Chapter 11

Ostracods and other microfossils

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INTRODUCTION

As with many other categories of biological remains, ostracods have potential not only to reconstruct climate and palaeoenvironment, but also to contribute to biostratigraphic dating. Ostracods are microscopically small, bivalved aquatic crustaceans (their diagnostic shells mostly being between 0.1 and 2mm long), usually completely invisible to the naked eye *in situ* in unprocessed sediment. Therefore, their presence and prevalence in sediment sequences needs to be investigated to a certain extent blindly, relying on their tendency to be preferentially preserved in fine-grained calcareous sediments to guide selection of samples for evaluation.

Several phases of evaluation for ostracods thus took place whilst fieldwork was in progress, as potentially promising new sedimentary horizons were revealed during the excavation. As discussed below, most of these evaluations were negative. However, a relatively rich and diverse ostracod fauna was identified in context 40143, the white silt capping the tufaceous channel-fill sequence (Phase 6b) and this was consequently sampled more intensively, leading to the results presented below.

Following fieldwork, a much more systematic post-excavation assessment for ostracods was carried out, based on sub-sampling from the extensive monolith and bulk sample archive, to investigate for ostracod presence throughout all phases of the site sequence. Although mostly negative, this did however reveal the completely unexpected presence of a rich interglacial ostracod fauna in context 40062, from Phase 3 of the site sequence, interpretation of which is discussed below.

Finally, a very similar ostracod fauna to that from Phase 3 was recovered from test pits (TP) 31 and 33 from the 2006 Station Quarter South field evaluation immediately to the east of the elephant site (Wessex Archaeology 2006b). As discussed previously (Chapter 4), the contexts from which these samples came are here mostly interpreted as periodically desiccated lacustrine sediments equivalent to Phase 4 of the site sequence, and the results from this ostracod analysis are also presented here.

MATERIALS AND METHODS

Samples were either provided straight from fieldwork in a small plastic bag with provenance information written on the outside, or were provided post-excavation as sub-samples collected from monoliths or larger bulk samples. In the former case, each sample had its own unique number (with the exception of four early samples from the December 2003 field evaluation, which had duplicate numbers with pollen evaluation samples from the same sediments). In the latter case, samples were given the same number as the source sample suffixed by '/B' to indicate sub-sampling for ostracod analysis, and further suffixed by a depth range in centimetres for sub-samples collected from monoliths.

For each sample, the whole sample was processed, up to a maximum weight of 225g. Where over 225g was provided, the remainder was left in the bag, unprocessed. After weighing, all the samples were, if not completely dry to begin with, first placed in ceramic bowls and dried in an oven. When dry, a teaspoon of sodium carbonate was added to each sample to help in the subsequent removal of the clay fraction, and hot water poured on them. They were left to soak overnight. Washing was with warm/hot water through a 75 μm sieve, the resulting residues being returned to the bowls for final drying. Good breakdown was invariably achieved, but in a few cases this procedure had to be repeated to achieve a full breakdown. After drying, the sample residues were stored in plastic labelled bags and later picked of their microfaunal content under a binocular microscope. Each sample was dry-sieved through a nest of sieves (>500μm, >250μm, >150μm, and pan), the fractions being sprinkled, one at a time, onto a grid-lined picking tray. Useful organic remains, such as fish and small mammal remains, were picked out, and the presence of others (for example *Bithynia* opercula or other molluscan remains) merely recorded on a presence (x)/ absence basis. The ostracods, on the other hand, were picked out into 3x1" multi-squared faunal slides and the abundance of each species recorded semi-quantitatively (present/several specimens, common, etc).

EVALUATION DURING FIELDWORK

Four episodes of sample collection and processing for ostracod assessment took place during fieldwork (Table 11.1). Firstly, four samples were collected from the Phase 4 deposits at the central logged location (Log 40011, Fig. 11.2b) of the main west-facing section during the preliminary field investigation of December 2003; these were

Table 11.1 Evaluations for ostracods and other microfauna carried out during fieldwork, December 2003 to July 2004

Date	*Section*	*Phase*	*Context*	*Sample* <>	*Weight processed*	*Ostracods*	*Molluscs*	*Bithynia op.*	*Fish/ amphibians*	*Small mammals*	*Slug plate*	*Charophyte oogonia*	*Notes*
Dec 2003	Log 40011	6	40039	40007	225g	-	-	-	-	-	-	-	Totally decalcified with iron mineralisation
Dec 2003	Log 40011	5	40025	40009	225g	-	-	-	-	-	-	-	Totally decalcified with iron mineralisation
Dec 2003	Log 40011	4	40026	40012	225g	-	-	-	-	-	-	-	Totally decalcified with iron mineralisation
Dec 2003	Log 40011	4	40027	40015	225g	-	-	-	-	-	-	-	Totally decalcified with iron mineralisation; a few moulds of derived Tertiary gastropods
Mar 2004	Sec 40016	6	40068	40086	225g	-	-	-	-	-	-	-	
Mar 2004	Sec 40016	6b	40070	40087	225g	-	xx	-	xx	xx	-	-	Abundant molluscs and small vertebrates, but no ostracods
Mar 2004	Sec 40016	6b	40070	40088	225g	-	xx	-	xx	xx	-	-	Abundant molluscs and small vertebrates, but no ostracods
Jun 2004	Sec 40063	6b	40143	40248	134g	x	x	x	x	-	-	-	
Jun 2004	Sec 40063	6b	40143	40249	108g	x	x	x	x	-	-	x	
Jun 2004	Sec 40063	6b	40143	40250	128g	x	x	x	x	-	-	-	
July 2004	Sec 40068	6b	40143	40264	330g	-	x	x	x	x	-	-	
July 2004	Sec 40068	6b	40143	40265	330g	x	x	x	x	x	x	-	
July 2004	Sec 40068	6b	40143	40266	326g	x	x	x	x	x	x	-	
July 2004	Sec 40063	6b	40143	40268	246g	x	x	x	x	x	-	-	
July 2004	Sec 40063	6b	40143	40269	150g	x	x	x	x	-	-	x	
July 2004	Sec 40063	6b	40143	40270	158g	x	x	x	x	x	-	x	
July 2004	Sec 40063	6b	40143	40271	276g	xx	x	x	x	x	-	x	

x - present; xx - abundant

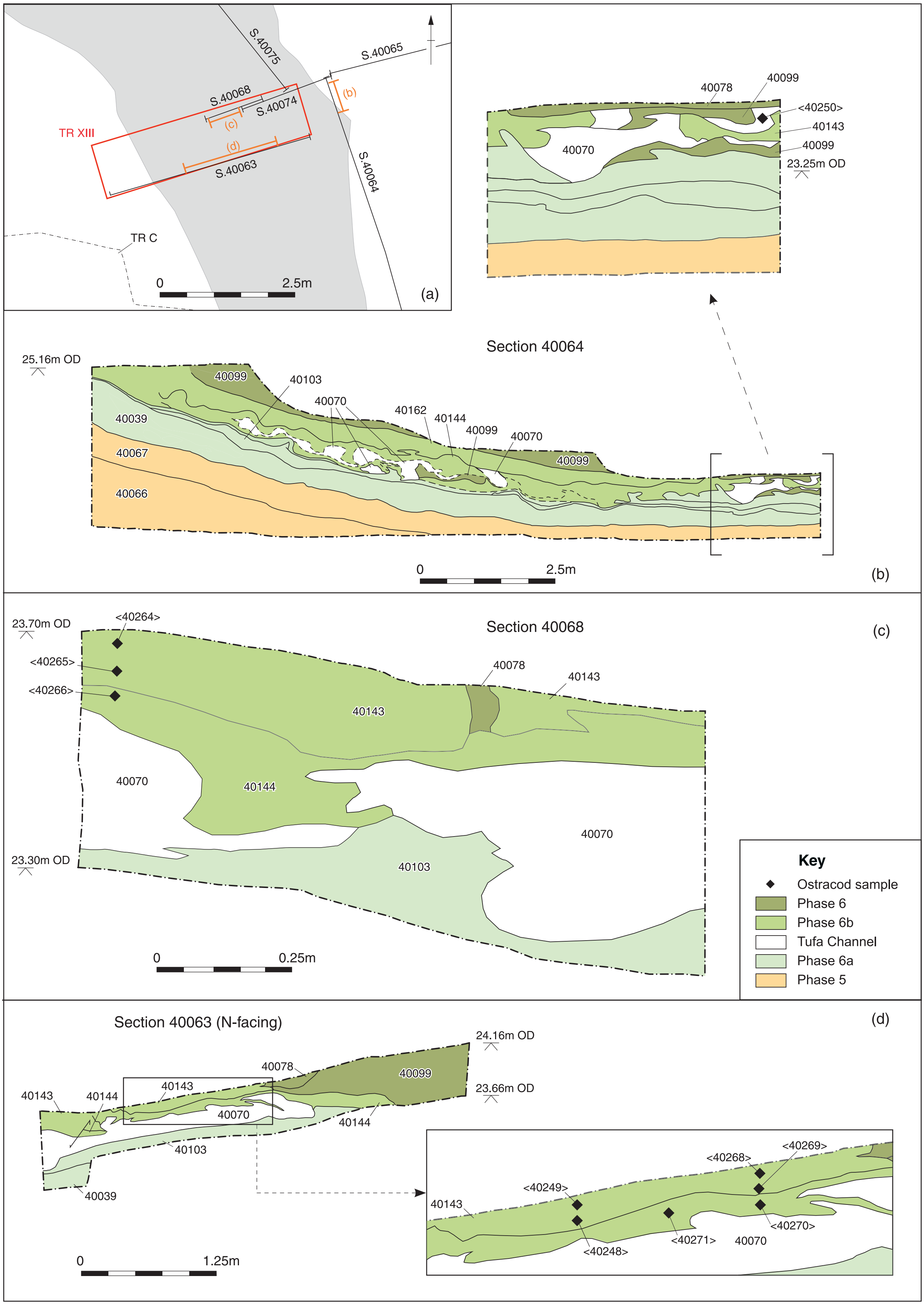

Figure 11.1 Ostracod sampling locations for context 40143: (a) thumbnail of sampling locations; (b) main east face of site (Section 40064); (c) Trench XIII, south-facing Section 40068; (d) north-facing Section 40063

found to be barren not only of ostracods, but also of all other Pleistocene remains. Secondly, three samples were collected from the Phase 6 sediments in the main east-facing section in March 2004, including two from context 40070, the main shell-rich bed of the tufaceous channel (Phase 6b). No faunal remains were present in the first of these and, somewhat surprisingly, the last two samples also proved to be barren of ostracods, despite their calcareous nature and the rich preservation of molluscan and small vertebrate remains. Thirdly, three samples: <40248>, <40249> and <40250>, were collected from the white silt (context 40143) capping the tufaceous channel-fill sequence, and assessed for ostracods in June 2004 (Fig. 11.1b, d). These, in pleasant contrast to the previous assessments, proved to contain a reasonably abundant and diverse ostracod fauna. Therefore, a fourth episode of sample collection and processing took place in July 2004, focusing on more intensive sampling of context 40143 in the sections of Evaluation Trench XIII, where there were the best and thickest exposures of this intermittently occurring horizon (Fig. 11.1c, d). Identification and interpretation of this ostracod fauna are presented below.

POST-EXCAVATION ASSESSMENT AND ANALYSIS

Once excavation was completed, a major programme of environmental assessment was carried out (Appendix 1), including an extensive investigation for the presence of ostracod remains throughout the finer-grained horizons of the site sequence. In total 57 samples were initially submitted for assessment (Table 11.2). These were then supplemented by nine additional samples from monolith <40068> (Fig. 11.2a), following the unexpected discovery in its lower part (context 40062, Phase 3) of a rich interglacial ostracod fauna, discussed in more detail below. Finally, analysis also took place of the residual ostracod fauna from bulk sample <40042>, also from context 40062 (Fig. 11.2a). This had been sieved through a mesh of 0.5mm to investigate for small vertebrate remains, but which it was later realised also contained remains of some of the larger ostracods present in this deposit.

Apart from this evidence from Phase 3, and sparse further remains from Phase 6b sediments (the tufaceous channel-fill), the post-excavation assessment proved entirely negative for ostracods. However some other micro-fauna were noted in some samples, and various other observations were made of interpretive potential, such as the occurrence of charophyte oogonia and fossilised rootlet hollows (Table 11.2). These allow some interpretation of depositional and post-depositional environments, and are also discussed where appropriate below.

Phase 3

The deposits investigated here as Phase 3 were equivalent to Unit 1 of the preliminary report (Wenban-Smith *et al.* 2006). As discussed above, on the west side of the site they comprised grey clay-silty sand with chalk pebbles, rich in derived Tertiary shell material (context 40028). They became thicker and more differentiated eastwards, with finer-grained more clay-silty deposits (contexts 40062 and 40063) forming the top of the Phase 3 sequence in the east-facing site section 40016 (Fig. 4.6a).

Figure 11.3 shows the results from analysis of the eight samples from monolith <40068>, together with sample <40042>, covering contexts 40063 and 40062 (Fig. 11.2a). Context 40062 proved to contain the richest freshwater ostracod faunas found during the present survey, and following the initial examination of two samples from samples 50-52cm and 56-58cm this was expanded to an analysis of the entire monolith, including the overlying context 40063. Surprisingly, the climatic/ecological results from the initial assessment (herein) proved to be at variance with the initial thinking that this phase of the site sequence represented cool/cold conditions (as proposed in Wenban-Smith *et al.* 2006). Another set of sub-samples from the same monolith provided for mollusc assessment seemed to be almost barren (Chapter 10). It was therefore considered possible that the two assessed ostracod samples (or their source monolith) might have been mis-labelled at some point in time. The finest grade of residue from an extra bulk sample <40042> was then provided via Simon Parfitt (who had sorted it for small mammal and fish/amphibian remains). This sample was undoubtedly from context 40062. Even though it had been put through a 500 μm sieve, its organic remains, including ostracods (although some of the smaller species were lost), were so near-identical to those recorded as from monolith <40068> (Fig. 11.3) that it has been concluded that the samples and their microfaunas described here from monolith <40068> are genuinely ascribed.

The uppermost two samples, from context 40063, are unfortunately weathered and decalcified, as is much of the material generally from other horizons at the site. However, context 40062 below (monolith <40068> 48-60cm; and sample 40042) provided an extremely rich, fully interglacial freshwater ostracod faunas (with at least 8 species found), together with molluscs, *Bithynia* opercula and charophyte oogonia (Fig. 11.3). Furthermore, they were identical to the faunas from Station Quarter South TPs 31 and 33 excavated a short distance to the east in 2006, reported on by Whittaker (2006) and discussed below. The ostracod fauna from TP 31 was recovered from sediments attributed to Phase 4, and that from TP 33 was from the top of a body of sediment attributed to Phase 3 (see Fig. 11.5). There is little difference between the finer-grained upper Phase 3 deposits at the site and the presumed Phase 4 lithology further east; in fact, they may interdigitate with each other, or the more developed eastern Phase 4 deposits may be lateral equivalents of the Phase 3 sediments.

The ostracod faunas indicate a shallow, swampy but clean, slow-moving waterbody rich in vegetation or a weedy shallow lake. This is supported by additional

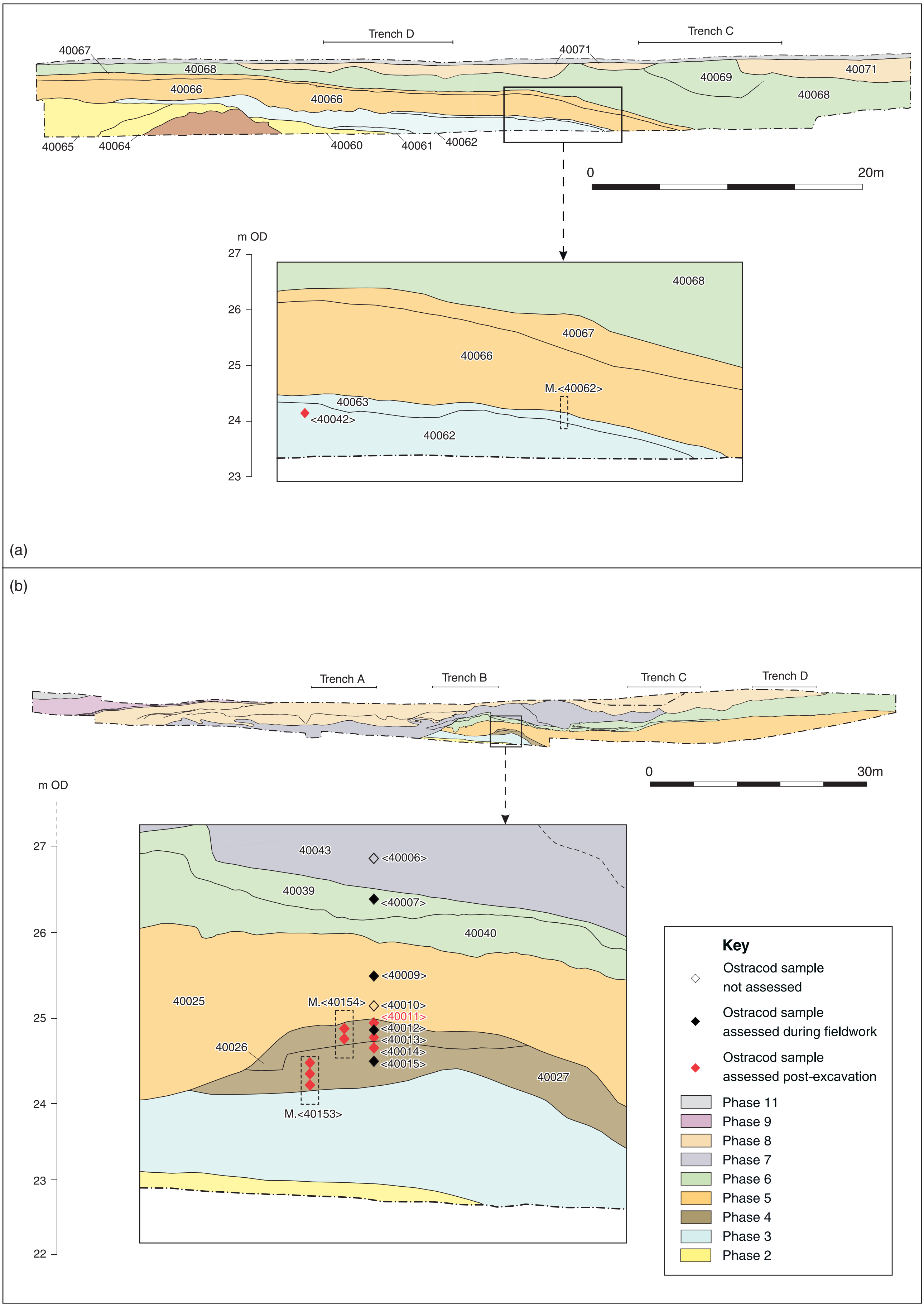

Figure 11.2 Ostracod sampling locations: (a) for Phase 3, in east face of site (Section 40016), monolith <40068> and bulk sample <40042>; (b) in west face of site, Log 40011, Section 40015

Table 11.2 Post-excavation assessment for ostracods and other microfauna, 2009–2010

Sample <>	*Context*	*Phase*	*Weight processed*	*freshwater ostracods*	*molluscs*	*Bithynia opercula*	*fish/amphibian remains*	*small mammal teeth*	*charophyte oogonia*	*iron + iron tubes (rootlets)*	*tufa*	*Assessment notes*
40420/B	40166	7	225g									Completely barren
40414/B	40166	7	225g							x		Iron mineral (?limonite and goethite) and iron tubes with imprints of plant stems and rootlets
40415/B	40166	7	225g							x		Iron mineral (?limonite and goethite) and iron tubes with imprints of plant stems and rootlets
40416/B	40166	7	225g							x		Iron mineral (?limonite and goethite) and iron tubes with imprints of plant stems and rootlets
40417/B	40166	7	225g							x		Iron mineral (?limonite and goethite) and iron tubes with imprints of plant stems and rootlets
40361/B	40164	7	225g									Completely barren
40418/B/0-2cm	40166	7	185g							x		Iron mineral (?limonite and goethite) and iron tubes with imprints of plant stems and rootlets
40418/B/5-7cm	40158	6	70g					x		x		
40418/B/13-15cm	40158	6	125g					x				
40311/B	40144	6b	225g				x					
40310/B	40070	6b	225g	x	x	x	x				x	
40313/B	40070	6b	225g	x	x	x	x	x			x	
40312/B	40103	6a	225g				x					
40282/B/0-2cm	40143	6b	50g	x	x	x	x	x			x	
40282/B/2-5cm	40144	6b	135g	x	x	x	x	x			x	
40282/B/5-8cm	40144	6b	160g	x	x	x	x				x	
40282/B/11-13cm	40070	6b	55g	x	x	x	x	x			x	
40282/B/17-19cm	40070	6b	80g		x	x	x	x			x	
40282/B/22-24cm	40103	6a	55g		x		x			x		
40321/B/1-5cm	40144	6b	80g									
40321/B/6-9cm	40144	6b	110g									
40321/B/10-14cm	40144	6b	110g									
40321/B/15-18cm	40144	6b	105g									
40321/B/19-22cm	40144	6b	110g				x					
40321/B/23-27cm	40144	6b	105g				x					
40321/B/29-31cm	40070	6b	*c* 80g		x	x	x				x	
40321/B/31-33cm	40070	6b	70g		x	x	x				x	
40321/B/33-36cm	40070	6b	95g	x	x	x	x				x	
40321/B/36-39cm	40070	6b	95g		x	x	x	x		x	x	
40321/B/39-42cm	40070	6b	75g		x	x	x	x		x	x	
40321/B/42-45cm	40103	6a	80g				x	x				
40157/B/3-5cm	40040	6a	95g									
40157/B/18-20cm	40040	6a	125g									
40157/B/31-33cm	40040	6a	105g							x		
40326/B/1-3cm	40103?	6a	45g							x		
40326/B/17-19cm	40103	6a	160g							x		
40326/B/31-33cm	40103	6a	135g							x		
40326/B/40-42cm	40025	5	105g							x		Iron tubes formed around plants or rootlets and suggests a shallow water-body or riverine setting whose sediments have subsequently been subject to weathering

Table 11.2 (continued)

Sample <>	*Context*	*Phase*	*Weight processed*	*freshwater ostracods*	*molluscs*	*Bithynia opercula*	*fish/amphibian remains*	*small mammal teeth*	*charophyte oogonia*	*iron + iron tubes (rootlets)*	*tufa*	*Assessment notes*
40154/B/26-28cm	40026	4	110g							x		
40154/B/41-43cm	40026	4	105g							x		
40153/B/0-2cm	40027	4	105g							x		
40153/B/12-14cm	40027	4	45g							x		
40153/B/27-29cm	40027	4	50g							x		
40011	40026	4	55g							x		
40013	40026	4	80g							x		
40014	40027	4	75g						x	x		
40068/B/10-12cm *	40066	5	90g							x		Iron tubes formed around plants or rootlets and suggests a shallow water body or riverine setting whose sediments have subsequently been subject to weathering
40068/B/23-25cm *	40066	5	110g							x		Iron tubes formed around plants or rootlets and suggests a shallow water body or riverine setting whose sediments have subsequently been subject to weathering
40068/B/32-34cm *	40066	5	80g							x		Iron tubes formed around plants or rootlets and suggests a shallow water body or riverine setting whose sediments have subsequently been subject to weathering
40068/B/38-40cm *	40063	3	115g							x		De-calcified upper part of context
40068/B/44-46cm *	40063	3	115g							x		De-calcified upper part of context
40068/B/48-50cm *	40062	3	125g	x	x	x			x	x		
40068/B/50-52cm	40062	3	105g	x	x	x			x	x		
40068/B/52-54cm *	40062	3	95g	x	x	x			x	x		
40068/B/54-56cm *	40062	3	115g	x	x	x			x			
40068/B/56-58cm	40062	3	80g	x	x	x			x			
40068/B/58-60cm *	40062	3	115g	x	x	x			x			
40095/B/10-15cm	40065	2	175g							x		Black iron mineral, probably goethite, suggests weathering
40078/B/46-51cm	40065	2	175g							x		Black iron mineral, probably goethite, suggests weathering
40076/B/33-38cm	40064	2	180g							x		Black iron mineral, probably goethite, suggests weathering
40073/B/4-9cm	40064	2	180g							x		Black iron mineral, probably goethite, suggests weathering
40098/B/16-22cm	40064	2	175g							x		Scraps of reworked Tertiary molluscs
40097/B/10-15cm	40064	2	175g									Completely barren
40066	40065	2	225g							x		Black iron mineral, probably goethite, suggests weathering
40062	40059	1	225g									Completely barren
40060	44057	1	225g							x		Iron (?) mineral, possibly reworked from Thanet Sand

* additional samples from monolith 40068, following initial assessment

Organic remains

CONTEXT	40063		40062						
SAMPLE	40068/B/38-40cm	40068/B/44-46cm	40068/B/48-50cm	40068/B/50-52cm	40068/B/52-54cm	40068/B/54-56cm	40068/B/56-58cm	40068/B/58-60cm	40042
iron mineral + iron tubes	x	x	x	x	x				
molluscs			x	x	x	x	x	x	x
Bithynia opercula			x	x	x	x	x	x	x
charophyte oogonia			x	x	x	x	x	x	x
freshwater ostracods			x	x	x	x	x	x	x

Ecology	weathered; decalcified	weedy shallow, but clean waterbody

Freshwater Ostracods

CONTEXT	40063		40062						
SAMPLE	40068/B/38-40cm	40068/B/44-46cm	40068/B/48-50cm	40068/B/50-52cm	40068/B/52-54cm	40068/B/54-56cm	40068/B/56-58cm	40068/B/58-60cm	40042
Fabaeformiscandona balatonica			xxx	xxx	xx	xx	xx	xx	xx
Herpetocypris reptans			xx	xx	xx	xx	xx	xx	xxx
Candona neglecta			x	x	x				x
Ilyocypris bradyi			x	x	x	x	x	x	
Cypridopsis vidua			x		o	x	o	x	
Ilyocypris quinculminata			o			o		o	
Cyclocypris sp.				x	x		x	x	
Potamocypris zschokkei				o					

Organic remains are recorded on a presence (x) / absence basis only
Ostracods are recorded: o - one specimen; x - several specimens; xx - common; xxx - abundant

Freshwater ostracods
Extinct, not known in sediments younger than MIS11 (Hoxnian)

Figure 11.3 Phase 3: ostracods from monolith <40068> and bulk sample <40042>

evidence from the charophytes (see discussion under Phase 4 sediments, below) and it is unfortunate that no associated molluscan evidence was recovered to complement the ostracod data. Ecological preferences of the three most common ostracods are given below, adapted from Meisch (2000).

Herpetocypris reptans (Baird, 1835) Waterbodies with rich vegetation and a muddy bottom; slow waters; swampy waters; springs.

Fabaeformiscandona balatonica (Daday, 1894) Shallow pools and swampy, shallow fringes of waterbodies that can dry up in summer.

Ilyocypris bradyi (Sars, 1890) Slow waters, swamps, etc. Waters flowing from springs, ponds fed from springs.

In the Station Quarter South assemblages (see below), the occurrence of *Ilyocypris quinculminata* was reported, so far the only age-diagnostic ostracod found on the site or in the vicinity; it is also present here, albeit rarely, in samples from 48-50, 54-56 and 58-60cm in monolith <40068>. This distinctive species is present in several Cromerian (MIS 13) sites: Little Oakley and Sidestrand, East Anglia; Waverley Wood, Warwickshire (MIS1 5); Boxgrove, West Sussex (MIS 13) but is not known from sediments younger than the Hoxnian (MIS 11). Its occurrences however in MIS 11 are curious (Whittaker and Horne 2009). In full, these are: Trysull (type-locality) and Froghall, Staffordshire; Hatfield, Hertfordshire; Copford, Marks Tey and Rivenhall, in Essex; and Elveden and Hoxne, in Suffolk. There is not a single occurrence, apart from this Southfleet Road site, from the Thames environs of this age. It has not been found during work in progress with Richard Preece and Tom White (Cambridge University) from sediments at Dierden's Pit, Swanscombe that are thought most likely equivalent to the Lower Middle Gravel of the Barnfield Pit sequence, slightly younger in MIS 11 than the suggested age of Phases 3-6 of the Southfleet Road site sequence (see Chapter 22). Nor has it been found in the Lower Loam at Barnfield Pit, which may be thought to be more of a correlative and the lower part of which was examined at Swanscombe for ostracods in the 1980s by Robinson (1996). This species, of course, may have been restricted to a particular facies or niche: the Southfleet Road site would have been a minor backwater compared to the major river represented at Barnfield Pit, but there is also the possibility that it may only occur within a part (or parts) of the Hoxnian interglacial.

That this may be early in the Hoxnian is evidenced both by the position of these Phase 3 deposits towards the base of the Southfleet Road sequence, and also by the amino acid ratios obtained from *Bithynia* opercula from context 40062 (see Chapter 13). It was initially thought during excavation (Oxford Archaeology 2005; Wenban-Smith *et al.* 2006) that the Phase 3 sediments were soliflucted or fluvio-glacial in their origin, and thus by implication, of late Anglian or very early Hoxnian age. However, there are no cold ostracod indicators whatsoever in the microfaunas of context 40062, and such markers are now very well-known from cold climate deposits, not only within MIS 11 (as at Beeches Pit, Suffolk, for example (Whittaker, *in* Preece *et al.* 2007)), but also from widespread younger, Devensian, solifluction deposits in the Warblingon-Bognor-Worthing region on the South Coast of England (see Bates *et al.* 2009). A mutual ostracod temperature range (MOTR) analysis of the ostracod species by one of us (DJH) from context 40062 (below) indicates a fully temperate environment, albeit probably with greater seasonality than today. The only molluscan remains recovered in context 40062 were *Bithynia* opercula, which were common. These are considered to be confined to interglacials and interstadials (Richard Preece, pers. comm.) so, assuming they are not reworked, these too suggest warm climatic conditions. Reworking must be considered a possibility though, since *Bithynia* would generally prefer cleaner flowing water than the quiet/stagnant, periodically desiccated, small lake/pond thought to be the dominant Phase 3 environment.

These Phase 3 deposits contain the oldest undoubted Pleistocene microfaunas in the Southfleet Road succession. The initial suggestion (Wenban-Smith *et al.* 2006) that they were formed by solifluction in a periglacial climate must be rejected, it also being highly improbable that the ostracod faunas are derived, or the sediments in some way rafted in as a whole block. Under these circumstances the microfaunas reported here would have undergone destructive damage and probably lost their ecological/climatic integrity as an assemblage. The ostracod *Herpetocypris reptans* in particular is very large and thin-shelled and would be expected to be totally destroyed under those circumstances.

There is however some reworking in the lower part of context 40062 as it contains much derived Tertiary molluscan material (mostly scraps) as well as the distinctive reworked ostracod, *Vetustocytheridea lignitarum*. The distribution of the latter is well known, being found in the Blackheath Beds (Harwich Formation) and the Woolwich Formation of the Late Palaeocene and in the Upnor Formation of earliest Eocene age (Lord *et al.* 2009). It occurs in abundance in the 'Lower and Upper Shelly Clays' and the 'Laminated Beds' (of the Woolwich Formation) in the Swanscombe sequence. Consequently it is therefore probable that the Phase 3 deposits at Southfleet Road contain derived material from this same deposit, washed downslope from the high ground previously (pre-quarrying) to the west of the site (Chapter 2).

As reported above, the two samples subsequently examined from monolith 40068, context 40063 (interval 38-46cm), directly above these fossiliferous deposits, were completely barren of ostracods, or any other Pleistocene fauna for that matter. Their only content was iron mineral (limonite and goethite) and iron tubes formed around plant tissue. This would appear to indicate weathering and decalcification of the upper Phase 3 sedimentary sequence.

Mutual Ostracod Temperature Range (MOTR) Analysis: Phase 3 sediments, monolith <40068>, context 40062

This type of analysis (Horne 2007) is similar to the Mutual Climate Range (MCR) method of Russell Coope for Coleoptera. It also uses proxy data (in this case, a large present-day ostracod database called NODE) to estimate past air temperature ranges. The July and January means for the Phase 3, Monolith <40068>, ostracods have thus been calculated as follows:

	Calibrated July Mean	*Calibrated January Mean*
Herpetocypris reptans	+10 to +25°C	-8 to +15°C
Fabaeformiscandona balatonica	+17 to +21°C	-4 to –1°C
Cypridopsis vidua	+9 to +28°C	-8 to +17°C
Cyclocypris ovum	+7 to +26°C	-17 to +4°C
Prionocypris zenkeri	+14 to +26°C	-4 to +6°C
Candona neglecta	+7 to +27°C	-10 to +13°C
Potamocypris zschokkei	+6 to +24°C	-10 to +9°C

Ilyocypris bradyi cannot be calibrated due to taxonomic uncertainties.
Ilyocypris quinculminata cannot be used, either, as it is extinct.
The calibration of *Fabaeformiscandona balatonica* is new and is based on only five records in NODE, so its reliability is rather questionable.

Application of the MOTR method gives:
July mean temperature range: +17 to +21°C
January mean temperature range: -4 to -1°C

If *F. balatonica* is omitted, results are:
July mean temperature range: +14 to +24°C
January mean temperature range: -4 to +4°C

Present day values for Ebbsfleet, by comparison, are July +17.5°C, January +4°C. Hence, July temperatures during the deposition of the Phase 3 sediments were essentially the same as today, although possibly they could have been a few degrees warmer. January temperatures were essentially the same as today, but possibly a few degrees colder. The presence of *F. balatonica*, however, might be taken to indicate winter temperatures at least 5 degrees colder than today. The MOTR analysis therefore indicates a fully temperate climate with perhaps greater seasonality than today.

Phase 4

Fig. 11.4 shows the results of the eight samples examined from contexts 40026 and 40027, from Phase 4 sediments in the central part of the main west-facing Section 40015, at or in the vicinity of Log 40011 (Fig. 11.2b). All eight samples contain iron mineral and iron tubes (formed around plant stems and rootlets). A significant find occurred in sample 40014 (context 40027) which contains charophyte oogonia (oospores), or rather their cortex preserved in iron. This gives some indication of the nature of the waterbody that once occurred at the site at this level, whose evidence has been mostly destroyed by subsequent weathering. Charophytes are water plants. They grow completely submerged in the water of wetlands, rivers, streams, lakes and swamps, in fact all sorts of non-marine watery habitats. They reproduce sexually via gametes produced by male and female reproductive organs (antheridia and oogonia, respectively), and they have seed-like oospores that germinate into the new plant. Charophytes are useful components of aquatic ecosystems. Many species require high water quality and clarity for survival, so their presence can indicate the existence of a healthy ecosystem. They decline when water becomes polluted, murky or eutrophic.

In contrast to this minimal evidence from the Phase 4 deposits at the site, rich ostracod faunas were recovered in 2006 from deposits thought to be equivalent in TPs 31 and 33 a short distance to the east, excavated as part of the Station Quarter South field evaluation (Wessex Archaeology 2006b; Chapter 4). These faunas were recovered from four samples in clayey silts with polygonal cracking indicating periodic drying out of a very quiet waterbody (Fig. 11.5). As discussed above, these deposits may directly overlie the Phase 3 sediments on the eastern side of the site, they may interdigitate with them, or they may in fact be direct lateral equivalents, continuing an eastward dipping/thickening and fining trend.

Samples <3> and <4> (contexts 3304 and 3306, respectively) came from towards the top of the sequence of TP 33 and have virtually identical faunas to each other (Fig. 11.6). The higher sample <3> was interpreted as coming from Phase 4 deposits, and the lower sample <4>

Organic remains

CONTEXT	40026		40027		
SAMPLE	40154/B/26-28cm	40154/B/41-43cm	40153/B/0-2cm	40153/B/12-14cm	40153/B/27-29cm
iron mineral + iron tubes	x	x	x	x	x
charophyte oogonia					
Ecology	?shallow waterbody; weathered				

CONTEXT	40026		40027
SAMPLE	40011	40013	40014
iron mineral + iron tubes	x	x	x
charophyte oogonia			x
Ecology	shallow waterbody with high water quality; subsequently weathered		

Organic remains are recorded on a presence (x) / absence basis only

Figure 11.4 Microfossil assessment: Phase 4

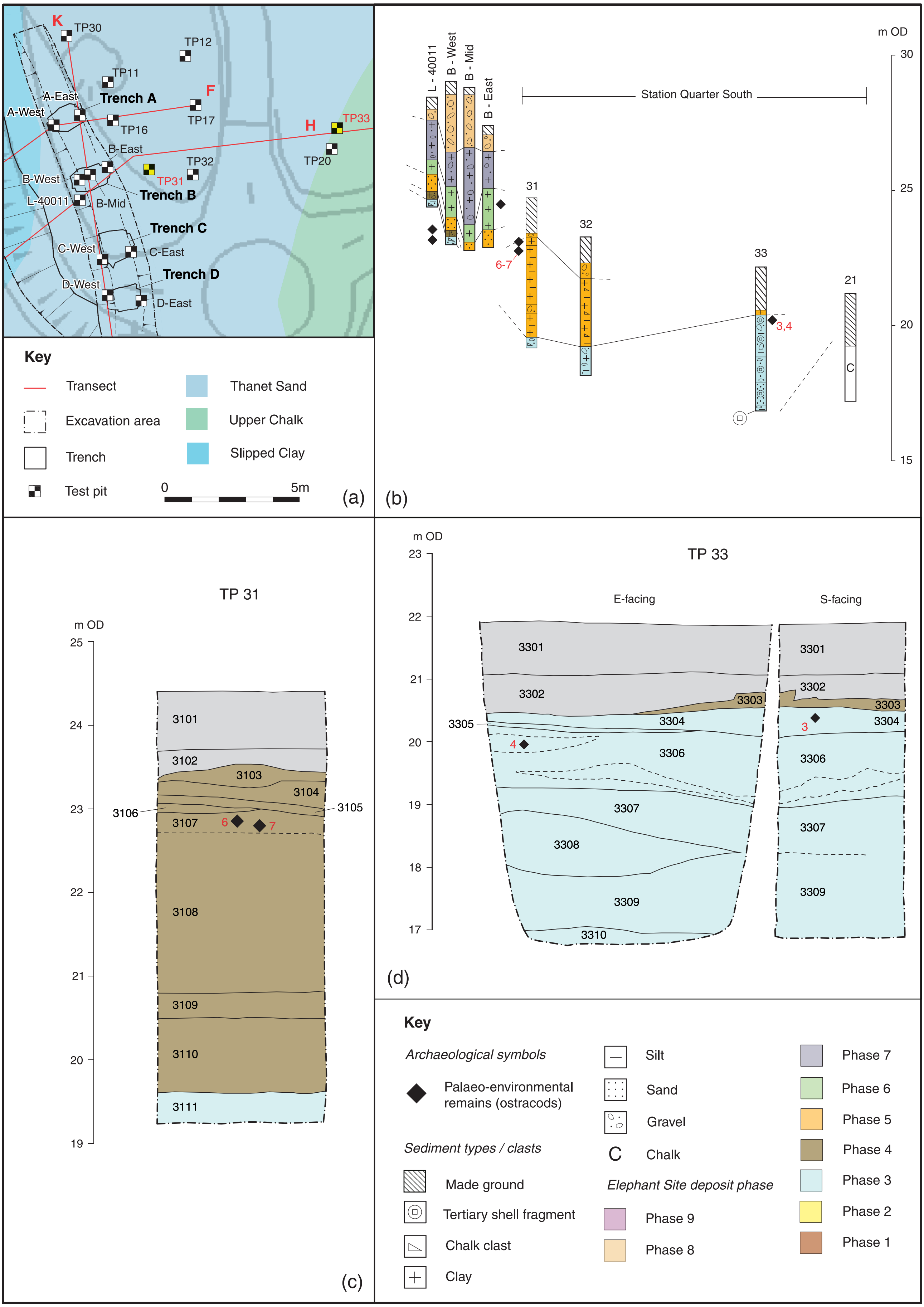

Figure 11.5 Ostracod sampling locations, Station Quarter South: (a) thumbnail of Test Pits 31 and 33 locations; (b) stratigraphic context of ostracod samples <3>, <4>, <6> and <7>; (c) Test Pit 31; (d) Test Pit 33

as from the top of Phase 3 deposits. Their organic remains are listed in the upper part of Fig. 11.6 and the ostracods below. Molluscan fragments occur again but this time with *Bithynia* opercula (in large numbers) and Pleistocene freshwater ostracods comprising the following species: *Herpetocypris reptans, Fabaeformiscandona balatonica, Ilyocypris bradyi, Cypriopsis vidua, Prionocypris zenkeri* and *Ilyocypris quinculminata*.

Samples <6> and <7> (context 3107) from TP 31 have a near-identical ostracod fauna to this, but in even greater numbers (Fig. 11.6); and the very same six species, with the addition of *Cyclocypris ovum*. The organic remains now include charophyte oogonia (fruiting bodies of the stonewort), slug plates and calcareous tubes clearly formed around the stems and rootlets of plants. Rather than this signifying samples <6> and <7> are necessarily coeval with <3> and <4>, it probably indicates nothing more than both were laid down in very similar environments.

The ecological requirements of the three commonest ostracods in the assemblages (*Herpetocypris reptans, Fabaeformiscandona balatonica* and *Ilyocypris bradyi*) are listed above (Phase 3, discussion); the less common species having similar preferences. Together, they indicate a shallow, swampy, slow-moving water body rich in vegetation, context 3107 even more so, in that it provides additional evidence of charophytes and the rootlets and stems of aquatic plants. All the ostracod species, save one, are found living in Britain today, so there is nothing to suggest that these deposits indicate anything other than a full interglacial. The exception, *Ilyocypris quinculminata*, however, is of great biostratigraphic value and immediately places them in the period MIS 13 (late Cromerian complex) to MIS 11 (the Hoxnian). This species is previously known from about 12 sites (all in South and Central England), listed above in the Phase 3 discussion. Curiously, however, the species has yet to be found in any of the classic Swanscombe 100-ft terrace deposits, such as at Barnfield Pit or Dierden's Pit.

	TP 31		TP 33	
PHASE	4		3	
CONTEXT	3107		3304	3306
ORGANIC REMAINS / SAMPLE NO.	<6>	<7>	<3>	<4>
molluscs	x	x	x	x
reworked microfossils				
fish/amphibian bone/teeth				
Bithynia opercula	x	x	x	x
charophyte oogonia	x	x		
freshwater ostracods	x	x	x	x
slug plates	x	x		
calcareous tubes (rootlets)	x	x		
OSTRACOD SPECIES				
Herpetocypris reptans	xx	xx	x	x
Fabaeformiscandona balatonica	xx	xx	x	x
Ilyocypris bradyi	xx	x	x	x
Cypridopsis vidua	x	x		x
Cyclocypris ovum	x	x		
Ilyocypris quinculminata	x		x	
Prionocypris zenkeri		x	x	x

Organic remains are recorded on a presence (x) / absence basis
x - present; xx - common/abundant
Extinct, not known in sediments younger than MIS11 (Hoxnian)

Figure 11.6 Ostracods from Station Quarter South Test Pits 31 and 33 (Phases 3 and 4 deposits)

Ostracods from the tufaceous channel-fill, Phase 6b

No ostracods were found in any of the samples from Phase 6 (undifferentiated clay, usually brecciated and/or browner with fragmentary rotted plant material) or 6a (the specific lower clay contexts, in ascending order 40040, 40039 and 40103 in the central part of the site). Many of the Phase 6a samples show evidence of weathering by the presence of iron minerals and iron tubes formed around plant tissue: contexts 40039, 40103 and 40158 (Table 11.2), or were completely barren (top of context 40040). All that can be said is that these sediments were probably deposited in a semi-terrestrial environment, with associated shallow waterbodies that subsequently were subject to desiccation and/or weathering.

In Phase 6b, the tufaceous channel-fill, evaluation while fieldwork was in progress failed to find any ostracods in the main basal mollusc-rich context 40070, but established that a relatively rich ostracod fauna was present in context 41043, the white silt capping the tufaceous channel-fill sequence. Ten samples from this deposit were analysed from three localities, all in or near Trench XIII, where the best exposures of context 40143 were present (Fig. 11.1). At Section 40068, a sequence of three samples (<40264>-<40266>) was taken down through the full thickness of the deposit (Fig. 11.1c). At section 40063, on the opposite face of Trench XIII, another sequence of three samples (<40268>-<40270>) was taken down through the full thickness of the deposit. This was supplemented here by samples <40249> and <40248> from towards the top of the deposit, and sample <40271> from the middle of the deposit (Fig. 11.1d). Finally, a single sample (<40250>) was taken at the third locality, the north end of Section 40064 (Fig. 11.1b).

Table 11.3 summarises all the microfauna found in the ten samples from Sections 40068, 40063 and 40064. There are slight differences in their associations, and more detailed reports on the small vertebrate and molluscan material are provided separately (Chapter 7 and Chapter 10, respectively). The material is in excellent condition and is comparable to that of the underlying tufa, all suggesting temperate conditions. Although fish remains are ubiquitous, the stratigraphic sequence from Sections 40068 and 40063 seem to show an increase in amphibian, reptile and small mammal remains towards the top, with a concomitant decrease in fish remains, possibly indicating drying out of the waterbody through time. This is considered further in the concluding discussion (Chapter 22), in conjunction with other lines of evidence.

All but one sample contains freshwater ostracods (Table 11.3). None is extinct and all are living in Britain today. Of these only one candonid is ubiquitous. It is usually

Table 11.3 Distribution of ostracods through context 40143 (tufaceous channel, Phase 6b) in samples from Sections 40063, 40068 and 40064

Section	*40068*			*40063*						*40064*
Sample <>	*40264*	*40265*	*40266*	*40249*	*40268*	*40248*	*40269*	*40271*	*40270*	*40250*
Vertical zone of context 40143	*Upper*	*Middle*	*Lower*	*Upper*	*Middle*	*Lower*	*All*			
Fabaeformiscandona balatonica		x(j)	x(j)	x(j)	x(j)	x(j)	x(j)	x	x(j)	o(j)
Ilyocypris bradyi		x	x		x		x	x		x
Pseudocandona rostrata			o(j)	o	x(j)		x	xx		
Herpetocypris reptans							x	x	x	
Pseudocandona longipes				x				x	x	
Cyclocypris sp.				o		o			o	
Potamocypris zschokkei						x				

o - one specimen; x - several specimens; xx - common; (j) juveniles only

represented only by juveniles, but in sample <40271> a few adults show the species to be *Fabaeformiscandona balatonica*. In the three sections another six ostracod species are also found in varying associations, which if *in situ* could indicate slightly different niches being represented. Overall, however, almost all of the ostracods live either in shallow waterbodies fed by springs (eg *Pseudocandona rostrata, P. longipes*), slow waters flowing from springs (eg *Ilyocypris bradyi*) or in the seepages/ springs themselves (*Potamocypris zschokkei*). The occurrence (only) in Section 40063 of *Herpetocypris reptans* (usually in the same samples as charophyte oospores) evidences well vegetated, unpolluted waters, but the reason for its restriction is unclear. The most common ostracod, *Fabaeformiscandona balatonica*, today prefers shallow and swampy pools that dry up in summer, often also in shady conditions, in woodland. The evidence of the small vertebrate fauna, as we have seen, could indeed indicate a pool drying out over time. However, the ostracod evidence points to a seasonal phenomenon, whereas the latter must have taken place over a much longer period of time. The presence of mainly juvenile candonids could also be a seasonal factor, but could also indicate some redeposition (supported by the occurrence of much molluscan shell debris and concentrated *Bithynia* opercula) as the waterbody overflowed from time to time. This may possibly have been dependent on season, but was never catastrophic as the sediments are fine grained and other fossil preservation (for example of fragile gastropods) is usually good.

Following completion of fieldwork, the more intensive post-excavation assessment investigated various sequences through the tufaceous channel-fill (Table 11.2), and recovered sparse ostracod assemblages in a number of places, including material from contexts 40070 and 40144, as well as some further material from context 40143 (Fig 11.7). Considering that the thin and intermittent remnants of context 40143 were often highly contorted and intermingled with the underlying sediments, it is questionable whether any of this material genuinely belongs to any context other than 40143. The numbers of ostracods were quite low and the broken nature of much of the associated molluscan fauna also indicates that there may have been some reworking or redeposition. The ostracod species that occur live today in shallow waterbodies fed by springs, slow waters flowing from springs or in the seepages/springs themselves. Because abundant tufa is found throughout most of these sediments, the ostracods may have been living in the actual tufa-springs and associated pools, but the ostracod numbers are surprisingly sparse if everything is *in situ*, as also indicated by the micritic nature of the tufa.

Phase 7 sediments

These sediments directly, conformably (despite the contorted geometry of the junction) overlie the dark brown brecciated clay of the Phase 6 deposits in the central part of the site (Chapter 4). A series of samples from the fine-grained context 40166 forming the base of the syncline infill in the centre of the 'skateboard ramp' feature were investigated for microfaunal remains. None was found, but mineralised imprints of plant stems and rootlets allow some interpretation.

Figure 11.8 shows the results of the seven samples examined from contexts 40164 and 40166. All were barren of ostracods and anything else calcareous. Two were completely barren but 5 of the 7 samples contained iron mineral (?limonite and goethite) and iron tubes. The tubes showed distinct imprints of plant stems and rootlets. According to Candy (in Ashton *et al.* 2005) this iron is associated with weathering or near-surface groundwater, formed prior to the onset of fully terrestrial conditions, or pedogenic activity. The coarse nature of some of these Phase 7 deposits may indicate a high energy setting at times, or more likely the mass movement of gravel-rich sediments, but these samples were totally barren. Samples <40420> and <40361> were gravel-rich, and also examined for clast lithology (see Chapter 6 and Fig. 6.1c; d). The occurrence of mineralised plant tissue fossils, in association with the finer-grained sediment of the other samples, indicates the former presence of wetland plants in a shallow waterbody or a much quieter riverine setting. The actual plant remains and any once-present faunal remains having been destroyed by post-depositional oxidation and weathering.

Organic remains

CONTEXT	40144	40070		40143	40144		40070		40144			
SAMPLE	40311/B	40310/B	40313/B	40282/B/0-2cm	40282/B/2-5cm	40282/B/5-8cm	40282/B/11-13cm	40282/B/17-19cm	40321/B/1-5cm	40321/B/6-9cm	40321/B/10-14cm	40321/B/15-18cm
fish bone and teeth	x	x	x	x	x	x	x	x				
tufa		x	x	x	x	x	x	x				
molluscs		x	x	x	x	x	x	x				
Bithynia opercula		x	x	x	x	x	x	x				
slug plates		x	x			x	x	x				
freshwater ostracods		x	x	x	x	x	x					
small mammal teeth			x	x	x		x	x				
amphibian bone					x	x						
iron												
Ecology	Actual tufa springs and associated pools, or redeposited from tufa springs			Actual tufa springs and associated pools, or redeposited from tufa springs					weathered			

Freshwater ostracods

CONTEXT	40144	40070		40143	40144		40070		40144			
SAMPLE	40311/B	40310/B	40313/B	40282/B/0-2cm	40282/B/2-5cm	40282/B/5-8cm	40282/B/11-13cm	40282/B/17-19cm	40321/B/1-5cm	40321/B/6-9cm	40321/B/10-14cm	40321/B/15-18cm
Ilyocypris gibba/bradyi		xx	x	x	x		o					
Prionocypris zenkeri		o										
Potamocypris zschokkei		o				x						
Pseudocandona sp. (juv.)		o										
Fabaeformiscandona balatonica				o	o							

Ostracods are recorded: o - one specimen; x - several specimens; xx - common; xxx - abundant
Organic remains are recorded on a presence (x) / absence basis only

Completely barren
Freshwater ostracods

Figure 11.7 *(above and right)* Phase 6b: microfossil assessment and ostracod analysis

Organic remains

CONTEXT	40166					40164	40166
SAMPLE	40420/B	40414/B	40415/B	40416/B	40417/B	40361/B	40418/B/0-2cm
iron mineral + iron tubes		x	x	x	x		x
Ecology	Weathered. Originally contained plants in either wetland or quiet riverine setting.						

Organic remains are recorded on a presence (x) / absence basis only

Completely barren

Figure 11.8 Microfossil assessment: Phase 7 sediments

CONTEXT	40144			40070			
SAMPLE	40321/B/19-22cm	40321/B/23-27cm	40321/B/29-31cm	40321/B/31-33cm	40321/B/33-36cm	40321/B/36-39cm	40321/B/39-42cm
fish bone and teeth	x	x	x	x	x	x	x
tufa			x	x	x	x	x
molluscs			x	x	x	x	x
Bithynia opercula			x	x	x	x	x
slug plates			x	x	x	x	x
freshwater ostracods					x		
small mammal teeth						x	x
amphibian bone						x	
iron						x	x
Ecology	Actual tufa springs and associated pools, or redeposited from tufa springs			Actual tufa springs and associated pools, or redeposited from tufa springs			

CONTEXT	40144			40070			
SAMPLE	40321/B/19-22cm	40321/B/23-27cm	40321/B/29-31cm	40321/B/31-33cm	40321/B/33-36cm	40321/B/36-39cm	40321/B/39-42cm
Ilyocypris gibba/bradyi					x		
Prionocypris zenkeri					o		
Potamocypris zschokkei							
Pseudocandona sp. (juv.)							
Fabaeformiscandona balatonica							

DISCUSSION AND CONCLUSIONS

The main value of the ostracods, where they occur, has been to assist in the palaeoenvironmental interpretation. Climatic information, made available through the MOTR method of Horne (2007), has also proven particularly useful and is emphasising the interglacial status of the Phase 3 sediments. The species *Ilyocypris quinculminata*, whose biostratigrapical distribution is now very well known, also suggests that the Phase 3 sediments at the site belong to the (?earlier) Hoxnian. Sediments further east (in Station Quarter South, interpreted here as equivalent to Phases 3 and 4 of the site sequence), have a virtually identical ostracod assemblage and likewise contain *Ilyocypris quinculminata*. They are not only formed under similar climatic/ecological conditions in the same time period, but are probably on lithostratigraphic grounds a lateral continuation of the same deposit.