xx	–	–	–	–	–	–	–	–
405	III	ARS	VI D2	RN	v H	1.6	xxx	xxx	x	–	xx	–	x	–	x	–	–	x	–	–	–
406	II	ARS	VI D2-3	RN	v H	1.2	xx	xx	–	xxx	xx	–	x	–	–	x	–	–	–	–	–
412	III	ARS	VI D2-3	RN	L	2.5	xx	x	–	–	–	xxx	xx	–	–	x	–	–	–	x	–
413	IV	KOS	VI D2-3	RN	v H	1.8	xxx	xxx	–	–	xxx	–	x	–	xxx	–	–	–	x	–	–
414	I	ARS	VI D2-3	RN	L	2.1	xx	xxxx	xx	–	xx	–	xx	x	–	–	–	–	–	–	–
415	IV	ARS	VI D2-3	RN	L	1.4	xx	xxx	–	–	xx	–	xx	–	xxx	–	–	–	–	–	–
418	IV	SM	VI D2-3	RN	v H	1.3	xxxx	xxx	x	x	xx	x	xx	–	–	–	x	–	–	–	–
419	IV	KOS	VI D2-3	RN	M	2	x	–	–	xxx	–	x	x	–	–	–	–	–	–	–	–
421	IV	KOS	VI D2-3	RN	M	1.5	xxx	xxx	xx	–	xxx	–	xx	–	–	–	–	–	–	–	–
422	IV	KOS	VI D2-3	RN	v H	1.7	xxx	xx	–	–	xx	–	x	–	–	–	–	–	–	–	–
429	I	ARS	VI D3b	DEP	M	0.6	x	xxx	xx	–	xx	x	xx	xxx	xx	–	–	–	–	–	–
433	I	KOS	VI D3b	DEP	H	0.7	xx	xx	xx	–	–	–	–	xxx	x	–	–	–	–	–	–
434	I	ARS	VI D2	DEP	L	0.6	x	xxxx	x	–	xx	–	xx	xxx	x	–	–	–	–	–	–
450	I	ARS	VI D	DEP	v H	0.9	xx	xx	–	–	x	–	x	x	xx	x	–	–	–	–	–
452	I	ARS	VI D2-3	T IM	v L	0.8	xx	xx	x	–	x	x	x	x	xx	–	–	–	–	–	–
455	I	ARS	VI D2-3	T IM	H	0.5	x	xx	x	–	x	–	x	x	xxx	–	–	–	–	–	–
458	I	ARS	VI D2-3	T IM	v L	0.8	–	xxx	x	–	x	x	x	xxx	xx	x	–	–	–	–	–
460	I	SM	VI D	DF	H	0.9	xx	x	xx	xx	x	x	x	x	xxx	–	–	–	–	–	–
462	I	ARS	VI D3	DEP	H	0.6	x	xxx	xx	–	xx	x	x	xxx	–	x	–	–	–	–	–
470	II	ARS	VII	RIB	H	0.8	xx	xx	xx	–	x	x	x	–	–	x	–	–	–	–	–
471	IV	ARS	VII	RIB	H	0.9	xx	xx	x	–	x	–	x	–	x	–	–	–	–	–	–
472	IV	ARS	VII	RIB	H	0.8	xx	xx	xx	–	x	–	x	–	x	–	–	–	–	–	–
473	IV	ARS	VII	RIB	H	0.9	xx	xx	xxx	x	–	–	–	–	x	–	–	–	–	–	–
474	IV	ARS	VII	RIB	L	1	xxx	x	x	–	x	x	–	–	xxx	–	–	–	–	–	–
475	I	ARS	VII	RIB	v H	0.7	x	x	–	–	–	x	–	x	xxx	–	–	–	–	–	–
476	III	ARS	VII	RIB	H	3	x	x	–	–	–	x	–	–	x	–	–	–	–	–	–
479	I	ARS	VII	RIB	v H	1.2	x	x	–	–	x	x	–	x	xx	–	–	–	–	–	–
480	IV	ARS	VII	RIB	L	1.2	x	xx	–	–	–	x	xx	–	xx	–	–	–	–	–	–
484	III	ARS	VII	RIB	H	1.2	x	x	–	–	–	x	–	–	xx	–	–	–	–	–	–
486	IV	ARS	VII	RIB	M	1.4	x	x	x	–	x	x	–	–	xx	–	–	–	–	–	–
487	II	ARS	VII	RIB	v H	2.5	x	xx	xx	–	–	x	–	–	xx	x	–	–	–	–	–
491	IV	ARS	VII	RIB	M	1.5	xxxx	xx	xx	–	–	x	xx	–	xxx	–	–	–	–	–	–
492	IV	ARS	VII	RIB	L	1.6	xxxx	xx	x	–	–	x	–	–	xx	–	–	–	–	–	–
494	IV	ARS	VII'	RIB	L	2.5	xxx	xx	x	xx	–	–	x	–	xx	–	–	–	–	–	–
497	IV	ARS	VII	RIB	M	2.8	xx	x	xx	xx	x	–	–	–	x	–	–	–	–	–	–
498	IV	ARS	VII	RIB	M	2.5	xxx	xx	xx	xx	x	x	x	–	x	–	–	–	–	–	–
500	I	ARS	VII	RIB	v H	3.6	xxx	xx	x	x	x	–	x	x	x	–	–	–	–	–	–
501	IV	ARS	VII	RIB	H	2.5	xxx	xx	xx	x	x	x	x	–	–	–	–	–	–	–	–
504	IV	ARS	VII	RIB	M	3.6	xx	xx	xx	x	x	x	–	–	xxx	–	–	–	–	–	–
505	IV	ARS	VII	CT	M	2	xx	xx	–	–	–	x	x	–	x	–	–	–	–	–	–
508	II	ARS	VII	CT	H	4	xx	xx	–	–	x	x	xx	–	xx	x	–	–	–	–	–
509	V	ARS	VII	CT	L	2.5	–	–	xx	–	–	–	–	–	–	–	–	–	–	–	–
510	IV	ARS	VII	CI	L	4	xxx	xxx	x	–	–	–	xx	–	x	–	–	–	–	–	–
513	IV	ARS	VII	TGC	L	2.5	xx	xx	xx	–	xx	x	x	–	x	–	–	–	–	–	–
514	IV	ARS	VII	TGC	H	10	xxxx	xx	x	–	–	–	xx	–	x	–	–	–	–	–	–
515	IV	ARS	VII	TGC	H	1	x	xx	xx	–	x	–	x	–	x	–	–	–	–	–	–
517	II	ARS	VII	TGC	L	2	xxxx	xx	x	–	–	–	xxx	–	xxx	x	–	–	–	–	–
520	IV	ARS	VII	TGC	H	1.8	x	x	x	–	x	x	–	–	xx	–	–	–	–	–	–
522	II	ARS	VII	TGC	L	0.8	–	xx	–	–	–	–	x	–	xx	x	–	–	–	–	x
523	IV	ARS	VII	TGC	M	0.6	–	xx	x	–	x	x	x	–	xx	–	–	–	–	–	–
527	I	GEL	VI C	DEP	v H	0.9	xx	xx	–	xx	x	x	x	xx	xxx	–	–	–	–	–	–
529	I	GEL	VI C	DEP	v H	0.8	xx	xx	xx	xx	–	–	–	xx	xx	–	–	–	–	–	–
531	I	GEL	VI C	DEP	H	3.2	xx	x	xx	xx	x	x	xx	xxxx	xx	–	–	–	–	–	–
533	I	GEL	VI C	DEP	v L	2	–	xxx	–	–	x	x	x	xxx	xxx	–	–	–	–	–	–
534	V	GEL	VI C	TFS	v L	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
535	V	ARS	VI C	TFS	Mc	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
539	V	ARS	VI C	TFS	v L	1.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
541	V	ARS	VI C	TFS	v L	0.1	xx	–	–	–	–	–	–	–	xxx	–	–	–	–	–	–
544	II	GEL	VI C	RN	M	1.8	x	xx	x	xx	x	–	x	–	xxx	x	–	–	–	–	–
545	IV	GEL	VI C	RN	M	2.7	xxx	xxxx	x	–	x	–	–	–	–	–	–	–	–	–	–
546	II	GEL	VI C	RN	M	2.5	xx	xx	–	–	x	x	xxx	–	–	x	–	–	–	–	–
547	IV	GEL	VI C	RN	L	0.7	xx	xxx	–	xx	x	x	x	–	xx	–	–	–	–	–	–
638	I	ARS	VI A	SF	v L	0.4	xxx	xx	x	–	xx	x	x	x	–	–	–	–	–	–	–

Ol	Srp	Dol	Gp	VF	Foss	Surf treat	TMax dim (mm)	Tvolc	Tmet	Tcarb	Cham	TPl	TQz	TPx	TKf	TBt	TMs	TAmph	Tredd Ol	TCc	TChl
–	–	–	–	x	–	–	1.6	–	x	–	–	–	–	–	–	x	–	x	–	–	x
–	–	–	–	–	–	EPS+IP	3.5	–	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	IS	2.8	x	x	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	–	1.6	x	x	–	–	x	–	x	–	–	x	–	–	–	–
–	–	–	–	–	–	ES+IPSIS+ES+engraving	1.2	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	x	–	–	x	–	ES	2.5	x	x	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	x	ES	1.8	–	–	x	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	x	ES	2.1	x	–	–	–	x	–	–	x	–	–	–	x	–	–
–	–	–	–	–	x	ES	1.4	x	–	x	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	–	1.3	–	–	x	–	x	x	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	2.0	x	x	–	–	x	–	–	–	–	–	x	–	–	–
–	–	–	–	–	x	–	1.5	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	ES	1.7	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.6	–	–	x	–	–	x	–	–	–	–	–	x	–	–
x	–	–	–	–	–	IS	0.5	x	–	x	–	x	–	x	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.6	–	x	x	–	–	x	–	–	–	–	–	x	–	–
x	–	–	–	x	–	IPDIP	0.7	x	–	x	–	–	–	–	–	–	–	x	x	–	–
–	–	–	–	x	x	EP	0.9	–	–	x	–	–	–	–	–	–	–	x	x	–	–
–	–	–	–	x	x	–	0.8	–	–	x	–	x	–	–	–	–	–	–	x	–	–
–	–	–	–	x	x	EP	0.5	x	–	–	–	x	x	–	–	–	–	x	x	–	–
–	–	–	–	x	–	–	0.8	x	x	x	–	–	–	–	–	–	–	x	x	–	–
–	–	–	–	–	–	EDIP	0.6	x	–	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	x	–	1.8	x	x	x	–	x	x	x	–	–	–	–	–	x	–
–	–	–	–	x	x	–	2.7	x	–	x	–	x	x	x	–	–	–	–	–	–	–
–	–	–	–	x	–	–	2.5	x	–	x	–	x	x	x	–	–	–	–	–	–	–
–	–	–	–	x	x	–	0.7	x	–	x	–	x	x	x	–	–	–	–	–	x	–
–	–	–	–	x	–	IS+ESDIP	0.9	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	IS+ESDIP	1.0	x	–	–	x	–	–	–	–	–	–	–	x	x	–
–	–	x	–	x	x	IS+ESDIP	0.7	x	x	–	–	–	–	–	–	–	–	x	–	x	–
–	–	x	x	x	x	ESDIP	3.0	x	–	x	–	–	–	–	–	–	–	–	x	x	–
–	–	xxx	x	x	x	IS+ESDIP	1.2	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	x	x	x	ESDIP	1.2	x	–	–	x	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	ESDIP	1.2	–	–	–	x	–	–	x	–	–	–	–	–	x	–
–	–	–	–	x	x	IS+ESDIP	1.4	x	–	–	x	x	–	–	–	–	x	–	–	x	–
–	–	x	–	x	x	ESDIP	2.5	x	x	–	x	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	IS+ESDIP	1.5	x	–	–	x	x	x	–	x	–	–	–	–	x	–
–	–	–	–	x	x	ESDIP	1.6	x	–	–	–	x	x	–	–	–	–	–	–	–	–
–	–	–	–	x	x	ESDIP	2.5	x	x	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	x	ESDIP	2.8	x	–	–	–	x	–	–	–	x	–	–	–	–	–
–	–	–	–	x	x	ESDIP	2.5	x	–	–	x	x	–	–	–	–	–	–	x	–	–
–	–	–	–	x	x	–	3.6	–	–	–	x	x	x	–	–	–	–	–	–	–	–
–	–	–	–	x	–	EP	2.5	x	x	x	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	3.6	x	–	–	–	x	x	–	–	–	–	x	–	–	–
–	–	–	–	x	–	IP	2.0	–	x	x	x	x	x	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	–	–	x	–	–	–	–	–	–
–	–	–	–	x	–	–	4.0	x	x	–	–	x	x	x	–	–	–	–	–	–	–
–	–	–	–	x	–	–	2.5	x	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	4.0	x	–	–	–	–	x	–	–	–	–	x	–	–	–
–	–	–	–	x	–	ES	2.5	x	–	–	x	–	–	–	–	x	–	–	–	–	–
x	–	–	–	–	–	–	10.0	x	–	–	–	x	x	–	–	–	–	–	–	–	–
–	–	–	–	x	–	IP	1.0	x	–	–	–	–	x	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	2.0	x	–	–	x	–	x	–	–	–	–	–	–	–	–
–	–	–	–	x	–	IS	1.8	–	x	–	x	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.8	x	–	x	–	–	x	–	x	–	x	–	x	–	–
–	–	–	–	–	–	IP	0.6	x	x	x	–	x	x	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.9	–	x	x	–	x	x	–	–	–	–	–	x	–	–
–	–	–	–	–	–	EPDIP	0.8	–	–	x	–	–	–	–	–	–	–	x	–	x	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.1	–	–	–	–	–	x	–	–	x	x	–	–	–	–
–	–	–	–	x	–	–	3.2	–	–	x	–	–	–	–	–	–	–	–	–	x	–
–	–	–	–	x	–	EP	2.0	x	–	–	–	x	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	ES	5.0	x	x	–	–	–	–	–	–	–	–	x	–	–	–
–	–	–	–	x	–	–	1.4	–	–	x	–	–	x	–	x	–	–	x	–	–	–
–	–	–	–	x	x	–	0.4	–	–	x	–	x	x	–	–	–	–	–	x	–	–

TABLE 1: *Continued*

Sample	PG	Prov	Relchr	Typ	Sort	Max dim (mm)	Pl	Qz	Px	Kf	Bt	Ms	Amph	Redd Ol	Cc	Ep	Ox	Zrn	Grt	Chl	Tur
639	I	ARS	VI A	SF	ML	0.4	xx	xxxx	xx	–	xx	x	–	xxxx	–	–	–	–	–	–	–
640	I	ARS	VI A	SF	ML	0.4	–	xx	x	–	x	–	–	xxx	–	–	–	–	–	–	–
643	IV	ARS	VI A	TN	ML	1.6	xxxx	xx	–	x	xx	–	–	–	–	–	–	–	–	–	–
646	I	ARS	VI D2	T IM	v L	0.2	xx	xxx	xx	xx	–	x	–	x	x	–	–	–	–	–	–
647	I	ARS	VI D2	T IM	ML	0.8	xxx	xx	x	–	–	–	–	xx	–	–	–	–	–	–	–
648	I	ARS	VI C	DEP	ML	0.5	xx	xxxx	xx	–	xx	–	–	x	–	–	–	–	–	–	–
656	IV	ARS	VI B1	RN	ML	2	x	xxx	–	–	–	–	–	–	xx	–	–	–	–	–	–
663	IV	ARS	VI B1	RN	H	1-2	–	xxx	–	–	–	–	x	–	–	–	xx	–	–	–	–
671	IV	ARS	VI B1	RN	ML	0.4	xxxx	xx	–	–	–	x	–	–	–	–	–	–	–	–	–
675	I	ARS	VI B1	RN	ML	1-3	–	xxxx	xx	–	x	–	–	x	–	–	–	–	–	–	–
677	IV	ARS	VI B1	RN	ML	1-3	x	xxx	x	xx	xx	–	x	–	–	–	–	–	–	–	–
678	IV	ARS	VI B1	RN	ML	0.6	xx	xx	–	–	x	x	x	–	–	–	–	–	–	–	–
681	IV	ARS	VI B1	RN	ML	0.5	–	xxxx	xx	–	–	xx	xxx	–	–	–	–	–	–	–	–
682	IV	ARS	VI B1	RN	ML	0.4	–	xxx	–	–	x	–	–	–	–	–	–	–	–	–	–
730	I	ARS-T	VI A	SF	ML	0.3	–	xx	–	–	x	–	x	xxx	–	–	xx	–	–	–	–
732	I	ARS-T	VI A	SF	H	0.8	–	xx	–	–	–	–	–	xxx	–	–	xx	–	–	–	–
733	I	ARS-T	VI A	SF	ML	0.5	x	xxx	–	–	xx	x	x	x	–	–	–	–	–	–	–
734	I	ARS-T	VI A	SF	H	0.8	xx	xxx	xxx	xx	–	–	–	–	x	–	–	–	–	–	–
735	I	ARS-T	VI A	SF	ML	0.5	xx	xx	xx	xx	–	–	–	–	x	xx	–	–	–	–	–
736	IV	ARS-T	VI A	RN	H	0.8	xx	xxx	xxx	–	xx	–	–	xx	–	xx	–	–	–	–	–
737	I	ARS-T	VI A	SF	ML	0.3	–	xxxx	xxx	–	–	–	–	x	x	x	–	–	–	–	–
739	IV	ARS-T	VI A	SF	ML	0.4	xx	xx	xx	xx	–	–	–	–	–	–	–	–	–	–	–
1000	IV	ARS	VII	CI	ML	0.8	xxx	xxxx	xxxx	xx	–	–	–	–	–	–	–	–	–	–	–

TABLE 2

Malatya plane archeological settlements. Radiometric ages of different periods.

Relative chronology	Period	Radiometric (^{14}C) age
VII	Late Chalcolithic	3700-3500 BC
VI A	Late Uruk	3200-3000 BC
VI B1	Ancient Bronze I	3000-2800 BC
VI B2	Ancient Bronze II	2900-2700 BC
VI C	Ancient Bronze II	2800-2500 BC
VI D	Ancient Bronze III	2500-2100 BC

Electron microscopy (SEM) was applied using a Cambridge Stereoscan model 250 MK3, with EDS (Energy Dispersed Spectroscopy) Link Model AN10/55S.

Modal compositions of pastes were obtained by point-count analyses; the semi-quantitative data-set refers to a total of 5000 counting points for each sample, with variable step scans for different grain-sizes.

Ceramic manufacture is a complex universe. It results from a combination of several cultural components, aspects of production organisation, and the nature of the production environment. An attempt to organise and represent these phenomena through the «logical steps» of mathematical language reduces research ambiguity and enables us to see how pottery was produced in Arslantepe.

The data-set of each sample was examined taking into account its chronological period and class, in order to verify the existence of relationships between archaeometric results and archaeological observations.

Two types of statistical analysis were applied, hierarchical clustering and discriminant analysis.

A first attempt to distinguish the pastes was carried out through hierarchical clustering applying the Ward method (Norusis, 1994) with Mahalanobis distances. This method is frequently used in the analytical context, since it can describe social aspects (Sadocchi, 1981; Rizzi, 1985). This type of procedure reveals how a new unit, described by the same variables selected for all the units already assigned to groups, can be attributed to one or another group, minimising the risk of erroneous classification (Sadocchi, 1981).

Discriminant analysis was applied by means of a correlation matrix among groups (Norusis, 1994), considering as independent variables chronological periods, petrographic groups, or

Ol	Srp	Dol	Gp	VF	Foss	Surf treat	TMax dim (mm)	Tvolc	Tmet	Tcarb	Cham	TPl	TQz	TPx	TKf	TBt	TMs	TAmph	Tredd Ol	TCc	TChl
–	–	–	–	–	–	–	0.4	x	x	–	x	–	–	–	–	x	–	–	x	–	–
–	–	–	–	x	x	–	0.4	–	x	x	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	x	–	–	0.0	–	–	–	–	x	–	–	–	–	–	–	–	–	–
xx	–	–	–	x	–	–	0.2	–	–	–	x	–	–	x	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.0	–	x	–	x	–	–	–	x	–	–	–	x	–	–
xx	–	–	–	x	–	–	0.5	–	–	x	–	x	x	–	–	–	–	–	x	–	–
–	–	–	–	x	–	–	0.1	–	–	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	0.0	x	x	–	x	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	x	–	0.4	–	–	–	–	x	x	–	–	–	–	–	–	–	–
–	–	–	–	x	x	–	0.0	x	–	–	–	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	x	–	–	0.6	–	–	x	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.0	–	x	–	–	x	x	–	x	x	–	–	–	–	–
–	–	–	–	x	–	ES	0.0	–	–	x	–	–	x	–	–	–	–	–	–	–	–
–	–	–	–	–	x	–	0.3	–	x	–	–	–	–	–	–	x	–	x	x	–	–
–	–	–	–	–	x	–	0.8	–	–	–	x	–	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.0	–	–	–	–	–	x	–	–	–	–	–	x	–	–
–	–	–	–	x	–	–	0.8	x	–	–	–	x	–	–	–	–	–	–	x	–	–
–	–	–	–	–	–	–	0.5	–	x	–	–	–	–	–	–	–	x	–	x	–	–
–	–	–	–	x	x	–	0.8	x	x	–	–	–	–	–	–	–	–	–	–	x	–
x	–	–	–	–	–	–	0.3	x	–	–	x	–	–	–	–	x	–	–	x	x	–
–	–	–	–	x	x	–	0.4	–	–	x	–	x	x	–	–	–	–	–	–	–	–
–	–	–	–	x	x	–	0.0	x	x	x	–	x	x	–	–	–	–	–	–	–	–
		–	–	–		–											–				

some specific productions, empirically observed, presuming that they had a certain degree of recognisability linked to dependent variables constituted by all the ceramic components (Table 1).

PETROGRAPHIC DATA

The petrographic results from 205 samples are listed in Table 1. Some samples containing several ARFs (Argillaceous Rock Fragments; Maritan, 1999; Tampellini & Mazzeo Saracino, 1999) and *chamotte* (ceramic fragments; Bianchin Citton and Crivellari, 1999) were observed.

Petrographic studies highlighted the following features, common to all samples:

1. occurrence of quite long, spiky vugs, attributable to burnt vegetable fibres; marks of such vegetable fragments were also noted on the outer and inner walls of pots;
2. the mineralogical/lithic component ratio varied considerably from specimen to specimen;
3. sherds belonging to class RN (coarse-tempered samples) were very rich in both mineralogical and lithic components;
4. the temper volume percentage ranged between 15-30% within the whole sampling;
5. mineral orientation inside the matrix was only observed in *wheel-made* samples.

On the basis of their mineralogical and petrographic features, samples were attributed to five different groups, as follows.

Group I

This group is mainly characterised by abundant large *reddish olivine* grains. Matrix colour ranges from reddish to brownish. The pots have variable amounts of carbonate fragments containing fossils and quite long, spiky vugs (burnt-out vegetable fibres). Magmatic, sedimentary and rare metamorphic rock fragments constitute the major lithic components. Pastes cover a wide range of sorting, as regards both rock fragments and minerals, the latter due to desegregation of rock fragments. The matrix is always the most abundant fraction. The mineralogical association, in order of decreasing abundance, is: plagioclase, quartz grains, calcite, biotite and muscovite laths, hornblende and pyroxene (augite). Within the temper, plagioclase, quartz, large reddish olivine crystals and rare Fe-Ti oxides are the most representative minerals (Photo 5). Maximum sizes are about 1 mm.

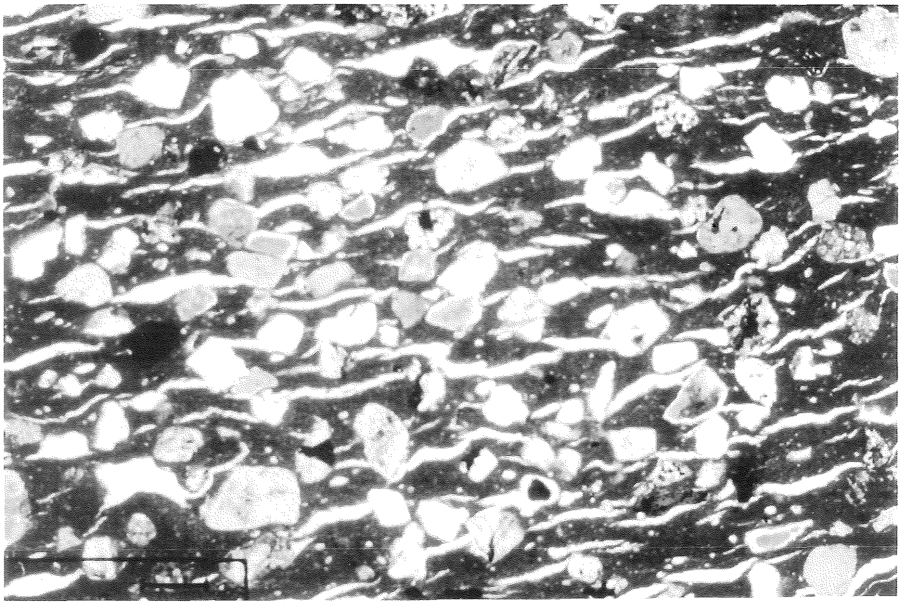

Photo 5 – Arslantepe site. Thin-section of sample 355, belonging to petrographic group I. Optical microscopy, plane-polarised. Abundant reddish olivine grains in paste. Scale bar = 30 μm.

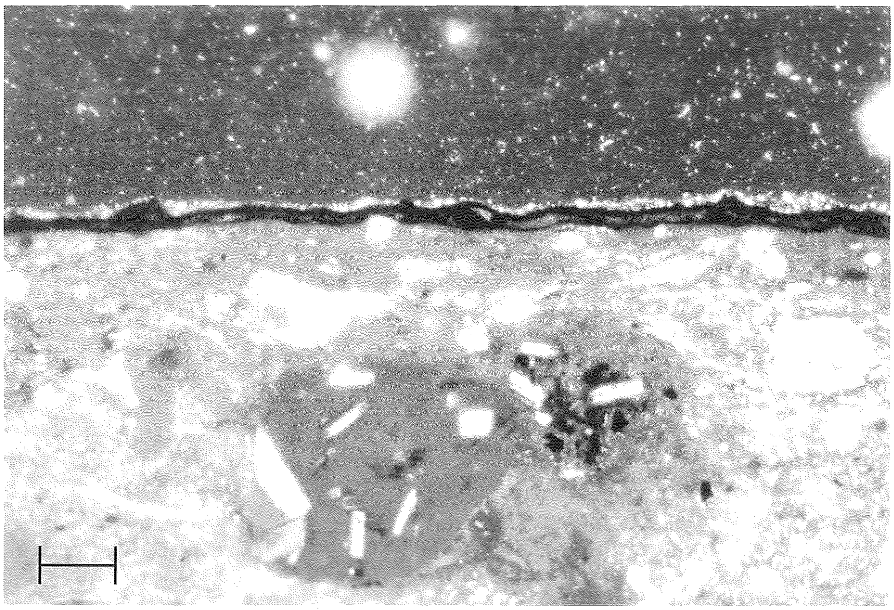

Photo 6 – Arslantepe site. Thin-section of sample 365, petrographic group I. Optical microscopy, cross-polarised. Reddish-brown east-west oriented ribbon represents painted surface, average thickness about 35 μm. Note minute grain-size and saturated colour. Paint was applied directly on untreated outer wall of piece. Central-bottom part of picture: reddish *chamotte* fragment. Scale bar = 80 μm. Top of picture (black portion): supporting glass of thin-section.

Photo 7 – Arslantepe site. Thin-section o
oriented burnisched surface. Outer layer
body: surface treatment carried out with a
Scale bar = 80 µm. Top of picture (black

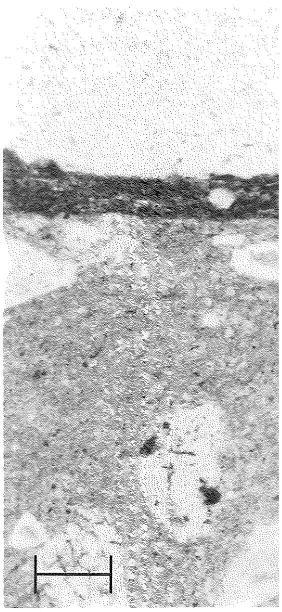

Photo 8 – Arslantepe site. Thin-section
painted surface. Note clearcut discontinu
than that of ceramic body. Scale bar = 80

Rare ceramic fragments *(chamottes)* are also observed (Photo 6). Lithic components are angular to sub-rounded rock fragments such as gabbro, lava, peridotite, limestone and serpentinite, larger (up to 2 mm) than the mineral ones.

With few exceptions, all group I samples have a thin painted superficial film (DIP) applied to the body of the pot (Photo 6), as confirmed by a structural discontinuity revealed by SEM.

Painted surfaces were occasionally observed, applied to another layer composed of the same/or different ceramic body material and characterised by very fine grain-size. These surfaces were recognised, respectively, as burnished (Photo 7) and slipped (RIB, RN, TRG, DIP etc.; Photo 8). The latter is a thin surface film applied later.

Group II

Mineralogically, this group is distinguished due to the almost ubiquitous occurrence of *epidote* grains and low carbonate minerals, besides plagioclase, quartz, biotite, muscovite, and other minerals common to all sampled pots.

Matrix colour ranges from reddish to brownish-black. Vegetable fibres and *chamotte* (the latter also occurring in Group I, see Photo 6) constitute essential added components. High to very high paste sorting is observed in all group II samples. The maximum size of the mineralogical component is about 1 mm. Lithics are represented by angular to sub-rounded rock fragments. Abundant metamorphic rocks and minerals deriving from their desegregation mainly constitute the lithic/mineralogical assemblages. The mineralogical association (Photo 9), observed

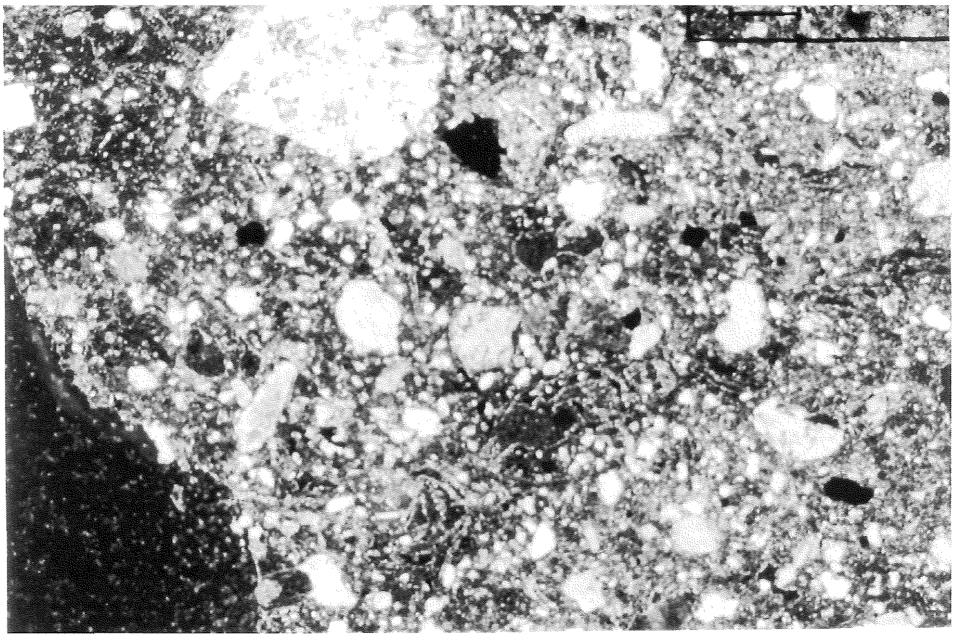

Photo 9 – Arslantepe site. Thin-section of sample 70, petrographic group II. Optical microscopy, cross-polarised. Abundant epidote (Ep) crystals and metamorphic fragments (Tmet) in paste. Scale bar = 30 µm. Bottom-left portion of picture (black): supporting glass of thin-section.

in the matrix, in order of decreasing abundance is: plagioclase, quartz grains, epidote, biotite and muscovite laths, hornblende, pyroxene (augite), rare calcite, and sporadic Fe-Ti oxides. The lithic component, mainly represented by metamorphic and subordinate magmatic varieties, is represented by angular to sub-rounded rock fragments such as schists and quarzite, occasionally reaching 10 mm.

Some samples belonging to this heterogeneous group have thin surfaces composed of the finest component of the ceramic paste.

The features of these surfaces are different from those of group I: they are always made of the same very fine paste materials of the ceramic body but were not applied later, as clearly shown by the absence of any structural discontinuity between outer/inner layers and body. They are interpreted as surface treatments carried out by passing a small stick over the ceramic wall (burnishing) (Photo 7), bringing the finest materials towards the treated surface. The final result is the more or less polished aspect typical of several pot samples from Arslantepe.

Group III

This group contains abundant fossils and vegetable components and lacks *chamotte* fragments. Minerals occurring in this group derive from magmatic and metamorphic rocks. Minute grains of some particular phases, like *tourmaline, gypsum, garnet* and *zircon,* are frequently found. The matrix shows variable carbonate contents and ranges in colour from reddish to brownish. Maximum dimensions of mineralogical components are around 1 mm. Rock fragments may reach 2.5 mm. The degree of sorting displays wide variations. Samples are characterised by abundant basic volcanic fragments. Metamorphic rocks occur sporadically. The mineralogical association, in order of decreasing abundance, is: plagioclase, quartz, biotite and muscovite laths, hornblende, pyroxene (augite), chlorite, sporadic tourmaline, garnet, gypsum, and small zircon crystals, with rare Fe-Ti oxides. A few samples belonging to this heterogeneous group show slipped surfaces.

Group IV

Group IV contains several pastes which *do not have any significant petrographic elements,* such as particular minerals or mineral assemblages.

The absence, for instance, of olivine, epidote, tourmaline, zircon and garnet, which are common in the pastes of the other groups, is a distinctive feature of group IV. The paste matrix has high carbonate contents and ranges in colour from yellow to reddish. Fossils and vegetable fibres are always abundant. All samples show a high sorting degree, except for sample 151. Maximum mineral sizes vary greatly up to 1.5 mm. Lavas, intrusives and carbonate rocks are the main lithic components of this heterogeneous group. The mineralogical components of the pots, occurring as temper, mainly derive from desegregation of volcanic rocks, which are also well represented within the matrix (Photo 10). Minerals characterising the other groups (reddish olivine, epidote, garnet, etc.) are lacking, and the following ones, in order of decreasing abundance, are common to all samples: plagioclase, quartz grains, calcite, hornblende, biotite laths, pyroxene (augite) grains, and minute Fe-Ti oxide grains. Sporadic K-feldspar also occurs. Rare *chamotte* is present in some samples.

The pottery of this group shows surface treatments (burnishing) similar to those of group II.

Group V

The few samples of this group do not show particular features detectable by thin-section analysis, due to their very fine grain-size. Clay colour varies from greenish to reddish (Photo 11). Notwithstanding their minute grain-size, these pots display surface treatments like slipping and/or burnishing.

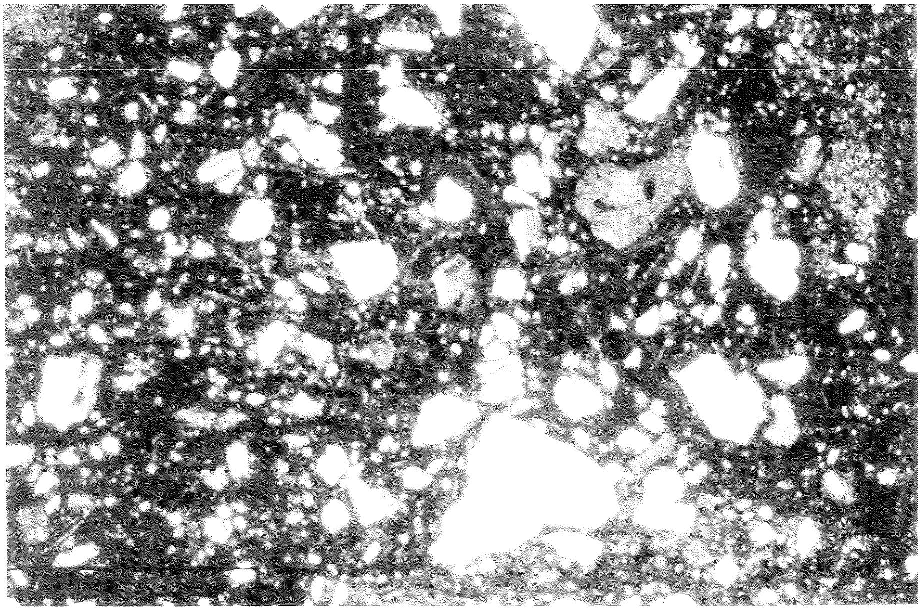

Photo 10 – Arslantepe site. Thin section of sample 418, petrographic group IV. Optical microscopy, cross-polarised. Paste containing plagioclase, quartz, biotite laths, etc. Scale bar = 30 μm.

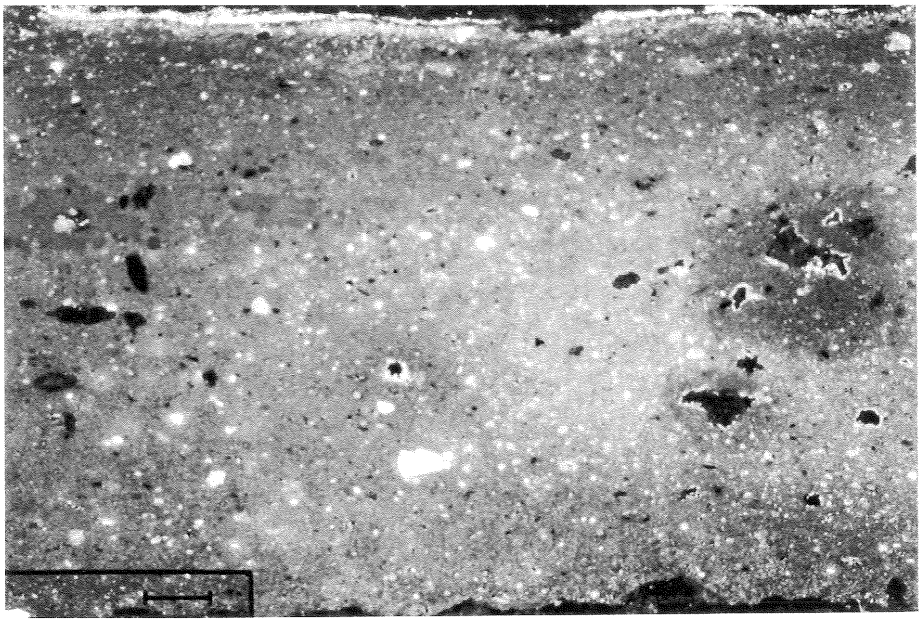

Photo 11 – Arslantepe site. Thin-section of sample 50, petrographic group V. Optical microscopy, cross-polarised. Microcrystalline paste, maximum size of rock or mineral fragments is < 25 μm. Scale bar = 30 μm.

DISCUSSION

The relationships between petrographic groups and archaeological ceramic classes were identified by applying hierarchical clustering and discriminant analysis. Petrographic and type data-sets show good reliability for the three principal paste categories, in which recurring variables indicate some kind of selection linked both to the search for particular raw materials and their greater or lesser distance. Cluster analysis (Fig. 4) suggests that this kind of recurrence in some archaeological classes (e.g., *wheel-made*, *chaff*, *red-black*) are characteristic of specific chronological periods.

Some variables influencing ceramic assemblage were clearly defined by discriminant analysis (Fig. 5). The major concentrations of identified paste categories are related to periods VII, VI A-VI B2 and VI C-VI D.

The statistic value of the ceramic data-set from period VI B1, exclusively composed of the *red-black* type (RN), is very low, since only 11 sherds were analysed.

As regards Fig. 5, the main parameters contributing to group separations are *chamotte*, quartz, vegetable fibres and dolomite (Function 1). Function 2 is represented by both raw materials and reddish olivine occurring as temper and clay skeleton. Production from period VII is typified by the significant occurrence (positive values) of *chamotte*, quartz, vegetable fibres and dolomite: the incidence of these parameters is negative for objects from periods VI A-VI B2, which show the same negative values for Function 2 parameters. Pots from periods VI C-VI D can be distinguished from the other two groups due to the positive occurrence of Function 2. Fig. 5 also indicates that, already in period VI C, other components began to be used to produce pots.

All these facts suggest the following:

– the production of period VII is always and completely different from that of all other groups;

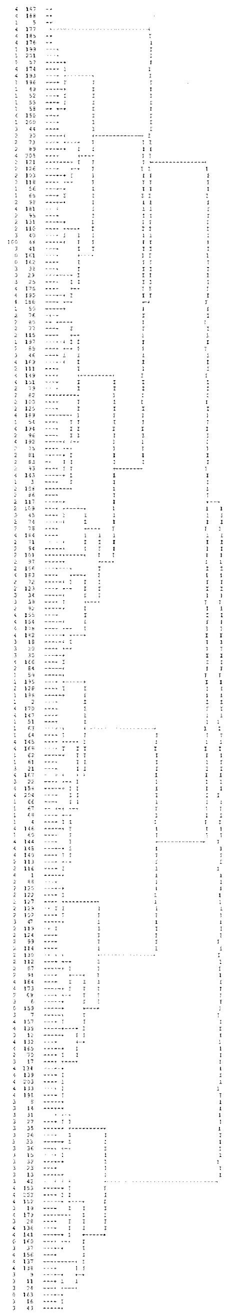

Fig. 4 – Arslantepe site. Hierarchical cluster analysis of all productions based on mineralogical and petrographic results. Three well-defined archaeological classes (*wheel-made*, «*chaff*», *red-black*) (Norusis, 1994).

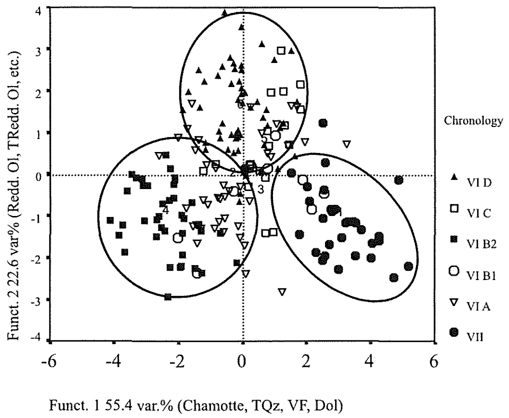

Fig. 5 – Arslantepe site. Discriminant scatter plot of mineralogical and petrographic data set related to chronological phases. Funct. = Function; var. = variance. For other abbreviations, see Tab. 1.

– the production of periods VI A-VI B2 shows substantial uniformity, due to temporal continuity in both raw material selection and amount of temper used;

– the productions of periods VI C-VI D overlap completely.

In general, diversification of pastes over time is observed, which may be explained by technological and thus «intentional» and/or contingent factors, as already mentioned. These observations fit the cultural and economic variations indicated by historical analysis of the Arslantepe site.

Seriation and distribution criteria of both cluster and discriminant analyses were used for further studies on the components defining the various petrographic groups, as follows.

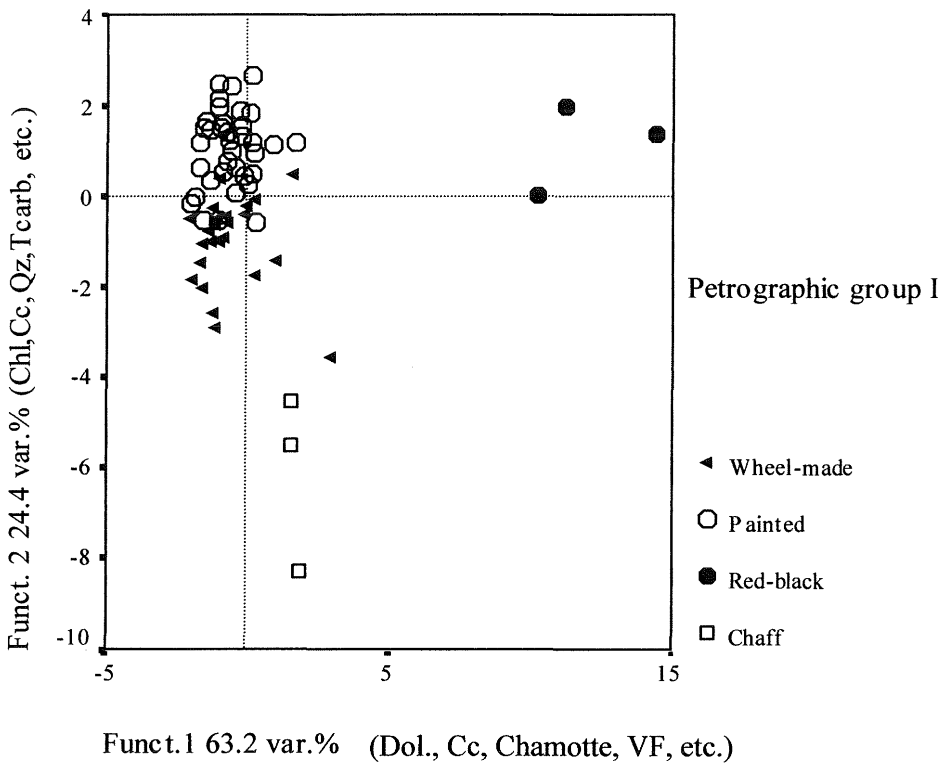

Fig. 6 – Arslantepe site. Discriminant scatter plot of petrographic group I related to «*chaff*», *red-black*, *painted* and *wheel-made* productions. Funct. = Function; var. = variance (Norusis, 1994). For other abbreviations, see Tab. 1.

Petrographic group I

The first paste category (Fig. 6), based on mineralogical and petrographic features, defines:

1. production characteristic of periods VI A and VI B2 (*wheel-made*);

2. production persisting from periods VI C to VI D (*painted* pots, DIP);

3. other minor types of production.

Wheel-made pots (periods VI A-VI B2) are a complex archaeological group, which includes objects for various functions (e.g., storage, food distribution, serving vessels), all with little temper.

Painted pots (periods VI C-VI D) have negative values with respect to Function 1, due to temper components such as dolomite, calcite, *chamotte*, vegetable fibres, etc. and positive values of Function 2 (chlorite, calcite, quartz, temper carbonate fragments, etc.).

Petrographic group II

This category (Fig. 7) almost exclusively contains *red-black* (RN) products because, here too, the other occurrences are statistically almost irrelevant.

It is interesting to note that RN represents a class of production whose characteristic shape remained almost unaltered, from its appearance (period VI A) to the end of period VI D.

It is also important to note that RN grain-size and lithic components persist in time, suggesting that its production was the result of careful study of technologies and sources of raw materials.

Particularly significant is the lack of *chamotte,* calcite and quartz.

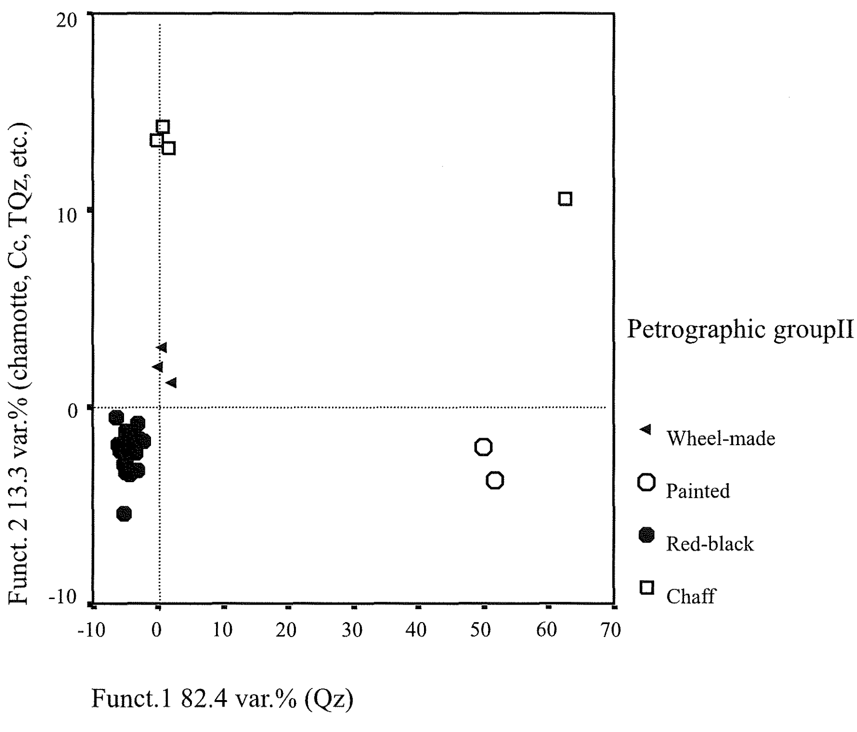

Fig. 7 – Arslantepe site. Discriminant scatter plot of petrographic group II of «*chaff*», *red-black*, *painted* and *wheel-made* productions (Norusis, 1994). Funct. = Function; var. = variance; for other abbreviations, see Tab. 1.

Petrographic group III

This category, containing only a few samples, includes a small fraction of RN production.

Petrographic group IV

This category (Figs. 8a, 8b) reveals large variations in mixture compositions and identifies three main pastes:

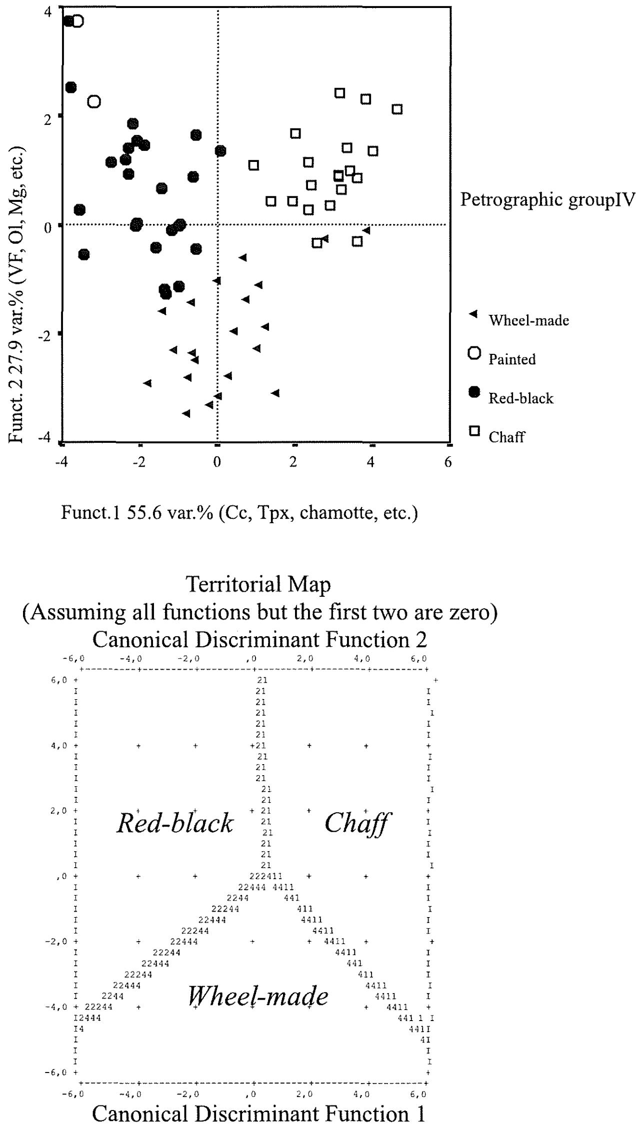

Fig. 8 – Arslantepe site. a) Discriminant scatter plot of petrographic group IV related to «*chaff*», *red-black*, *painted* and *wheel-made* productions. Funct. = Function; var. = variance; b) territorial map related to discriminant scatter plot of petrographic group IV, showing mineralogical and petrographic data-set of «*chaff*», *red-black*, *painted* and *wheel-made* productions (Norusis, 1994). Funct. = Function; var. = variance; for other abbreviations, see Tab. 1.

- *«chaff»* (period VII);
- *wheel-made* (periods VI A-VI B2);
- *red-black* (periods VI A-VI D).

«Chaff» production clearly contains calcite, temper pyroxene, *chamotte,* olivine and vegetable fibres, confirming both raw material selection and a particular technological aspect which does not appear in later productions.

As in petrographic group I, *wheel-made* products are evidenced by the low frequency of temper and vegetable fibres.

Red-black production is characterised by low calcite, *chamotte* and temper pyroxene (Function 1).

Petrographic group V

This category is prevalently composed of such fine carbonate clay that it was impossible to distinguish and define the low amount of the silicate fraction. It occurs only in a few specific productions such as the very fine *wheel-made* products from periods VI B2 (TFF) to VI C (TFS). These pots show peculiar technological aspects associated with both raw material selection and firing temperature.

Red-black and wheel-made productions

These two classes contemporarily belong to different petrographic groups. Taking into account that raw material selection may be related to chronological, functional or technological aspects, we hypothesise that the pastes were changed for several reasons, e.g., arrival of new peoples with new traditions, impossibility of obtaining some materials, changes in production technologies.

Distribution analysis (discriminant) on class RN revealed the importance of epidote, temper metamorphic fragments, and vegetable fibres (Fig. 9).

As class RN persists from periods VI A to VI D, the existence of chronological recurrence was checked by cluster analysis: the only recurrence emerged among the production of period VI B2 in petrographic group II, which seems to have little statistical relevance. At the same time, a correlation between functional type (i.e., bowls, jars, fruit stands, etc.) and petrographic pastes was found. Also in this case, the primary use of an object cannot be related to a specific petrographic group (paste) composition.

Further studies concerning the end-use of the products were made on objects destined as serving vessels or for food preparation and preservation. They revealed:

1. both coarse-grained products and *pithoi* (large containers used to store food) mainly fall in petrographic group 2;
2. fine-grained products mainly fall in petrographic groups 1, 3 and 4.

Discriminant Function 1 is controlled by epidote, metamorphic fragments, vegetable fibres, etc. (Fig. 9). In particular, products of petrographic group 4 are characterised by negative values of Function 2, perhaps due to both technical methods of ceramic production and secondary functional effects. The extensive occurrence of vegetable fibres as temper and the lesser frequency of mineralogical components make the paste finer, more porous, and more plastic, for better modelling of particular articles. This type of paste, with poor resistance, is not suitable for making cooking vessels and/or large articles.

To elucidate the occurrence of two different petrographic groups (I and IV) within the same production, distribution analysis was also applied to the *wheel-made* class (Fig. 10).

Our first aim was to highlight the distribution of this type of production with respect to chronological periods (pots belonging to period VI A and also falling in petrographic group I were not considered as a statistically valid reference). The occurrence of both periods (VI A and VI B2) was almost always similar within the two petrographic groups.

Our second aim concerned the distribution of objects from both functional and qualitative points of view. Study again ranged over the steps described for RN production. As regards paste type, also in this case a correlation trend, but not a rule, was observed: the objects of

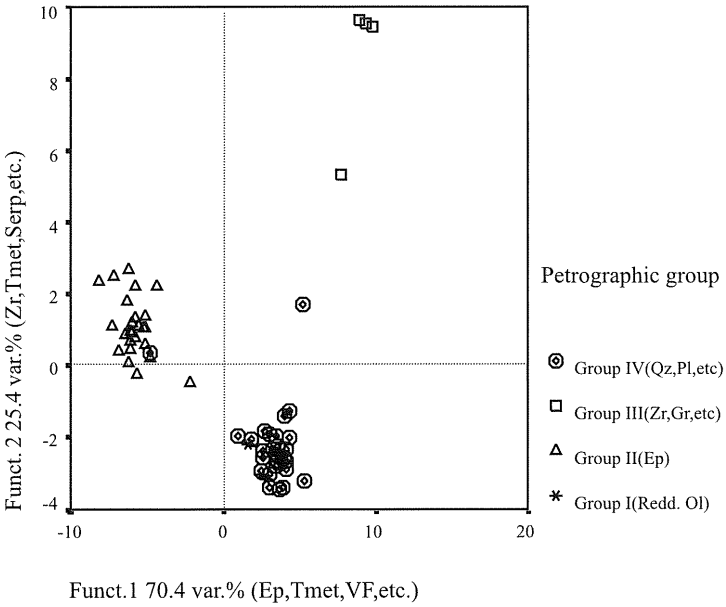

Fig. 9 – Arslantepe site. Discriminant scatter plot of *red-black* production of petrographic groups (Norusis, 1994). Funct. = Function; var. = variance; for other abbreviations, see Tab. 1.

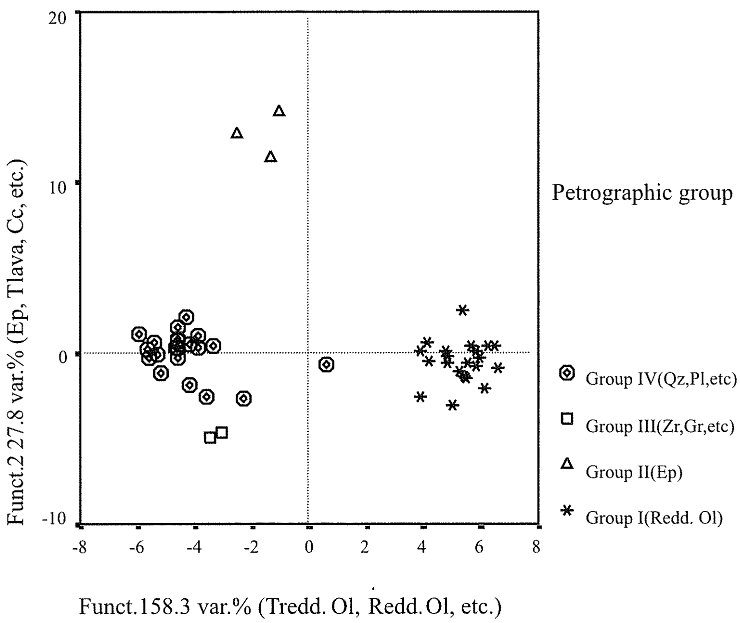

Fig. 10 – Arslantepe site. Discriminant scatter plot of *wheel-made* production of all petrographic groups (Norusis, 1994). Funct. = Function; var. = variance; for other abbreviations, see Tab. 1.

petrographic group IV appear to have been used mainly for the smallest fine-grained pots, whereas those of group I were probably widely used in the semi-fine-grained products used for storing food and for «mass-production».

Nevertheless, almost all the functional types are made of different pastes, perhaps due to the contemporaneous presence of several workshops producing the same kinds of objects, thus explaining different sources of raw materials.

The most important difference in paste compositions is represented by reddish olivine. Since this component is not crucial for the technical response of the clay mixture, it cannot have been intentionally added to the ceramic paste.

Lastly, two other aspects deserve further discussion:

– the compatibility of the mineralogical and petrographic features of the paste with local geology;

– the presence of minerals and/or mineralogical assemblages constraining firing temperatures.

All the mineralogical and petrographic components of the pastes are completely compatible with local geology, mainly olivine gabbro, serpentinite, andesite, limestone, and schists. The sites of the wide Malatya Plain have abundant thick clay deposits (Baykal and Erentöz, 1966; Marcolongo & Palmieri, 1983; Palmieri, 1984).

The various rock types identified in the pastes are distributed along the Euphrates Valley where the samples were collected. Pots from the five sites in the Malatya Plain do not show particularly significant differences in paste composition, probably due to the similarities of both clay deposits and rock suites outcropping in this small area.

As regards firing temperatures, the presence of calcite in pots indicates that kiln temperatures did not exceed calcite decarbonation, since $CaCO_3 \rightarrow CaO + CO_2$ reaction begins at about 750°C at P_{atm} in the absence of CO_2 in the fluid (Maggetti, 1982; Duminuco *et al.*, 1996). The stability of calcite is lowered by the presence of quartz because the reaction:

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2 \text{ Wollastonite}$$

begins at atmospheric pressure, in the absence of CO_2 in the fluid, at about 550°C. The association of calcite and quartz and the absence of wollastonite in the paste of our samples indicate that firing temperature was lower than 600°C (Skippen, 1972). This temperature may be increased by taking into account the probable increase in the molar fraction of CO_2 in the kiln, due to the burning of vegetable fibres used as temper.

To better define the real range of firing temperatures, more detailed studies on phyllosilicate transformations and hematite production are necessary. Thus, studies concerning kinetics of reactions and phyllasilicates transformation are in progress.

The persistence of chlorite in some pastes supports the above temperatures, because the chlorite family of minerals breaks down in the thermal range 700°-800°C (Mignucci, 1999). Our preliminary results on firing temperatures do not completely fit those suggested by Amadori *et al.* (1994) and Trojsi *et al.* (2000; 750°C) on the same types of pots.

Conclusions

The identification of some paste categories closely associated with various classes of pots shows how different degrees of production took place.

During chronological period VII, the most ancient, significant homogeneity in raw materials, independent of the production of various objects, was identified. The peculiar characteristics of the paste (both clay and temper) from period VII does not occur again in any of the later production. This feature regards paste composition (both raw materials and added components). Modelling and surface treatment technology, clearly distinguishable from those of the following periods, is associated with already noted aspects.

The «production modes» of period VII, which are also found in the absence of centralised organisation and worked by several potters (as confirmed by some identification «markers» found on the ceramic surfaces; Trufelli, 1994), may have been due to an economic structure that was able to control product quality.

During the later chronological periods, a double and profound transformation occurred: on one hand, the use of a wheel became systematic; on the other hand, RN Transcaucasian production began to appear. The contemporaneous occurrence in the same site of both is clearly reported in Frangipane (1996).

The results of the present study confirm that *wheel-made* and *red-black* productions are different, and indicate that more than one workshop operated in the site. Technological aspects were probably managed by different potters who, although making *wheel-made* and *red-black* products, did not work together.

The difference in raw materials never influenced product quality. For example, the well-known «mass-produced» bowls (TG) are made of the same paste as the great jars (SF, TF). This signifies that the potters' technical capacity, and not so much their raw materials, drove product quality towards buyers' requirements.

All these data suggest intricate levels and interactions in the productive process:

– contemporary occurrence of various types of raw materials;

– careful selection of temper;

– contemporary presence of several modelling techniques and technologies;

– contemporary presence of several firing technologies;

– contemporary presence of potters and/or workshops specialising in different types of production.

Potters who were able to offer highly differentiated products made articles for a single buyer (the palace) which adsorbed, accepted and managed activities.

As regards chronological periods, this wealth of production methods decreased after changes in the social-economic conditions of the community. Although two different ceramic pastes continued to be used for *red-black* production, more complex organisation of potter workshops does not appear. Nor does control of production seem to have been applied to any significant extent, since product shape variability was very high.

Lastly, potters making *red-black* ware worked consistently in the Arslantepe site, as shown by the fact that they conserved and handed down the same production technique and kept wide pot shapes for more than one thousand years.

The whole data-set shows that ceramic pastes consisted of raw materials variously added with temper for suitable object functionality. The similarity of pastes confirms the hypothesis of local production, and the rock-types identified outcrop along the Euphrates Valley, explaining the great similarity among samples coming from different sites on the Malatya Plain.

Comparisons between archaeological (chronology of ceramic objects and their functions) and petrographic data are interesting. In particular, petrographic data reveal pastes of different compositions from periods VII to VID and confirme previous chemical results (Angle *et al.*, 1995, 1996; Ramous *et al.*, 1995).

The occurrence of some classes with homogeneous petrographic features (SFG, TFG, DIP) or selected temper sizes (RIB, RN) suggests that technological experimentation aimed at specific functionality of articles.

Firing temperatures may be set at about 600°C, and classes such as RN (showing signs of reduction on the outer surfaces and oxidation on the inner ones) indicate that potters were able to exert close control on reducing and/or oxidising conditions during firing. Knowledge of production technology was clearly deeply rooted in the culture of Arslantepe.

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