From seashore to Neolithic floor: origins and spatial distribution patterns of shell bead assemblages at WF16, a Pre-Pottery Neolithic A settlement in Southern Jordan

Article

Published Version

To link to this article DOI: http://dx.doi.org/10.1016/j.jasrep.2023.104357

Publisher: Elsevier

Journal of Archaeological Science: Reports 53 (2024) 104357

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

From seashore to Neolithic floor: origins and spatial distribution patterns of shell bead assemblages at WF16, a Pre-Pottery Neolithic A settlement in Southern Jordan

Dave B. Smith [a,*], Heeli C. Schechter [b], Daniella E. Bar-Yosef Mayer [c], Steven J. Mithen [a]

[a] Department of Archaeology, University of Reading UK
[b] Institute of Archaeology, The Hebrew University of Jerusalem, Israel
[c] The Steinhardt Museum of Natural History, Tel Aviv University, Israel

ARTICLE INFO

Keywords:
Shells
Beads
Decoration
Origin
Manufacture
Faynan
WF16
Jordan
Neolithic
PPNA
Dentalium

ABSTRACT

Shells have been collected and used as body adornments by *Homo sapiens* for at least 140,000 years. Major increases in their use occurred during the Late Pleistocene and, with the gradual transition to the Neolithic, likely reflected new forms of social interaction associated with larger communities and less mobile lifestyles. We explore this development by considering the shell bead assemblage from WF16, a Pre-Pottery Neolithic A (PPNA) site in southern Jordan. This assemblage is one of the largest known from the early Neolithic and can be divided between two PPNA phases. We identify a changing preference for shell types between these phases, one that parallels a change in the wider region which may be associated with evolving social networks during the early Neolithic.

1. Introduction

Shells have been collected and used for symbolic purposes and personal ornamentation by *Homo sapiens* for at least 140,000 years (e.g., Bar-Yosef Mayer et al., 2020; Sehasseh et al., 2021). With their seemingly crafted shapes and wide variety of patterns and colours, coming from the mysterious sea and once housing strange creatures, one can readily appreciate why shells were so appealing to the earliest modern minds. They not only provided attractive objects, but invited symbolic interpretation, lent themselves to storytelling and, with their variation in size, shape and colour, provided an ideal medium for expressing individual and group identities. Along with other items of personal adornment such as stone beads, pigments and feathers, the use of shells may provide insights into the social dynamics of the early Neolithic, enabling comparison with those of technological and economic change (e.g., Bar-Yosef Mayer & Bosch, 2019; Baysal, 2013; Micheli, 2012; Knappett, 2005).

In this contribution, we describe, analyse and interpret an assemblage of 577 coral, marine and freshwater shells and artefacts from the early Pre-Pottery Neolithic A (PPNA) site of WF16, located in Faynan, southern Jordan. WF16 has a relatively deep stratigraphy for a PPNA site, providing a unique opportunity to explore changes in the use of shell beads during the course of the PPNA. It also has a diverse range of structures, enabling us to explore the spatial distribution of shells and their associations with other types of material culture. Although analytical studies remain on-going, our current results contribute to our interpretation of site-specific activities at WF16, the role of this settlement within the Southern Levant and regional patterns of change during the Neolithic transition from mobile hunting and gathering to settled farming lifestyles.

1.1. The settlement of WF16

WF16 is located approximately 50 km south of the Dead Sea, roughly equidistant from both the Mediterranean and Red Seas (Fig. 1). It is located at the confluence of Wadi Ghuwayr and Wadi Faynan at approximately 400 m above sea level, immediately adjacent to the

* Corresponding author.
E-mail addresses: d.b.smith@pgr.reading.ac.uk (D.B. Smith), heelis@savion.huji.ac.il (H.C. Schechter), baryosef@tauex.tau.ac.il (D.E. Bar-Yosef Mayer), s.j.mithen@reading.ac.uk (S.J. Mithen).

https://doi.org/10.1016/j.jasrep.2023.104357
Received 30 September 2023; Received in revised form 11 December 2023; Accepted 11 December 2023
Available online 6 January 2024

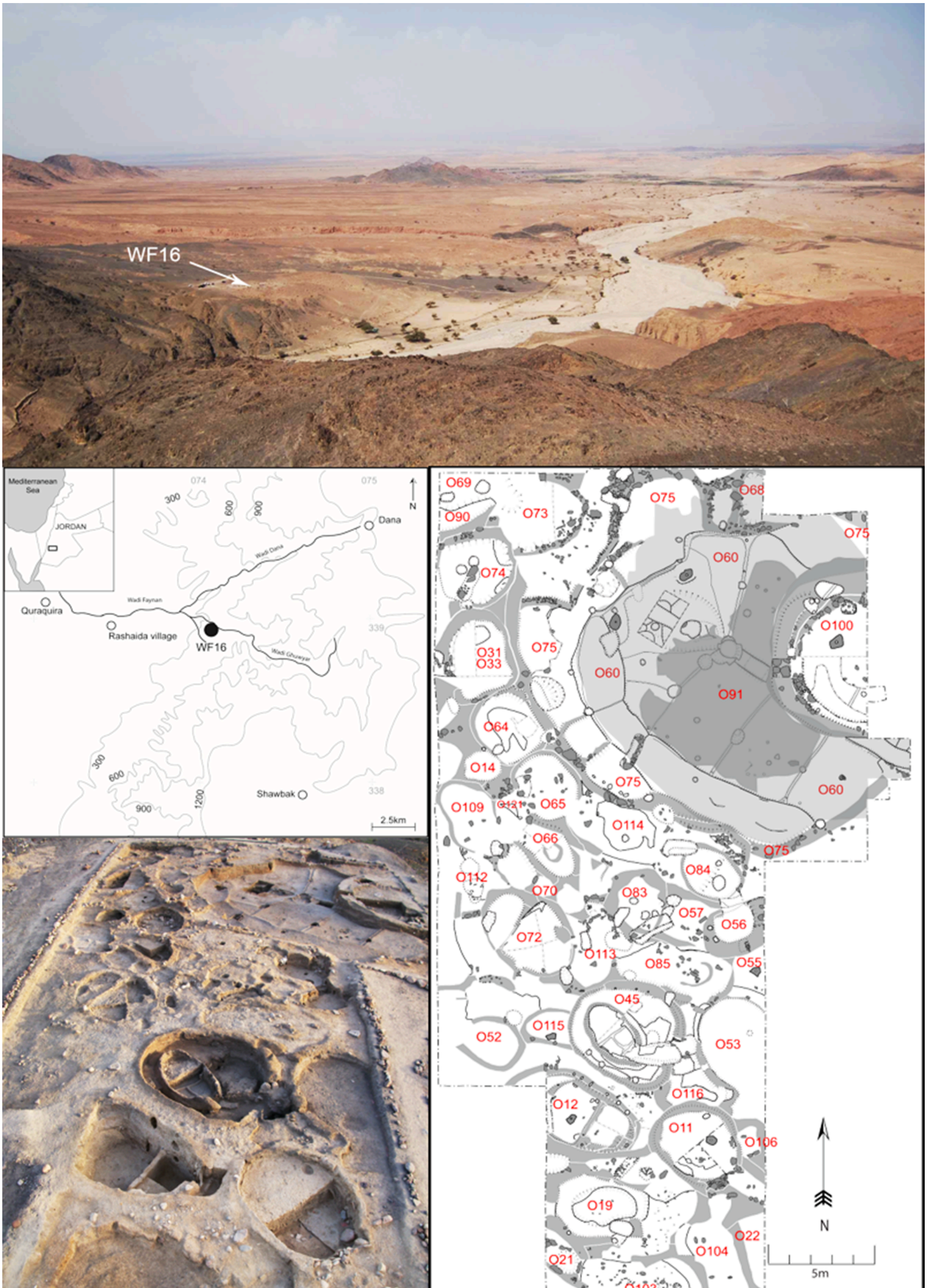

Fig. 1. The early Neolithic site of WF16 (a) looking east along the Wadi Faynan towards the Wadi Araba; (b) location in southern Jordan (c) excavation in April 2010; (d) site plan.

escarpment that climbs to the Jordanian plateau. The site was discovered in 1996, evaluated between 1997 and 2003 (Finlayson & Mithen, 2007) and subject to an area excavation between 2008 and 2010 (Mithen et al., 2018; Fig. 1d). That revealed numerous, densely clustered semi-subterranean structures that had been used for domestic activities, storage, workshops and gathering places.

Those structures, along with other distinct structural elements of the settlement, such as floors, middens and pits, are referred to as 'Objects'. For instance, a larger amphitheatre-like structure, one of a unique size (*c.* 300 m^2) and design for the Pre-Pottery Neolithic (Mithen, 2020), is referred to as Object 75 (O75) and an extensive area of midden is designated as Object 60 (O60). None of these Objects was entirely excavated, with no more than *c.* 20% of the total deposits removed across the site. The excavation involved the dry sieving of 213 kilolitres of sediment, producing 578.5 kg of animal bone, 2,731.3 kg of chipped stone tools and debitage, and a diverse range of material culture.

Initial assessment indicates that the animal fauna is consistent with that from the 1997–2001 evaluation: a dominance of *Capra* sp. with the presence of *Gazella*, *Bos*, equids and a low frequency of carnivores (Carruthers & Dennis, 2007). Archaeobotanical remains suggest exploitation of diverse wild plants with a possibility of cultivation of wild barley (Mike Charles, pers. comm.), similar to that evident from contemporary settlements (e.g., Dhra; Colledge et al., 2018). WF16 is also notable for having relatively large quantities of bird bones as well as numerous decorated and potentially symbolic objects for the PPNA, especially with regards to the southern Levant (White et al., 2021a; Mithen et al., 2022; Mithen et al., 2023).

Radiocarbon dating and use of lithic tool typology have identified three broad phases of activity at WF16 (Mithen et al., 2018):

Phase 1: 11.84–11.30 ka cal BP, is represented by small sub-circular, semi-subterranean structures with mud and stone walls. These were scarce and poorly preserved, providing few remains. Only one structure exposed by the 2008–10 excavation might possibly be related to Phase 1 activity, Structure O73 (Mithen et al., 2018, Figure 33.2). That requires confirmation by absolute dating methods, and hence for this contribution we include O73 within Phase 2 activity. Its excavation yielded a single *Dentalium sp.* shell bead to the site total of 577 shell beads. As such, it will not significantly affect the statistical analysis should O73 be confirmed as belonging to an earlier phase.

Phase 2: 11.30–10.80 ka cal BP, is represented by a dense cluster of semi-subterranean pisé-walled structures, of various designs and sizes including the large communal structure O75.

Phase 3: 10.80–10.24 ka cal BP, is represented by a freestanding circular pisé- and stone-walled structure O100 (Mithen et al., 2018, Figure 36.3) constructed within the boundaries of the earlier O75. It has an external mud-plaster floor (O91), while a large midden, O60, accumulated immediately adjacent to O100.

It is likely that several free-standing circular structures similar to O100 had once been constructed at WF16, these all having been lost by erosion but represented by large stone mortars remaining on the surface of the site (Mithen et al., 2018). O100 survived because its lower courses of walling had been protected through placement within the former semi-subterranean floor of structure O75. Most of the WF16 Neolithic burials are attributed to Phase 3, which were cut into the floors and walls of the underlying Phase 2 structures. The construction of free-standing architecture and the prevalence of burials in Phase 3 suggest significant social and economic change had occurred at WF16, likely involving longer periods of occupation, potentially leading to sedentism.

Three different types of PPNA chipped stone assemblages have been identified at WF16, each characterised by distinctive raw materials, core reduction strategies and range of artefact types (Smith, 2015). **Type A** is the most abundant and typical of the Southern Levantine PPNA, manufactured mainly on local wadi cobbles of medium-grained opaque chert. It is the only assemblage type occurring in Phase 2 of the site and is also present within the lower levels of the Phase 3 O60 midden. Assemblage **Type B** is characterised by lower proportions of retouched tools, points and microliths and a higher proportion of burins, alongside the introduction of some non-local chert material. **Type C** utilised a much higher proportion of non-local brown chert material and lacks any trace of the microburin technique.

Types B and C are restricted to Phase 3, and are found exclusively within Objects O60, O91 and O100. Type C assemblages always overlie those of Type B. Although the stratigraphic relationship between Type A and Type B assemblages within the O60 midden could not always be established, the excavators and chipped stone specialists are confident that a chronological succession is represented by Phase 2 Type A, Phase 3 Type A, Phase 3 Type B and Phase 3 Type C (2A, 3A, 3B, 3C) chipped stone assemblages (see further discussion in Smith (2015) and Mithen et al., (2018,539-542)).

WF16 has been interpreted as a domestic settlement that also functioned as a node within an extensive hunter-gatherer social network through which people, material items, foodstuff and ideas flowed (Mithen et al., 2023). The settlement has also been proposed as a locus for shamanic activity that was both embedded into the daily routines of its occupants and undertaken at seasonal gatherings for people from dispersed locations (Mithen, 2022). Such interpretations continue to be evaluated and developed as further material from the site is catalogued, analysed and interpreted.

1.2. The marine and freshwater shell assemblage

601 marine and freshwater shell beads and other marine-related artefacts were recovered from the 2008–10 excavation indicative of human usage and deposition (Table 1), along with over 1 kg of marine shell extracted through the post-excavation bulk sieving and flotation processes (Fig. 2).

The WF16 assemblage is one of the largest shell bead assemblages from the PPNA of the southern Levant, although substantially exceeded by the > 3400 shell beads from the PPNA levels of Abu Madi 1 (Bar-Yosef Mayer, 1999; 2010). While the size of the WF16 assemblage may partly reflect the spatial area excavated, depth of deposits and the extent of dry sieving, it also suggests a more substantial use of shell beads at WF16 than at most other known sites, potentially reflecting WF16′s proposed role as a locus for social gatherings and ritual (Mithen, 2022, Mithen et al., 2023).

The assemblage includes nine examples of Serpulidae (sea worms) that are unworked (which are similar in appearance to the many Dentaliidae examples recovered from the site), six unmodified marine fossils (two sea urchins, two gastropods and two of unidentified species) and nine fragments of unmodified freshwater crab claws, the latter possibly of natural occurrence due to seasonal flooding. These have been excluded from the following shell/bead analysis. Of the remaining 577 shells and beads included in the analysis, 36 have been identified as freshwater snail shells (Melanopsidae) and nine as worked/modified pieces of coral (Acroporidae). The remaining 532 marine shells represent at least 19 taxonomic families originating from both the Mediterranean and Red Seas. Eighteen shells (3.1% of the assemblage) still require an identification to family level.

Dentaliidae is the most common family across all phases of the site, constituting approximately 40% of the total WF16 assemblage (Fig. 3). The dominance of Dentaliidae is consistent with other PPNA shell

Table 1
Total of Shells, Beads, Amulets and Pendants identified at WF16 (by material class).

Material Class	bead, shell or bead preform/blank	Amulet or pendant	Site Total
Bone	16	3	19
Marine/Freshwater Shell or Coral	575	2	577
Stone	407	15	422
Site Total	**998**	**20**	**1018**

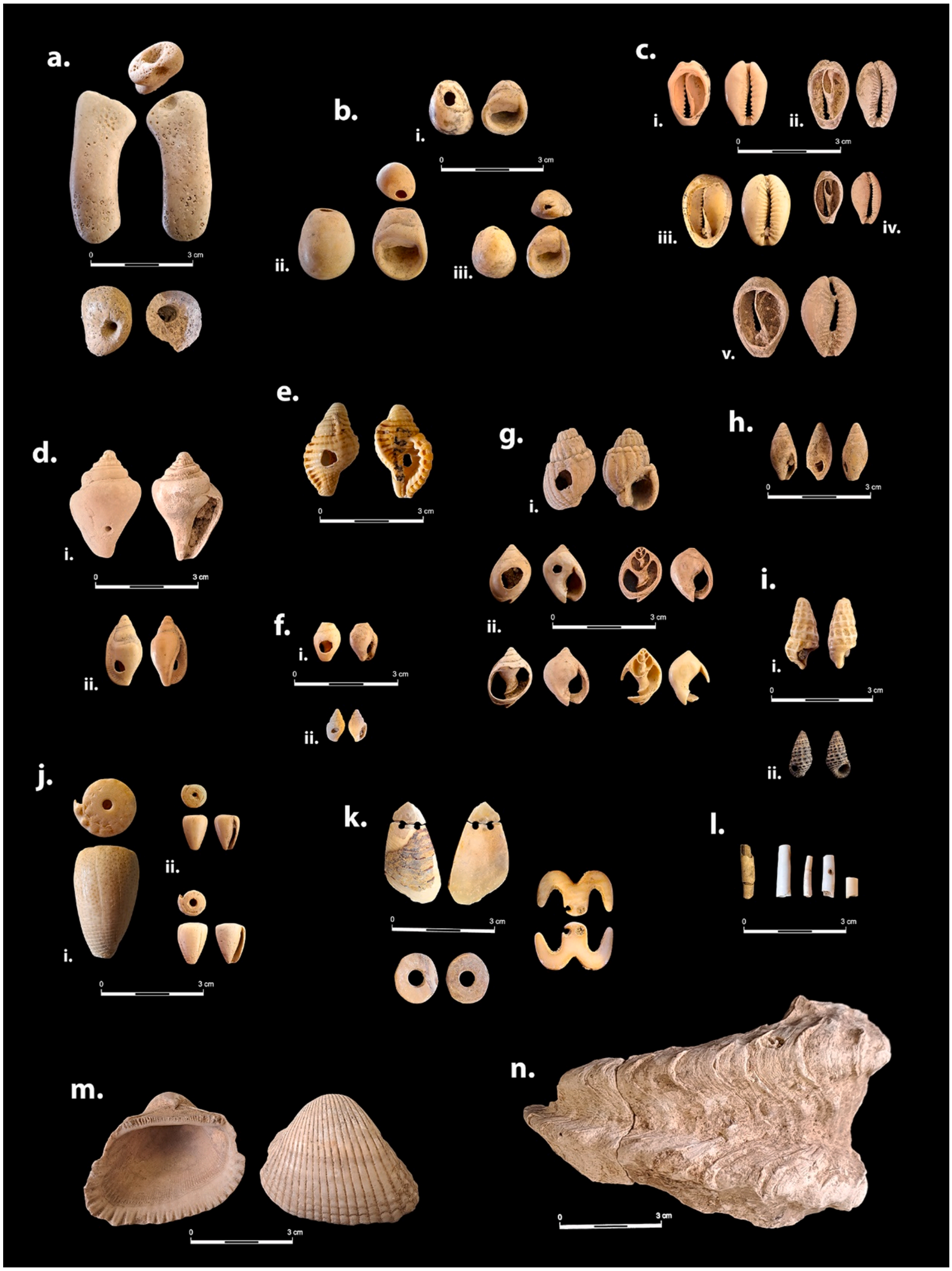

Fig. 2. A representative sample of marine shells and corals from Phases 2 and 3 at WF16. (a) Acroporidae: *Acropora sp*. (coral). (b) Neritidae: i-ii. *Nerita orbignyana*. iii. *Nerita sanguinolenta*. (c) Cypraeidae: i. *Monetaria moneta*. ii. *Naria spurca*. iii, v. *Naria turdus*. iv. *Purpuradusta gracilis*. (d) Strombidae: i. *Canarium mutabile*. ii. *Conomurex fasciatus*. (e) Charoniidae: *Septa marerubrum*. (f) i. *Columbella rustica*. ii. *Euplica festiva*.(g) Nassariidae: i. *Nasrius rufus*. ii. *Tritia gibbosula*. (h) Mitridae: *Mitra* cf. *cornicula*. (i) Cerithiidae: i. *Cerithium* cf. *columna*. ii. *Clypeomorus clypeomorus*. (j) i. Conidae: *Conus arenatus*. ii. *Harmoniconus parvatus*. (k) Margaritidae: *Pinctada margaritifera*. (l) Dentaliidae. (m) Arcidae: *Anadara uropigimelana*. (n) Cardiidae: *Tridachna* sp.

assemblages in the region, although Dentaliidae frequencies are generally higher elsewhere, typically averaging 50% or greater (Fig. 4). Cypraeidae (Cowrie), Conidae (*Conus*) and Neritidae (*Nerita*) together represent a further 34.3 % of the entire WF16 assemblage, all at relatively high frequencies compared to other PPNA assemblages of the region, while Nassariidae (*Tritia*, 8%) and Glycymerididae (*Glycymeris*, 0.7%) are relatively scarce at WF16. WF16 is also notable for the presence of Melanopsidae, freshwater snails that account for 6.2% of the total shell assemblage. We are cautious about the inter-site comparisons because of the small number of PPNA sites that have published shell bead assemblages and the low numbers of identified shells at those sites, particularly at Gilgal II and Salibiya IX (Bar-Yosef Mayer, 2010).

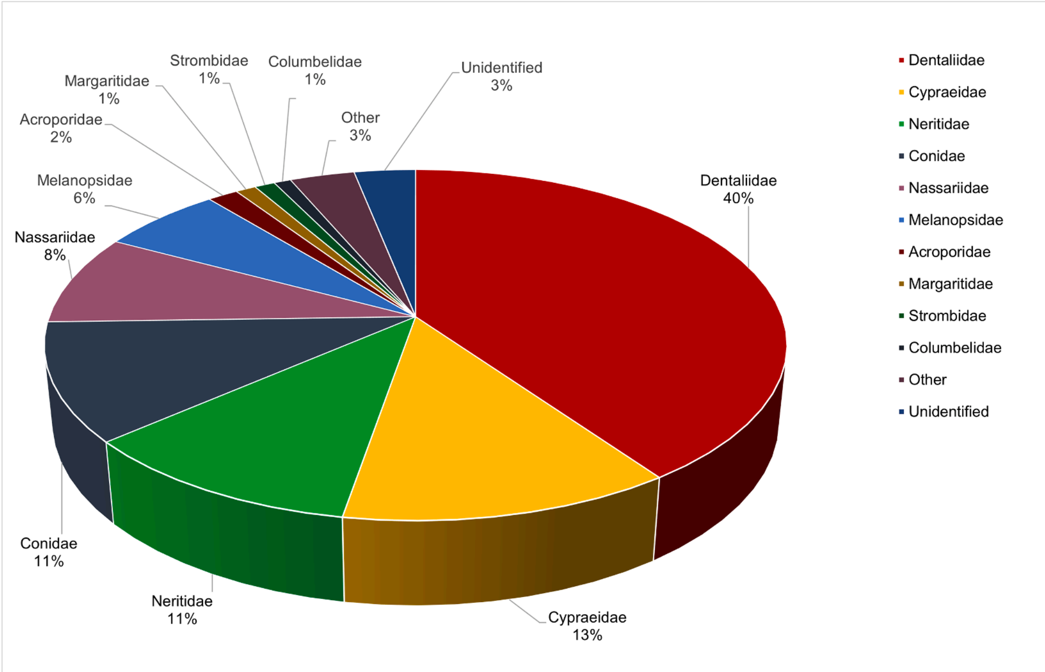

Fig. 3. Composition by family of the shell bead, shell and coral assemblage at WF16.

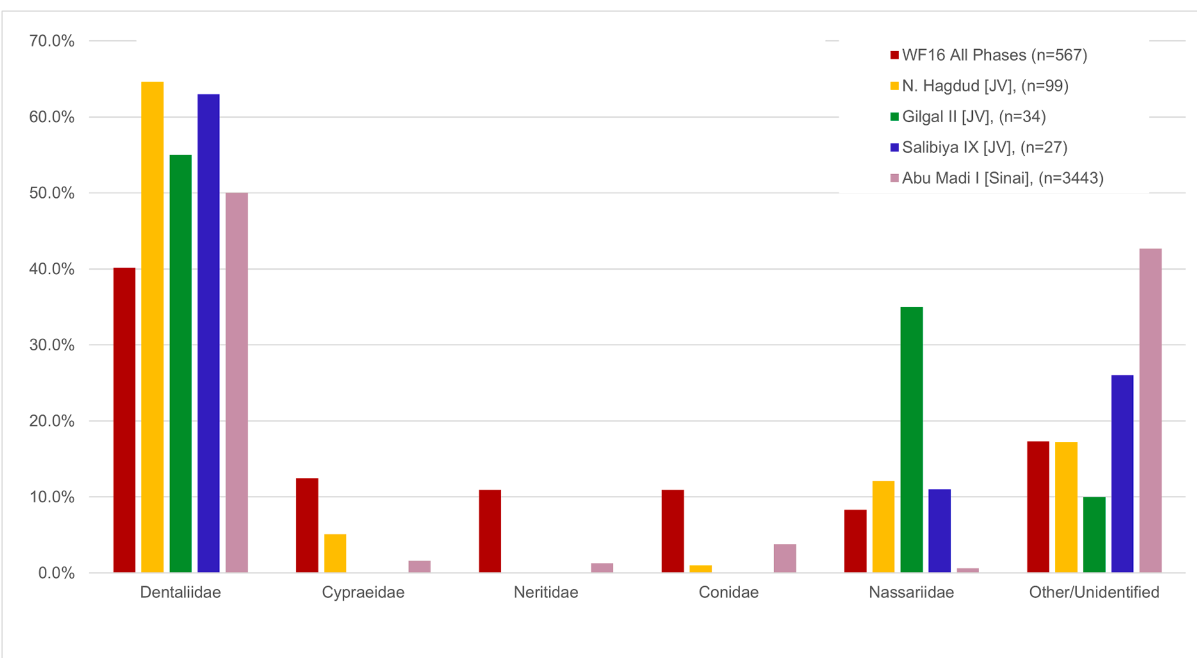

Fig. 4. Comparison by major families of the WF16 shell bead assemblages with those from PPNA sites in the southern Levant (Data from Bar-Yosef Mayer & Porat, 2008).

1.3. Chronological change in shell-type frequencies at WF16

A clear difference is evident in the types of shell beads used in Phase 2 and Phase 3 (Fig. 5). The quantity of sediment sifted/floated and the overall number of beads are comparable between the two phases (305 beads from 116 kilolitres of sediment [2.6:1] in Phase 2, and 273 from 91 kilolitres [3:1] in Phase 3). This specific comparison of site phases necessarily excludes shells from the overburden, Object O111, which had been subject to post-depositional mixing and likely contains shells from both phases of activity at WF16. Similarly, Object O99, a collection of burials inserted into the settlement during the Nabataean and Byzantine periods, has also been excluded for the same reasons, even though the burials contain PPNA material culture within their backfill.

There is a marked decline in the proportion of Dentaliidae (50.3% to 28.9%) and Nassariidae (13.5% to 2.6%) between the two phases, alongside an equivalent increase in Cypraeidae (5.3% to 20.5%) and Neritidae (2.6% to 20.1%), and to lesser extent Conidae (8.2% to 13.9%). The overall number of identified families between Phase 2 and 3 drops, from 17 to 12 (Table 2), with eight families disappearing from the artefact record and three new families appearing in Phase 3.

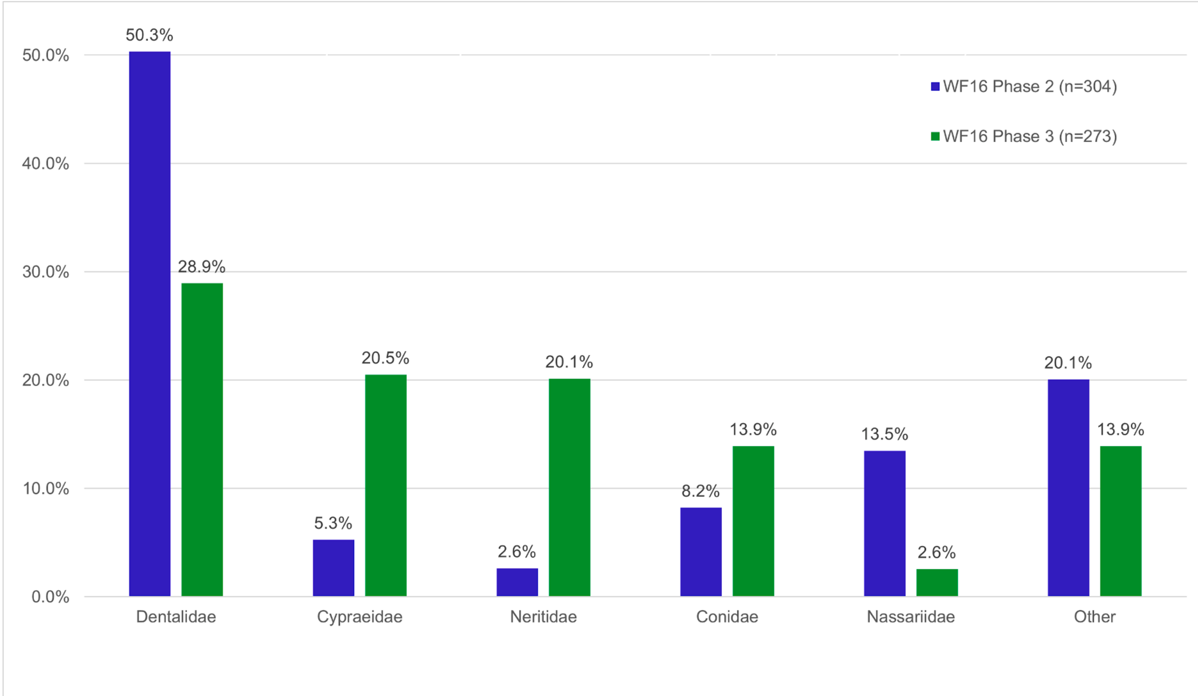

Fig. 5. Comparison of major shell family frequencies from WF16 Phase 2 and Phase 3.

Table 2
Shell and Coral families represented at WF16.

Family	Phase 2	Phase 3	Site Total
Dentaliidae	153	79	232
Cypraeidae	16	56	72
Neritidae	8	55	63
Conidae	25	38	63
Nassariidae	41	7	48
Melanopsidae	18	18	36
Acroporidae	6	3	8
Margaritidae		1	6
Strombidae	1		6
Columbelidae	1		5
Glycymerididae	4		4
Cardiidae		2	4
Cerithiidae	1		2
Veneridae	5		3
Mitridae	3	1	1
Ancillariidae	6		1
Arcidae	1		1
Charoniidae	4	2	1
Pectinidae	1		1
Turbinidae		3	1
Unidentified to date	10	8	20
Site Total	**304**	**273**	**577**
Total Represented Families	**17**	**12**	**20**

The composition of the Phase 2 shell assemblage now has a greater resemblance to that of PPNA shell assemblages from other contemporary sites in the region than did the complete assemblage (Fig. 6). In contrast, the Phase 3 assemblage aligns more closely to the composition of some known Pre-Pottery Neolithic B (PPNB) sites (Fig. 7), albeit with slightly higher proportions of Dentaliidae. This is particularly the case when comparing to the PPNB assemblages from the south Sinai locations of Ujrat-el-Mehed and Wadi Tbeik (Bar-Yosef Mayer, 1997). It should be noted, however, that these Sinai assemblages are from mixed context sources across their excavation sites – including floors and middens – that constrains the confidence we can have in their comparison to WF16.

A finer grained chronological division of the WF16 shell assemblage may be possible by further segmenting it according to those excavated contexts associated with the Type A, B and C chipped stone assemblages, which are believed to form a chronological succession (Table 3). As Fig. 8 illustrates, when the shell bead assemblage is placed into four subphases (2A, 3A, 3B, 3C), a clear time-dependent decrease in the frequency of Dentaliidae and Nassariidae becomes apparent, with notable changes in assemblage composition between Phase 2 and 3A/3C with regard to the frequencies of Cypraeidae and Neritidae. While chronology is likely to partly explain the change, we must allow for differences in depositional context (Phase 3A being within a midden) that might have influenced the types of shells discarded, potentially accounting for some of the changes in assemblage composition apparent between Phases 2 and 3. It is also not inconceivable that some portion of this earlier Phase 3A assemblage, particularly at the lower levels of the O60 midden, might contain discarded items (and particularly Dentaliidae shell) that could have originated from the deposition of Phase 2 material.

Also notable is the atypical Phase 3B assemblage composition. This has lower numbers of Cypraeidae, Neritidae and Nassariidae (the latter of which disappears completely from the Phase 3B record) but an increase in Conidae and the freshwater shell Melanopsidae, which represents 20% of the assemblage (n=50).

2. Origins/Sources of shells

304 (87.6%) of the non-scaphopod shells and corals from WF16 have so far been identified to species level and their sources identified to either the Red or the Mediterranean Sea. Only 5% of scaphopods (n=12) have so far been sourced. The identification of the remainder requires additional expert knowledge, preventing a discussion of the specific origin and varieties of species of most scaphopods in this contribution. However, of those we have sourced, it is clear that a variety of specimens of both *Dentalium sp.* and *Antalis sp.* is present, although the two *Antalis sp.* artefacts so far identified, both of Mediterranean origin, were located only within sub-phase 3A of the O60 midden. Of the total 316 marine specimens definitively sourced, including the 12 identified Dentaliidae, 71.5% (n=226) were collected along the Red Sea shores, and 17.1% (n=54) were brought from the Mediterranean (Fig. 9a), with the remainder identified as freshwater shells (11.4%, n=36).

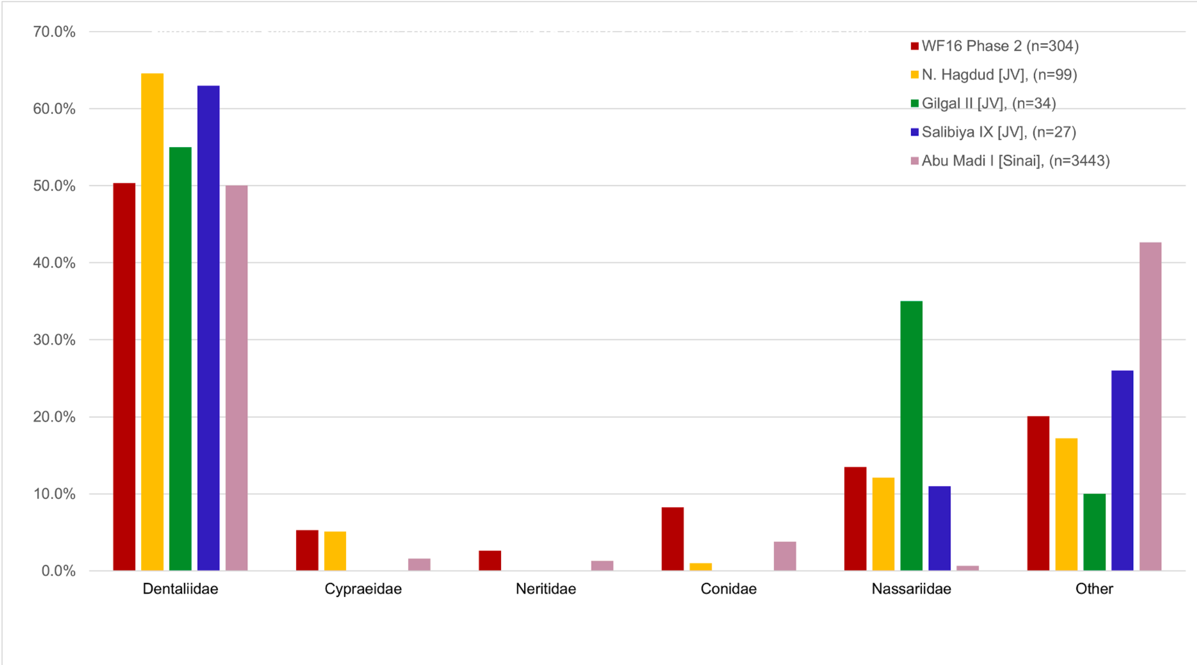

Fig. 6. Comparison by major families of the WF16 Phase 2 shell bead assemblages with those from PPNA sites in the southern Levant (comparison data from Bar-Yosef Mayer, 1999, Bar-Yosef Mayer & Porat, 2008).

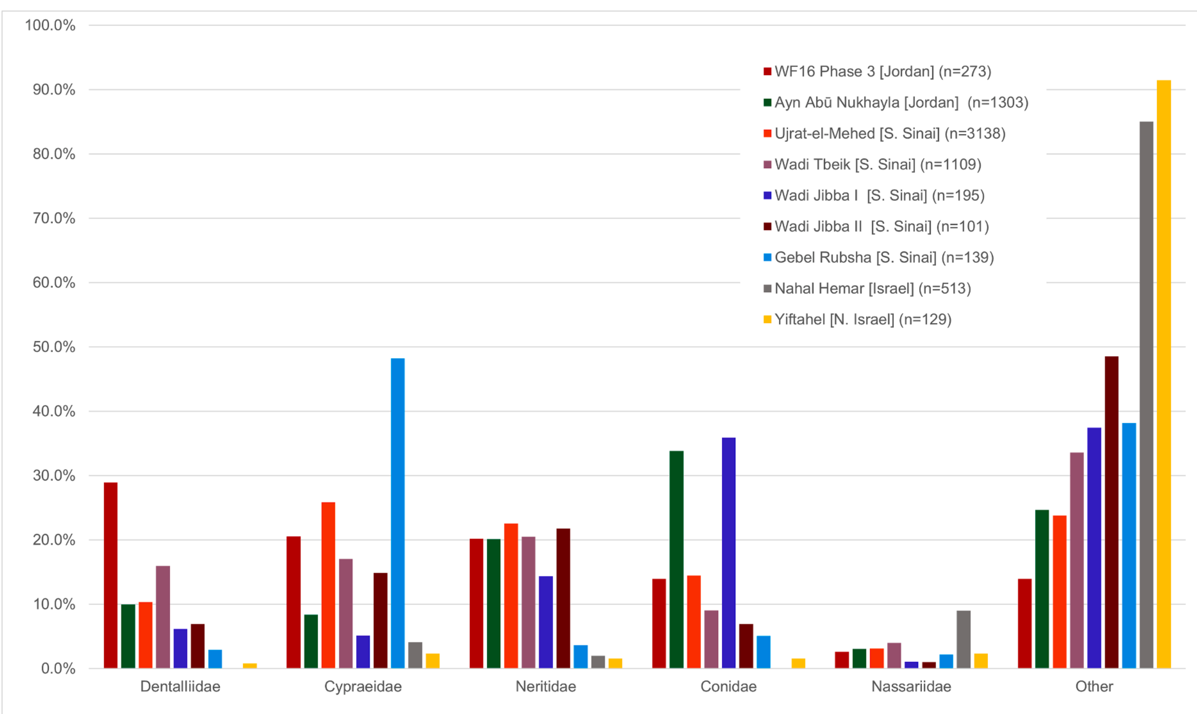

Fig. 7. Comparison by major families of the WF16 Phase 3 shell bead assemblages with those from PPNB sites in the southern Levant and southern Sinai (Data from Bar-Yosef Mayer, 1997).

Looking at the diachronic perspective, specimens from the Red Sea account for 55% of the Phase 2 assemblage and 84% of the overall Phase 3 assemblage, with Mediterranean sourced shells declining from 31.6% in Phase 2 to 6.1% of the overall Phase 3 assemblage. We appreciate that once the source of the remaining Dentaliidae shells has been established, the *Red Sea:Mediterranean* proportions in both Phase 2 and Phase 3 may change, with a potentially greater impact on Phase 2 because of the higher frequency of Dentaliidae in that phase. However, a shift towards Red Sea origins will still be evident, since the Phase 3 sub-phases (3A, 3B, 3C) also show an increasing trend over time towards a Red Sea source for shell beads (Fig. 9b). This will remain the case even if all of the Dentaliidae Phase 2 shells eventually source to a Red Sea origin. Sub-

Table 3
Shell & coral assemblage according to site phase (2, 3) & stone assemblage type (a, b, c).

	Sub-Phase & Assemblage Type				Sub-Phase & Assemblage Type			
	2A	**3A**	**3B**	**3C**	**2A**	**3A**	**3B**	**3C**
Dentaliidae	153	56	13	10	50.3 %	33.9 %	26.0 %	17.2 %
Cypraeidae	16	31	6	19	5.3 %	18.8 %	12.0 %	32.8 %
Neritidae	8	30	6	19	2.6 %	18.2 %	12.0 %	32.8 %
Conidae	25	24	10	4	8.2 %	14.5 %	20.0 %	6.9 %
Nasariidae	41	4		3	13.5 %	2.4 %	0.0 %	5.2 %
Melanopsidae	18	7	10	1	5.9 %	4.2 %	20.0 %	1.7 %
Acroporidae	5	1	2		1.6 %			
Margaritidae	6				2.0 %	0.0 %	0.0 %	
Strombidae	4	2			1.3 %			
Columbelidae	5				1.6 %	0.0 %		
Glycymerididae	3	1			1.0 %			
Cardiidae	4				1.3 %	0.0 %		0.0 %
Cerithiidae		1		1	0.0 %	0.6 %		
Veneridae		3			0.0 %			
Mitridae		1			0.0 %			
Ancillariidae	1				0.3 %			
Arcidae	1				0.3 %			
Charoniidae	1				0.3 %			
Pectinidae	1				0.3 %	0.0 %		
Turbinidae	1				0.3 %	0.0 %		
Not identified/other	11	4	3	1	3.6 %	2.4 %	6.0 %	1.7 %
Total Sub-phases	304	165	50	58	100 %	100 %	100 %	100 %
Total Phase 2, 3	**304**		**273**					

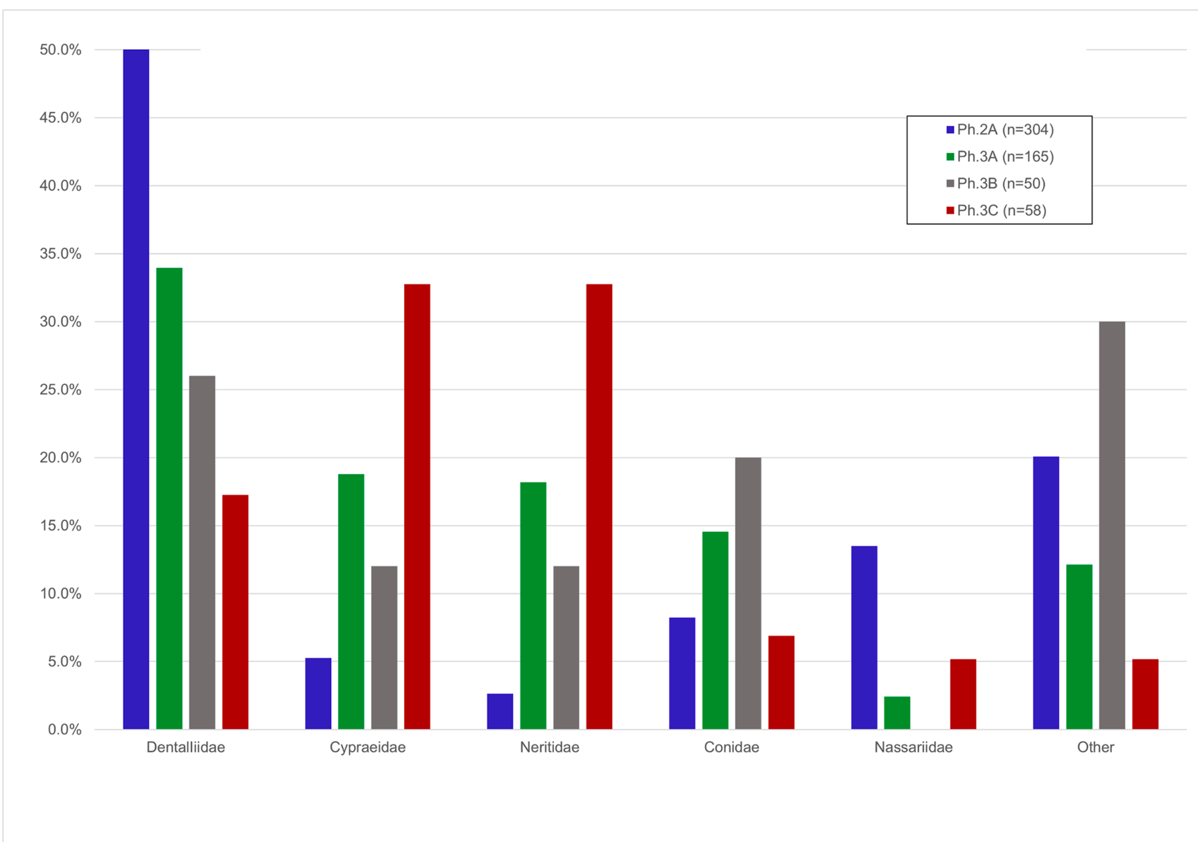

Fig. 8. Comparison by major families of the WF16 Phase 2A, 3A, 3B and 3C shell bead assemblages.

phase 3B is anomalous because only 10 local freshwater shells account for 28.6% of its assemblage (reducing to zero in sub-phase 3C), at the expense of marine sourced shells from both the Red Sea and the Mediterranean. However, with only 35 shells identified for sub-phase 3B, we are cautious about reading any significance into the high frequency of freshwater shells.

3. Manufacture and use

We assume the shell beads were primarily used as a form of personal or household adornment to express individuality, a social identity or a belief system. As indicated by ethnographic studies (e.g., Falci et al., 2019; Davies, 2020), the shells might have been used in their natural state or turned into beads by perforation; they might have been coloured

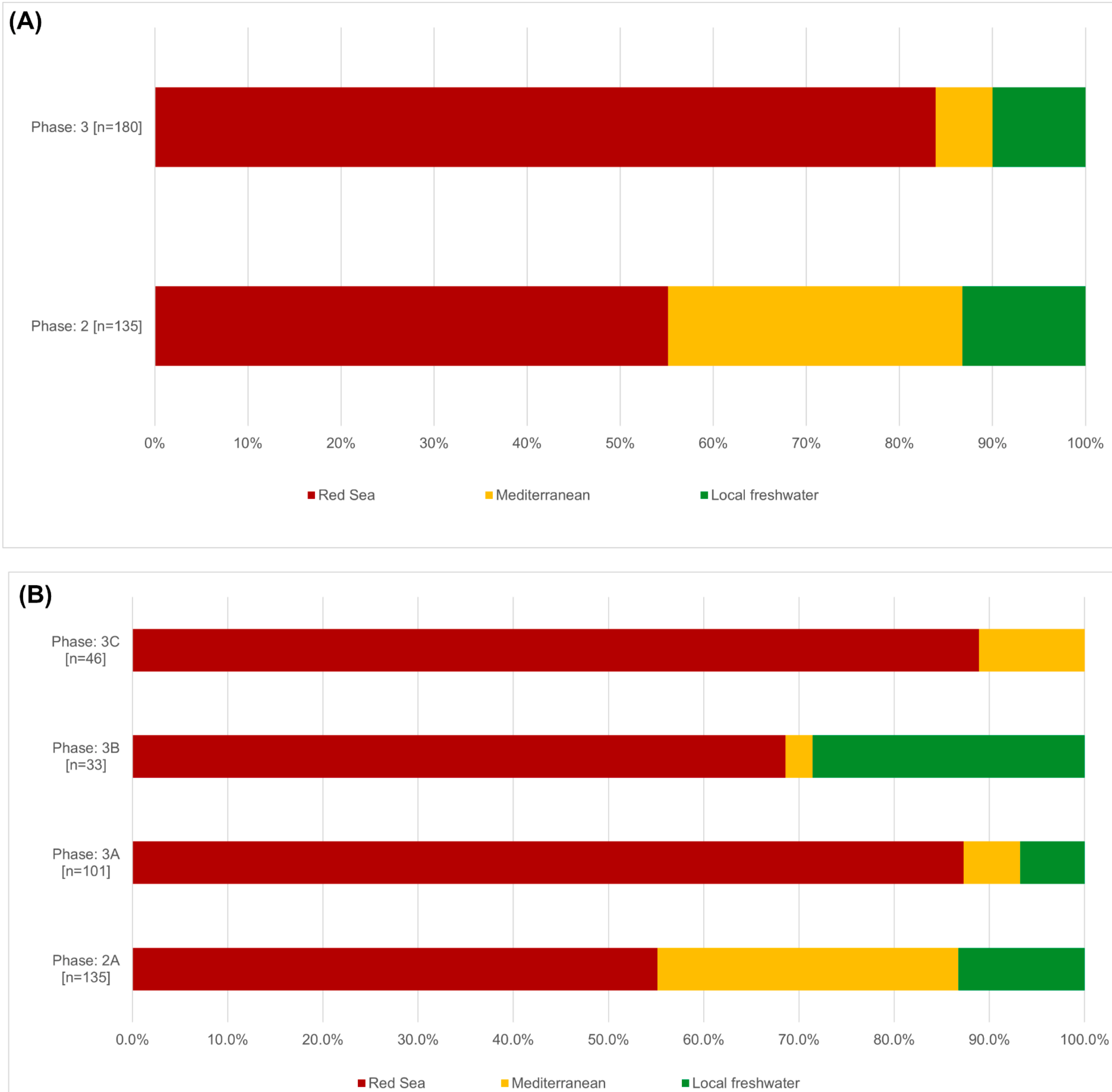

Fig. 9. a, b. Shell Bead Sea origins by site phase (Phase 2, 3) & sub-phases (3A, 3A, 3B, 3C).

and/or modified to be either stitched onto garments or worn on strings as necklaces, pendants, anklets and bracelets. They could have also served to decorate other artefacts or specific locations, possibly being combined with other organic materials or bird feathers that were extensively used at WF16 (White et al., 2021b). While such a diversity of use provides a challenge to archaeological interpretations, further studies of manufacturing and wear traces could provide insights into the most likely possibilities (e.g., Vanhaeren et al., 2013; Dimitrijević et al., 2021; Schechter, 2023).

A preliminary visual analysis of the 184 non-Dentaliidae shell beads from WF16 that show definitive signs of modification indicates that *c.* 62% had been worked by grinding (n=114), *c.* 15% by percussion/hammering (n=28), and *c.* 11% by cutting/slicing or sawing (n=21), as illustrated in Fig. 10. Initial assessments were based on these broad comparative classifications used to assess shell bead manufacture at other sites from this period (e.g., Bar-Yosef Mayer, 1997; Bar-Yosef Mayer, 2014; Schechter, 2023), although additional scientific analysis will be required to accurately ascertain the specific modification techniques and associated tools used to work each type of shell. A further 20 shell beads (*c.* 11%) show natural abrasion wear patterning that eventually resulted in breakage, with one of these 20 showing signs of being re-worked by grinding. Grinding was used on 44% of the Cypraeidae, Neritidae, Conidae and Nassariidae shells. Percussion techniques were applied to Nassariidae (27%, n=13), Strombidae (100%, n=6), Columbellidae (60%, n=3) shells, and a small proportion of Neritidae. A cutting or sawing process was primarily used on Cypraeidae shells, 25% of which display cut marks. As yet, we have not conducted additional studies to identity the type of tool likely employed for these specific cutting processes. Drilling is only associated with one Mother of Pearl pendant (*Pinctada margaritifera*) and a limited number of coral beads.

Grinding and percussion were used in both Phase 2 and 3, but cutting was restricted to Phase 3 for the Cypraeidae shells. Percussion was more frequently employed in Phase 2 than Phase 3, accounting for 24 examples (*c.* 86%) in Phase 2 of the total 28 across all phases. All of the drilling specimens come from Phase 2.

In summary, results indicate that there is clear evidence of an association between technique and taxa at WF16, that different techniques seem to have been used over different periods of time, and in some cases that multiple techniques were used on a single item to achieve different results.

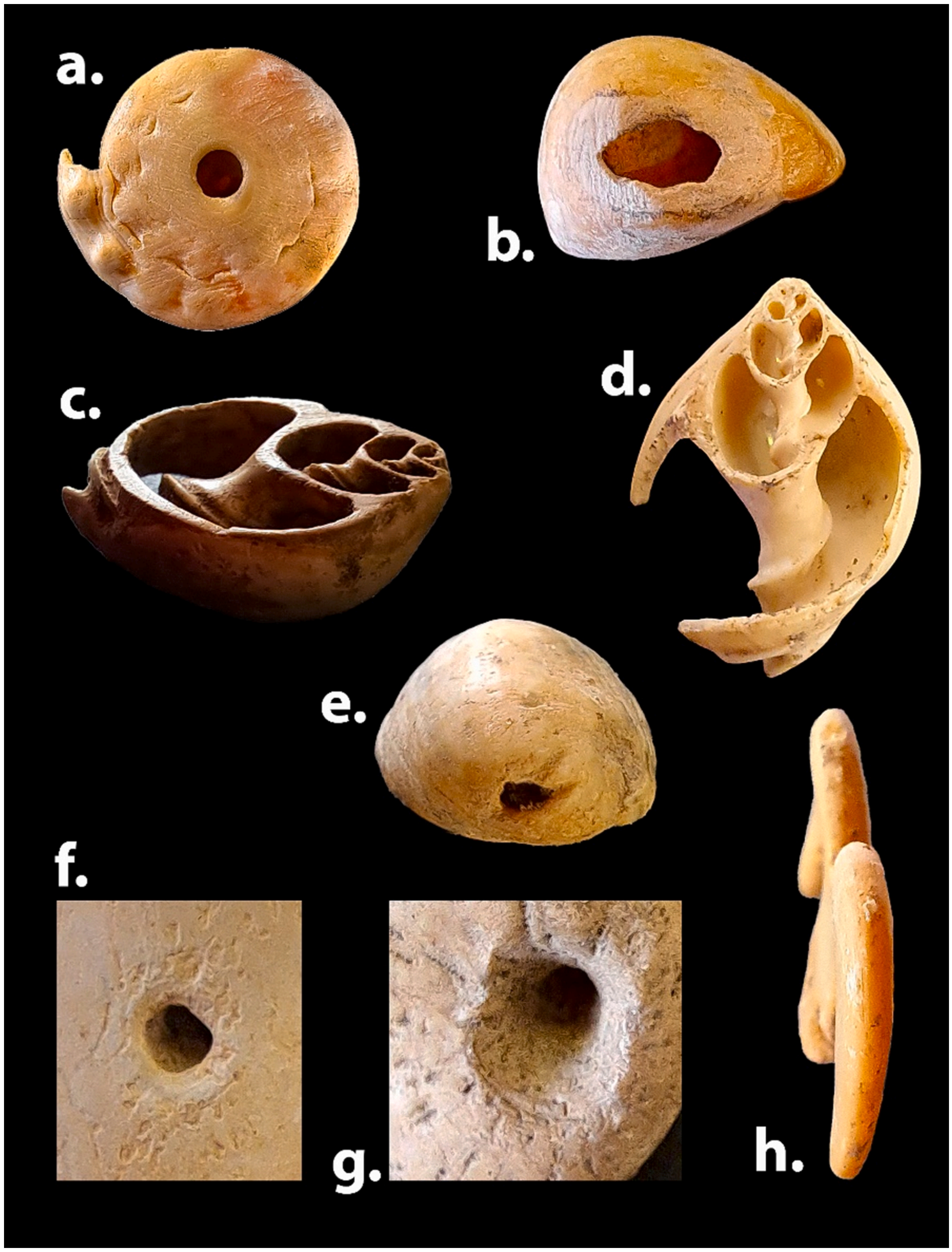

Fig. 10. Shell bead manufacturing techniques at WF16. a-b. ground perforation. c. naturally abraded dorsum ground flat. d. dorsum removed by percussion/pecking. e. cut perforation. f. pecked perforation. g. drilled perforation. h. edge-rounding by grinding/polish.

4. The spatial distribution of shell beads and artefacts at WF16

Shells and shell beads were ubiquitous within the excavated deposits at WF16, being found at low frequencies throughout the entire extent of the site (Table 4). Fig. 11a illustrates the distribution of the absolute number of shells by Object, while Fig. 11b illustrates their relative distribution in terms of density (per kilolitre of sediment); these figures also provide a comparison with the distribution of stone and bone beads. Fig. 12a and 12b provide 'spatial heatmaps' for occurrences of Dentaliidae, Nassariidae, Neritidae, Conidae and Cypraeidae across Phases 2 and 3 at a context level. Note that for the excavation and sampling of the O60 Phase 3 midden, a 3D geometric grid system was employed, with samples recorded to 1 m x 1 m squares, in 10 cm spit depths. This methodology influences the visual rendering of the heatmaps for areas of the O60 midden, as bulk samples of sediment were generally allocated a geospatial coordinate at the centre of their excavated 0.1 m^3 cuboid.

The highest number of shells originates from the Phase 3 O60 midden (n=239). While such a quantity must reflect the volume of sediment excavated from O60, on the basis of shell relative density O60 is only ranked eighth out of all Objects containing shells and beads. Because Floor O91 and Object O100 are the only other surviving features from Phase 3, and because the O60 midden might also contain redeposited sediment from Phase 2, we cannot ascertain whether the intensity of shell bead usage had increased from Phase 2 to Phase 3.

The highest densities of shell beads (Fig. 11b) are found within small structures that had been subjected to a limited extent of excavation, notably O74 (n=14), O83 (n=3), O90 (n=2), O73 (n=1) and O56 (n=6). These Objects also had high densities of stone beads associated with them. However, with such small absolute numbers of shell beads, and with smaller volumes of examined sediment in three of these Objects (O73, O90, O83), care must be taken with the interpretation of calculated densities. Consequently, we cannot necessarily attribute any

Table 4
Bulk weights and densities of shell materials, WF16 site.

Object	volume of bulk material sifted (litres) per object [*excludes large volumed "boulders"*]	Bulk Weight of marine shell through sieving (excl. beads) [g]	Bulk Marine Shell density [g/kl]
O64/O14	2553.32	166.0	65.01
O111 (Overburden)	5877.54	176.1	29.96
O56	1243.57	21.0	16.89
O85	997.95	11.0	11.02
O99	5184.08	30.6	5.90
O100 (ph. 3)	7048.38	40.0	5.68
O69 (midden)	8769.32	49.1	5.60
O91 (ph. 3)	7190.70	36.0	5.01
O60 (ph. 3, midden) + O108	75612.67	390.2	5.16
O103	2173.46	10.0	4.60
O45/O92	10781.26	33.6	3.12
O83	557.38	1.5	2.69
O53	3868.07	10.3	2.66
O75/O68	34859.60	52.8	1.51
O11/O20/O23/O106	4592.27	2.9	0.63
O70	700.13	0.4	0.57
O12	10415.17	2.4	0.23
O19	3838.08	0.7	0.18
O65/O121	2814.35	0.3	0.11
O31/O33	3331.59	0.3	0.09
O66	2072.43	0.0	0.00
O84	4085.51	0	0.00
O72	2426.98	0.0	0.00
O73	409.71	0.0	0.00
O90	742.10	0.0	0.00
O74	1081.66	0.0	0.00
Site Totals/ Average		1035.2	8.85

significance to the roles of some of these structures solely from this analysis.

The floor deposits of the large amphitheatre-like structure O75 provide a relatively large number of shells and shell beads (n=74), albeit at a lower relative density than in the midden. This structure, with its massive 20 m x 18 m elliptically shaped footprint, has been proposed as a location for social gathering and shamanic performance (Mithen, 2022). Such activities might have contributed to the greater diversity of bead types discarded here than elsewhere in the settlement. The O75 shell bead assemblage is notable for the diversity of shell families located within this one particular Object, and especially for the relatively high frequency of Conidae, which comprises *c.* 24% of the O75–specific assemblage. Examples of Conidae shell occurrences are relatively scarce in many PPNA shell assemblages (Fig. 4), although at Ayn Abu Nukheyla, deliberate caches of Conidae were made beneath floor levels or overturned querns, implying they had some value to occupants that were planning their site abandonment and anticipating their return in the short term (Spatz et al., 2014:247-249). However, the spatial distribution of the O75 Conidae shows that they are unlikely to be deposited as a single cache. Object O45, a particularly well-preserved Phase 2 structure, is also notable for a relatively high number, diversity and density of shell beads (n=37), with a significant number of those (n=7) from freshwater Melanopsidae.

The heatmap plots also show the ubiquity of Dentaliidae across the site, with particular concentrations in Phase 2 (Fig. 12a, b) around O84, O14, O72, O74, O45 and O12. Nassariidae occurrences also show similar clustering around Objects O45 and O12, and generally these shells are more common in the south-central and north-western areas of the Phase 2 site, with very few appearing in the huge O75 structure. Curiously, in both Phases 2 and 3, although different shell families are found within an excavated Object, there are very few instances where they coincide at the same precise context or geospatial co-ordinate location within that Object – i.e., they may be in geographical proximity, but not necessarily always associated directly by context, or otherwise. In Phase 3, the locations of shell beads across the O60 midden and into the newer O100 structure have a similar pattern to Phase 2, with different shell taxa occurring only in small numbers at discrete but precise locations and in individual contexts.

There are some interesting pattern combinations to certain groups of dispersed shells within the WF16 structures. For example, Phase 2 Object O11 contains only Dentaliidae and Cypraeidae shells, whilst O72 (also Phase 2) has Dentaliidae, Neritidae and Nassariidae grouped together, which is an unusual combination for the site. Such clusters are open to varying interpretations. They might derive from the decoration of a household object that had been made from organic material and hence did not survive. Alternatively, the shell types and association might have been socially or symbolically meaningful to either the occupants of the structure, to the structure itself (or even different areas within the structure), or to whatever activities occurred within it. Beliefs in the 'magical' properties of specific stones and shells for protection and healing are still practised in more modern populations of the region (e.g., Mershen, 1989) , and similar belief attachments to material objects might easily have applied to the Neolithic. We intend to address such possibilities as further classes of material are catalogued and analysed, along with exploring potential ethnographic analogies.

Within the entire site, there are very few contexts where significant clustering of shell beads of the same family occurs. In midden Context 363 (O60 Midden, Phase 3C) a cluster of seven Cypraeidae shells is found alongside 43 other significant decorative artefacts, including a bone pendant, noteworthy pieces of highly decorated stone and greenstone, and a collection of raptor bones (predominantly *Buteo buteo*). This could characterise the final disposal of 'waste' decorative or ritual items from an earlier culturally significant location into the O60 midden layers, although there are a significant number of greenstone and non-greenstone beads and marine shells within the context which would conceivably still have had relevance or usage value in this later Phase 3C period. It could also represent some sort of cache, to be revisited at a later point in time. In Context 923 (O100, Phase 3C just beneath the earliest floor level) an additional cluster of 12 Neritidae shells was uncovered, found in conjunction with a handful of other shell beads.

Overall, given that the final deposition of shell beads is rarely clustered, there seems to be little evidence that the deliberate caching of shells was taking place (with the possible exception of the two small clusters described above, both from Phase 3C), or that the deposition patterns can be definitively linked to single items of complex decoration (such as an intricate necklace or headdress) that would have contained significant numbers of shells or beads. The discard patterns most likely indicate that shells were simply dropped or disposed of as individual personal items around all locations of the site, or that they could have been discarded or lost in places of work or living quarters. For example, they might have originally been displayed as part of a household decorative item, or as symbolic ornament representing a belief system, such as a household talisman, whose function or appeal eventually lost its relevance.

A similar sparse distribution patterning across the extent of the site is also evident from our preliminary studies of the spatial distribution of stone beads and artefacts, where only *c.* 20% of the discarded greenstone artefacts and beads are found in conjunction with discarded shell, again with very little evidence of clustering of the stone beads.

5. Bead manufacture locations at WF16

In terms of manufacturing activity, there appears to be little definitive evidence for shell bead workshops within the structures of the site. However, density patterns of the bulk marine shell (which would include primarily fractional pieces of marine shell) obtained though the

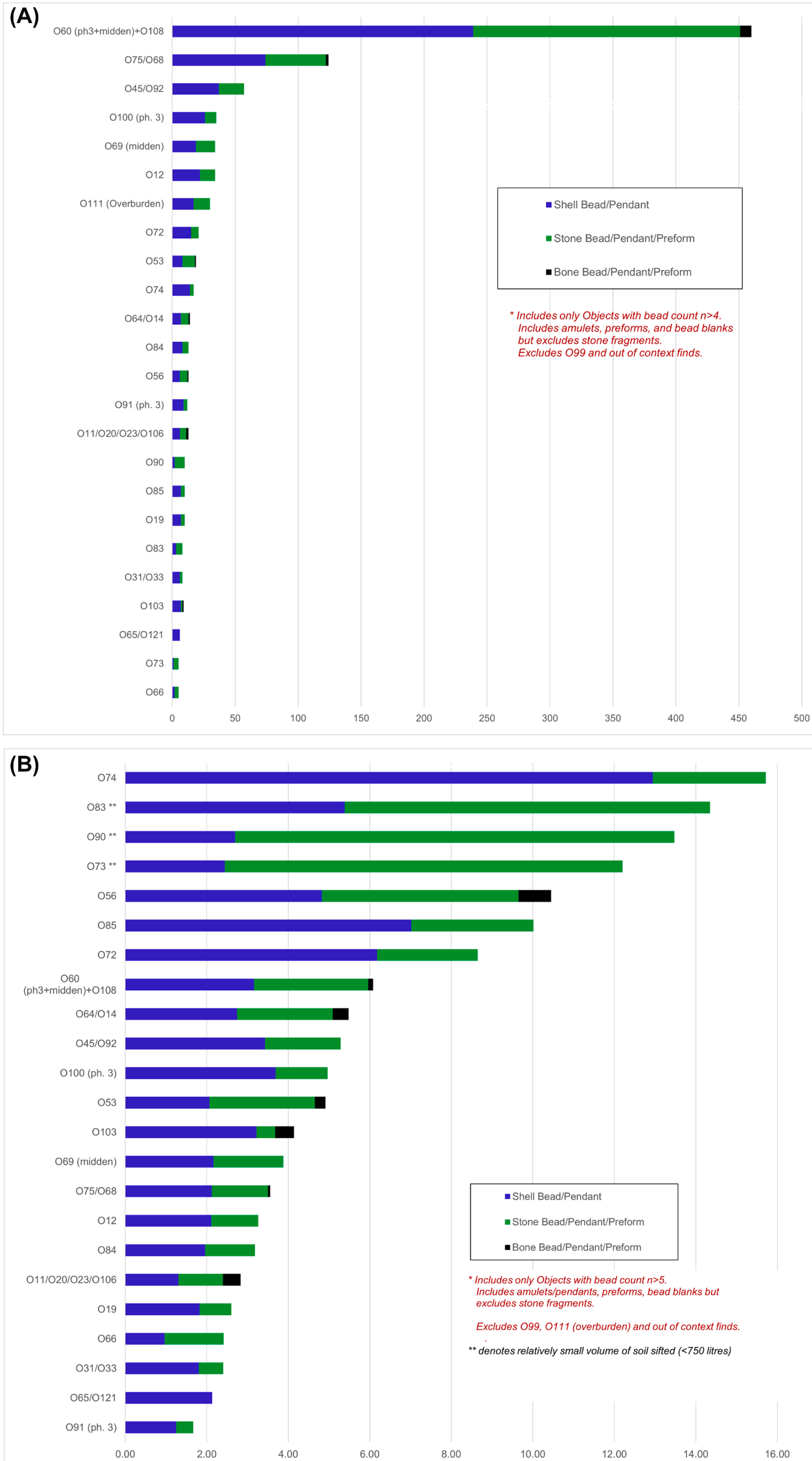

Fig. 11. a, b. Shell, stone bead and bone beads by Object (a) absolute numbers and (b) density (by 1000 L of excavated sediment).

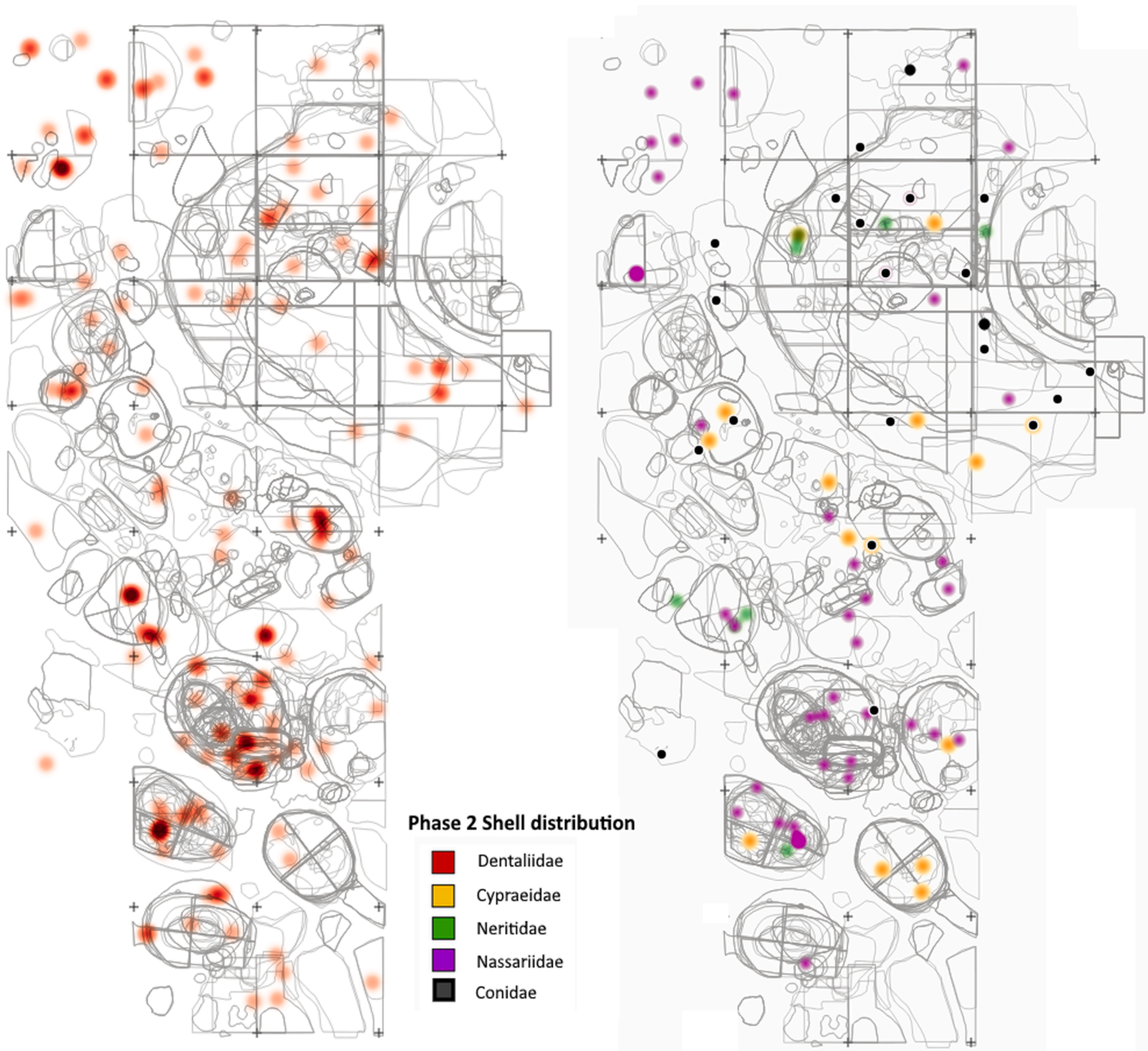

Fig. 12. Heat maps for shell artefacts (a) Phase 2 (b) Phase 3 (all subphases 3A-3C), (c) bulk marine shell density for all subphases 2A – 3C.

sieving and flotation processes may hint at some possible locations, particularly in Phase 2 (Fig. 12c). Object O14 defines a pit that was excavated adjacent to structure O64, and this Object displays the highest density concentrations of bulk marine material on the site (Fig. 12c, labelled). It also yielded a number of Dentaliidae shell beads (although, curiously, no other type of shell bead was found in this location). To the far north-west of the site lies the Phase 2 O69 midden that also features as a hotspot for this material. Phase 3A identifies some bulk shell clustering towards the edges of the O60 midden and around the walls of O100, with phase 3B and 3C displaying no significant groupings within the area of excavation.

Structure O56, a small, semi-subterranean Phase 2 structure on the eastern edge of the excavation area, had previously been interpreted as a stone bead workshop by the excavation team. This was based on the discovery of a stone workbench, found in association with a number of stone beads and bead blanks (Mithen et al., 2018: Figure 17.19; Mithen, 2022). Analysis of the bulk marine shell indicates that O56 also displays as a likely density hotspot for this material in Phase 2A, and so could potentially support the workshop interpretation. Objects O45 and O75 in Phase 2 also display strong bulk marine shell density profiles (Fig. 12c) in some precise locations within their structures, which could possibly indicate shell working or the discard of items containing multiple shells at that specific spot. All three of these structures also have been proposed as possible candidates for Phase 2 shamanic activities (Mithen, 2022) on the basis of their high concentrations of bird bones, particularly of raptors, as well as a number of unique stone and bone artefacts recovered from these locations.

6. Comparison with stone beads and bird bones

It is not unreasonable to assume that shell beads might have been combined with those of stone or bone within items of personal adornment. 422 stone beads (including blanks, preforms and pendants but excluding eight fragments) and 19 bone beads/pendants were recovered from WF16. The stone beads were made from a variety of raw materials including malachite, sandstone, limestone, chert, quartzite, and other blue/green–coloured minerals currently awaiting mineralogical identification. Similarly, there is a diverse range of sizes and shapes, all of which will be reported on separately in a future publication.

Fig. 13 demonstrates the strong correlation between the number of shell beads and stone beads from objects at WF16. (N.B., Fig. 13 excludes data from Object O60, which is not directly represented on the plot curve due to the large quantities of beads from O60, although it does maintain a similar correlation ratio as represented by the plot curve). Of

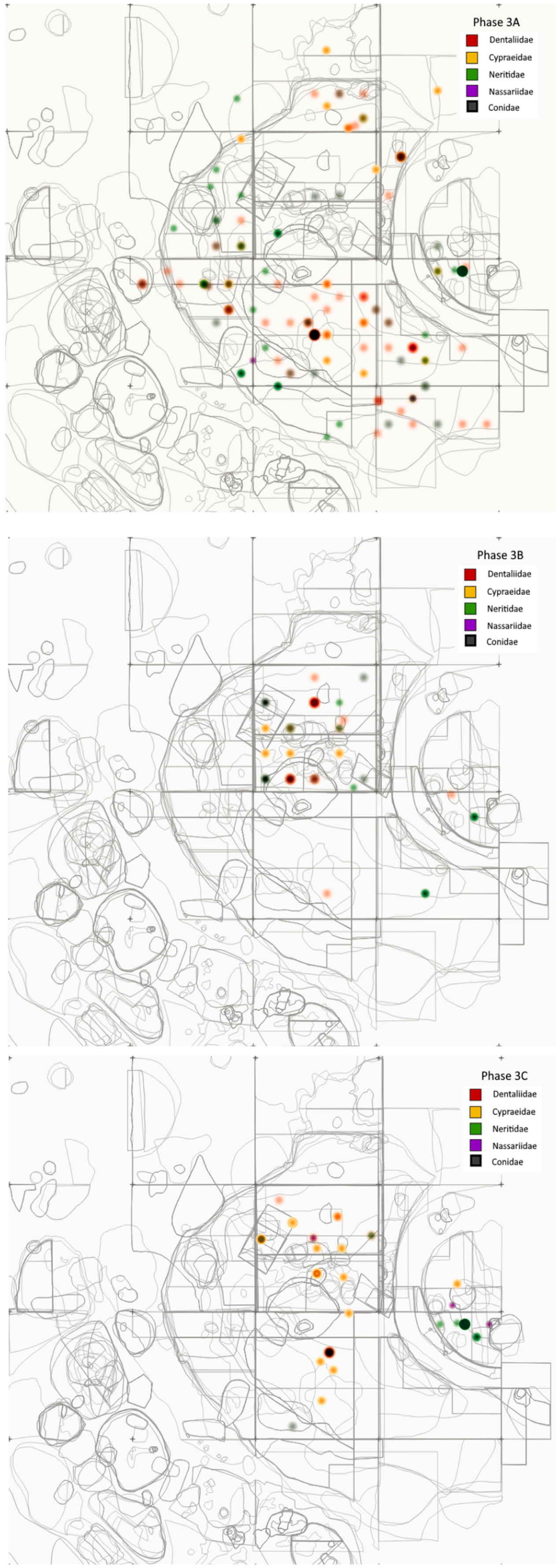

Fig. 12. (*continued*).

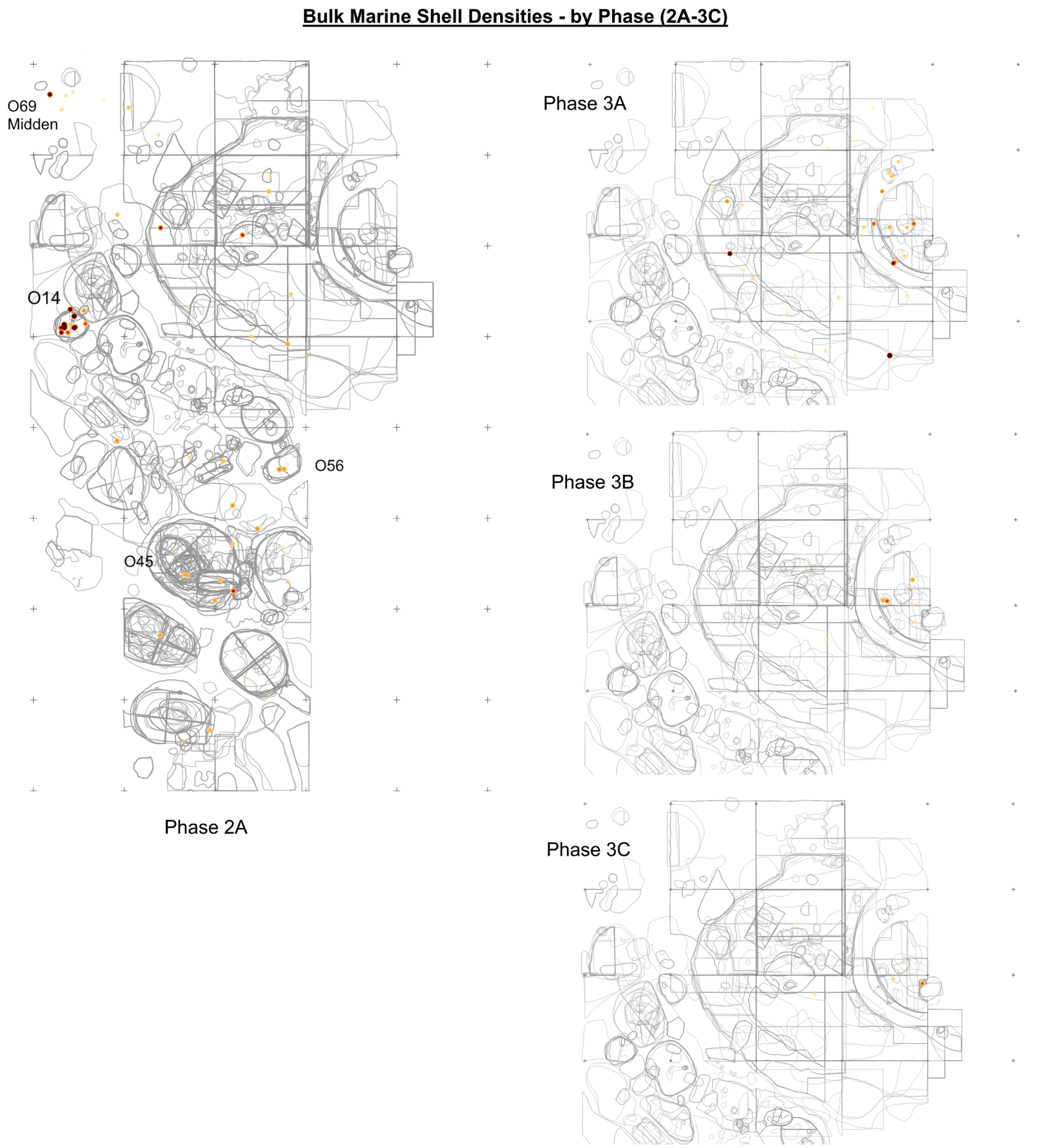

Fig. 12. (*continued*).

interest are the objects with the highest residuals from the correlation, those below the trend line having statistically a higher proportion of shell beads relative to stone beads, whilst those above the trend line displaying the opposite bias.

Object O74 has the highest shell bead residual with a ratio of 14:3 (shell beads: stone beads). O74 is a small structure in the north-west area of the settlement that had undergone minimal excavation, yet also exhibits the highest density of beads at WF16. The structure is also notable for having the largest concentration of bones from the northern bald ibis, *Geronticus eremita*, at WF16 (n=23), a bird of impressive plumage (White et al., 2021). While feathers and beads might have been combined in adornments, there is no evident association between the distribution of bird bones and beads at a context level in O74. Nevertheless, of the three Objects with the highest density of bird bones (O11, O45 and O56) (Mithen et al., 2022), both O45 and O56 display higher densities of beads or bulk marine shell material at some very specific co-ordinates within those Objects. In all likelihood, feathers were treated separately from the bones and often appear in different contexts within these locations, although a further detailed analysis is being undertaken on O45 and O56 specifically to determine whether there could be a relationship between the two artefact types within these structures.

7. Discussion

The overall number and diversity of shell beads at WF16 potentially supports Mithen et al.'s (2023) interpretation of the site as a location for social gathering, at which the display of personal and social identity was important. Although lacking in the scale, elaborate architecture and art

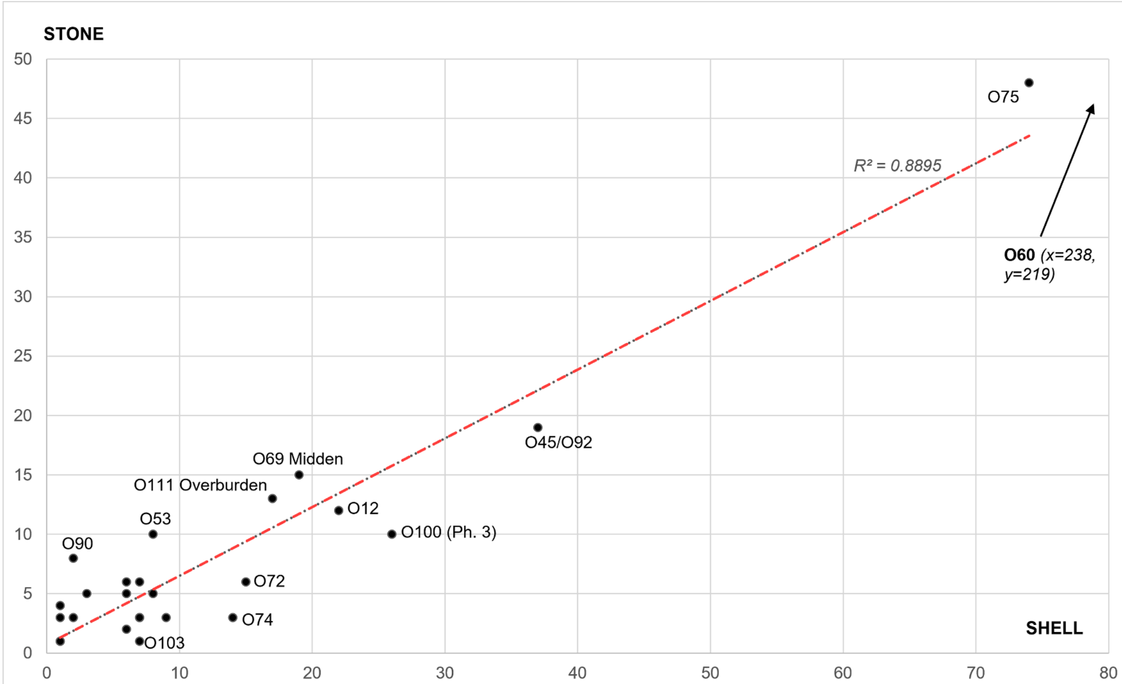

Fig. 13. Scattergram showing relationship between numbers of shells and numbers of stone bead by object.

of sites such as Jericho in the southern Levant, and Göbekli Tepe and Hallan Çemi further to the north, they nevertheless suggest that WF16 might have played a role similar to these sites, acting as a hub within an extensive social network that had connections reaching from the Mediterranean down to the Red Sea.

The most significant outcome of our study is the evidence for changing frequencies of shell types within the course of the PPNA at WF16. The reduced frequency of Dentaliidae and increase in Cypraeidae and Neritidae during Phase 3 pre-empts the change that is otherwise evident at the PPNA–PPNB transition within the wider region. Because WF16 documents this change as occurring within the PPNA, it suggests that changes in social networks and/or the expression of social/individual identities were potentially happening prior to the technological and economic shifts represented by the PPNB.

The changes in shell type frequencies are associated with a shift in emphasis from the Mediterranean to the Red Sea as a source. Of the non-Scaphopod shell beads, the overwhelming majority of Mediterranean shells present in Phase 2 were Nassariidae, and the numbers of these shell bead occurrences declined significantly in Phase 3, as the focus of origin of the shell beads shifted towards a preference for those originating at the Red Sea. In Phase 3, we still see a small number of examples of Mediterranean shell beads (Cypraeidae, Nassariidae, Mitridae) but these are much fewer in number compared to Phase 2.

It is difficult to know which was the driver of this change: did the shift in source cause the changes in shell type frequencies, or did the desire for Cypraeidae and Neritidae cause more visits to, or contact with people from, the Red Sea coast? If the former, might this have been caused by environmental factors that increased the costs of collecting Mediterranean shells compared to those of the Red Sea, or social factors that inhibited access to the Mediterranean coast or the people from that region? If the latter, we need to explore why shell types might come into or go out of fashion, which again relates to changing social dynamics during the Neolithic.

In geographical terms, the Red Sea lies 130 km to the SSW of WF16, easily approachable through the wide course of the Wadi Araba. The Mediterranean shores, however, are reached 145 km to the WNW of WF16, necessitating the crossing of the mountainous and arid Negev Desert, making direct access to the Mediterranean shore more difficult. It is doubtful, however, that people from WF16 directly collected all (or even any) of their shell material. A form of gift-exchange or even a trade network is likely, possibly using down-the-line exchanges between adjacent groups (Spatz, 2017). If this were the case, the shift to an emphasis on the Red Sea could point to a changing alignment over time towards communities to the south of WF16 and away from the north and west - at least for the acquisition of shells. The shell bead assemblages in Phase 3 at WF16 certainly indicate a resemblance to some of the PPNB assemblages of south Sinai sites such as Ujrat-el-Mehed (Bar-Yosef Mayer, 1997), and comparative studies to other sites in the immediate region around WF16 will need to be undertaken to ascertain whether a similar shift in marine source preference also occurred at other sites around this period.

Further analysis and comparative studies of the variations in WF16 material culture through time, such as the chipped stone, stone bead and bone tool assemblages, may also shed light on whether the driver of change was primarily a shift in social identity, one that required specific items of personal adornment, or a re-alignment of social networks. Moreover, WF16 provides the opportunity to explore the latter stages of the PPNA with its pre-emptive PPNB-like shell assemblages in detail via the Phase 3A, 3B and 3C sub-phases.

At the present time, however, we can recognise the shell assemblage from WF16 as having already made a significant contribution to our knowledge of the use and deposition of shell beads in the early Neolithic of the Levant, and to the overall human interest in found objects which so easily lend themselves to body adornment.

CRediT authorship contribution statement

Dave B. Smith: Conceptualization, formal analysis, Investigation, Methodology, Writing. **Heeli C. Schechter:** Formal analysis, Investigation, Methodology, Validation, Writing – review & editing. **Daniella E. Bar-Yosef Mayer:** Formal analysis, Investigation, Supervision, Writing – review & editing. **Steven J. Mithen:** Conceptualization, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Bar-Yosef Mayer, D., 1997. Neolithic Shell Bead Production in Sinai. Journal of Archaeological Science 24, 97–111. https://doi.org/10.1006/jasc.1995.0097.

Bar-Yosef Mayer, D., Bosch, M., 2019. Humans' Earliest Personal Ornaments: An Introduction. PaleoAnthropology 2019, 19–23. https://doi.org/10.4207/PA.2019.ART121.

Bar-Yosef Mayer, D., Groman-Yaroslavski, I., Bar-Yosef, O., Hershkovitz, I., Kampen-Hasday, A., et al., 2020. On holes and strings: Earliest displays of human adornment in the Middle Palaeolithic. PLoS One 15 (7), e0234924.

Bar-Yosef Mayer, D., Porat, N., 2008. Green stone beads at the dawn of agriculture. PNAS 105 (25), 8548–8551.

Bar-Yosef Mayer, D. 1999. The Role of Shells in the Reconstruction of Socio-Economic Aspects of the Neolithic through early Bronze Age Societies in Sinai. PhD. Thesis, Hebrew University of Jerusalem: March 1999.

Bar-Yosef Mayer, D. 2010. Shell assemblages of the Gilgal sites. In: Bar-Yosef, Ofer, A., Goring-Morris, N. & Gopher, A. (Eds.), Gilgal: Early Neolithic Occupations in the Lower Jordan Valley (The Excavations of Tamar Noy). Oxbow Books, 2010. pp. 239 -243.

Bar-Yosef Mayer, M., D., 2014. Temporal changes in shell bead technologies based on Levantine examples. In Archaeomalacology: Shells in the Archaeological Record. BAR International Series 2666, 91–100.

Baysal, E., 2013. A tale of two assemblages: Early Neolithic manufacture and use of beads in the Konya Plain. Anatol. Stud. 63, 1–15.

Carruthers, D., Dennis, S., 2007. The mammalian faunal remains. In: Finlayson, B., Mithen, S. (Eds.), The Early Prehistory of Wadi Faynan, Southern Jordan. Council for British Research in the Levant/Oxbow Books, Oxford, pp. 372–386.

Colledge, S., Conolly, J., Finlayson, B., Kuijt, I., 2018. New insights on plant domestication, production intensification, and food storage: the archaeobotanical evidence from PPNA Dhra'. Levant 50, 14–31. https://doi.org/10.1080/00758914.2018.1424746.

Davies, S., 2020. Adornment: What self-decoration tells us about who we are. Bloomsbury, London.

Dimitrijević, V., Naumov, G., Fidanoski, L., Stefanović, S., 2021. A string of marine shell beads from the Neolithic site of Vršnik (Tarinci, Ovče), and other marine shell ornaments in the Neolithic of North Macedonia. Anthropozoologica 56, 57–70.

Falci, C.G., Cuisin, J., Delpuech, A., Van Gijn, A., Hofman, C.L., 2019. New insights into use-wear development in bodily adornments through the study of ethnographic collections. J. Archaeol. Method Theory 26, 755–805.

Finlayson, B., Mithen, S. (Eds.), 2007. The Early Prehistory of Wadi Faynan, Southern Jordan: Archaeological Survey of Wadis Faynan, Ghuwayr and Al Bustan and Evaluation of the Pre-Pottery Neolithic A Site of WF16, ISBN: 9781842172124. Oxbow Books, Oxford.

Knappett, K., 2005. The affordances of things: A post-Gibsonian perspective on the relationality of mind and matter. In: Demarrais, E., Gosden, C., Renfrew, C. (Eds.), Rethinking Materiality: the Engagement of Mind with the Material World. University of Cambridge (McDonald Institute Monographs), Cambridge, pp. 43–52.

Mershen, B., 1989. Amulets and jewelry from Jordan – A study on the function and meaning of recent bead necklaces. Tribus 38, 43–58.

Micheli, R., 2012. Personal ornaments, Neolithic groups and social identities: some insights into Northern Italy. Documenta Praehistorica XXXIX: pp 227–256. Documenta Praehistorica 39, 227. https://doi.org/10.4312/dp.39.16.

Mithen, S., 2020. Lost for words: an extraordinary structure at the early Neolithic settlement of WF16. Humanities and Social Science Communications 7 (1), 125. https://doi.org/10.1057/s41599-020-00615-7.

Mithen, S., Richardson, A., Finlayson, B. 2023. The flow of ideas: shared symbolism during the Neolithic emergence in Southwest Asia: WF16 and Gobekli Tepe. Antiquity pp. 1-21. Doi: 10.15184/aqy.2023.67.

Mithen, S., Finlayson, B., Maricevic, D., Smith, S., Jenkins, E., Najjar, M., 2018. WF16: Excavations at an early Neolithic site in southern Jordan, Stratigraphy, chronology, architecture, burials. Council for British Archaeology in the Levant, London.

Mithen, S., White, J., Finlayson, B., Greet, B., Khoury, F., 2022. Birds as indicators of early Holocene biodiversity and the seasonal nature of human activity at WF16, an early Neolithic site in Faynan, Southern Jordan. J. Quat. Sci. 37 (6), 1148–1163. https://doi.org/10.1002/jqs.3429.

Mithen, S. 2022. Shamanism at the transition from foraging to farming in SW Asia: Sacra, ritual, and performance at Neolithic WF16 (southern Jordan). Levant 54, pp.158-189. https://doi.org/10.1080/00758914.2022.2104559.

Schechter, H.C., 2023. Experimental with Levantine Neolithic shell-bead production and use – A low magnification perspective. J. Archaeol. Sci. Rep. 52, 104231 https://doi.org/10.1016/j.jasrep.2023.104231.

Sehasseh, E.M., Fernandez, P, Kuhn, S., Stiner, M. et al. 2021. Early Middle Stone Age personal ornaments from Bizmoune Cave, Essaouira, Morocco. Sci.Adv.7, eabi8620 (2021). Doi: 10.1126/sciadv.abi8620.

Smith, S. 2015. The chipped stone assemblages. In: Mithen S., et al, WF16: The Excavation of an Early Neolithic Settlement in Southern Jordan.. Council for British Research in the Levant/Oxbow Books, Oxford. pp. 527-578.

Spatz, A., 2017. Ornamental Shell Beads as Markers of Exchange in the Pre-Pottery Neolithic B of the Southern Levant. In: Bar-Yosef Mayer, D., Bonsall, C., Choyke, A. (Eds.), Not Just for Show: the Archaeology of Beads. Oxbow Books, Beadwork and Personal Ornaments Oxford, pp. 69–80.

Spatz, A., Bar-Yosef Mayer, D., Nowell, A., Henry, D., 2014. Ornaments of Shell and Stone: Social and Economic Insights. In: Henry, D., Beaver, J. (Eds.), The Sands of Time: the Desert Neolithic Settlement at Ayn Abū Nukhayla. Bibliotheca Neolithica Asiae Meridionalis Et Occidentalis. Ex Oriente, Berlin, pp. 245–258.

Vanhaeren, M., d'Errico, F., van Niekerk, K., Henshilwood, C., Erasmus, R., 2013. Thinking string: Additional evidence for personal ornament use in the Middle Stone Age at Blombos Cave, South Africa. J. Hum. Evol. 64 https://doi.org/10.1016/j.jhevol.2013.02.001.

White, J., Finlayson, B., Makarewicz, C., Khoury, F., Greet, B., Mithen, S., 2021a. The bird remains from WF16: An early Neolithic settlement in southern Jordan: assemblage composition, chronology and spatial distributions. Int. J. Osteoarchaeol. 31, 975–1288. https://doi.org/10.1002/oa.3016.

White, J., Khoury, F., Greet, B., Mithen, S., 2021b. The utilization of birds at Neolithic Wf16, southern Jordan: cut marks, body parts and experimental skinning. Int. J. Osteoarchaeol. 31, 1203–1216. https://doi.org/10.1002/oa.3031.