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Ceramic composition at Chalcolithic Shiqmim, northern Negev desert, Israel: investigating technology and provenance using thin section petrography, instrumental geochemistry and calcareous nannofossils

Margie M. Burton[1], Patrick S. Quinn[2], Anthony Tamberino[1] and Thomas E. Levy[1]

Technological innovations in ceramic production and other crafts are hallmarks of the Chalcolithic period (4500–3600 BCE) in the southern Levant, but details of manufacturing traditions have not been fully investigated using the range of analytical methods currently available. This paper presents results of a compositional study of 51 sherds of ceramic churns and other pottery types from the Chalcolithic site of Shiqmim in the northern Negev desert. By applying complementary thin section petrography, instrumental geochemistry and calcareous nannofossil analyses, connections between the raw materials, clay paste recipes and vessel forms of the selected ceramic samples are explored and documented. The study indicates that steps in ceramic manufacturing can be related to both technological choices and local geology. Detailed reporting of the resulting data facilitates future comparative ceramic compositional research that is needed as a basis for testable regional syntheses and to better resolve networks of trade/exchange and social group movement.

Keywords ceramic composition, technology, provenance, Chalcolithic, Israel

Introduction

Archaeological research beginning in the 1930s in the southern Levant has highlighted the Chalcolithic period (4500–3600 BCE) as an era of technological innovation in craft production, including ceramics and metallurgy (Albright 1932; Levy 1998; Rowan and Golden 2009). Chalcolithic ceramic assemblages in the southern Levant exhibit significant changes from their Neolithic predecessors, including a proliferation of new form types (Amiran 1969) and the earliest use of the potter's wheel or 'tournette' (Baldi and Roux 2016; Commenge-Pellerin 1987: 34–35; 1990: 10–13). Cast copper 'prestige' objects manufactured using clay casting moulds and evidence of local smelting and copper tool production in the southern Levant are found for the first time at some Chalcolithic sites (Golden 2010; Golden *et al.* 2001; Levy and Shalev 1989; Shalev *et al.* 1992; Shugar 2001). These, and other developments in material culture, were accompanied by demographic shifts and apparently increasing population density in some areas, such as the northern Negev desert, along with new social practices, such as the establishment of sanctuaries and extramural cemeteries (Levy 1998; 2006; Levy and Alon 1982; 1987; Seaton 2008; Ussishkin 1980). Many researchers have considered the emergence of Chalcolithic culture to be primarily autochthonous in origin (e.g., Kaplan 1958; 1969; Levy 1998; Moore 1973; Seaton 2008). However, it is possible that some innovations may have been introduced from the north

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and/or east (de Vaux 1970; Kenyon 1979; Perrot 1955), and that pulses of population movement from Anatolia and northern Mesopotamia (Harney *et al.* 2018) may have contributed to radical technological change and the observed regionalism in southern Levantine Chalcolithic artifact assemblages and architecture (e.g., Epstein 1978; Garfinkel 1999; Gilead 1995; Rowan and Golden 2009).

The site of Shiqmim is one of the largest, newly established, agricultural villages during the Chalcolithic period in the northern Negev desert. Multi-disciplinary excavations since the 1980s have revealed three architectural levels and yielded an abundant material record for the investigation of technological trajectory (Levy 1987; Levy *et al.* 1991). Shiqmim is similar in material culture and architecture to other large (*c.* 10 ha) Chalcolithic village sites in the Beersheva Valley, including Bir es-Safadi and Abu Matar (Perrot 1955; 1968; 1984) and Horvat Beter (Dothan 1959), as well as to smaller hamlet sites, such as Mezad Aluf (Levy *et al.* 2006). Ceramic assemblages from these sites have been studied in considerable typological detail (Burton 2004: 182–232; Commenge-Pellerin 1987; 1990; Levy and Menahem 1987). Some macroscopic and microscopic technological studies, including mineralogical and petrographic analyses, of ceramics from these and related sites have also been carried out (Boness *et al.* 2016; Commenge-Pellerin 1987: 28–36, 1990: 4–15; Goren 1988; 2006; Goren and Fabian 2002; Goren and Gilead 1987; Levy *et al.* 1997; Porat 1989). However, results for Beersheva Valley sites, which have been mainly published as generalized regional syntheses, lack detailed systematic descriptions of ceramic fabrics present at individual sites (e.g., Gilead and Goren 1989; Goren 1995).

The goal of this paper is to characterize in detail the composition of the Chalcolithic ceramics of Shiqmim using thin-section petrography, instrumental geochemistry and calcareous nannofossil analysis, and to interpret the nature of their raw materials, clay recipes and other aspects of manufacturing technology. The combined analytical approach is the most successful in detecting and documenting meaningful patterns in composition within site assemblages that may relate to craft technology and trade/exchange (Quinn 2013: 1; Tite 1999). It also provides a basis for future comparative studies that may address broader issues such as intra- and inter-regional trade/exchange and population movements.

Shiqmim and its ceramics

Shiqmim is located on the northern bank of the Nahal Beersheva, approximately 18 km west of the modern

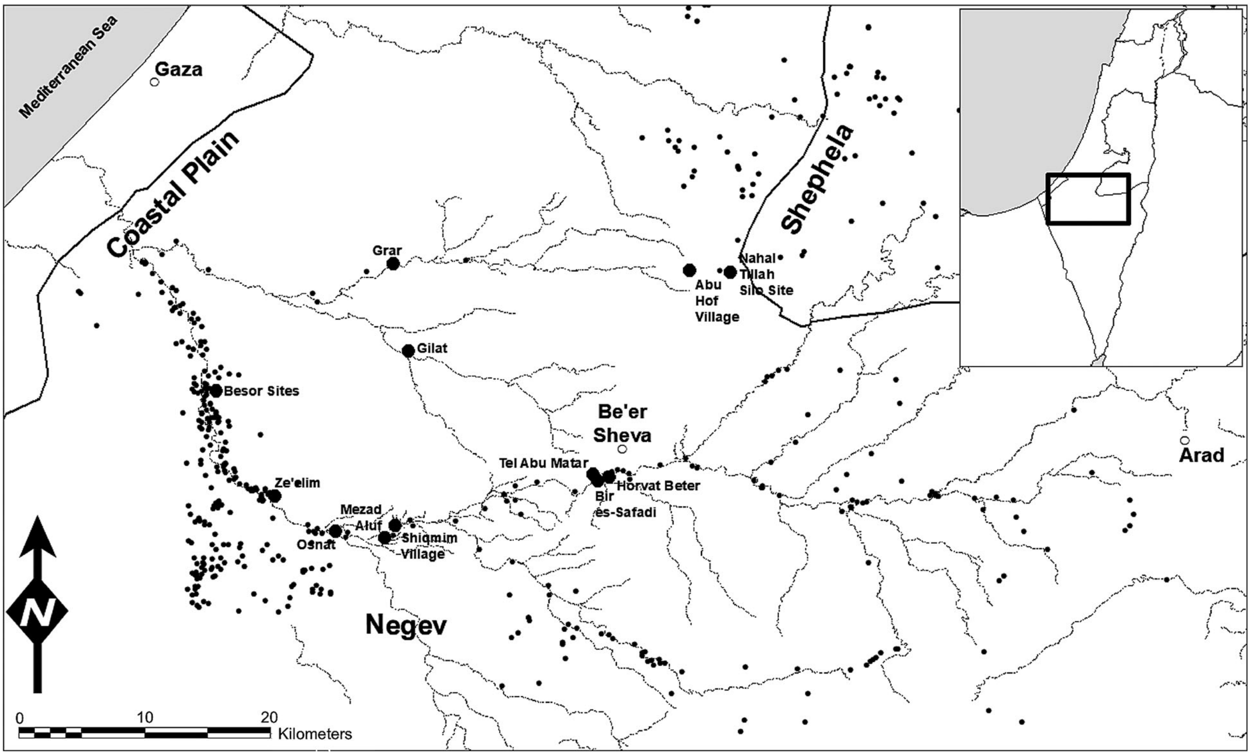

Figure 1 Map of the study area showing Chalcolithic archaeological sites (solid black dots) and geographic regions. Modern towns are indicated by open circles.

city of Beersheva and the other important Chalcolithic settlements Abu Matar, Bir es-Safadi and Horvat Beter (Fig. 1). The Beersheva Valley environment is ecotonal, lying along the boundary between the semi-arid Irano-Turanian and Saharo-Arabian phytogeographic zones (Levy *et al*. 1991). Alluvial terraces along the banks of the Nahal Beersheva provided a base for agricultural activity and settlement expansion; local loessial soils have been cultivated for centuries in historic times. Archaeological excavations at Shiqmim were carried out by T. E. Levy and D. Alon in 1982–1984 (Phase I, Levy 1987) and 1987–1989, 1993 (Phase II, Levy *et al.* 1991). An 'upper village', represented by relatively thin cultural deposits on loessial hills about 6 m above the present-day wadi bed, and a 'lower village' situated on a terrace some 1.5 to 2 m above the channel have been described (Levy *et al.* 1991). These hills are riddled with subterranean rooms and tunnel complexes (Witten *et al*. 1995). Cultural material in the lower village extends as much as 5 m below the topsoil. The excavators defined three main architectural strata (I, II, III), with Stratum I being the most recent. Architecture included both rectilinear above ground rooms and courtyards, and subterranean tunnels and chambers. The subterranean system is similar to those found at the other major Beersheva Valley sites of Abu Matar and Bir es-Safadi (Perrot 1955; 1968; 1984). Evidence for on-site copper-smelting and tool production, including ore, slag and crucible fragments, was associated with Strata I and II (Golden *et al.* 2001). A copper prestige/cult object made using the lost-wax casting method was also found (Shalev *et al.* 1992). The total excavated area including the main village, Area X (with eastern and western subareas) and Area Z exceeded 4000 m^2, comprising 4.5% of the estimated site surface area of 9.5 ha (Fig. 2). The cultural assemblages and a total of 42 ^{14}C dates place occupation at Shiqmim wholly within the Chalcolithic period (*c.* 4500–3800 BCE; Burton 2004: 657, appendix 5.1; Burton and Levy 2011), after which time the site was abandoned and not re-occupied.

More than 3000 kg of ceramic sherds have been recovered from Shiqmim (Burton 2004: 182). The ceramic assemblage includes the distinctive 'V-shaped bowls' (Fig. 3:1) and 'churns' (Fig. 4) that are recognized as *fossile directeurs* for the Chalcolithic period (Burton 2004: 184–232; Levy and Menahem 1987). Other major vessel form types are basins, hole-mouth jars, and necked jars (Fig. 3:4–12). Rilling, a macroscopic surface feature of vessel walls evidencing the effects of Rotational Kinetic Energy (RKE) and associated with

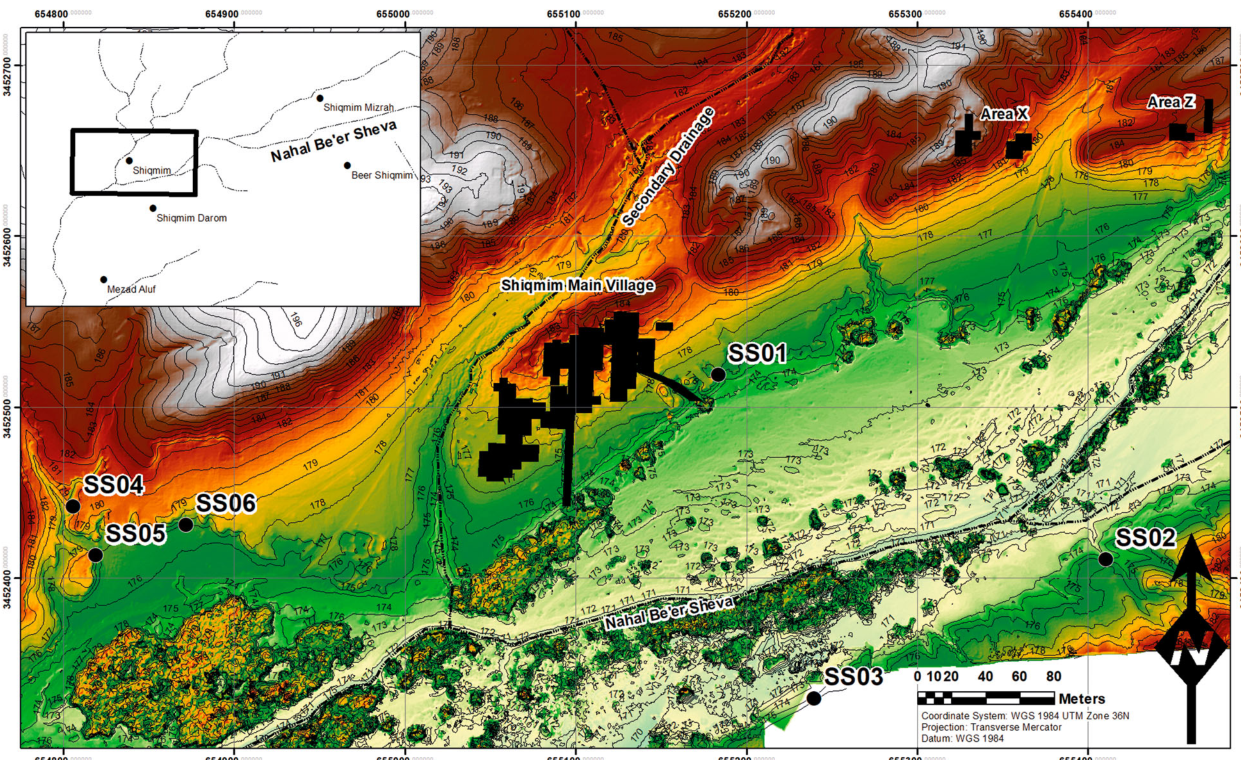

Figure 2 Topographic 3D rendering of the Nahal Beersheva in the Shiqmim vicinity showing Shiqmim excavation areas and collection locations of clayey sediment samples SS01–SS06. Numerals indicate elevation in metres.

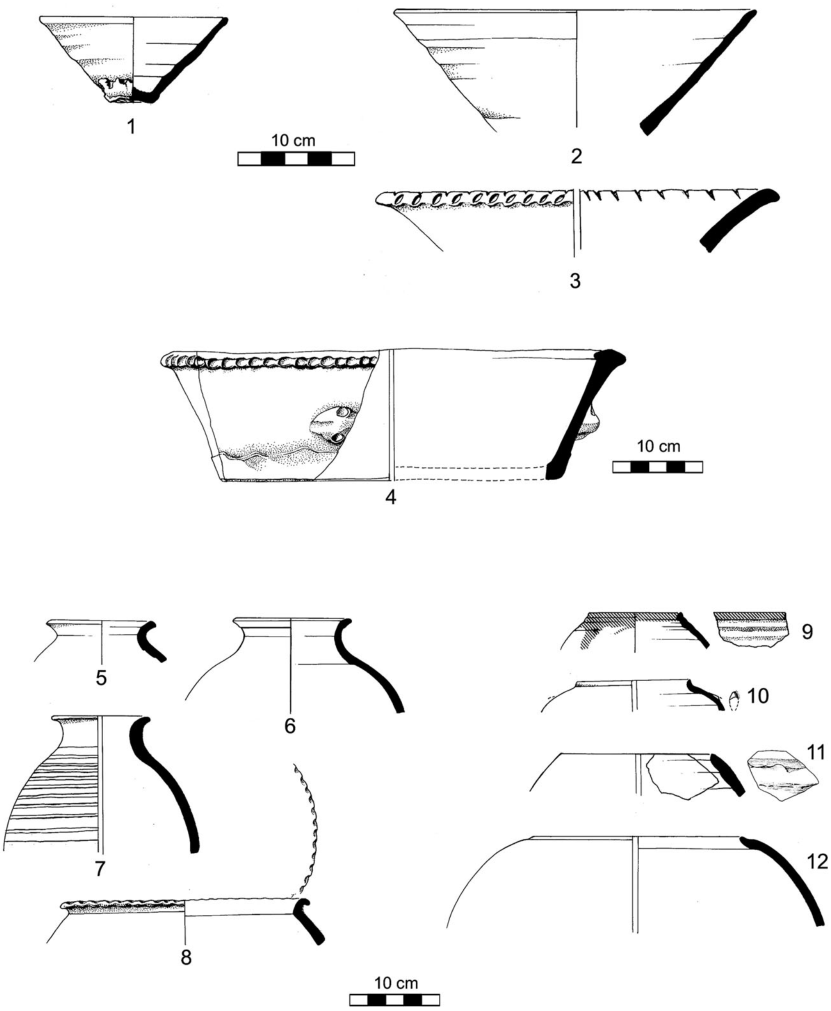

Figure 3 Examples of the main vessel form types in the Shiqmim assemblage. 1: Small V-shaped bowl. 2–3: Medium and large bowls. 4: Basin. 5–8: Necked jars. 9–12: Hole-mouth jars. Note rilling on bowls 1, 2 and jar 9. Note coil join on jar 11. (*Source*: Burton 2004: pls 5.1–5.6, 293–304).

manufacture using a wheel or tournette (Courty and Roux 1995; Roux and Courty 1998; Rye 1981), is visible on nearly all V-shaped bowl sherds and on some necked jar sherds and churn necks. A concentric pattern of string-cut marks on some small vessel bases (Burton 2004: pl. 5.16, 324) is further evidence of RKE and wheel-use at Shiqmim. Courty and Roux (1997; see also Roux and Courty 1998) have described a 'wheel-fashioning' or 'wheel-coiling' technique using a slow wheel, rather than wheel-throwing, for southern Levantine Chalcolithic pottery. Large basin and jar bodies show evidence of coiling at Shiqmim. Macroscopic examination of mineral inclusions in the clay matrix visible in the breaks and surfaces of diagnostic sherds indicates that small vessels are associated with inclusions ≤ 1 mm, and large vessels are associated with inclusions >1 mm and up to 3 mm in diameter. This observation is consistent with the preliminary report of a petrographic study by Goren and Gilead (1987) of 35 sherds from the Shiqmim Phase I (1982–1984) excavation. Their report presents inclusion sizes and frequencies for quartz, carbonates and chert in the 35 samples, but does not define petrographic fabric groups for the sample set. Decoration on Shiqmim ceramics is limited mainly to whitish slip and red paint rims or bands; however, there is some occasional applied, thumb-impressed, incised or punctate decoration. Cornets, another Chalcolithic *fossile directeur*, were not found in stratified deposits at Shiqmim. Generally, cornets are rare at Beersheva Valley sites, but are common at other northern Negev sites such as Grar (Gilead and Goren 1995) and Abu Hof Village (Burton and Levy 2012) on the Nahal Grar *c.* 20–30 km to the north. It is unclear whether this spatial distribution represents a chronological or cultural disjuncture within northern Negev Chalcolithic settlement (Burton and Levy 2011).

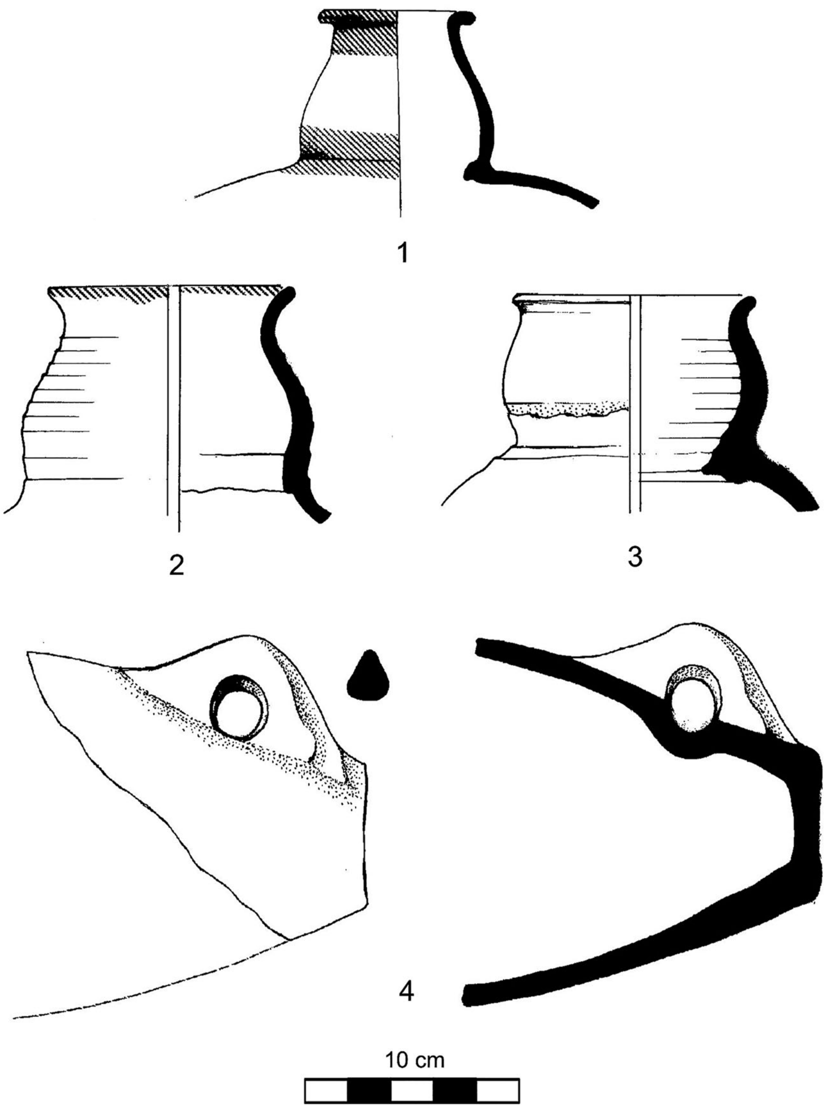

Figure 4 Examples of churns in the Shiqmim assemblage. 1–3: Churn necks. 4: Flat end of churn body with handle. Note rilling on churn necks 2, 3. Note neck join to body on churn neck 3. (*Source*: Burton 2004: pl 5.7, 305–06).

Although churns are considered a hallmark of Chalcolithic ceramics, they typically constitute only a very small proportion of a site assemblage. During the Shiqmim Phase II excavations (1987–1989, 1993), 387 churn sherds were identified, representing 2.2% of the entire assemblage of 17,523 diagnostic sherds (Burton 2004: 214–16). Amiran (1969) suggested that churns were used for carrying water. Levy and Menahem (1987: 318) asked whether Chalcolithic ceramic churns, which appear to mimic the shape of goatskin churns used by historical Negev Bedouin tribes (Amiran 1969: 33; see also Commenge-Pellerin 1987: 50–51), were primarily cultic rather than utilitarian items. Churns are indeed prominent iconographic elements in unique Chalcolithic figurines such as the 'Gilat lady' (Alon 1976) and a bovine statuette from the En Gedi 'sanctuary' (Ussishkin 1980). One miniature churn found at Shiqmim (1993 Area D, Locus 4081) had a body length and maximal width of 17 cm and 8.5 cm respectively, and was filled with 4692 tiny beads of malachite, copper, carnelian and shell. Such a small vessel is unlikely to have had a utilitarian function and points to the importance of the churn in Chalcolithic symbolism. On the other hand, the notion that churns may have been utilitarian elements of the ceramic repertoire is supported by fatty acid residues detected by gas chromatography/mass spectrometry (GC/MS) within their porous walls (Burton 2004: 595). Results from analysis of five Chalcolithic churn sherds revealed that four contained appreciable levels of fatty acids exhibiting compositional profiles similar to degraded animal fat (Burton 2004: 596, fig. 9.9, 677, appendix 9.2).

Utilitarian function is further suggested by find spots on the floors of apparently domestic spaces, such as surface rectilinear Room 25 and Subterranean Rooms 8 and 9 during the Shiqmim Phase II excavations (Burton 2004: 249, table 5.17). Goren and Gilead's (1987) previous petrographic study of Shiqmim ceramics included two churn samples. Of 19 churn samples studied petrographically from Gilat, a site that may represent an early phase of Chalcolithic settlement sequence in the northern Negev (Levy and Burton 2006), 84% were determined to be of non-local origin (Goren 2006: appendix A). The current study includes 34 churn samples from Shiqmim in an attempt to more closely examine correspondence between ceramic composition and this enigmatic vessel form.

Materials and methods

Ceramic samples

Ceramic samples were chosen for this study from a set of diagnostic sherds from the Shiqmim Phase II (1987–1989, 1993) ceramic assemblage that had previously been selected for organic residue analysis (Burton 2004: 566–613; Evershed *et al.* 2008). This set includes the main Beersheva Valley Chalcolithic vessel form types: bowls, basins, hole-mouth jars, necked jars and churns. Fifty-one Shiqmim sherds, representing all of these vessel form types, were selected (Table 1). In order to provide some regional context, also included within the total set of 59 samples are a small number of sherds from the Chalcolithic occupations of three additional excavated settlement sites: Mezad Aluf (n = 1; Levy *et al.* 2006), Abu Hof Village (n = 5; Burton and Levy 2012), and the Nahal Tillah Silo Site (n = 2; Levy *et al.* 1997). All of the sites are located within Israel's semi-arid Irano-Turanian zone northern Negev desert region. Abu Hof Village and the Nahal Tillah Silo Site lie near the north-eastern boundary of this region, bordered by the wetter Mediterranean zone southern Shephela to the north (Fig. 1).

Thin section petrography

Standard (30 μm) petrographic thin sections were prepared from each of the selected sherds (Quinn 2013: 3–33). These were analysed under a polarizing light microscope using a modification of the holistic, descriptive approach pioneered by Whitbread (1989; 1995). This approach focuses on characteristics of the clay matrix and voids in addition to the more conspicuous aplastic inclusions (Quinn 2013: 80–102).

The ceramic thin sections were sorted into petrographic fabrics under the microscope without regard to vessel form type and site. Individual petrographic fabrics were then characterized in detail by interpreting the type(s) of raw materials and the various steps involved in their manufacture, as well as their relationship to other fabrics. Compositional, microstructural and textural criteria were used to identify technological practices such as raw material processing, the intentional addition of different types of particulate matter ('temper') and the atmosphere and degree of firing (Quinn 2013: 153–203). Quantitative textural data on the size distribution of inclusions was also collected for representative samples of the major fabrics. This was done by point counting a total of 300 evenly spaced points (Quinn 2013: 102–11) using a PETROG digital stepping stage and software.

Instrumental geochemistry

All sherds were analysed via portable X-ray fluorescence spectroscopy (pXRF) in order to characterize their bulk geochemical composition. Despite concerns about the quality of data from these miniaturized portable devices (Speakman and Shackley 2013) and the heterogeneity of coarse ware sherds (Tykot *et al.* 2013), this technique holds significant potential for the rapid, non-destructive, *in-situ* analysis of ceramics if used properly (Holmqvist 2016; Hunt and Speakman 2015; Speakman *et al.* 2011). By optimizing sample preparation, calibration and data quality control, it is possible to generate geochemical data that approaches that of destructive analytical techniques such as INAA (Wilke 2017; Wilke *et al.* 2017).

Irradiation of the sherds was performed with an Olympus Innox-X Delta Premium hand-held device using a Rh source and a 2 mm Al filter. Analysis was undertaken at 40 kV for 120 seconds live time. The resulting spectra were deconvoluted in the Bruker ARTAX software in order to correct for the individual Fe absorption/enhancement of each element in non-calcareous pottery, as well as specific spectral interferences, including Rb Kß/Y Kα, Y Kß/Nb Kα and Sr Kß/Zr Kα. A Rayleigh scatter distance correction was used to account for the curved shape of pottery sherds. The resulting net counts were converted into concentrations via an in-house calibration for high calcareous ceramics. The in-house calibration was developed using a set of homogeneous fired clay samples spiked with four different concentrations of each of the eight elements Fe, Ga, Nb, Rb, Sr, Ti, Y and Zr (32 spikes) considered to be discriminative for pottery sourcing as described by Wilke *et al.* (2017). These bespoke reference samples were developed specifically for pXRF calibration due to the absence of natural geochemical

Table 1. Details of Chalcolithic ceramic sherds analysed from Shiqmim and nearby archaeological sites in this report, including petrographic fabric assignment and data on geochemical composition. Fabrics: 1, Silty Calcareous Fabric; 2, Sand-Tempered Silty Calcareous Fabric; 3, Sand and Plant-Tempered Silty Calcareous Fabric; 4, Sandy Calcareous Fabric; 5, Highly Calcareous Micritic Limestone Fabric.

							Percent Weight			Parts per million (ppm)				
Analytical Code	Site	Year	Area/Square/Locus	Stratum	Vessel Type	Fabric Code	CaO	Fe_2O_3	K_2O	Rb	Sr	Ti	Zn	Zr
NNCC001	Shiqmim	1989	J/L11/3315	III	Churn	2	14.42	6.55	1.14	31	345	6935	90	320
NNCC002	Shiqmim	1993	D/P14/4084	IA	Medium Bowl	2	4.17	6.40	2.00	36	296	6921	114	288
NNCC003	Shiqmim	1993	D/O13/4100	IIA	Jar	2	8.55	5.62	1.40	24	287	7334	72	268
NNCC004	Shiqmim	1993	D/O13/4100	IIA	Necked Jar	2	6.94	6.41	2.03	31	369	8080	88	377
NNCC005	Shiqmim	1993	D/O13/4101	IIA/B	Necked Jar	3	3.94	7.39	1.84	34	322	7455	100	292
NNCC007	Shiqmim	1993	D/Q14/4149	IA/B	Small V-shaped Bowl	1	4.69	6.45	2.21	43	316	6996	84	337
NNCC008	Shiqmim	1993	D/O12-P12/4180	IIB	Hole-mouth Jar	2	9.72	7.05	1.69	36	383	7544	84	331
NNCC009	Shiqmim	1993	D/P14/4198	IIB	Medium Bowl	5	43.69	3.92	0.73	14	299	4128	32	129
NNCC010	Shiqmim	1993	D/P14/4198	IIB	Cooking Pot	2	6.34	5.47	1.71	35	407	6369	96	303
NNCC011	Shiqmim	1988	Y/L10-M10/434	II	Hole-mouth Jar	2	5.88	6.17	1.99	31	276	6005	89	249
NNCC012	Shiqmim	1993	X/O18/4515	IIB	Large Bowl	2	9.79	6.61	1.53	34	397	6683	85	255
NNCC013	Shiqmim	1993	X/P1/4521	IIA	Small Hole-mouth Jar	3	9.57	6.78	1.87	43	441	6154	90	342
NNCC014	Shiqmim	1993	X/A18/4542	IIA	Small V-shaped Bowl	1	4.98	6.09	1.94	35	369	6750	96	422
NNCC015	Shiqmim	1988	D/O12/730	IIB?	Large Pithos thumbed	3	3.39	6.08	2.14	35	402	7598	88	304
NNCC016	Shiqmim	1988	D/P12/734	III	Small Hole-mouth Jar	4	7.25	5.67	2.11	31	322	5528	103	246
NNCC017	Shiqmim	1988	D/O12/744	IIA	Basin	2	5.50	6.14	2.35	36	406	6860	70	326
NNCC018	Shiqmim	1987	S.Trench/K5/9	I	Churn	2	10.03	4.01	1.71	21	317	4297	73	221
NNCC019	Shiqmim	1988	Y/J10/366	I	Churn	2	5.44	5.89	1.46	39	290	6111	71	288
NNCC020	Shiqmim	1988	Y/L10/435	II	Churn	2	6.73	5.24	2.11	28	299	5092	104	244
NNCC021	Shiqmim	1988	P/H8/559	I	Churn	2	10.35	4.26	1.55	21	295	4149	83	201
NNCC022	Shiqmim	1988	D/Q11/708	IIA	Churn	2	9.56	4.33	1.58	21	428	5552	72	299
NNCC023	Shiqmim	1989	D/P14/3507	IA/B	Hole-mouth Jar	2	3.92	6.31	1.92	35	338	5975	125	320
NNCC024	Shiqmim	1989	D/P14/3507	IA/B	Churn	2	5.27	5.87	1.83	34	347	5163	128	261
NNCC025	Shiqmim	1988	Y/L10/435	II	Churn	3	6.16	6.03	2.17	45	284	5848	99	326
NNCC026	Shiqmim	1989	D/P14/3508	IA	Churn	2	6.08	4.85	1.28	26	328	4694	99	271
NNCC027	Shiqmim	1988	D/P12/713	IIA	Churn	2	7.62	5.25	1.70	27	422	5289	104	253
NNCC028	Shiqmim	1988	P/H7/520	I	Churn	2	5.39	5.37	1.93	30	271	4952	133	228
NNCC029	Shiqmim	1987	N. Trench/M7/268	IA	Churn	3	7.66	5.89	2.42	31	505	5479	90	281
NNCC030	Shiqmim	1987	N. Trench/L7/283	IIA	Churn	2	5.49	4.72	1.82	22	377	5235	89	247
NNCC031	Shiqmim	1987	N. Trench/K6/217	IA	Churn	2	10.90	4.29	2.05	21	347	4713	85	207
NNCC032	Shiqmim	1989	J/M12/3262	II	Necked Jar	2	6.40	5.92	1.72	28	336	6118	113	233
NNCC033	Shiqmim	1987	N. Trench/M6/259	IA	Churn	2	6.43	5.48	2.12	27	363	5640	119	293
NNCC034	Shiqmim	1989	J/M11/3270	I	Churn	2	7.81	4.51	1.57	21	368	5734	67	250
NNCC035	Shiqmim	1988	P/G9/512	I	Churn	2	4.38	6.25	2.54	33	435	6082	107	293
NNCC036	Shiqmim	1988	P/G9/531	II	Churn	2	8.45	4.63	1.45	26	345	4270	97	217
NNCC037	Shiqmim	1988	D/N12/739	IIB	Churn	2	23.57	2.88	2.54	13	311	3024	99	141
NNCC038	Abu Hof Village	1996	AHVL/D20/544	IIIA/IIIB	Churn	5	21.02	2.48	1.74	8	1090	2530	98	93
NNCC039	Shiqmim	1989	Y/M10-L10/3041	III	Churn	2	6.14	5.17	2.44	30	319	4896	96	273
NNCC040	Shiqmim	1993	X/P20-Q20/4527	IIA	Churn	2	7.30	5.22	1.57	31	262	4659	105	209
NNCC041	Shiqmim	1989	J/L12/3279	II	Churn	3	1.53	6.81	1.60	27	260	6616	132	261
NNCC042	Shiqmim	1988	Y/L11/438	II	Churn	2	10.39	4.61	1.87	28	374	5434	77	293

Continued

Table 1. ***Continued***

							Percent Weight			Parts per million (ppm)				
Analytical Code	Site	Year	Area/Square/Locus	Stratum	Vessel Type	Fabric Code	CaO	Fe_2O_3	K_2O	Rb	Sr	Ti	Zn	Zr
NNCC043	Shiqmim	1988	Y /M10-L10-M11-L11/432	III	Churn	2	6.00	5.79	2.70	37	382	5209	155	258
NNCC044	Shiqmim	1993	X/O18-P18/4501	I	Churn	2	12.22	3.01	1.01	22	463	2768	62	223
NNCC045	Shiqmim	1988	D/P12/734	III	Churn	2	7.25	5.67	4.47	31	322	5528	103	246
NNCC046	Shiqmim	1988	P /G9-G10/515	I	Churn	3	6.49	6.00	2.16	28	350	5841	112	238
NNCC047	Shiqmim	1993	X/P20-Q20/4536	IIA	Churn	2	8.71	4.80	1.37	22	388	4590	76	211
NNCC048	Shiqmim	1988	P/G9/568	II	Churn	2	11.26	3.70	1.64	20	443	4384	72	236
NNCC049	Shiqmim	1988	Y/J10/382	I	Churn	2	6.43	4.74	2.16	28	427	5368	112	260
NNCC050	Shiqmim	1993	X/A19-B19/4556	IIA	Churn	2	11.61	4.60	1.34	33	361	4457	80	282
NNCC051	Shiqmim	1987	N. Trench/L9/258	IA	Churn	2	3.71	5.90	1.97	27	458	5967	129	310
NNCC052	Shiqmim	1989	Y/M10/3037	III	Churn	2	12.50	4.04	1.57	22	345	4691	64	283
NNCC053	Shiqmim	1988	Y/M11/415	I	Churn	2	13.47	4.47	1.38	34	338	3854	87	275
NNCC054	Shiqmim	1989	J/L12/3263	I	Churn	3	5.16	5.50	1.83	33	430	5223	116	289
NNCC055	Abu Hof Village	1996	AHVL/Topsoil/560	I	Small V-Shaped Bowl	5	25.54	3.24	1.10	13	641	3739	57	128
NNCC056	Abu Hof Village	1996	AHVL/C1/525	IIIA	Necked Jar	5	39.88	1.53	0.74	5	485	1093	43	65
NNCC057	Abu Hof Village	1996	AHVL/B1/543	IIIB	Churn	5	18.97	3.52	1.64	18	971	3104	76	126
NNCC058	Nahal Tillah Silo Site	1996	A/V19/124	IIIBEarly	Churn	5	19.95	2.74	2.76	17	384	2796	65	138
NNCC059	Nahal Tillah Silo Site	1996	C-West/E16/739	IV	Churn	5	9.09	5.53	2.21	32	374	5431	108	255
NNCC060	Mezad Aluf	1993	Mezad Aluf/SE/1	NA	Small V-shaped Bowl	1	3.11	6.55	1.91	37	377	6520	90	306
SS01	Sample					Clay	6.59	3.43	1.42	35	272	5367	53	451
SS02	Sample					Clay	6.14	2.37	1.13	25	223	5914	35	506
SS03	Sample					Clay	7.40	3.20	1.30	27	241	6498	45	579
SS04	Sample					Clay	4.87	2.37	1.02	24	228	4912	33	425
SS05	Sample					Clay	7.56	3.54	1.23	32	291	5530	52	395
SS06	Sample					Clay	15.04	1.93	0.81	16	458	4211	33	383

reference materials with just one interfering element of variable concentration and the affected elements having a fixed concentration (Wilke 2017). The spiked samples have a clay matrix that is representative for mass absorption of mid-Z elements in a broad range of clay and other aluminosilicates with a total matrix composition of elemental O, Al and Si greater than 90%. In addition to the eight spiked elements, the calibration also measured Ca, Co, Cu, K, Mn, Pb and Zn, providing data on a total of 15 elements.

The surfaces of the sherds were abraded prior to analysis with silicon carbide paper to remove any possible surface contamination or decorative slip layers. Two approximately 9 mm diameter circular areas (*c.* 64 mm^2), representing the analytical spot size of the device, were analysed per sherd to account for possible heterogeneity caused by large inclusions or areas of clay mixing. The results from these were averaged after calibration.

The performance of the Olympus Innox-X Delta Premium and the in-house calibration for the 15 recorded elements (Ca, Co, Cu, Fe, Ga, K, Mn, Nb, Pb, Rb, Sr, Ti, Y, Zn, Zr) was determined by analysing 14 powdered certified reference materials (CRMs) of rock, ore, sediment, soil and ceramic in a sample cup or cuvette with a 4 micron prolene film. The accuracy of quantification for each element was assessed across the concentration range typical for prehistoric earthenware ceramics based on the INAA datasets of Day *et al.* (2011) (Bronze Age Greece), Quinn *et al.* (2010) (Neolithic Greece) and Quinn and Burton (2015) (Pre-contact California). Analysis of the CRMs indicated that the in-house calibration produced results with relative errors of 15% or less for the eight elements Ca, Fe, K, Rb, Sr, Ti, Zn and Zr (Supplementary Material Appendix 1). The CRM measurements provide a means by which future geochemical studies of related ceramic material can be compared to the data collected in this study.

Calcareous nannofossils

Due to the calcareous, fossiliferous nature of the analysed sherds and the geology of the northern Negev

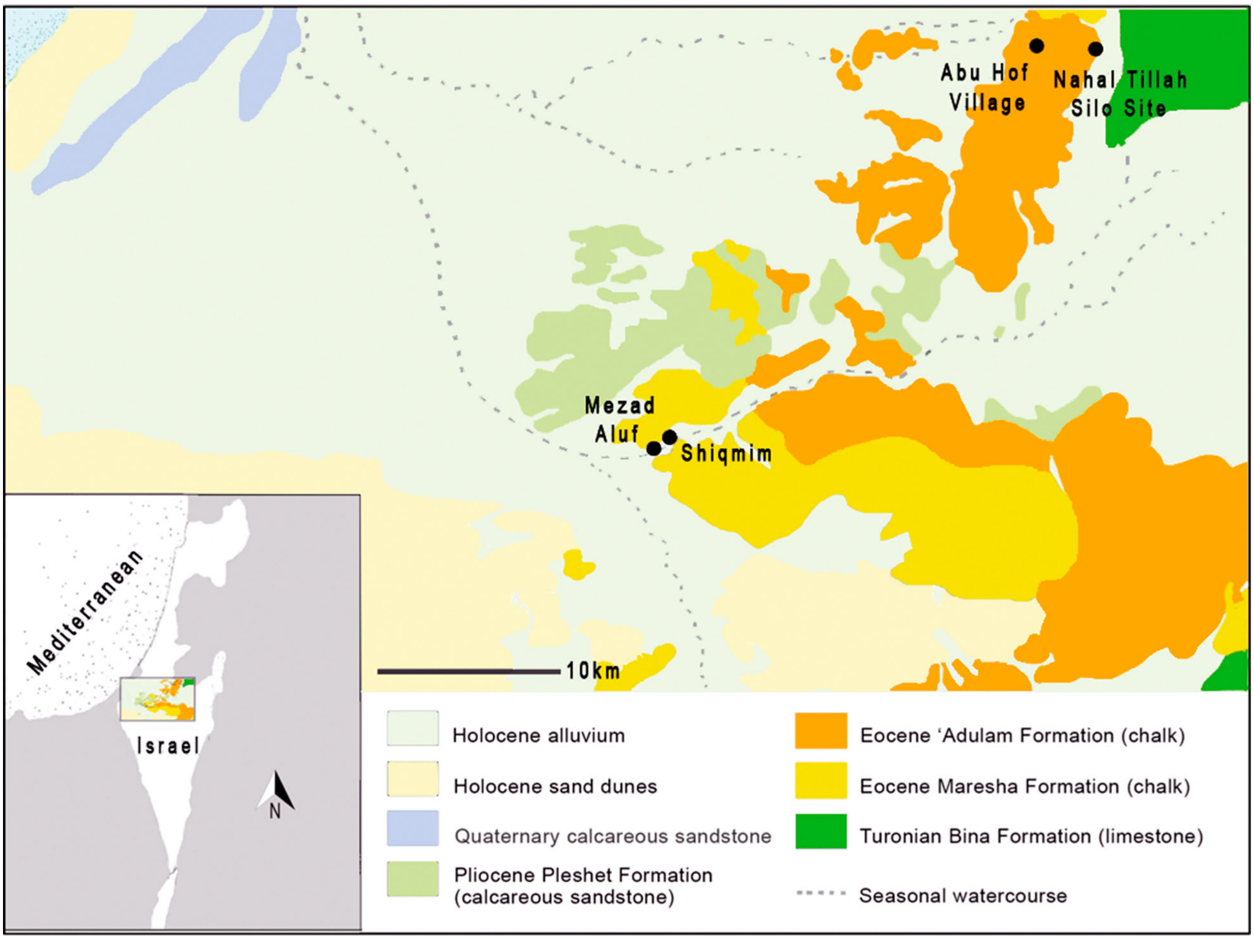

Figure 5 **Simplified geological map indicating major geological formations in the vicinity of the archaeological sites with ceramic samples included in this study (based on Sneh *et al.* 1998. Prepared by D. Walker).**

(Fig. 5), calcareous nannofossil smear slides (n = 5) were prepared of representative samples from the detected petrographic fabrics. Calcareous nannofossils are <10 µm calcite structures originating from single-celled marine phytoplankton, which can be used to date geologically the sedimentary rocks in which they occur. They can also occur in inorganic artifacts, including fired pottery, where this information has been used, alongside petrography and geochemistry, to interpret ceramic raw material type and production location (e.g., Quinn 2017; Quinn and Day 2007). The samples were prepared by scraping a few milligrams of powder from the sherd onto a glass slide and studying this under a petrographic microscope at 1000x. The 'nannoflora' present in each sample was characterized in detail, in terms of the different genera and species present, using identification guides (e.g., Bown 1998). A geological date was assigned based on the known ranges of the taxa and this was compared to information on the geological age of sedimentary strata in the study area using geological maps (e.g., Sneh *et al*. 1998).

Raw material sampling and analysis

In order to shed light on the possible sources of raw materials and provenance of the analysed ceramic samples, as well as their paste processing techniques, several clayey sediment samples were collected in the field. Most of the geological history of the north-western Negev is one of platform sedimentation resulting in accumulations of shallow-water carbonates and sandstones (Arkin *et al*. 1984: 97). These are overlain in places by Late Quaternary silts, clays and sands (Goldberg 1986). Holocene wadi systems drain the highlands from east to west into the Mediterranean, cutting into these sedimentary deposits and redistributing them. Fluviatile and aeolian silts accumulated during the Chalcolithic period and most recently between *c*. 1750–600 BP based on radiocarbon dates and corresponding with Byzantine settlement of the area (Goldberg 1986). Eocene chalk and Pliocene calcareous sandstone formations outcrop in the vicinity of Shiqmim and Mezad Aluf (Fig. 5). Abu Hof Village and the Nahal Tillah Silo Site are located in an area of Eocene chalk and Cretaceous limestone.

The six geological field samples collected for this study came from recent alluvium within the Beersheva Valley near Shiqmim (Fig. 2, Supplementary Material Appendix 2). Samples were selected based on simple field tests of their workability. Once collected, a small amount of each sample was embedded in resin and thin sectioned for analysis of its mineralogical and petrographic composition. A larger portion was refined in a 1 mm sieve to remove large particles, then mixed with water and fashioned into a test tile or 'briquette'. Once dry the test tiles were fired in an electric kiln at a temperature of 700°C for one hour in an oxidizing atmosphere. The fired samples were thin sectioned and compared under the microscope to both the ceramic fabrics and the unprocessed clay samples. The sediment samples were also analysed via portable X-ray fluorescence spectroscopy (pXRF) in order to characterize their bulk geochemical composition following the method described above for the ceramics. Calcareous nannofossil smear slides (n = 3) were prepared and analysed from selected sediment samples in the manner described above and the results were compared to the nannofossil assemblages detected in the ceramics.

Results

Ceramic composition and technology

Fabrics

Five distinct fabrics were identified within the Shiqmim sample set (Table 1). These are described briefly below and in detail in Supplementary Material Appendix 3. The distribution of the fabrics across major vessel form categories is shown in Table 2. Three of the fabrics — the Silty Calcareous Fabric (Fabric 1; Fig. 6A), the Sand-Tempered Silty Calcareous Fabric (Fabric 2; Fig. 6B), and the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3; Fig. 6C) — share the same moderately calcareous base clay. This base clay has well-sorted naturally occurring silt and fine sand-sized grains. These three fabrics differ in terms of whether and what kinds of ingredients were added as temper by the potter. They represent different clay 'recipes' and are, therefore, not related as sub-fabrics (Quinn 2013: 77). Two additional fabrics — the

Table 2. Percent distribution of petrographic fabrics by major vessel form category for the Shiqmim ceramic samples (n = 51).

Fabric	Bowls and Basins (n = 6)	Jars (n = 11)	Churns (n = 34)
1. Silty Calcareous Fabric	33	—	—
2. Sand-Tempered Silty Calcareous Fabric	50	64	80
3. Sand and Plant-Tempered Silty Calcareous Fabric	—	27	20
4. Sandy Calcareous Fabric	—	9	—
5. Highly Calcareous Micritic Limestone Fabric	17	—	—
	100	100	100

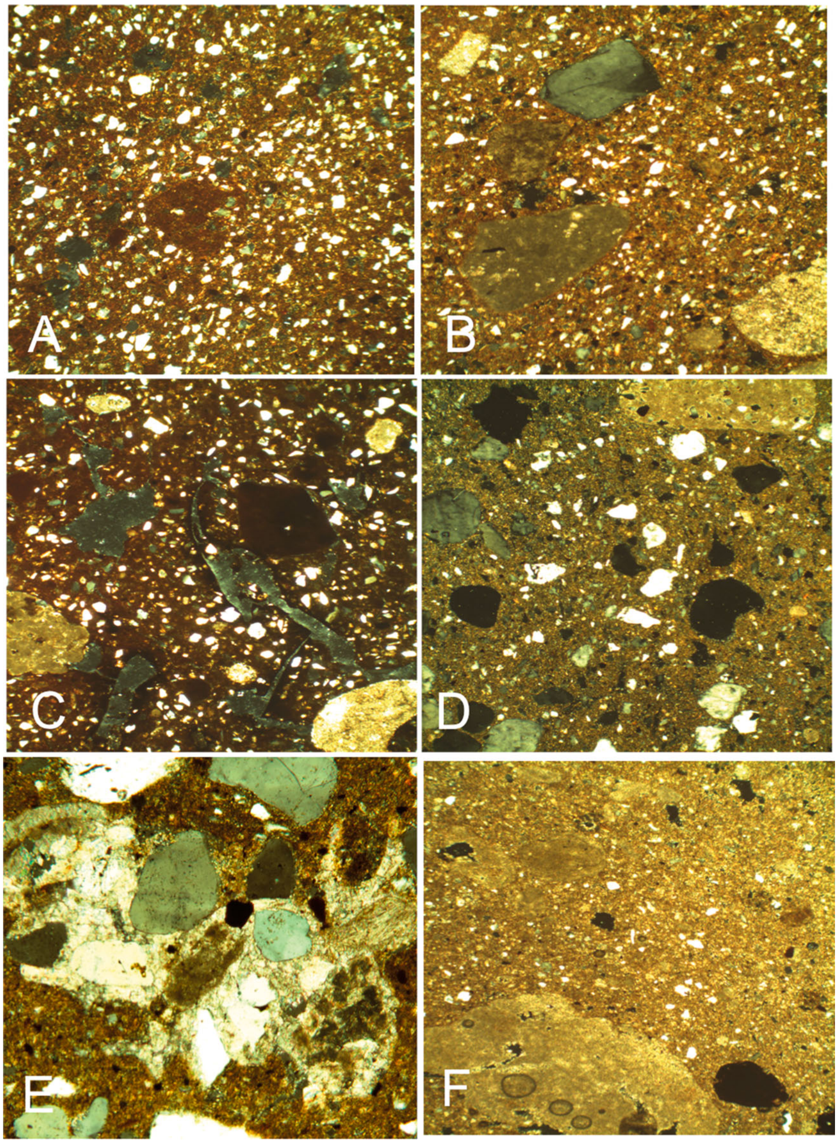

Figure 6 **Photomicrographs of petrographic fabrics detected within the Shiqmim sample set. A, Silty Calcareous Fabric (Fabric 1, Sample NNCC007), image width = 3.0 mm. B, Sand-Tempered Silty Calcareous Fabric (Fabric 2, Sample NNCC004), image width = 3.0 mm. C, Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3, Sample NNCC005), image width = 3.0 mm. D, Sandy Calcareous Fabric (Fabric 4, Sample NNCC016), image width = 3.0 mm. E. Kurkar inclusion in Sandy Calcareous Fabric (Fabric 4, Sample NNCC016), image width = 1.2 mm. F, Highly Calcareous Micritic Limestone Fabric (Fabric 5, Sample NNCC009), image width = 3.0 mm. All images taken with crossed polars.**

Sandy Calcareous Fabric (Fabric 4; Fig. 6D) and the Highly Calcareous Micritic Limestone Fabric (Fabric 5; Fig. 6F) — are represented by one specimen each in the Shiqmim sample set. These latter two fabrics are more calcareous than the Silty Calcareous Fabric, the Sand-Tempered Silty Calcareous Fabric, and the Sand and Plant-Tempered Silty Calcareous Fabric, and do not appear to have been refined or tempered in any way.

In the sample tested, only small V-shaped bowls were made from the Silty Calcareous Fabric (Fabric 1). This fine-grained fabric is characterized by the presence of well sorted sub-angular to rounded silt-sized inclusions (Fig. 7B), mainly of quartz in a moderately calcareous clay matrix. The maximum sustained firing temperature was <800°C, as indicated by the optical activity of the clay matrix (Quinn 2013: 190–91) and the preservation of calcareous inclusions (Cultrone *et al.* 2001). The samples do not have dark cores. A small V-shaped bowl sherd from Mezad Aluf (NNCC060), a satellite 'hamlet' located downstream from Shiqmim on the banks of the Nahal Beersheva (Levy *et al.* 2006), was also classified within the Silty Calcareous Fabric, suggesting that it was manufactured with similar raw materials and technology as the Shiqmim samples.

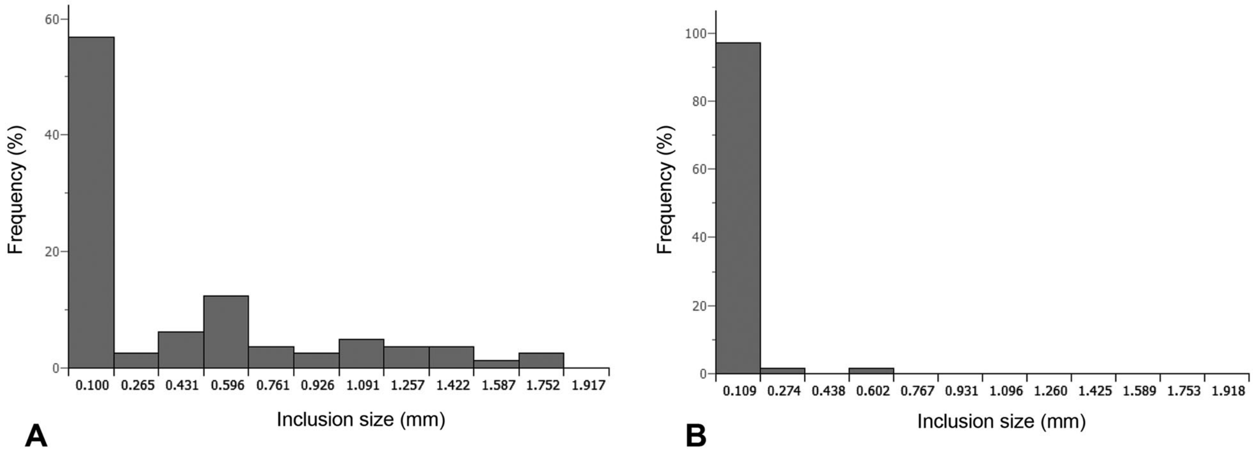

Figure 7 Grain-size distribution histograms of inclusions within selected Shiqmim ceramic samples. A. Sample NNCC001, Sand-Tempered Silty Calcareous Fabric (Fabric 2); B. Sample NNCC014, Silty Calcareous Fabric (Fabric 1).

The dominant fabric across all vessel form categories is the Sand-Tempered Silty Calcareous Fabric (Fabric 2) (Table 2). This is a coarse-grained fabric characterized by the presence of coarse sand-sized inclusions of sub-angular to rounded grains of quartz, micritic microfossiliferous calcite, limestone and chert in a moderately calcareous clay matrix with argillaceous inclusions. This coarse material, most likely a polymict sand of alluvial or aeolian origin coming from the erosion of several types of sedimentary rock, appears to have been added as temper to the calcareous base clay. This interpretation is supported by the bimodal size distribution of inclusions (Fig. 7A). Firing was generally oxidizing with a maximum sustained temperature below the degradation temperature of calcite (*c.* 800°C; Cultrone *et al.* 2001). The samples do not have dark cores.

Vegetal matter, along with polymict sand, was sometimes added to the clay used for the manufacture of jars and churns in this sample set. The plant matter added to the coarse-grained Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3) could, given the thin curved shape of the voids left after firing, have been some sort of grass. This may have been agricultural waste related to the farming of wheat and barley at Shiqmim (Kislev 1987; Rosen 1987). The maximum sustained firing temperature was <800°C based on the survival of calcite (Cultrone *et al.* 2001). Some of the samples assigned to the Sand and Plant-Tempered Silty Calcareous Fabric have a dark core due to the soot produced by the carbonization of the plant matter.

The Sandy Calcareous Fabric (Fabric 4) is represented by one small hole-mouth jar sherd (NNCC016) in the Shiqmim sample set. This specimen is medium coarse-grained and characterized by the presence of medium sand to silt sized sub-angular to rounded inclusions mainly of quartz in a calcareous matrix. One agglomeration of quartz sand bound by calcite ('kurkar') is present (Fig. 6E). Less common inclusions include micritic limestone, plagioclase feldspar, zircon, opaques and chert. The size distribution of the inclusions is unimodal and poorly sorted, suggesting that they were naturally occurring in a sandy calcareous clay deposit rather than added as temper. Firing was oxidizing and <800°C, as indicated by the optical activity of the clay matrix and the preservation of the rare calcareous inclusions (Cultrone *et al.* 2001). This sample lacks a dark core.

Within the Shiqmim sample set, there was one specimen, a medium bowl sherd (NNCC009), belonging to the Highly Calcareous Micritic Limestone Fabric (Fabric 5). All other examples of this fabric came from Abu Hof Village and the Nahal Tillah Silo site *c.* 30 km north-east of Shiqmim. This coarse-grained fabric is characterized by the presence of poorly sorted, generally rounded, sand-sized micritic limestone inclusions and quartz silt in a highly calcareous matrix. The limestone inclusions and quartz silt appear to be naturally occurring and not added as temper. This raw material may have come from the erosion of micritic fossiliferous limestone. It is more calcareous than the other four fabrics identified in this study. All the samples in this fabric were well oxidized and fired below the degradation temperature of calcite (*c.* 800°C; Cultrone *et al.* 2001). One sample (NNCC057) has a dark core.

Correspondence between fabrics and geochemistry

The geochemical composition of the analysed ceramic samples corresponds well with their petrographic fabric assignments. Principal Components Analysis (PCA) of the raw data from the eight elements with an accuracy of 15% relative error or less (Ca, Fe, K, Rb, Sr, Ti, Zn and Zr) explained 73% of the variance in the dataset. A scatterplot of principal components 1 and 2 (Fig. 8A) revealed good discrimination of all but one of the Highly Calcareous Micritic Limestone Fabric (Fabric 5) samples from the other sherds, due to their high Ca (and related high Sr) and lower Fe, Rb and Ti (Fig. 8B; Table 1). The other Fabric 5 sample (NNCC059) is, however, chemically distinct from the other six and may therefore have been produced using a different, but petrographically similar, clay source. The dominant Sand-Tempered Silty Calcareous Fabric (Fabric 2) forms a distinctive group in the scatterplot, thus confirming the geochemical coherence of these petrographically related sherds. The sherds classified in thin section as the rarer Fabrics 1, 3 and 4 plot at one end of this large cloud. This seems to support the idea that the Silty Calcareous Fabric (Fabric 1) and the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3) were manufactured with a silty calcareous clay source similar to that used for Fabric 2, but with the addition of sand temper in Fabric 2 and sand and plant temper in Fabric 3, and that this base clay was made by the levigation of the material used in the Sandy Calcareous Fabric (Fabric 4). The Silty Calcareous Fabric (Fabric 1) samples have high values for Ti and Zr and the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3) samples have relatively high iron (Fig 8B; Table 1). The samples assigned to each of these fabrics plot close to one another in the scatterplot, thus confirming their petrographic classification in thin section.

Correspondence between fabrics and calcareous nannofossils

Calcareous nannofossils were detected in several of the selected sherds that were prepared as smear slides (Fig. 10; Supplementary Material Appendix 4). In a few cases these were sufficiently abundant and well preserved to characterize the taxa present and assign geological ages to the material from which they derived. Sample NNCC041 of the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3) contained a mixed assemblage of nannofossil taxa deriving from the Late Cretaceous period and the Eocene and Oligocene epochs of the Cenozoic period. Sample NNCC038 of the Highly Calcareous Micritic Limestone Fabric (Fabric 5) also contained mixed Mesozoic and Cenozoic nannofossil specimens, including taxa from the Jurassic, Late Cretaceous and Paleogene periods. While reworked older nannofossils can be present in marine sedimentary deposits, the mixed nature of the floras detected in these two samples is likely to be due to the use of recent sedimentary material eroded from rocks of different ages (Quinn 2017). It could also be due to the addition of fossiliferous temper of one age to clay containing nannofossils of another. It is difficult to distinguish between these possibilities from nannofossil smear slides, which represent a bulk sample of the taxa within a sherd. The mixed age nannofossil assemblage of these samples is in keeping with the use of wadi alluvium eroded from the Mesozoic and Cenozoic marine strata that outcrop in the region. These may include the Eocene chalk of the Adulam

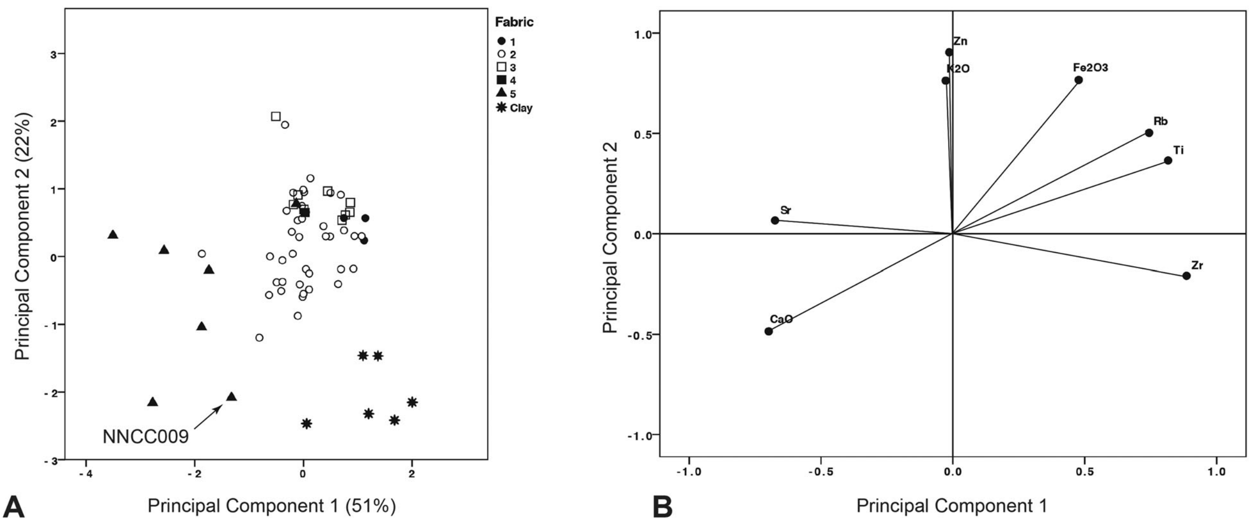

Figure 8 Statistical classification of geochemical data collected on Shiqmim sherds and comparative clay samples. A. Principal components analysis plot with ceramics labelled according to petrographic fabric and sample NNCC009 indicated. B. Loading plot indicating the influence of the utilized elements on the classification, as well as their relationships with one another. The elements Zr (zirconium), Ti (titanium), Rb (rubidium) and iron (Fe_2O_3) have large positive loadings on component 1; calcium (CaO) has a large negative loading on both components 1 and 2.

and Maresha Formations and the Cretaceous Bina Formation.

Comparison with raw material field samples

All of the clayey sediment samples are silt-rich and contain abundant quartz clasts with varying amounts of sand-sized grains (Fig. 9). In addition to quartz, which dominates the silt fraction and is sub-rounded to sub-angular, the samples contain micritic calcite, sparry calcite, plagioclase, mollusc shell, amphibole, chert, foraminifera and zircon, all of which are present as inclusions in ceramics belonging to the Silty Calcareous Fabric (Fabric 1), the Sand-Tempered Silty Calcareous Fabric (Fabric 2), the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3), and the Sandy Calcareous Fabric (Fabric 4). Generally, chert does not seem to be as common in the sediment samples as in the ceramics. Larger sand-sized grains occur in varying amounts in the field samples, with SS03, SS04 and SS06 containing more than SS01, SS02, and especially SS05. The larger clasts are more rounded and are dominated by micritic limestone with foraminifera, which is present in the Sand-Tempered Silty Calcareous Fabric (Fabric 2), the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3), and the Highly Calcareous Micritic Limestone Fabric (Fabric 5). This is particularly true of sample SS06 (Fig. 9F) that has more lumps (up to 1 mm) of limestone and therefore bears some resemblance to the Highly Calcareous Micritic Limestone Fabric (Fabric 5). Otherwise, however, sample SS06 is a poor match for the ceramics in this fabric. The latter have many large, rounded, micritic limestone and shell inclusions

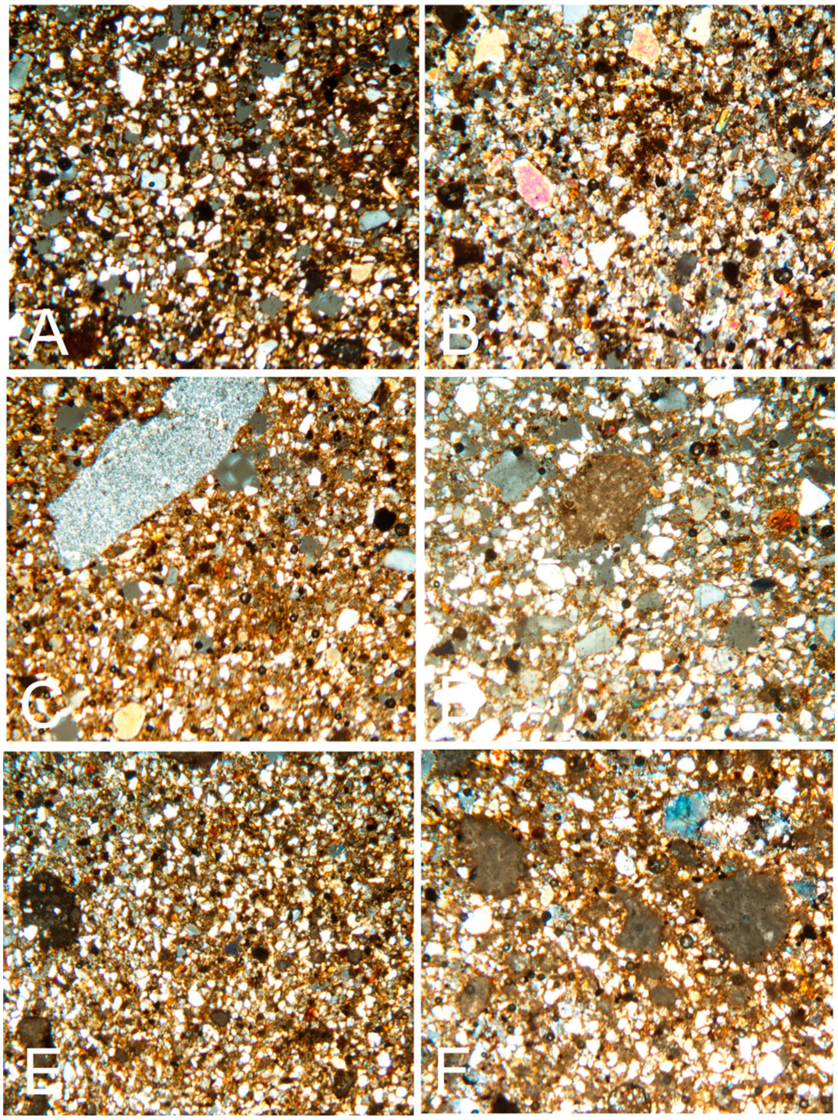

Figure 9 Photomicrographs of clayey sediment samples collected at Shiqmim. A. SS01; B. SS02; C. SS03; D. SS04; E. SS05; F. SS06. See Fig. 2 for collection location and Supplementary Material Appendix 2 for details. All images taken with crossed polars. Image width = 3.0 mm.

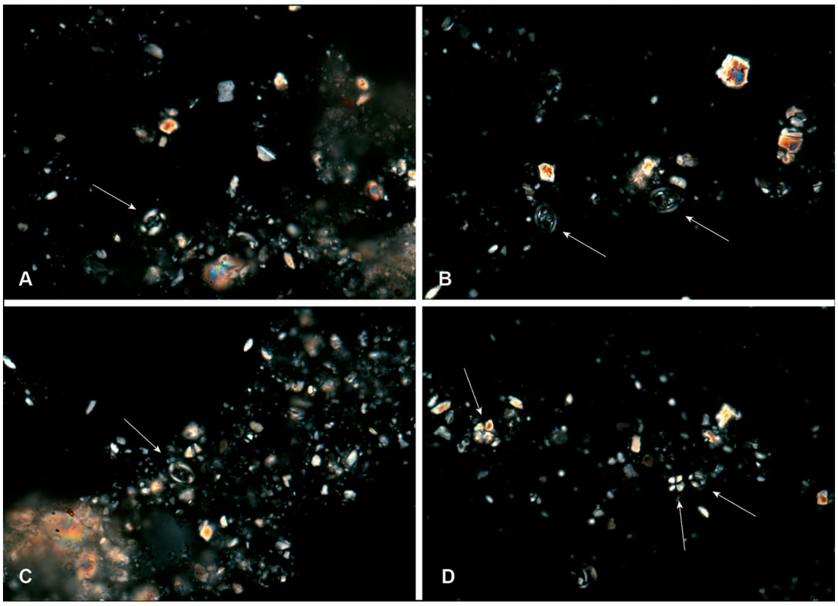

Figure 10 Calcareous nannofossil specimens visible in smear slide prepared from Shiqmim ceramic sample NNCC038. Specimens indicated with arrow and given identified species name and geological ranges. A. *Cruciplacolithus intermedius* (Paleocene). B. Two specimens of *Zeugrhabdotus noeliae* (Early to Late Cretaceous). C. *Tegumentum stradneri* (Early to Late Cretaceous). D. From left to right *Micula staurophora* (Late Cretaceous), *Sphenolithus moriformis* (middle Paleocene to middle Miocene), *Coccolithus pelagicus* (early Paleocene to Recent). Images taken with crossed polars. Image width = 0.1 mm.

that are not seen in clayey sediment sample SS06. Quartz can occur as rounded sand grains, such as in samples SS03 and SS04. In this respect sample SS04 (Fig. 9D) exhibits some similarity to the Sandy Calcareous Fabric (Fabric 4) (Fig. 6D). A large sand grain of sub-rounded chert occurs in sample SS03 (*c.* 1.5 mm; Fig. 9C), however, this seems to be less common among the coarse grains than in the two sandy petrographic fabrics, the Sand-Tempered Silty Calcareous Fabric (Fabric 2) and the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3). The larger sand-sized clasts in some of the sediment samples are less common than in the Sand-Tempered Silty Calcareous Fabric (Fabric 2) and the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3) and do not form a distinct fraction. As a result, the grain size distribution in the sediment samples is not as bimodal as that in the ceramics. This seems to support the idea that these two ceramic fabrics were tempered with sand. Small rare fragments of plant matter occur in some samples, such as SS01 and SS06, though this is much less abundant and finer than the vegetal voids that occur in the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3). The silt and sand-sized grains in all six sediment samples are surrounded by a calcareous matrix containing abundant micrite and clay. This matches that of the ceramic samples, although, based upon the crumbly nature of the fired test tiles, the sediment samples do not contain enough clay to be a viable source of raw material for pottery production.

Geochemically, the analysed raw material field samples are not a good match for the ceramic sherds (Fig. 8A). They group separately from the ceramic samples in the PCA scatterplot due to their higher Zr and lower Fe, K, Sr and Zn (Fig. 8B; Table 1). The clayey sediment samples are rather sandy and have lesser clay content than the ceramics, which may explain some of these differences, such as their greater proportion of Zr and lower Fe. It is not clear whether such material could have been levigated to yield a clay source similar to that used in one or more of the fabrics represented by the ceramics. However, in their current form they are not chemically related.

Calcareous nannofossils are present in some of the raw material field samples (Supplementary Material Appendix 4). Sample SS06 contains a very abundant, well-preserved assemblage that may be due to the frequent micritic limestone clasts in this sediment. The nannofossil specimens recorded under the microscope include taxa of Palaeogene, Neogene and possibly Quaternary age. No Mesozoic nannofossils were encountered in this material, perhaps confirming that it is not a match for the Highly Calcareous Micritic Limestone Fabric (Fabric 5). A mixture of Mesozoic and Cenozoic nannofossils were detected in raw material samples SS01 and SS04 and these assemblages have some specimens in common with some of the ceramics.

Discussion

The sizes of inclusions in the five petrographic fabrics identified in this study correspond well to the previously observed macroscopic subdivisions of northern Negev Chalcolithic ceramics into 'fine' ware (inclusions < 1 mm) and 'coarse' ware (inclusions > 1 mm) (Gilead and Goren 1989; 1995; *cf.* Commenge-Pellerin 1987: 28; 1990: 4–6). Consistent with these previous studies that relate the fine ware to small V-shaped bowls manufactured using a wheel or tournette, the fine-grained Silty Calcareous Fabric (Fabric 1) in this study is associated exclusively with small V-shaped bowls (Table 1). Although some researchers have suggested that sieved fine wadi sand was added to the local silty loess clay to produce the northern Negev Chalcolithic fine ware (e.g., Gilead and Goren 1995; Goren and Gilead 1987), samples of the Silty Calcareous Fabric in this study show no evidence for the addition of sand temper in thin section. The silt-sized inclusions in the ceramic samples are similar to naturally occurring silt clasts in the analysed field samples. It is possible that the fine alluvial clay, available in the Beersheva Valley wadi drainage, was advantageous for the introduction of wheel-based pottery manufacture that occurred in the southern Levant, during the Chalcolithic period (Baldi and Roux 2016).

Wheel-use is also reported for local ceramic production at other Beersheva Valley sites including Bir-es Safadi (Commenge-Pellerin 1990) and Abu Matar (Commenge-Pellerin 1987), and at sites on the Nahal Grar, including Grar (Gilead and Goren 1995) and Abu Hof Village (Burton and Levy 2012). It seems likely that the small V-shaped bowls at Shiqmim were the products of specialized potters due to the time needed to gain proficiency in the demonstrated technical skills (Roux and Corbetta 1989), and considering the relatively high degree of vessel metric uniformity (Burton 2004: 257–59, table 5.19; Burton and Levy 2012: 178). The presence of V-shaped bowls in vessel caches that may be ceremonial offerings or foundation deposits at the Shiqmim village (Levy *et al.* 1991) and in cemetery contexts near Shiqmim (Levy and Alon 1982) suggests some symbolic significance; however, they are also found in domestic spaces and throughout the site (Burton 2004: 185, table 5.2, 249, table 5.17).

Beyond the northern Negev, Courty and Roux (1997) reconstructed a wheel-shaping method for V-shaped bowls found at early 4th millennium BC Abu Hamid in the central Jordan Valley and identified the 'remote' Negev as the main production centre based on their study of 'microfabrics'. As described (Courty and Roux 1997: 34–36, planche 2a,b), their '*Groupe 1*' ceramic samples, which they attribute to a source within the Negev generally, may be similar to the Shiqmim ceramic samples in this study assigned to the Silty Calcareous Fabric (Fabric 1), the Sand Tempered Silty Calcareous Fabric (Fabric 2), and/or the Highly Calcareous Micritic Limestone Fabric (Fabric 5). Courty and Roux (1997) suggested that the V-shaped wheel-made bowls functioned as a kind of cultural marker and were circulated from specialized production centres across a Late Chalcolithic regional political-cultural entity in the southern Levant. Alternatively, they suggested that itinerant specialist potters may have travelled from site to site to manufacture certain vessel types for ritual purposes, bringing raw materials with them (Roux and Courty 2005). A more detailed comparative study, including geochemistry, of the ceramic composition of the V-shaped bowls from Abu Hamid and other contemporary sites might distinguish Shiqmim, or other particular sites in the Beersheva Valley and/or Nahal Grar drainage, as production locales or sources of raw materials involved in their proposed '*vaste communauté politico-cultuelle*'.

At Shiqmim, coarse sand was added to the paste that was used to produce the ceramics of both the Sand Tempered Silty Calcareous Fabric (Fabric 2) and the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3). These two coarse ware fabrics are associated with the larger vessels, including medium-to-large bowls and basins, necked jars, hole-mouth jars, and churns. Large vessels were formed by coiling with the necks of the jars and churns sometimes shaped using a wheel (Figs 3, 4; Burton 2004: 182–232; *cf.* Burton and Levy 2012; Commenge-Pellerin 1987; 1990; Gilead and Goren 1995; Levy *et al.* 2006). As the bodies of the large churns were formed in the same manner as the hole-mouth jars, then turned on their sides for the addition of the neck and handles (Fig. 4; cf. Commenge-Pellerin 1987: 33; Gilead and Goren 1995), it is perhaps not surprising that the large churns, despite their different and probably specialized functions, were manufactured using the same clay paste recipes as other large vessels.

Other researchers have noted the presence of vegetal matter in northern Negev ceramics (e.g., Boness *et al.*

2016; Commenge-Pellerin 1987: 28; 1990: 6; Goren 1995), but have not defined a separate petrographic class based on this criterion. In the study reported here, plant matter is abundant in the ceramic samples of the Sand and Plant-Tempered Silty Calcareous Fabric (Fabric 3) and these sherds are closely related geochemically within the general 'cloud' of Shiqmim ceramics (Fig. 8A). These data support the recognition of plant matter as an ingredient in a distinct clay recipe, rather than the incidental presence of plant matter in base clay (*cf* Commenge-Pellerin 1990: 6 that vegetal matter traces observed in the pottery at Bir es-Safadi are accidental and aeolian in origin). According to Velde and Druc (1999: 118), organic temper may create a locally reducing environment during firing thereby ' … promoting fusion of the clays present.' Additionally, organic temper added to ceramics increases porosity due to the voids left after firing. Porosity decreases heat transfer (Quinn 2013: 219). The consequent insulating properties were likely known to the site's inhabitants, as suggested by the use of plant matter as temper in the ceramic walls of copper smelting installations at Shiqmim (Golden *et al.* 2001). Another kind of technical ceramic found at Shiqmim and other Chalcolithic Beersheva Valley sites are crucibles (Golden *et al.* 2001). These have been studied for archaeometallurgical remains by some researchers (Golden 2010: 115–18; Shalev and Northover 1987), but have not been analysed in a manner that allows comparison with the pottery fabrics reported here. In the case of the Shiqmim jars and churns, plant matter may have been added to clay by the potter in order to increase permeability that results from the presence of connected pores in the fired vessel walls. This permeability would help cool liquid contents stored in the vessels through the process of slow seepage and evaporation (Rye 1976). Shiqmim was a farming community (Kislev 1987; Rosen 1987); the vegetal matter added to the clay may have been agricultural waste, such as chaff.

'Kurkar' — quartz sandstone bound by calcite — is considered to be a characteristic component of wadi sand from the Nahal Grar, but rare or absent in the Beersheva area (Gilead and Goren 1995). In this study, kurkar was detected in one ceramic sample, a small hole-mouth jar from Shiqmim (NNCC016) (Fig. 6E) assigned to the Sandy Calcareous Fabric (Fabric 4). Large kurkar grains may have been removed from clays by levigation or sieving. However, kurkar was not observed in the prepared thin sections of any of the six clayey sediment samples from Shiqmim.

All five fabrics in this study correspond to the 'Loess-calcareous sand/quartzitic sand' main petrographic fabric defined in a regional study by Goren (1995: 301–02) as well as to the similarly defined 'Northern Negev/Shephelah Loess (LSS)' of Boness *et al.* (2016). The higher proportion of carbonates compared to quartzose sand in the Highly Calcareous Micritic Limestone Fabric (Fabric 5) identified in this study suggests that the samples in this group correspond more specifically to Gilead's and Goren's (1989) Shephela 'petrographic cluster' — a geographically defined grouping of ceramic assemblages having in common high proportions of carbonatic sand as the non-plastic component in thin section studies. Indeed, of the seven ceramic samples attributed to the Highly Calcareous Micritic Limestone Fabric (Fabric 5), six are from Abu Hof Village and the Nahal Tillah Silo Site, located on the northern Negev/Shephela fringe (Fig. 1; Table 1) and within the 'Shephela cluster' area (Gilead and Goren 1989: 8, fig. 2). The remaining member of the Highly Calcareous Micritic Limestone Fabric (Fabric 5) is a medium bowl from Shiqmim (Sample NNCC009). It is possible that this vessel was imported from the Nahal Grar area, *c.* 20–30 km to the northeast. Notably, sample NNCC009 differs technologically from the other coarse-grained pottery samples from Shiqmim in that it is not tempered with sand; the inclusions appear to be naturally-occurring. Furthermore, geochemically, sample NNCC009 plots outside of the general cloud of Shiqmim ceramic samples (Fig. 8A) lending support to the notion that it was not manufactured at Shiqmim.

There is, however, variability in the relative proportions of siliceous versus calcareous components of ceramic raw materials within the immediate vicinity of the Shiqmim site (Fig. 9). Also, Goren (1995, figs 6–7) points to overlapping spatial distributions of the 'loess-calcareous sand' and 'loess-quartzitic sand' ceramic compositions in the northern Negev/southern Shephela region. Thus, it is currently unclear to what extent these spatial patterns reflect the use of several compositionally different clay deposits by potters at a site, versus trade/exchange in ceramics between Chalcolithic sites in this area. Expanded geochemical studies of ceramics and raw materials from different locations may help to clarify the factors contributing to the observed distributions.

Our petrographic, geochemical, and calcareous nannofossil data appear to be consistent with previous interpretations by other researchers (Commenge-Pellerin 1987; 1990; Gilead and Goren 1995), that during the Chalcolithic period in the Beersheva

Valley most pottery was manufactured on site, for local consumption, using locally available raw materials. There is certainly little evidence to rule this out, as the silt-sized inclusions in the ceramics are of similar size, shape and composition to clasts in the analysed clayey sediment samples from the vicinity of Shiqmim. Three different clay recipes appear to have been used at Shiqmim, involving the addition of coarse sand and in some cases both coarse sand and plant matter for the manufacture of large vessels such as large bowls, jars and churns, and possibly levigation to produce a fine-grained fabric for small bowls. It is likely that the temper raw materials would have been locally procured. The diversity of production locales for churns at Gilat, as identified based on petrographic analysis by Goren (2006), thus stands in contrast with the Shiqmim churn samples (n = 34) in this study, all of which appear to be have been made on or near the site. Goren (2006: 384–88) describes four of the 19 Gilat churn samples tested, as having a loess matrix with quartz and limestone or chalk inclusions. Since Gilat and Shiqmim both lie within the northern Negev-southern Shephela geographic area that is the source of these ceramic raw materials, it is not possible to distinguish either site, or others in that area such as Abu Hof Village, as the production locale for the Gilat churns on the basis of Goren's (2006: 373–74) descriptions alone. Future comparative geochemical analysis might be helpful in this regard.

The availability and use of both fine alluvial clay and sand and plant-tempered fabrics at Shiqmim, indicates knowledge and deployment of raw materials that are appropriate for the manufacture of ceramic moulds typically used in the lost-wax method of copper casting (Goren 2008; Levy *et al.* 2008: 117–19). Such moulds are made of an inner layer of fine clay and an outer layer of coarse, vegetal-tempered clay. The data reported here could provide a comparative framework for future petrographic, geochemical and calcareous nannofossil analyses of ceramic mould fragments that may be recovered from Beersheva Valley Chalcolithic sites (cf. Goren 2008). This kind of research may help to assess the possibility suggested by Shugar (2018) that 'prestige' copper objects were manufactured at these sites using the lost-wax technique. The required technological knowledge and metallurgical resources might have been introduced by populations coming from Anatolia and northern Mesopotamia, as suggested by ancient DNA findings (Harney *et al.* 2018). Possible contacts between the southern Levant and northern Mesopotamia at the end of the 5th millennium BC are also pointed out by Baldi and Roux (2016) based on petrographic analysis of 'exogenous material' used to produce 'wheel-coiled' V-shaped bowls found at late 5th millennium BC sites in the Lebanon area. Although innovations in ceramic and metallurgical production are not necessarily linked, a shared theme in explanations of technological breakthroughs during the Chalcolithic period in the southern Levant is the emergence of elites that may have created a demand for special items or prestige goods, such as the V-shaped bowls and cast copper objects (e.g., Baldi and Roux 2016; Levy 1998).

Summary

Technological innovations in ceramic production during the Chalcolithic period in the southern Levant have been highlighted by researchers who have taken a scientific approach to the analysis of archaeological assemblages within an environmental and social milieu (e.g., Baldi and Roux 2016; Commenge-Pellerin 1987; 1990; Courty and Roux 1997; Gilead and Goren 1989; 1995; Goren 2006; Goren and Gilead 1987; Roux and Courty 2005). These studies have featured both macroscopic and microscopic analyses that illuminate steps in pottery manufacture and provide data to address key issues including where, when and why specialized production emerged and how ceramics functioned, probably as both utilitarian objects and cultural symbols, across a broad geographic area. In this study of pottery from Shiqmim and some other northern Negev Chalcolithic sites, thin section petrography, instrumental geochemistry and calcareous nannofossil analyses were employed in a combined manner to provide complementary data for understanding how ceramic raw materials were procured, prepared and deployed for pottery-making. The results evidenced five distinct ceramic recipes, two of which involve the use of temper, and indicate that the Shiqmim pottery was manufactured from raw materials that have as their source the Holocene alluvium that is widespread throughout the study area. The mineralogical composition of the Shiqmim ceramic samples tested was similar to clayey sediment samples collected from wadi banks near the site. The ceramic composition of churns, a '*fossile directeur*' for the southern Levantine Chalcolithic with an enigmatic function, perhaps both utilitarian and symbolic, indicates local manufacture at Shiqmim using clay preparation methods typical of other large vessel types found at the site. The presence at Shiqmim of a bowl constructed from a highly calcareous fabric, characteristic of ceramics from Chalcolithic sites at the southern

Shephela boundary and with a distinctive geochemical profile, suggests the possibility of transport between settlements on the Nahal Grar and Nahal Beersheva. Although the results of this study generally correspond well with the work of other researchers, the data further point to the potential of a combined analytical approach to better resolve production locales within the northern Negev-southern Shephela area. Study of additional ceramic and geological samples, using a combination of petrographic, geochemical and calcareous nannofossil analytical methods, is needed to better understand within-site ceramic compositional variation and patterns of production and distribution during the Chalcolithic period in the northern Negev and neighbouring regions. Detailed site-specific systematic reporting of results, such as that provided in this paper, offers a basis for testable regional syntheses and may help, in future, to clarify networks of trade/exchange and social group movement.

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Supplementary material

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