Appendix 1

Environmental sample inventory and assessment

Table A1.1 Sample inventory

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Bulk-sed	9b	40053	40023	30L	Small verts	Prelim assessment April 2004 - nothing found	-	
Bulk-sed	8c	40018	40004	10L	Clast lithology	-	Clast lithology & angularity/roundness	
Bulk-sed	8c	40018	40005	10L	Clast lithology	-	Lost	
Bulk-sed	8c	40071	40001	10L	Clast lithology	-	Clast lithology & angularity/roundness	
Bulk-sed	8c	40071	40002	10L	Clast lithology	-	Clast lithology & angularity/roundness	
Bulk-sed	8c	40071	40044	30L	Small verts	Prelim assessment April 2004 - nothing found	-	
Bulk-sed	6	40078	40100	220L	Elephant bits	Assessed for small vertebrates, larger identifiable elephant bones and lithic artefacts, 2009	-	
Bulk-sed	6	40078	40101	110L	Elephant bits	Assessed for small vertebrates, larger identifiable elephant bones and lithic artefacts, 2009	-	
Bulk-sed	6	40078	40128	100L	megafauna	Assessed for small vertebrates, 2009	-	
Bulk-sed	6	40078	40159	110L	Elephant bits	Assessed for small vertebrates, larger identifiable elephant bones and lithic artefacts, 2009	-	
Bulk-sed	6	40078	40194	10L	megafauna	-	-	
Bulk-sed	6	40078	40275	40L	Small verts	Assessed for small vertebrates, 2009	-	
Bulk-sed	6	40078	40276	10L	Insects	-	-	
Bulk-sed	6	40078	40327	20L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6	40100	40176	30L	Small verts	Prelim assessment April 2004 - nothing found	-	
Bulk-sed	6c	40039	40238	0.2L	Small verts	Assessed for SVs & molluscs	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6	40068	40026	30L	Small verts	Prelim assessment April 2004 - nothing found	-	
Bulk-sed	6	40068	40032	30L	Small verts	Prelim assessment April 2004 - a few frags of large animal bone	-	
Bulk-sed	6	40068	40203	10L	Charred remains	Assessed 2009	Wood ID and C14 by Oxford Archaeology	
Bulk-sed	6	40069	40029	30L	Small verts	Prelim assessment April 2004 - nothing found	-	
Bulk-sed	6	40162	40346	20L	Insects	Assessed for insects, 2009	-	
Bulk-sed	6b	40070	40035	30L	Small verts	Prelim assessment April 2004 - abundant molluscs and small vertebrates	Material forms basis of mollusc and SV analyses in J Quaternary Sci paper (Wenban-Smith et al. 2006); small vertebrates analysed in 2010	
Bulk-sed	6b	40070	40160	50L	Small verts	Prelim assessment April 2004 - abundant molluscs and small vertebrates	-	
Bulk-sed	6b	40070	40162	50L	Small verts	Prelim assessment April 2004 - abundant molluscs and small vertebrates	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6b	40070	40182	20L	Small verts	Prelim assessment April 2004 - scarce molluscs and common small vertebrates	-	
Bulk-sed	6b	40070	40183	50L	Small verts	-	-	
Bulk-sed	6b	40070	40184	40L	Small verts	-	-	

Table A1.1 (continued 1)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Bulk-sed	6b	40070	40185	10L	Small verts	-	-	
Bulk-sed	6b	40070	40186	20L	Small verts	Prelim assessment April 2004 - no molluscs, but common small vertebrates	-	
Bulk-sed	6b	40070	40237	190L	Small verts	-	-	
Bulk-sed	6b	40070	40241	300L	Small verts	-	-	Sieved, not picked; residue retained for archive
Bulk-sed	6b	40070	40251	150L	Small verts	-	-	
Bulk-sed	6b	40070	40274	80L	Small verts	-	-	
Bulk-sed	6b	40070	40277	10L	Small verts	Taken away by SA Parfitt	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6b	40070	40280	10L	Small verts		-	
Bulk-sed	6b	40070	40288	100L	Small verts	-	-	
Bulk-sed	6b	40070	40289	100L	Small verts	-	-	
Bulk-sed	6b	40070	40310	10L	Small verts	Assessed for ostracods & small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis; also, a few ostracods	
Bulk-sed	6b	40070	40313	10L	Small verts	Assessed for ostracods & small vertebrates, 2010	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6b	40070	40324	30L	Small verts	-	-	
Bulk-sed	6b	40070	40412	100L	Small verts	-	-	Sieved, not picked; residue retained for archive
Bulk-sed	6b	40143	40267	100L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6b	40143	40284	10L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate & molluscan material contributes to 2010 analysis	
Bulk-sed	6b	40144	40311	10L	Small verts	Assessed for small vertebrates, pollen and ostracods, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6b	40144?	40297	30L	Small verts	Straight-to-analysis	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6a	40039	40022	30L	Small verts	Prelim assessment April 2004 - no molluscs, but common small vertebrates	-	
Bulk-sed	6a	40039	40261	60L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6a	40040	40021	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	6b	40070	40283	30L	Small verts	-	-	
Bulk-sed	6a	40103	40175	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	6a	40103	40312	20L	Small verts	Small vertebrates, ostracods & molluscs (tufa channel, Column 3 - eastern offset)	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	6	40158	40262	30L	Small verts	Assessed for small vertebrates, 2009	-	
Bulk-sed	6	40158	40263	20L	Insects	Assessed for insects, 2009	-	

Table A1.1 (continued 2)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Bulk-sed	6	40158	40413	20L	Insects	Assessed for insects, 2009	-	
Bulk-sed	7	40043	40350	30L	Small verts	Prelim assessment Aug 2004 -	-	
Bulk-sed	7	40164	40361	40L	Small verts; PLUS clast lithology	Assessed for ostracods & small vertebrates, 2009	Clast lithology & angularity/roundness	
Bulk-sed	7	40166	40349	30L	Small verts	Prelim assessment Aug 2004 -	-	
Bulk-sed	7	40166	40414	40L	Small verts	Assessed for pollen, ostracods & small vertebrates, 2009	-	
Bulk-sed	7	40166	40415	10L	Small verts	Assessed for pollen, ostracods & small vertebrates, 2009	-	
Bulk-sed	7	40166	40416	40L	Small verts	Assessed for pollen, ostracods & small vertebrates, 2009	-	
Bulk-sed	7	40166	40417	10L	Small verts	Assessed for pollen, ostracods & small vertebrates, 2009	-	
Bulk-sed	7	40167	40003	10L	Clast lithology	-	Clast lithology & angularity/roundness	
Bulk-sed	7	40167	40420	50L	Clast lithology	Assessed for ostracods and small vertebrates, 2009	Clast lithology & angularity/roundness	
Bulk-sed	6	40039	40242	10L	Small verts	-	-	
Bulk-sed	6	40100	40161	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	5	40025	40020	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	5	40025	40285	10L	Small verts	Assessed for small vertebrates, 2009	-	
Bulk-sed	5	40025	40286	100L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	5	40025	40343	100L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	5	40025	40348	100L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	5	40025	40380	280L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	5	40025	40411	200L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed	5	40066	40040	30L	Small verts	Prelim assessment April 2004 -		
Bulk-sed	5	40067	40041	30L	Small verts	-	-	
Bulk-sed	3	40028	40292	20L	Small verts	Prelim assessment July 2004 -	-	
Bulk-sed	3	40062	40042	30L	Small verts	Prelim assessment April 2004 -	Small vertebrates, molluscs and ostracods	
Bulk-sed	3	40062	40043	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	3	40062	40045	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	3	40062	40291	100L	Small verts	Assessed for small vertebrates, 2009	-	
Bulk-sed	2	40064	40064	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	2	40064	40114	20L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	2	40065	40065	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	2	40077	40116	30L??	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	1	40056	40115	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	1	40057	40059	30L	Small verts	Prelim assessment April 2004 -	-	

Table A1.1 (continued 3)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Bulk-sed	1	40058	40055	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed	1	40059	40046	30L	Small verts	Prelim assessment April 2004 -	-	
Bulk-sed (p-sieved)	6b?	40144?	40336	10L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed (p-sieved)	6b	40070	40290	100L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40329	??	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40330	??	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40331	??	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40332	20L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40335	80L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40337	??	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40338	10L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40339	1L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40347	75L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40351	10L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40070	40381	40L	Small verts	-	Sieved and residues sorted for larger identifiable remains	
Bulk-sed (p-sieved)	6b	40144	40333	60L	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-sed (p-sieved)	6b	40144	40334	80L	Small verts	Assessed for small vertebrates, 2009	-	
Bulk-sed (p-sieved)	5	40025	40382	??	Small verts	Assessed for small vertebrates, 2009	Small vertebrate material contributes to 2010 analysis	
Bulk-inc	6b	40070	40314	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	
Bulk-inc	6b	40070	40315	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	
Bulk-inc	6b	40070	40316	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	

Table A1.1 (continued 4)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Bulk-inc	6b	40070	40317	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	
Bulk-inc	6b	40070	40318	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	
Bulk-inc	6b	40070	40319	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	
Bulk-inc	6a	40103	40320	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	
Bulk-inc	6a	40103	40325	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 2)	
Bulk-inc	6	40078	40293	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6b	40144	40294	10L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6b	40144	40295	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6b	40070	40296	10L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6b	40070	40298	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6b	40070	40299	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6a	40070	40300	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6a	40103	40301	40L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6a	40039	40302	40L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	5	40025	40303	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	5	40025	40304	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 1)	
Bulk-inc	6b	40144	40305	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 3 - eastern offset)	
Bulk-inc	6b	40070	40306	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 3 - eastern offset)	
Bulk-inc	6b	40070	40307	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 3 - eastern offset)	
Bulk-inc	6b	40070	40308	20L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 3 - eastern offset)	
Bulk-inc	6b	40070	40309	30L	Small verts	Straight-to-analysis	Small vertebrates & molluscs (tufa channel, Column 3 - eastern offset)	
Spot-sed	9b	40053	40024	100g	Ostracods	-	-	
Spot-sed	9b	40053	40025	100g	Pollen	Prelim assessment July 2004	-	
Spot-sed	7	40023	40006	100g	Ostracods	-	-	
Spot-sed	7	40023	40006	100g	Pollen	Prelim assessment January 2004	-	
Spot-sed	6a	40024	40007	100g	Ostracods	Prelim assessment January 2004	-	
Spot-sed	6a	40024	40007	100g	Pollen	Prelim assessment January 2004	-	
Spot-sed	6a	40039	40278	0.5	Molluscs	Assessed for SVs & molluscs	Small vertebrate material contributes to 2010 analysis	
Spot-sed	6	40158	40407	75cc	Pollen	Prelim investigation July 2004 (C Turner)	-	
Spot-sed	6	40158	40408	75cc	Pollen	Prelim investigation July 2004 (C Turner)	-	
Spot-sed	6	40158	40409	75cc	Pollen	Prelim investigation July 2004 (C Turner)	-	

Table A1.1 (continued 5)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Spot-sed	6	40158	40410	250cc	Plant macro remains	Prelim investigation July 2004 (C Turner) -	-	Azolla spore; amorphous non-cellular organic detritus
Spot-sed	6	40078	40132	100g	Pollen	Prelim investigation July 2004 (C Turner)	Countable pollen	
Spot-sed	6	40078	40133	100g	Pollen	Prelim investigation July 2004 (C Turner)	Countable pollen	
Spot-sed	6a	40039	40279	0.5L	Charred/rotted plant remains??	Lost	-	
Spot-sed	5	40025	40130	100g	Pollen	Prelim investigation July 2004 (C Turner) -	-	
Spot-sed	5	40025	40131	100g	Pollen	Prelim investigation July 2004 (C Turner) -	-	
Spot-sed	6	40069	40030	100g	Ostracods	-	-	
Spot-sed	6	40069	40031	100g	Pollen	-	-	
Spot-sed	6	40068	40027	100g	Pollen	Prelim investigation July 2004 (C Turner) -	-	
Spot-sed	6	40068	40028	100g	Ostracods	-	-	
Spot-sed	6	40068	40033	100g	Ostracods	-	-	
Spot-sed	6	40068	40034	100g	Pollen	-	-	
Spot-sed	6	40068	40086	100g	Ostracods	Prelim assessment March 2004 -	-	
Spot-sed	6b	40143	40248	200g	Ostracods	Prelim ostracod assessment June 2004; pollen assessment 2009	Ostracods present and analysed	
Spot-sed	6b	40143	40249	200g	Ostracods	Prelim ostracod assessment June 2004; pollen assessment 2009	Ostracods present and analysed	
Spot-sed	6b	40143	40250	200g	Ostracods	Prelim ostracod assessment June 2004; pollen assessment 2009	Ostracods present and analysed	
Spot-sed	6b	40143	40253	1L	Molluscs	Taken away by SA Parfitt	Small vertebrate material contributes to 2010 analysis	
Spot-sed	6b	40143	40271	200g	Ostracods	Prelim assessment July 2004 -	Ostracods present and analysed	
Spot-sed	6b	40070	40036	100g	Ostracods	-	-	
Spot-sed	6b	40070	40037	100g	Pollen	-	-	
Spot-sed	6b	40070	40038	2L	Molluscs	-	-	
Spot-sed	6b	40070	40039	100g	Ostracods	-	-	
Spot-sed	6b	40070	40087	100g	Ostracods	Prelim assessment March 2004 -	-	
Spot-sed	6b	40070	40088	100g	Ostracods	Prelim assessment March 2004 -	-	
Spot-sed	6b	40070	40134-1	100g	Pollen	Prelim investigation July 2004 (C Turner) -	-	
Spot-sed	6b	40070	40134-2	25 g	Plant macro remains	-	-	
Spot-sed	6b	40070	40252	1L	Molluscs	Taken away by SA Parfitt	Small vertebrate material contributes to 2010 analysis	
Spot-sed	6b	40070	40422		Small verts	-	-	
Spot-sed	6	40029	40008	100g	Ostracods	-	-	
Spot-sed	6	40029	40008	100g	Pollen	-	-	
Spot-sed	5	40025	40129	100g	Pollen	Prelim investigation July 2004 (C Turner) -	-	

Table A1.1 (continued 6)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Spot-sed	6	40100	40257	10L	Molluscs	Assessed for molluscs	-	
Spot-sed	2	40065	40066	100g	Ostracods	Ostracod assessment 2009	-	
Spot-sed	2	40065	40067	100g	Pollen	Pollen assessment 2009	-	
Spot-sed	1	40059	40062	100g	Ostracods	Ostracod assessment 2009	-	
Spot-sed	1	40059	40063	100g	Pollen	Pollen assessment 2009	-	
Spot-sed	1	40057	40060	100g	Ostracods	Ostracod assessment 2009	-	
Spot-sed	1	40057	40061	100g	Pollen	Pollen assessment 2009	-	
Spot-sed	6	40100	40256	10L	Molluscs	-	-	
Sed-increment	5	40025	40009	100g	Ostracods	Prelim assessment January 2004	-	
Sed-increment	5	40025	40009	100g	Pollen	Prelim assessment January 2004; Re-assessed July 2004	-	
Sed-increment	5	40025	40010	100g	Ostracods	-	-	
Sed-increment	5	40025	40010	100g	Pollen	-	-	
Sed-increment	4	40026	40011	100g	Ostracods	Ostracod assessment 2009	-	
Sed-increment	4	40026	40011	100g	Pollen	-	-	
Sed-increment	4	40026	40012	100g	Ostracods	Prelim assessment January 2004 -	-	
Sed-increment	4	40026	40012	100g	Pollen	Prelim assessment January 2004; Re-assessed July 2004	-	
Sed-increment	4	40026	40013	100g	Ostracods	Ostracod assessment 2009	-	
Sed-increment	4	40026	40013	100g	Pollen	-	-	
Sed-increment	4	40027	40014	100g	Ostracods	Ostracod assessment 2009	-	
Sed-increment	4	40027	40014	100g	Pollen	-	-	
Sed-increment	4	40027	40015	100g	Ostracods	Prelim assessment January 2004 -	-	
Sed-increment	4	40027	40015	100g	Pollen	Prelim assessment January 2004; Re-assessed July 2004	-	
Sed-increment	6	40100	40366	20L	Small verts	-	-	
Sed-increment	6	40100	40367	20L	Small verts	-	-	
Sed-increment	6	40078	40368	20L	Small verts	-	-	
Sed-increment	6	40099	40369	20L	Small verts	-	-	
Sed-increment	6a	40103	40370	20L	Small verts	-	-	
Sed-increment	6a	40103	40371	20L	Small verts	-	-	
Sed-increment	6a	40039	40372	20L	Small verts	-	-	
Sed-increment	6b	40143	40264	200g	Ostracods	Prelim assessment July 2004	Ostracods present and analysed	
Sed-increment	6b	40143	40265	200g	Ostracods	Prelim assessment July 2004	Ostracods present and analysed	
Sed-increment	6b	40143	40266	200g	Ostracods	Prelim assessment July 2004	Ostracods present and analysed	
Sed-increment	6b	40143	40268	200g	Ostracods	Prelim assessment July 2004	Ostracods present and analysed	

Table A1.1 (continued 7)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Sed-increment	6b	40143	40269	200g	Ostracods	Prelim assessment July 2004	Ostracods present and analysed	
Sed-increment	6b	40143	40270	200g	Ostracods	Prelim assessment July 2004	Ostracods present and analysed	
Sed-increment	6	40162	40398	20L	Small verts	-	-	
Sed-increment	6	40162	40399	20L	Small verts	-	-	
Sed-increment	6	40162	40400	20L	Small verts	-	-	
Sed-increment	6	40162	40401	20L	Small verts	-	-	
Sed-increment	6	40162	40402	20L	Small verts	-	-	
Sed-increment	6a	40103	40403	20L	Small verts	-	-	
Sed-increment	6a	40103	40404	20L	Small verts	-	-	
Sed-increment	6a	40039	40405	20L	Small verts	-	-	
Sed-increment	6	40162	40393	20L	Small verts	-	-	
Sed-increment	6	40162	40394	20L	Small verts	-	-	
Sed-increment	6	40162	40395	20L	Small verts	-	-	
Sed-increment	6	40162	40396	20L	Small verts	-	-	
Sed-increment	6	40162	40397	20L	Small verts	-	-	
Sed-increment	6	40100	40387	20L	Small verts	-	-	
Sed-increment	6	40078	40388	20L	Small verts	-	-	
Sed-increment	6	40078	40389	20L	Small verts	-	-	
Sed-increment	6	40099	40390	20L	Small verts	-	-	
Sed-increment	6	40099	40391	20L	Small verts	-	-	
Sed-increment	6a	40103	40392	20L	Small verts	-	-	
Sed-increment	6	40100	40373	20L	Small verts	-	-	
Sed-increment	6	40100	40374	20L	Small verts	-	-	
Sed-increment	6	40100	40375	20L	Small verts	-	-	
Sed-increment	6	40078	40376	20L	Small verts	-	-	
Sed-increment	6	40078	40377	20L	Small verts	-	-	
Sed-increment	6	40099	40378	20L	Small verts	-	-	
Sed-increment	6	40099	40379	20L	Small verts	-	-	
Monolith	6b	40070	40328	63cm	Pollen/ micro-pal/ Soil m-morph	-	-	
Monolith	7	40043	40018	135cm	Pollen	-	-	
Monolith	6b	40143	40282	24cm	Pollen/ micro-pal Soil m-morph	Assessed for molluscs & ostracods, 2009	Molluscs analysed; Small vertebrate material contributes to 2010 analysis; also, a few ostracods	

Table A1.1 (continued 8)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Monolith	6b	40070	40281	27cm	Pollen/ micro-pal/ Soil m-morph	Pollen assessment 2009	-	
Kubiena	6	40100	40229		Soil m-morph	-	-	
Kubiena	6	40100	40230		Soil m-morph	-	-	
Kubiena	6	40100	40231		Soil m-morph	-	-	
Kubiena	6	40099	40232		Soil m-morph	-	-	
Kubiena	6a	40103	40233		Soil m-morph	-	-	
Kubiena	6a	40039	40234		Soil m-morph	-	-	
Kubiena	6a	40039	40235		Soil m-morph	-	-	
Kubiena	6a	40040	40236		Soil m-morph	-	-	
Kubiena	6b	40070	40322	10cm	Soil m-morph	-	-	
Kubiena	6a	40039	40323	12cm	Soil m-morph	-	Soil micro-morphology	
Kubiena	6	40100	40260	1 foil tin (15cm)	Soil m-morph	-	-	
Kubiena	6	40100	40259	1 foil tin (18cm)	Soil m-morph	-	-	
Kubiena	6	40039	40258	1 foil tin (17cm)	Soil m-morph	-	-	
Kubiena	6	40100	40225	12cm	Soil m-morph	-	-	
Kubiena	6	40100	40226	10cm	Soil m-morph	-	-	
Kubiena	6	40039	40227	10cm	Soil m-morph	-	-	
Mon-inc	7	40166	40418	50cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen & ostracods, 2009	Soil micro-morphology; some pollen	
Mon-inc	6	40158	40419	50cm	Pollen/ micro-pal/ Soil m-morph	-	-	
Mon-inc	7	40043	40158	50cm	Pollen	-	-	
Mon-inc	6a	40040	40157	45cm	Pollen	Assessed for molluscs & ostracods, 2009	-	
Mon-inc	6a	40040	40156	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40155	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40154	45cm	Pollen	Assessed for ostracods, 2009	-	
Mon-inc	4	40027	40153	50cm	Pollen	Assessed for ostracods, 2009	-	

Table A1.1 (continued 9)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Mon-inc	7	40101	40148	55cm	Pollen	-	-	
Mon-inc	6	40100	40149	50cm	Pollen	-	Soil micro-morphology	
Mon-inc	6	40078	40150	45cm	Pollen	-	Soil micro-morphology	
Mon-inc	6a	40103	40151	45cm	Pollen	-	Soil micro-morphology	
Mon-inc	6a	40039	40152	50cm	Pollen	-	-	
Mon-inc	6	40099	40142	45cm	Pollen	-	-	
Mon-inc	6	40099	40143	40cm	Pollen	-	-	
Mon-inc	5	40025	40144	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40145	45cm	Pollen	Sieved for small vertebrates	Small vertebrate material contributes to 2010 analysis	
Mon-inc	5	40025	40146	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40147	50cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	6a	40039	40135	45cm	Pollen	-	-	
Mon-inc	5	40025	40136	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40137	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40138	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40139	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40140	50cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40141	60cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	6	40100	40364	55cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	Some pollen	
Mon-inc	6	40078	40365	55cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	Soil micro-morphology	
Mon-inc	6	40100	40362	54cm	Pollen/ micro-pal/ Soil m-morph	-	-	
Mon-inc	6	40078	40363	53cm	Pollen/ micro-pal/ Soil m-morph	-	-	
Mon-inc	6	40099	40352	58cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	-	
Mon-inc	6	40099	40353	54cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	-	

Table A1.1 (continued 10)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Mon-inc	6	40162	40344	67cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	-	
Mon-inc	6	40162	40345	67cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	-	
Mon-inc	6	40162	40340	75cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	-	
Mon-inc	6	40162	40341	75cm	Pollen/ micro-pal/ Soil m-morph	-	-	
Mon-inc	6	40162	40342	75cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, 2009	-	
Mon-inc	6	40078	40321	40cm	Pollen/ micro-pal/ Soil m-morph	Assessed for pollen, molluscs & ostracods, 2009	Molluscs analysed; also, a few ostracods	
Mon-inc	6a	40103	40326	50cm	Pollen/ micro-pal/ Soil m-morph	Assessed for molluscs & ostracods, 2009	-	
Mon-inc	5	40067	40072	75cm	Pollen	-	-	
Mon-inc	5	40066	40071	65cm	Pollen	-	-	
Mon-inc	5	40066	40070	70cm	Pollen	-	-	
Mon-inc	5	40066	40069	55cm	Pollen	-	-	
Mon-inc	5	40062	40068	50cm	Pollen	Assessed for molluscs & ostracods, 2009	Ostracods present and analysed	
Mon-inc	6	40100	40196	50cm	Pollen	Assessed for pollen, 2009	Soil micro-morphology	
Mon-inc	6	40100	40195	50cm	Pollen	Assessed for pollen, 2009	Soil micro-morphology	
Mon-inc	6	40100	40194	50cm	Pollen	Assessed for pollen, 2009	Soil micro-morphology	
Mon-inc	6	40100	40193	50cm	Pollen	Assessed for pollen, 2009	Soil micro-morphology	
Mon-inc	6	40039	40192	50cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40191	45cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40189	55cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40188	55cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40025	40187	55cm	Pollen	Sieved for small vertebrates	-	

Table A1.1 (continued 11)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Mon-inc	6	40068	40113	55cm	Pollen	-	-	
Mon-inc	6	40068	40112	55cm	Pollen	-	-	
Mon-inc	6	40068	40111	55cm	Pollen	-	-	
Mon-inc	6	40068	40110	55cm	Pollen	-	-	
Mon-inc	6	40068	40109	55cm	Pollen	-	-	
Mon-inc	6	40068	40108	55cm	Pollen	-	-	
Mon-inc	6	40068	40102	60cm	Pollen	-	-	
Mon-inc	5	40067	40103	45cm	Pollen	-	-	
Mon-inc	5	40066	40104	55cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40066	40105	65cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40066	40106	60cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	5	40066	40107	55cm	Pollen	Sieved for small vertebrates	-	
Mon-inc	2	40065	40095	45cm	Pollen	Assessed for pollen & ostracods, 2009	-	
Mon-inc	2	40065	40079	55cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	2	40065	40078	60cm	Pollen	Assessed for pollen & ostracods, 2009	-	
Mon-inc	2	40065	40077	55cm	Pollen	-	-	
Mon-inc	2	40065	40076	65cm	Pollen	Assessed for pollen & ostracods, 2009	-	
Mon-inc	2	40064	40075	50cm	Pollen	-	-	
Mon-inc	2	40064	40074	50cm	Pollen	-	-	
Mon-inc	2	40064	40073	60cm	Pollen	Assessed for pollen & ostracods, 2009	-	
Mon-inc	2	40064	40099	57cm	Pollen	-	-	
Mon-inc	2	40064	40098	55cm	Pollen	Assessed for pollen & ostracods, 2009	-	
Mon-inc	2	40064	40097	50cm	Pollen	Assessed for pollen & ostracods, 2009	-	
Mon-inc	2	40064	40096	63cm	Pollen	Assessed for pollen & ostracods, 2009	-	
Mon-inc	1	40059	40094	50cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	1	40059	40093	45cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	1	40059	40092	50cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	1	40058	40085	50cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	1	40058	40084	55cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	1	40058	40083	65cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	1	40058	40082	50cm	Pollen	Assessed for pollen, 2009	Soil micro-morphology	
Mon-inc	1	40057	40081	60cm	Pollen	Assessed for pollen, 2009	-	
Mon-inc	1	40056	40080	60cm	Pollen	-	-	
Mon-inc	1	40056	40089	50cm	Pollen	-	-	

Table A1.1 (continued 12)

Sample type	*Phase*	*Context*	*Sample <no.>*	*Sample size*	*Sampled for*	*Assessment programme*	*Analysis*	*Comments*
Mon-inc	1	40056	40090	50cm	Pollen	-	-	
Mon-inc	1	40056	40091	60cm	Pollen	-	-	
OSL-tube	9b	40087	40254		OSL dating	-	1st batch	
OSL-tube	9a	40051	40056		OSL dating	-	1st batch	
OSL-tube	8c	40049	40057		OSL dating	-	1st batch	
OSL-tube	8b	40047	40058		OSL dating	-	-	
OSL-tube	8a	40098	40244		OSL dating	-	2nd batch	
OSL-tube	8a	40098	40245		OSL dating	-	-	
OSL-tube	8a	40045	40243		OSL dating	-	-	
OSL-tube	6b	40144	40247		OSL dating	Assessed for molluscan remains	-	Assessed for molluscan remains
OSL-tube	6b	40070	40246		OSL dating	-	-	
OSL-tube	6b	40070	40255		OSL dating	-	-	
OSL-tube	5	40163	40354		OSL dating	-	-	
OSL-tube	5	40163	40355		OSL dating	-	-	
OSL-tube	5	40066	40052		OSL dating	-	-	
OSL-tube	5	40066	40053		OSL dating	-	2nd batch	
OSL-tube	5	40066	40054		OSL dating	-	-	
OSL-tube	5	40066	40358		OSL dating	-	-	
OSL-tube	5	40066	40359		OSL dating	-	-	
OSL-tube	5	40163	40356		OSL dating	-	-	
OSL-tube	5	40163	40357		OSL dating	-	-	
OSL-tube	2	40065	40047		OSL dating	-	-	
OSL-tube	2	40065	40048		OSL dating	-	-	
OSL-tube	2	40064	40049		OSL dating	-	-	
OSL-tube	2	40060	40051		OSL dating	-	-	
OSL-tube	1	40056	40050		OSL dating	-	-	
Other	8c	40018	40016	na	Clast orientation study	-	-	
Other	8c	40018	40017	na	Clast orientation study	-	-	
Other	6b	40070	40421	??	Molluscs	-	-	
Other	6	40078	40240	??	Wood species ID	-	-	
Other	6	40100	40190	??	Wood species ID Assessed 2009		-	

Appendix 2

Loss-on-ignition and magnetic susceptibility of the sedimentary sequences at Southfleet Road

by John Crowther

INTRODUCTION

Loss-on-ignition (LOI) and low frequency mass-specific magnetic susceptibility (χ) determinations were made on 105 bulk samples from the sediments at Southfleet Road in the hope that they might provide evidence of possible soils/land surfaces within the sequences of deposits. As the sediments accumulated, it would be anticipated that former soils/land surfaces would have had a relatively high organic matter content (as estimated by LOI) as a result of plant growth and inputs of organic litter. An enhanced magnetic susceptibility would also be expected as a consequence of natural fermentation processes within soils (Le Borgne, 1955). It should be noted, however, that both properties may have been significantly affected by post-depositional processes. Organic matter content is likely to have diminished as a result of decomposition processes, and magnetic susceptibility may have been affected by the mobilisation (through gleying), leaching and reprecipitation of iron (Fe) compounds as a result of waterlogging. Also, χ is affected both by the degree enhancement and the Fe content – and where (as is likely to be the case in these sedimentary sequences) the latter is quite variable then χ may poorly reflect the levels of enhancement. The LOI and χ data do therefore need to be interpreted with caution.

METHODS

Analysis was undertaken on the fine earth fraction (ie < 2mm) of the samples. LOI was determined by ignition at 375˚C for 16hrs (Ball 1964), previous studies having established that there is no significant breakdown of carbonates at this temperature. In addition to χ, determinations were made of χ_{max} (maximum potential magnetic susceptibility, which generally closely reflects the Fe content) on 20 samples, representative of the range of χ values recorded, by subjecting a sample to optimum conditions for susceptibility enhancement in the laboratory. χ_{conv} (fractional conversion), which is expressed as a percentage, is a measure of the extent to which the potential susceptibility has been achieved in the original sample, viz: (χ/χ_{max}) x 100.0 (Tite 1972; Scollar *et al.* 1990). In many respects this is a better indicator of magnetic susceptibility enhancement than raw χ data, particularly in cases where sediments have widely differing χ_{max} values (Crowther and Barker 1995; Crowther 2003). A Bartington MS2 meter was used for magnetic susceptibility measurements. χ_{max} was achieved by heating samples at 650°C in reducing, followed by oxidising conditions. The method used broadly follows that of Tite and Mullins (1971), except that household flour was mixed with the soils and lids placed on the crucibles to create the reducing environment (after Graham and Scollar 1976; Crowther and Barker 1995).

RESULTS (Tables A2.1-A2.6)

The analytical data are presented in Table A2.6, summary statistics relating to samples form particular contexts and sequences in Tables A2.1–A2.5, a plot of the fractional conversion data in Fig. A2.1, and plots of variations in LOI and χ down individual sediment sequences in Figs. A2.2–2.3. Here, a broad overview of the individual properties is presented, before consideration of the results from individual contexts and sequences.

Overview of individual properties

1. Loss-on-ignition. The samples are predominantly minerogenic (Table A2.1), with 99 of the 105 samples

Table A2.1 Summary statistics for all samples

	No.	*Minimum*	*Maximum*	*Mean*	*Std dev*
LOI (%)	105	0.375	6.69	1.88	0.776
χ (10^{-8} m^3 kg^{-1})	105	2.0	27.4	10.7	4.48
χ_{max} (10^{-8} m^3 kg^{-1})	20	22.0	7390.0	1230	2030
χ_{conv} (%)	20	0.08	37.7	6.60	10.1

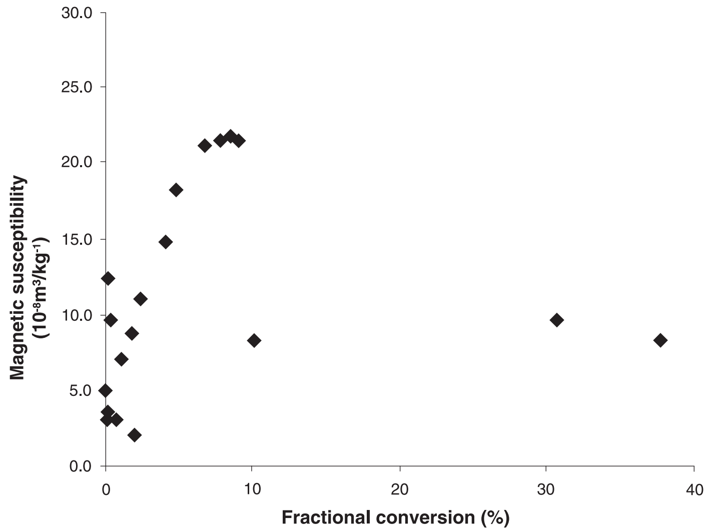


Figure A2.1. Plot of χ against χ_{conv} for 20 representative samples

having a LOI < 3.00%. Of the remaining samples, only one sample from context 40158 stands out as having a notably higher LOI of 6.69%. Because of post-depositional organic decomposition, these data inevitably underestimate and may well poorly reflect the original organic matter content of the sediments. It should also be noted that a number of samples which appeared (by virtue of their darker colour) to be more organic, did not necessarily have relatively high LOI values. The samples were found to vary quite markedly in texture and, while there is unlikely to be any breakdown of clays at the temperature (375°C) used for ignition, it is possible that some of the variability in organic matter content may be directly related to texture in that finer sediments are more likely to contain more resistant clay-humus complexes and will tend to be less well aerated and therefore less vulnerable to decomposition. It would be interesting to investigate whether there is an underlying correlation between LOI and texture.

2. Magnetic susceptibility. The most striking feature of the magnetic susceptibility data is the extremely high variability in χ_{max} with values ranging from 22.0–7390 x 10^{-8} m^3 kg^{-1} (Table A2.1). Given this exceptionally high variability, and the relatively low variability in χ (range, 2.0–27.4 x 10^{-8} m^3 kg^{-1}), it is highly unlikely that there will be a strong relationship between χ and χ_{conv} (Crowther 2003), and this is borne out by Fig. A2.1. Furthermore, since such variability in χ_{max} is likely to be largely attributable to variations in Fe content, which in these sedimentary sequences could well have been subject to post-depositional change through gleying and associated leaching/reprecipitation, the χ and χ_{max} data may poorly reflect the characteristics of the sediments at the time of deposition. Thus, little reliance can be placed on the magnetic susceptibility data – with samples with a high χ_{conv} (maximum, 37.7%) not necessarily being indicative of significant enhancement in the original sediments. In these circumstances, the χ data need to be interpreted with extreme caution.

Table A2.2 Summary of LOI (%) data for each context

	No.	*Minimum*	*Maximum*	*Mean*	*Std dev*
40025	5	0.375	0.844	0.530	0.187
40039	11	1.18	3.04	1.68	0.538
40040	4	0.511	1.98	1.18	0.605
40043		0.912	1.44	1.18	0.373
40056	5	1.39	1.91	1.62	0.188
40057	7	1.18	1.55	1.37	0.136
40058	3	0.972	1.09	1.05	0.065
40070	1	3.23	3.23	3.23	-
40078	7	2.02	2.30	2.17	0.087
40099	6	1.95	2.35	2.15	0.164
40100	20	1.21	2.36	1.87	0.254
40103	8	0.820	3.19	2.38	0.753
40158	5	1.75	6.69	3.49	1.87
40160	2	0.946	1.03	0.988	0.059
40162	18	1.78	2.52	2.19	0.176
40166	1	1.38	1.38	1.38	-

Comparison of different contexts

1. Loss-on-ignition. Many of the individual contexts display quite marked variability in LOI (Table A2.2). Of the 10 contexts for which ≥ 5 samples were analysed, three have a standard deviations of ≥ 0.500%, which are high for contexts with such low mean LOI values. Heterogeneity of this magnitude within individual contexts suggests that significant changes in environmental conditions occurred as each context developed, with the more organic-rich samples being likely associated with periods of soil development/surface exposure.

Table A2.3 Summary of $\chi(10^{-8}\ m^3\ kg^{-1})$ data for each context

	No.	*Minimum*	*Maximum*	*Mean*	*Std dev*
40025	5	2.9	5.1	3.9	0.873
40039	11	6.6	14.3	9.1	2.79
40040	4	3.0	9.6	6.6	2.74
40043	2	7.6	9.3	8.5	1.20
40056	5	19.5	21.7	20.6	0.887
40057	7	14.7	21.6	19.2	2.34
40058	3	15.9	27.4	19.7	6.64
40070	1	12.3	12.3	12.3	-
40078	7	9.0	10.4	9.8	0.544
40099	6	9.2	12.5	10.9	1.48
40100	20	8.1	12.3	10.0	0.851
40103	8	2.0	13.9	10.4	3.82
40158	5	7.6	10.0	8.8	0.950
40160	2	4.8	4.9	4.9	0.071
40162	18	7.7	10.4	9.4	0.775
40166	1	8.3	8.3	8.3	-

Table A2.4 Summary of LOI (%) data for each sequence

	No.	*Minimum*	*Maximum*	*Mean*	*Std dev*
1	5	0.912	1.98	1.47	0.453
2	10	0.511	6.69	2.24	1.83
3	23	0.375	3.19	1.76	0.809
4	20	1.21	2.36	1.82	0.287
5	4	0.82	3.23	1.70	1.06
6	7	1.89	2.46	2.19	0.199
7.1	5	1.78	2.52	2.18	0.276
7.2	4	2.13	2.42	2.30	0.132
7.3	7	2.06	2.27	2.17	0.084
7.4	5	1.93	3.07	2.43	0.412
8.1	5	0.972	1.37	1.14	0.149
8.2	10	1.23	1.91	1.51	0.193

Table A2.5 Summary of $\chi(10^{-8}\ m^3\ kg^{-1})$ data for each sequence

	No.	*Minimum*	*Maximum*	*Mean*	*Std dev*
1	5	6.5	9.6	8.3	1.27
2	10	3.0	10.0	7.2	2.26
3	23	2.9	14.3	8.9	3.39
4	20	7.0	12.3	9.8	1.15
5	4	2.0	12.3	7.5	4.29
6	7	9.3	12.5	11.3	1.37
7.1	5	7.7	9.6	8.8	0.783
7.2	4	8.7	10.1	9.6	0.638
7.3	7	8.9	10.4	9.9	0.516
7.4	5	8.3	11.8	9.8	1.31
8.1	5	14.7	27.4	18.4	5.18
8.2	10	19.2	21.7	20.5	0.972

Table A2.6 Analytical data

Sequence	*Sample*	*Depth (cm)*	*Sequence depth (cm)*	*Context (rev)*	*LOI (%)*	*χ ($10^{-8}m^3kg^{-1}$)*	*$χ_{max}$ ($10^{-8}m^3kg^{-1}$)*	*$χ_{conv\ (\%)}$ ($10^{-8}m^3kg^{-1}$)*
1	40158	7-8	7.5	40043	0.912	7.6		
1	40158	17-18	17.5	40043	1.44	9.3		
1	40158	27-28	27.5	40039	1.85	8.4		
1	40158	37-38	37.5	40040	1.98	9.6	2200	0.44
1	40158	46-47	46.5	40040	1.15	6.5		
2	40418	2-3	2.5	40166	1.38	8.3		
2	40418	12-13	12.5	40158	6.69	8.2	81	10.1
2	40418	25-26	25.5	40158	1.75	7.6		
2	40418	36-37	36.5	40160	1.03	4.9	6310	0.08
2	40418	44-45	44.5	40158	3.12	10.0		
2	40419	4-5	49	40160	0.946	4.8		
2	40419	11-12	56	40158	2.81	8.7	454	1.92
2	40419	21-22	66	40158	3.10	9.4		
2	40419	31-32	76	40040	1.09	7.3		
2	40419	42-43	87	40040	0.511	3.0	2080	0.14
3	40148	4-5	4.5	40100	1.76	10.0		
3	40148	11-12	11.5	40100	2.11	10.3		
3	40148	21-22	21.5	40078	2.30	10.3		
3	40148	30-31	30.5	40078	2.23	10.4		
3	40148	43-44	43.5	40078	2.13	10.1		
3	40149	15-16	40.5	40078	2.14	9.8		
3	40149	22-23	47.5	40078	2.17	9.0		
3	40149	32-33	57.5	40078	2.17	9.2		
3	40149	44-45	69.5	40099	2.06	9.3		
3	40150	7-8	77.5	40099	1.95	9.2		
3	40150	17-18	87.5	40099	2.01	10.4		
3	40150	32-33	102.5	40103	3.19	13.8		
3	40150	42-43	112.5	40103	2.76	13.9		
3	40151	8-9	111	40039	3.04	14.3		
3	40151	17-18	120	40039	1.63	14.0		
3	40151	24-25	127	40039	1.70	7.3		
3	40151	34-35	137	40039	1.31	7.6		
3	40151	44-45	147	40039	1.18	6.6		
3	40152	8-9	148.5	40025	0.493	3.5	1610	0.22
3	40152	15-16	155.5	40025	0.844	5.1		
3	40152	24-25	164.5	40025	0.534	4.5		
3	40152	33-34	173.5	40025	0.405	3.6		
3	40152	43-44	183.5	40025	0.375	2.9	399	0.73
4	40196	4-5	4.5	40100	2.36	10.7		
4	40196	14-15	14.5	40100	2.01	10.1		
4	40196	24-25	24.5	40100	2.19	10.9		
4	40196	34-35	34.5	40100	1.84	9.9		
4	40196	44-45	44.5	40100	1.69	10.6		
4	40195	6-7	44	40100	1.84	10.2		
4	40195	16-17	54	40100	1.21	8.1		
4	40195	26-27	64	40100	2.05	10.2		
4	40195	36-37	74	40100	2.05	10.3		
4	40195	46-47	84	40100	2.02	9.8		
4	40194	6-7	81.5	40100	1.72	10.3		
4	40194	9-10		40100	Not sampled			
4	40194	16-17	91.5	40100	1.70	12.3		
4	40194	26-27	101.5	40100	1.62	9.3		
4	40194	36-37	111.5	40100	1.70	9.4		
4	40194	46-47	121.5	40100	1.99	10.5		
4	40193	7-8	122.5	40100	1.82	9.4		
4	40193	17-18	132.5	40100	1.62	9.0		
4	40193	27-28	142.5	40100	2.01	9.4		
4	40193	37-38	152.5	40039	1.73	8.2		
4	40193	47-48	162.5	40039	1.21	7.0	652	1.07
5	40322	4-5	4.5	40070	3.23	12.3	7390	0.17

Table A2.6 (continued)

Sequence	*Sample*	*Depth (cm)*	*Sequence depth (cm)*	*Context (rev)*	*LOI (%)*	χ ($10^{-8}\,m^3kg^{-1}$)	χ_{max} ($10^{-8}\,m^3kg^{-1}$)	$\chi_{conv\,(\%)}$ ($10^{-8}\,m^3kg^{-1}$)
5	40322	11-12	11.5	40103	0.82	2.0	97	2.06
5	40323	2-3	22.5	40039	1.45	8.7		
5	40323	11-12	31.5	40039	1.28	6.8		
6	40365	4-5	4.5	40078	2.02	9.5		
6	40365	9-10	9.5	40099	2.22	12.5		
6	40365	15-16	15.5	40099	2.30	12.4		
6	40365	23-24	23.5	40099	2.35	11.6		
6	40365	30-31	30.5	40103	1.89	9.3		
6	40365	40-41	40.5	40103	2.46	12.4		
6	40365	50-51	50.5	40039	2.11	11.1	455	2.44
7.1	40344	9-10	9.5	40162	2.30	9.4		
7.1	40344	24-25	24.5	40162	1.78	7.7		
7.1	40344	29-30	29.5	40162	2.52	9.6		
7.1	40344	43-44	43.5	40162	2.24	8.8		
7.1	40344	55-56	55.5	40162	2.07	8.3	22	37.7
7.2	40345	4-5	4.5	40162	2.25	8.7		
7.2	40345	11-12	11.5	40162	2.42	10.1		
7.2	40345	43-44	43.5	40162	2.38	10.0		
7.2	40345	55-56	55.5	40162	2.13	9.6		
7.3	40340	7-8	7.5	40162	2.27	10.2		
7.3	40340	17-18	17.5	40162	2.08	10.4		
7.3	40340	27-28	27.5	40162	2.12	10.2		
7.3	40340	37-38	37.5	40162	2.06	10.0		
7.3	40340	47-48	47.5	40162	2.20	9.5	31	30.7
7.3	40340	57-58	57.5	40162	2.26	9.8		
7.3	40340	67-68	67.5	40162	2.19	8.9		
7.4	40342	6-7	6.5	40162	2.29	9.1		
7.4	40342	18-19	18.5	40162	1.93	8.3		
7.4	40342	38-39	38.5	40103	2.43	10.2		
7.4	40342	54-55	54.5	40103	2.45	9.8		
7.4	40342	70-71	70.5	40103	3.07	11.8		
8.1	40082	8-9	8.5	40058	0.972	15.9		
8.1	40082	18-19	18.5	40058	1.09	27.4	1000	2.74
8.1	40082	28-29	28.5	40058	1.08	15.9		
8.1	40082	38-39	38.5	40057	1.18	14.7	348	4.22
8.1	40082	51-52	51.5	40057	1.37	18.2	373	4.88
8.2	40081	5-6	5.5	40057	1.36	19.2		
8.2	40081	8-9	8.5	40057	1.23	19.6		
8.2	40081	15-16	15.5	40057	1.52	19.7		
8.2	40081	18-19	18.5	40057	1.35	21.6	239	9.04
8.2	40081	25-26	25.5	40057	1.55	21.5	270	7.96
8.2	40081	28-29	28.5	40056	1.39	21.7	255	8.51
8.2	40081	35-36	35.5	40056	1.62	21.2	311	6.82
8.2	40081	38-39	38.5	40056	1.56	20.5		
8.2	40081	45-46	45.5	40056	1.91	20.0		
8.2	40081	48-49	48.5	40056	1.64	19.5		

The extreme case is context 40158 (std dev., 1.87%), for which individual LOI values range from 1.75–6.69%. Allowing for post-depositional organic decomposition, then it seems likely that the most organic rich of these samples is from a sediment that was originally very humic (possibly peaty) in composition. Other contexts, by comparison, are much more uniform in terms of LOI (e.g. the 18 samples from context 40162 have a range of 1.78–2.52%), and in these cases there is therefore less evidence for changing environmental conditions as the sediments were deposited.

In addition to within-context variability, there are also differences in mean LOI between the contexts. Clearly, care needs to be exercised when comparing mean values based on small numbers of samples. Of the contexts with ≥ 5 samples, the mean values range from 0.530% (40025) to 3.49% (40158). Such differences probably reflect significant differences in the sedimentary environment at the time of deposition, with those contexts with a higher mean LOI being most likely to be associated with periods of soil development/surface exposure.

2. Magnetic susceptibility. As with LOI, the χ data display quite marked within- and, in this case particularly between-context, variability (Table A2.3). For example, contexts 40056 and 40057 stand out as having relatively high mean χ values (20.6 and 19.2 x 10^{-8} m^3 kg^{-1}, respectively), whereas the remaining contexts for which $\geq$ 5 samples were analysed have means of $\leq$ 10.9 x 10^{-8} m^3 kg^{-1}, with a minimum of 3.9 x 10^{-8} m^3 kg^{-1} (40025). As noted above, these data do need to be interpreted with caution because of the difficulties of distinguishing between enhancement through organic fermentation processes and the effects of Fe content, the latter of which may well have been subject to post-depositional change.

Comparison of different sequences

Summary LOI and χ data for each of the sequences are presented in Tables A2.4 and A2.5, respectively. Since many of the sequences include samples from more than one context, there is inevitably both within- and between-sequence variability in the data sets. Of potentially greater interest are the patterns of variation down individual sedimentary sequences, and these are presented in Figs. A2.2–A2.13. Interestingly, despite the serious reservations concerning the interpretation of the χ data, in several of the sequences there is a very close correlation between χ and LOI. This is particularly well illustrated by Sequence

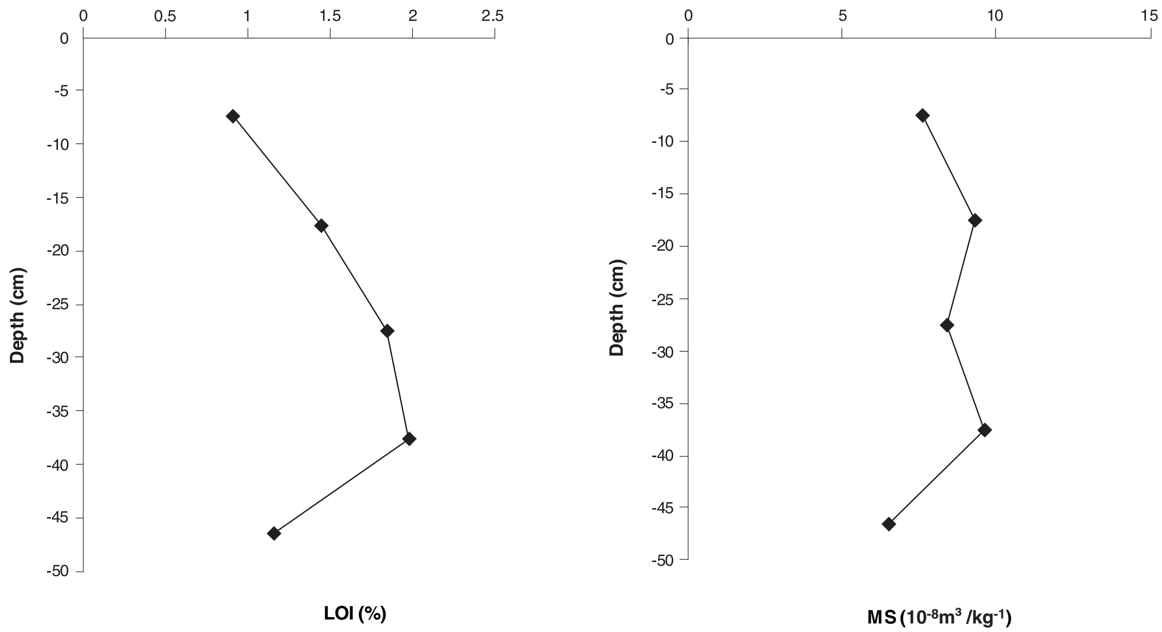


Figure A2.2 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1} down Sequence 1

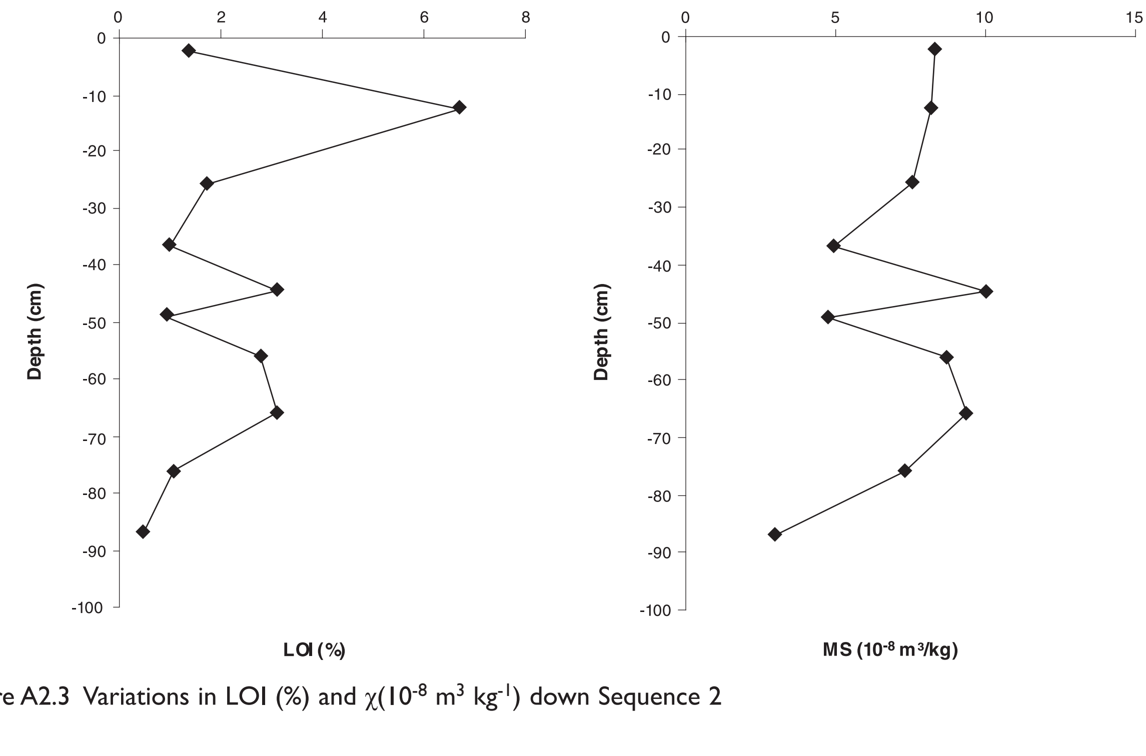


Figure A2.3 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 2

3 (Fig. A2.4), and in cases like this, where χ supports the LOI evidence, the χ data are perhaps more likely to reflect the degree of enhancement. Clearly, the detailed patterns will need to be examined in light of other evidence (colour, texture, composition, etc.). However, principal points to emerge from the LOI and χ plots are as follows (all depths refer to sequence depth):

Sequence 1 (Fig. A2.2): Generally higher LOI at 27.5–37.5cm, though not especially high (maximum, 1.98%). Sample at 37.5cm (context 40040) would appear from LOI and χ to be more similar to sample at 27.5cm (context 40039) than the underlying sample from context 40040.

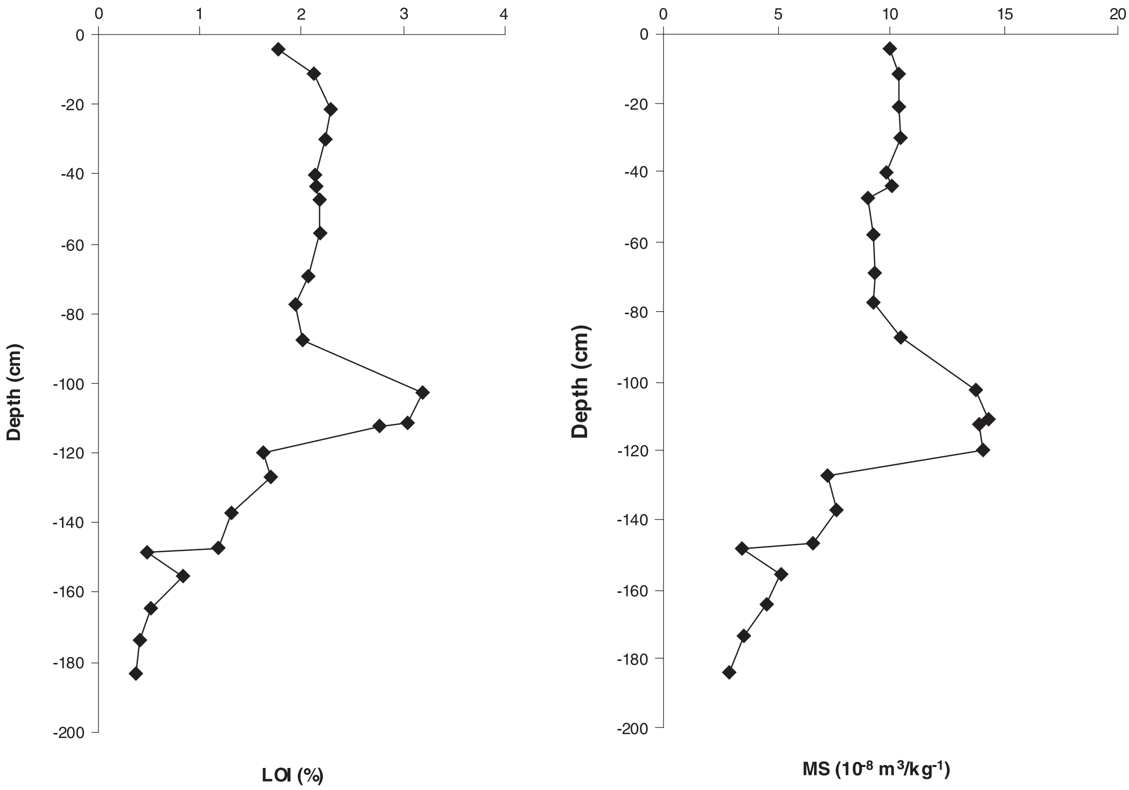


Figure A2.4 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 3

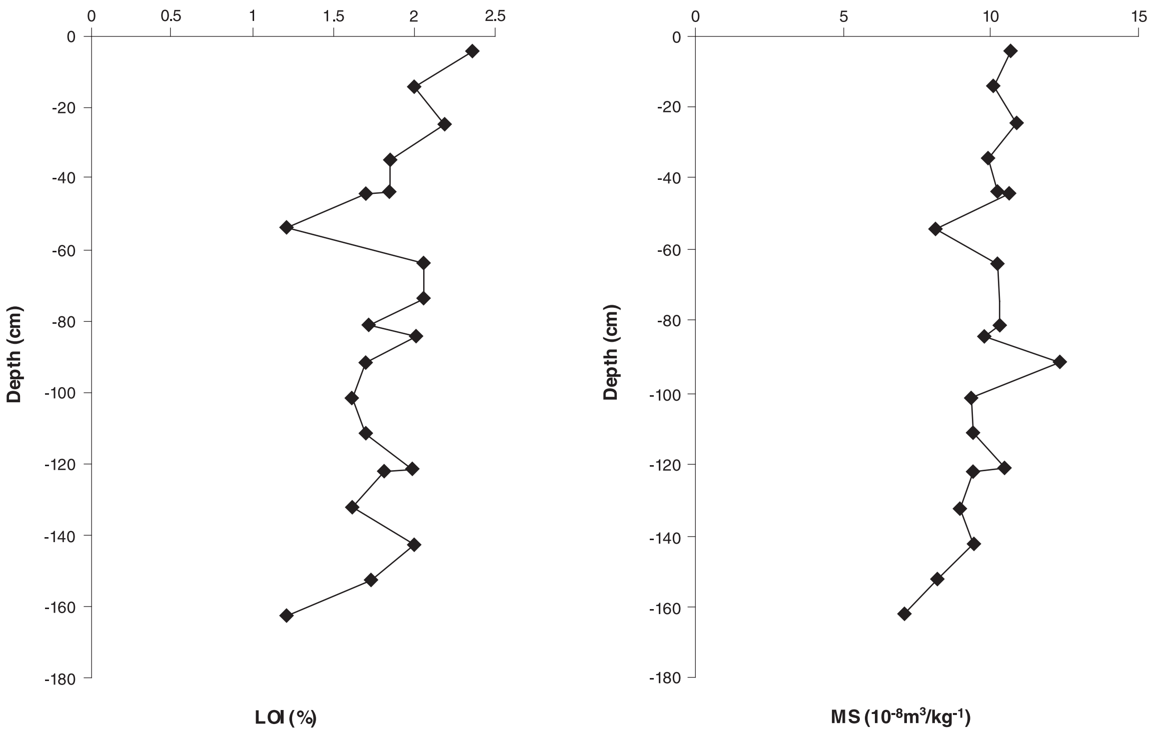


Figure A2.5 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 4

Sequence 2 (Fig. A2.3): The higher LOI and, to some extent, χ values are associated with interdigitated context 40158, with only the sample at 25.5cm within this context having a notably lower LOI (1.75%). The very high peak in LOI at 12.5cm (6.69%) is almost certainly associated with soil (possibly peat?) formation, and the secondary peaks at 44.5 and 56–66cm also seem likely to be associated with periods of soil development/surface exposure.

Sequence 3 (Fig. A2.4): Clear peak in LOI and χ at 102.5–111cm (i.e. context 40103) which is likely to be associated with soil development/surface exposure. Sediments become increasingly minerogenic towards base of sequence (contexts 40039 and, especially, 40025).

Sequence 4 (Fig. A2.5): Context 40100, which extends down to *c* 145cm, displays mostly relatively minor variations in LOI, with several possible minor peaks (at 4.5, 24.5, 64–74, 84, 121.5 and 142.5cm) and one sample (at 54cm) showing a notably lower LOI (1.21%). Several of the peaks in LOI correspond with peaks in χ.

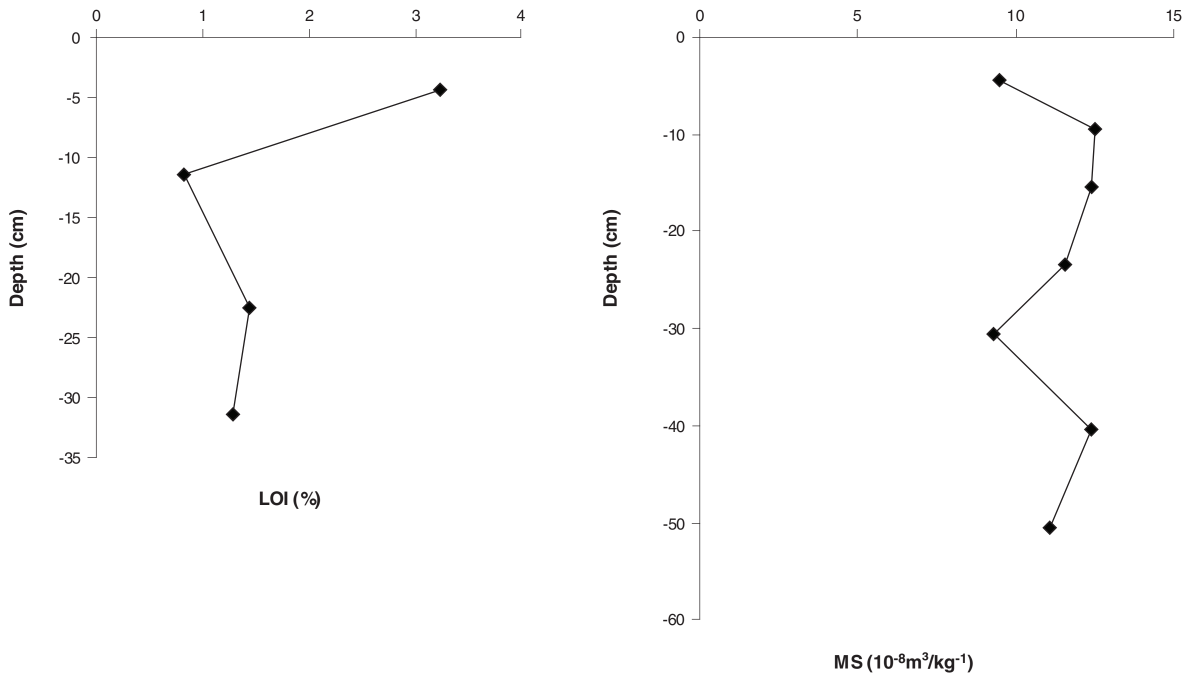


Figure A2.6 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 5

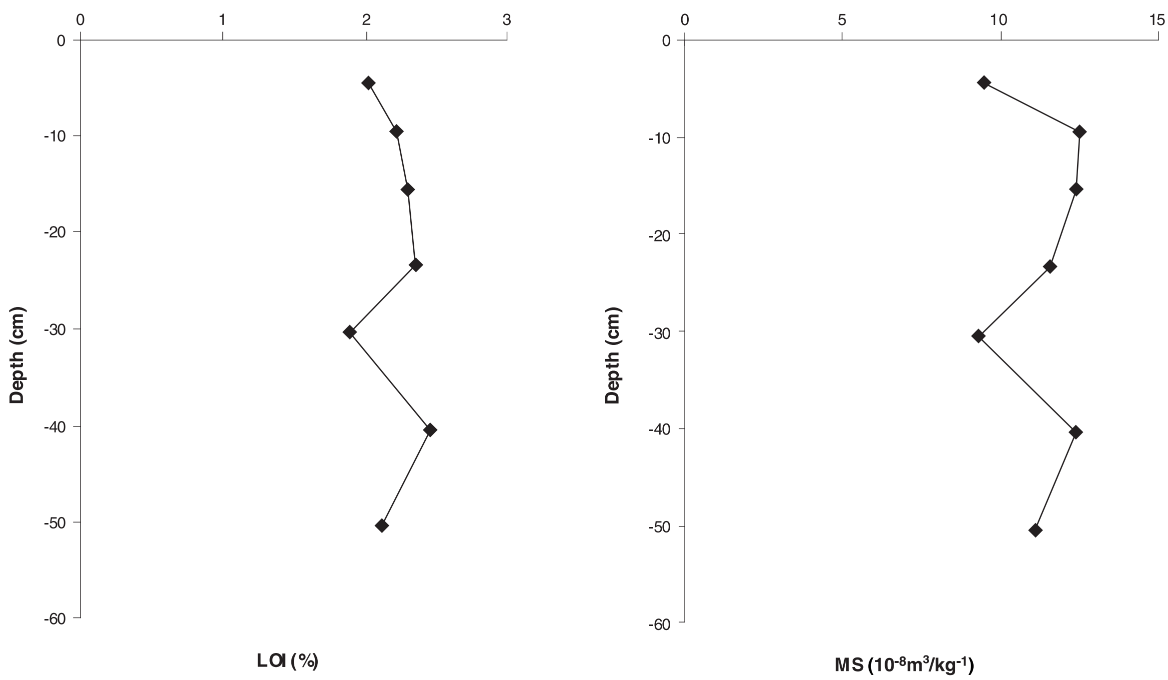


Figure A2.7 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 6

Sequence 5 (Fig. A2.6): This sequence reveals a close correlation between LOI and χ, and a clear distinction between context 40070, which has a higher LOI and χ, and the underlying contexts (40103 and 40039).

Sequence 6 (Fig. A2.7): This sequence also reveals a close correlation between LOI and χ, with both showing a minor peak towards the base of context 40103 (at 40.5cm).

Sequence 7.1 (Fig. A2.8): A single context (40162) showing a close correlation between LOI and χ, with both showing a minor peak at 29.5cm.

Sequence 7.2 (Fig. A2.9): A single context (40162) showing a close correlation between LOI and χ, though the range of variation down the sequence is relatively small.

Sequence 7.3 (Fig. A2.10): A single context (40162) showing a possible minor peak in LOI and χ at 57.5cm, though the range of variation down the sequence is relatively small.

Sequence 7.4 (Fig. A2.11): A close correlation between LOI and χ, and, though the range of variation down the sequence is relatively small, the lower context (40103)

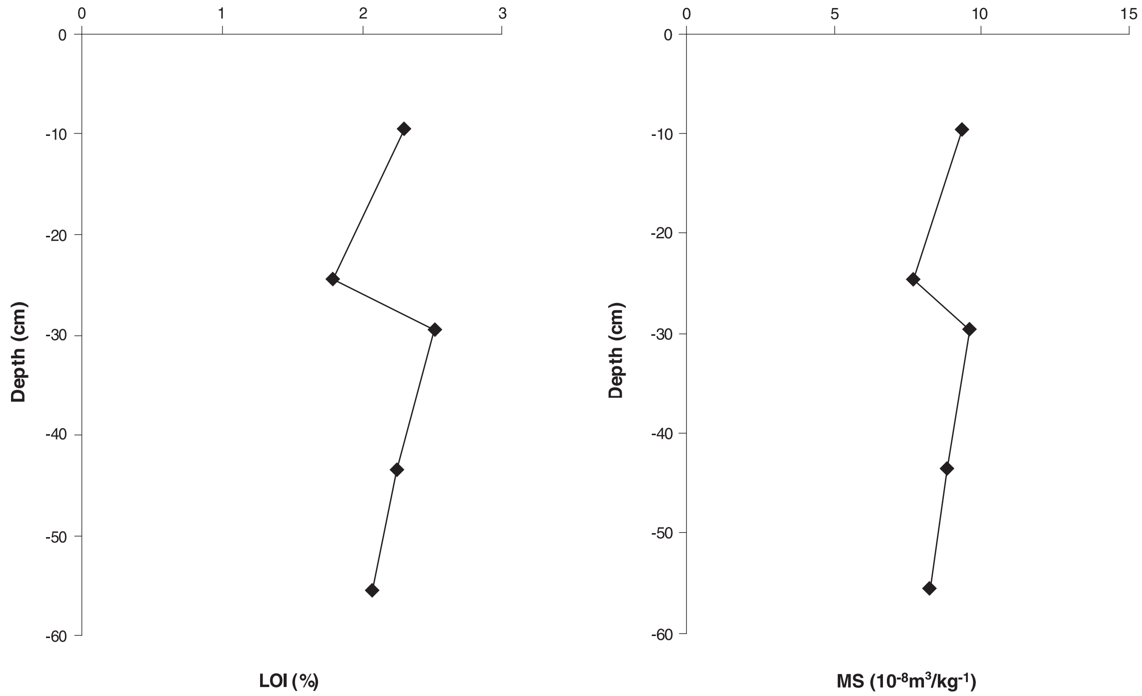


Figure A2.8 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 7.1

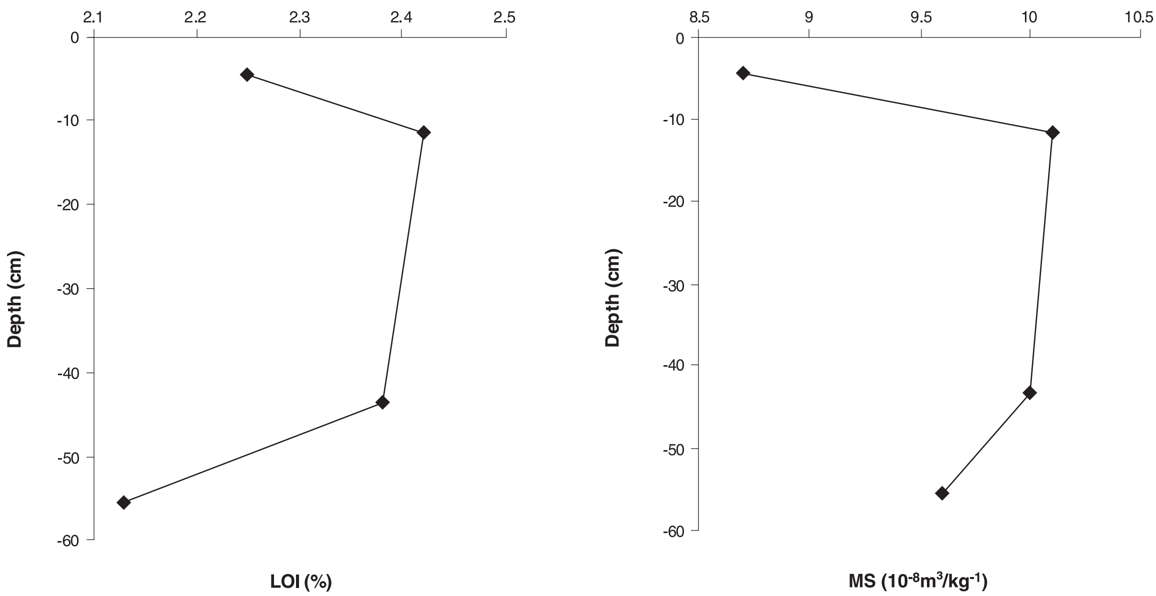


Figure A2.9 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 7.2

has a somewhat higher LOI and χ than the upper (40162).

Sequence 8.1 (Fig. A2.12): A general increase in LOI down the section from context 40058 to 40057, and a notably high χ (27.4 x 10^{-8} m^3 kg^{-1}) at 18.5cm. It should be noted that the latter sample has a relatively high χ_{max} (1000 x 10^{-8} m^3 kg^{-1}) and needs therefore to be interpreted with caution – ie the higher χ may well simply reflect a higher Fe content.

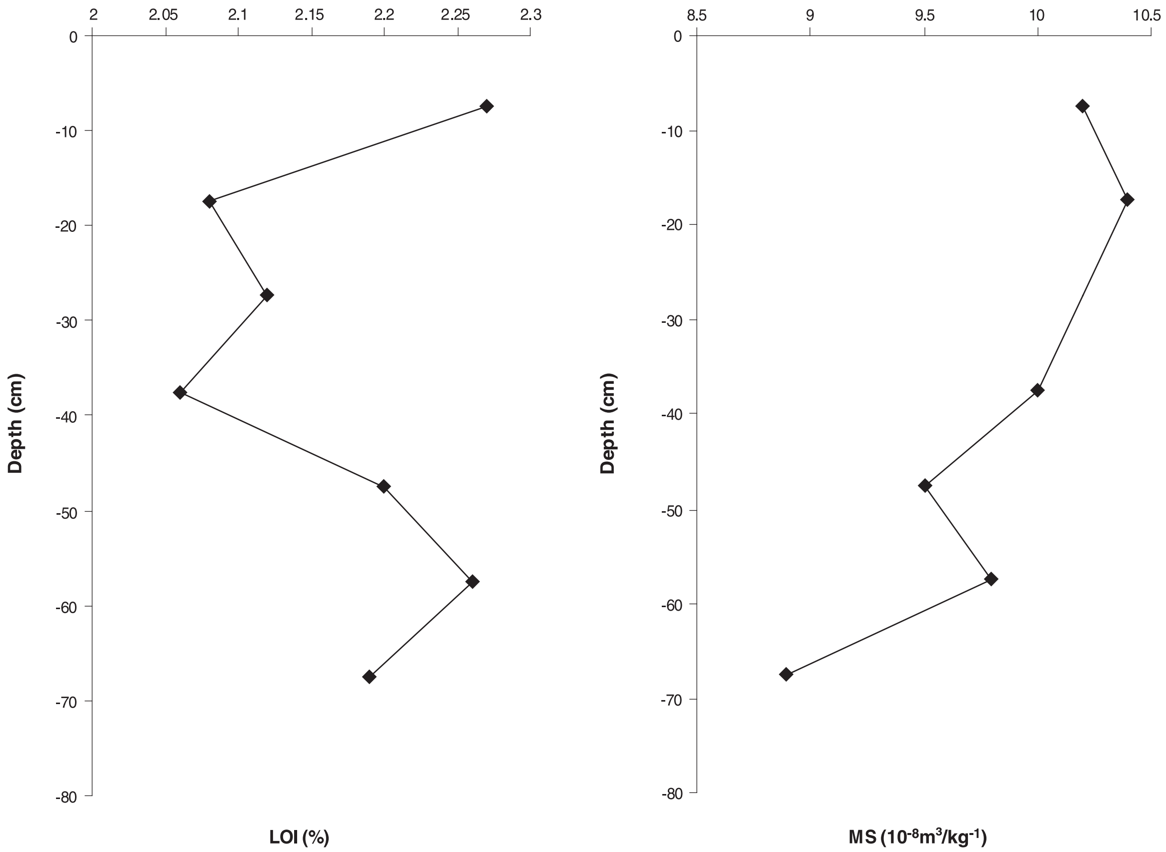


Figure A2.10 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 7.3; [horizontal scales do not start at 0.0 (ie plots exaggerate differences between samples]

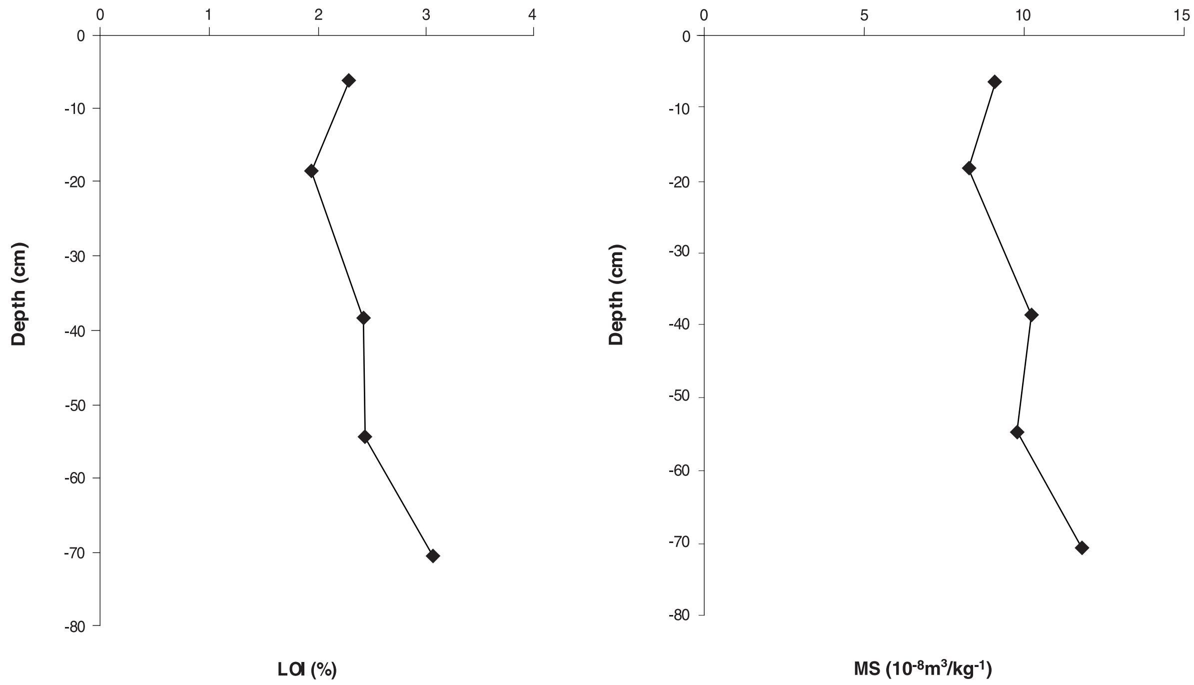


Figure A2.11 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 7.4

Sequence 8.2 (Fig. A2.13): A general increase in LOI down the section from context 40057 to 40056, with a possible minor peak at 45.5cm in context 40056. The peak in χ shown in the plot is relatively small and is unlikely to be of significance.

CONCLUSIONS AND RECOMMENDATIONS

As noted in the introduction, LOI and χ data from these sequences may well poorly reflect the character of the initial sediments, because of likely post-depositional organic decomposition and mobilisation of Fe. As the investigations of the relationship between χ and χ_{conv} have shown, interpretation of the χ data is further complicated by what would appear to be wide variations in Fe content through the sequences of deposits. Nonetheless, the results have revealed quite marked variability both within and between contexts. One major peak in LOI (probably the remains of a humic or even peaty deposit) has been identified in context 40158 (Sequence 2), which is very likely to be associated with

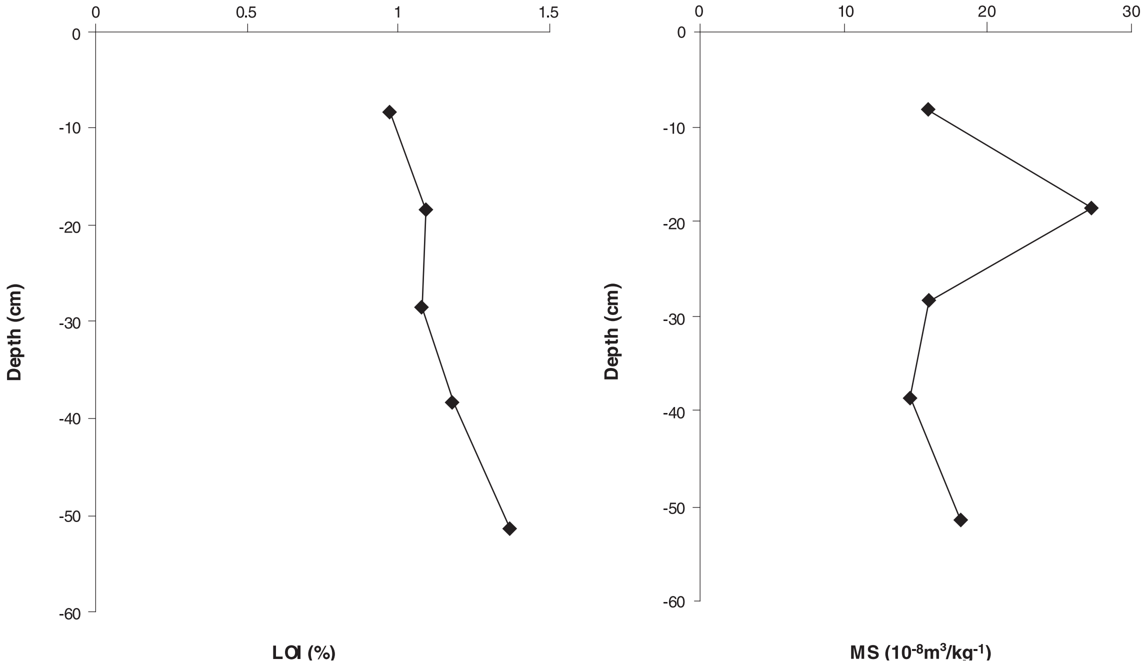


Figure A2.12 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 8.1

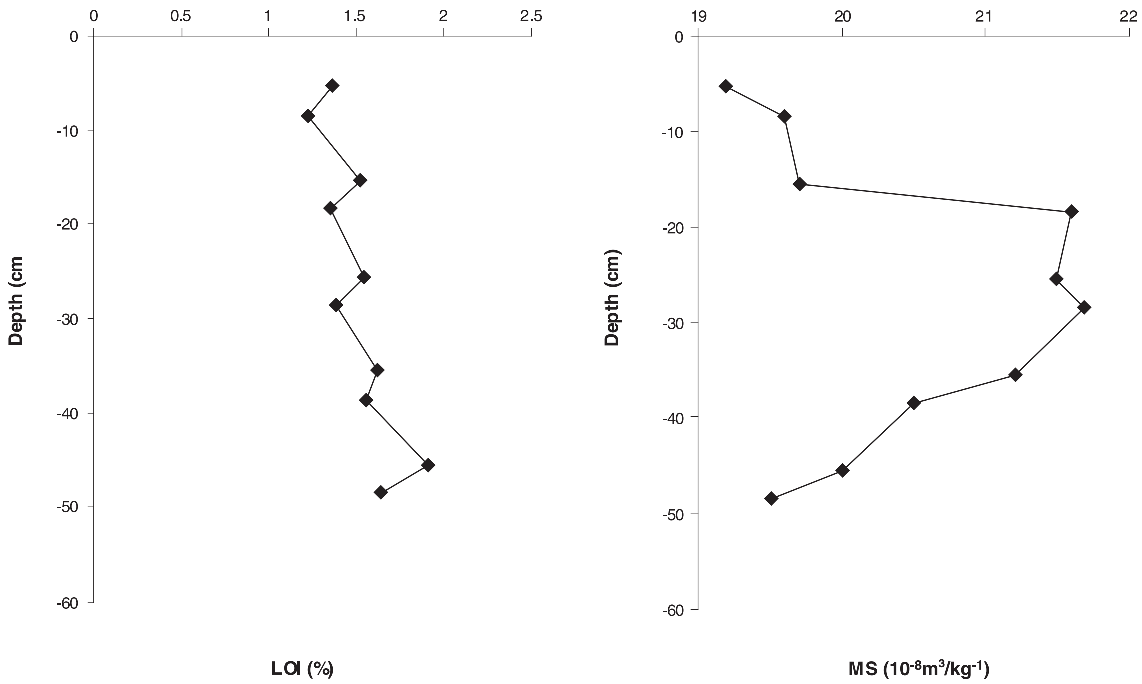


Figure A2.13 Variations in LOI (%) and χ(10^{-8} m^3 kg^{-1}) down Sequence 8.2
[horizontal scale for χ does not start at 0.0 (ie plot exaggerates differences between samples)]

a significant period of soil development/surface exposure. Elsewhere, various minor peaks in LOI have been identified, which may also be indicative of periods of soil development/surface exposure, particularly where there is a close correlation with χ.

It is recommended that the present data are examined in the light of other field and post-excavation evidence – eg textural and compositional variations (which may affect both LOI and χ), and the results of thin section investigations.

Appendix 3

Diatom assessment of samples from Southfleet Road

by Nigel Cameron

INTRODUCTION

The aim of the diatom assessment was to evaluate the potential to use diatom analysis of the Southfleet Road sediments for environmental reconstruction and in particular to determine the types of aquatic environment in which the sediments were deposited.

A total of 32 samples for diatom assessment were sub-sampled from monolith and bulk sediment samples taken from the Lower Palaeolithic site at Southfleet Road, Ebbsfleet (Wenban-Smith 2009; Wenban-Smith *et al.* 2006) The sample details are listed below (Table A3.1) along with the laboratory diatom sample number that each sample was given at UCL. Note in particular that the order of groups of diatom sample numbers does not follow the order in which sediment samples are listed in the original sample tables supplied by F. Wenban-Smith, B. Silva and E. Stafford. The order of the diatom sample numbers was determined by the priority for assessment of the samples and the order in which groups of samples arrived. In addition, samples of lower priority are listed as possible samples for diatom evaluation in the table, however, sediments for some these were not sent for diatom analysis (Diatom sample number recorded here as 'none'). Further, there is no diatom sample 'D25' because the sub-sample from Sample 40340, 12-13cm was not sent for analysis (see Table 1. Samples assessed for diatoms from the site at Southfleet Road).

Table A3.1 Samples/sub-samples selected for diatom assessment

Diatom Sample No.	*Source sample/sub-sample <>*	*Context*	*Phase*
D1	40250/D	40143	6b
D2	40249/D	40143	6b
D3	40248/D	40143	6b
D4	40281/D/nn-nn	40070	6b
D5	40281/D/nn-nn	40070	6b
D6	40281/D/nn-nn	40103	6a
D7	40364/D/6-7cm	40100	6d
D8	40364/D/33-34cm	40078	6d
D9	40364/D/52-53cm	40099	6c
D10	40365/A/0-1cm	40078	6d
D11	40365/D/29-30cm	40103	6a
D12	40068/D/10-12cm	40066	5
D13	40068/D/44-46cm	40063	3
D14	40068/D/50-52cm	40062	3
D15	40068/D/56-58cm	40062	3
D16	40342/D/3-4	40162	6
D17	40352/D/3-4	40100	6
D18	40352/D/51-52	40099	6
D19	40352/D/18-19	40099	6
D20	40353/D/36-37	40099	6
D21	40321/D/5-6cm	40144	6b
D22	40321/D/14-15cm	40144	6b
D23	40321/D/23-24cm	40144	6b
D24	40321/D/44-45cm	40103	6a
D26	40340/D/39-40cm	40162	6c
D27	40342/D/48-49cm	40103	6a
D28	40344/D/9-10cm	40162	6c
D29	40344/D/39-40cm	40162	6c
D30	40344/D/60-61cm	40162	6c
D31	40345/D/12-13cm	40162	6c
D32	40345/D/48-49cm	40162	6c
D33	40353/D/9-10cm	40099	6c

Table A3.2 Summary of diatom evaluation results for Southfleet Road

Diatom Sample	*Diatoms assemblage*	*Diatom numbers*	*Quality of preservation*	*Diversity*	*Assemblage type*	*Potential for % count*
D1	absent	-	-	-	-	none
D2	see text	one fragment	extremely poor	-	unknown	none
D3	absent	-	-	-	-	none
D4	absent	-	-	-	-	none
D5	absent	-	-	-	-	none
D6	absent	-	-	-	-	none
D7	absent	-	-	-	-	none
D8	absent	-	-	-	-	none
D9	absent	-	-	-	-	none
D10	absent	-	-	-	-	none
D11	absent	-	-	-	-	none
D12	absent	-	-	-	-	none
D13	absent	-	-	-	-	none
D14	absent	-	-	-	-	none
D15	absent	-	-	-	-	none
D16	absent	-	-	-	-	none
D17	absent	-	-	-	-	none
D18	absent	-	-	-	-	none
D19	absent	-	-	-	-	none
D20	absent	-	-	-	-	none
D21	absent	-	-	-	-	none
D22	absent	-	-	-	-	none
D23	absent	-	-	-	-	none
D24	absent	-	-	-	-	none
D26	absent	-	-	-	-	none
D27	absent	-	-	-	-	none
D28	absent	-	-	-	-	none
D29	absent	-	-	-	-	none
D30	absent	-	-	-	-	none
D31	absent	-	-	-	-	none
D32	absent	-	-	-	-	none
D33	absent	-	-	-	-	none

METHODS

Diatom preparation followed standard techniques (Battarbee 1986, Battarbee *et al.* 2001). Two coverslips of different concentrations were made from each sample and fixed in Naphrax for diatom microscopy. A large area of the coverslips on each slide was scanned for diatoms at magnifications of x200, x400 and x1000 under phase contrast illumination.

RESULTS AND DISCUSSION

The results of the diatom evaluation are shown in Table A3.2. A single, small striate fragment from an indeterminate pennate diatom species was recorded in D2. Diatom assemblages were absent from all thirty-two samples. It is not therefore possible to comment on the aquatic environments in which these sediments were deposited.

Given the ubiquity of diatoms in natural water bodies, the absence of their remains from waterlain sediments is likely to be the result of taphonomic processes rather than absence of diatoms from the water. In particular this can be the result of silica dissolution caused by factors such as high sediment alkalinity, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, exposure of sediment to the air or the rapid accumulation of flood deposits (eg, Flower 1993; Ryves *et al.* 2001). However, these factors do not preclude the preservation of diatoms. Unfortunately because of the absence of diatoms here it is not possible to comment further on the nature of sediment deposition or changes in water quality.

CONCLUSIONS

Diatoms assemblages were absent from all thirty-two samples. The loss of diatom assemblages from these deposits may have been the result of one or more taphonomic factors leading to diatom valve breakage and silica dissolution, and consequently there is no further potential for diatom analysis of these samples.

Appendix 4

Plant macrofossils and wood charcoal

by Denise Druce and Francis Wenban-Smith

INTRODUCTION

Visible fragments of what looked like soft, black remnants of plant material or wood were ubiquitous in contexts 40078, 40158 and 40167, as well as occurring as occasional sparse patches in contexts 40039, 40068 and 40100. Samples from 40158 were taken and processed for charcoal and plant macrofossil remains in conjunction with those taken for pollen analysis (Chapter 12) and assessment of insect remains (Appendix 5). Nothing woody was found during the insect assessment, but a megaspore of the water fern *Azolla filiculoides* was found during sieving before pollen analysis. No other identifiable plant remains were recovered, merely some amorphous non-cellular organic detritus. Four samples were specifically collected with charcoal and wood remains analysis in mind, focusing on patches found during excavation that were thought to be charcoal-rich (Table A4.1).

ASSESSMENT

Unfortunately, of these four samples, all except one was misplaced once taken off-site, so the only sample investigated was <40203>. It produced a very sandy flot. A couple of very small charcoal pieces (<2mm) were picked out, as well as several pieces of black vitrified material which looked plant-derived, although poorly preserved. Several more pieces of this black material were recovered from the heavy residue. This organic material was thought possibly suitable for radiocarbon dating. There was much modern root material in the flot, so there is a possibility that the small quantity of charcoal which was present may be from more recent contamination. Considering the possibility of modern intrusion, balanced against the significance of any wood identification, it was therefore decided to proceed with identification of the wood remains and also to carry out radiocarbon dating to establish whether or not they were likely to be of Pleistocene origin.

RESULTS

The majority of charcoal fragments from <40203> were highly comminuted and measured less than 0.5mm. A few, however, were large enough to warrant a reasonably clear transverse section. Six fragments were identified as coniferous wood; however, they were too small to enable positive identification to species level. The flot also contained modern plant remains and rare molluscan remains, as well as common heat-affected vesicular material, which probably equates to the indeterminate organic material observed during the initial assessment and also the sieving of samples <40407>-<40410> carried out during pollen analysis. Given the presence of the coniferous wood in the sample, it is tempting to interpret this material as the remains of burnt resin; however this is by no means conclusive.

DISCUSSION

The identified wood charcoal could represent any of the native British and northern European coniferous woods, which includes yew *Taxus baccata*, pine *Pinus sylvestris*, silver fir *Abies alba*, and spruce *Picea abies*. All four have been recorded in middle Pleistocene deposits at Clacton-on-Sea (Bridgland *et al.* 1999), and both pine and yew pollen have been recorded in early-to-mid Holocene deposits from other sites in the

Table A4.1 Samples taken for charcoal/plant macro-fossil assessment

Sample No.	*Context*	*Phase*	*Weight/volume collected*	*Collection notes*
40190	40100	6	Unrecorded	Wood remains in clay between Trenches B and C
40240	40078	6	Unrecorded	A piece of degraded wood within clay 40078 near *Palaeoloxodon* spread
40203	40068	6	*c* 10L	A small patch of charcoal-rich clay identified during machining between Trenches B and C
40279	40039	6a	0.5L	Fragments of charcoal (?) found within 40039 near rhino maxilla group Δ.42477

Thames Valley including Ebbsfleet HS1 and STDR4.

Although the sample of coniferous charcoal from sample <40203> was sent to the Scottish Universities Environmental Research Centre AMS Facility for dating, unfortunately the sampled failed due to insufficient carbon yield (GU-24990).

Appendix 5

Assessment of samples for insect remains

by Russell Coope

INTRODUCTION

Although the majority of the sediments at the site did not appear especially promising for insect preservation, the darker brown, more organic-rich brecciated clay of contexts 40158 and 40162 (in the central part of the site, near the elephant skeleton) did appear to have some potential for insect preservation, particularly in light of the confirmed pollen preservation, the presence of rotted plant material and the suggestion (see Chapter 5) that the sediment would previously have been more ‘peaty’ in nature. Therefore three samples were selected for assessment for insect remains.

METHODS

Half of each sample was washed over a 300µm sieve, and any resulting residue dried and examined.

RESULTS AND CONCLUSIONS

No vestige of insect remains, or indeed any other floral or faunal remains, was found from any of the samples investigated, listed below.

Table A5.1 Samples/sub-samples selected for insect assessment

Sample No.	*Context*	*Phase*	*No. of boxes*	*Weight processed*
40263	40158	6	1 – 10L	11.5kg
40413	40158	6	1 – 10L	11kg
40346	40162	6	1 – 10L	12kg

Samples selected for assessment

The three samples selected are listed below (Table A5.1). Two (samples <40263> and <40413>) came from context 40158, the very dark brown brecciated clay rich in fragmentary organic material that formed the full thickness of the Phase 6 sequence at the foot of the synclinal ‘skateboard ramp’, in the central part of the site, south of Trench B. The third (sample <40346>) came from context 40162, a slightly browner and sandier facies within the lower part of the Phase 6 clay in the central part of the site. This deposit was considered possibly to have some organic preservation.

Sample <40346>
Sample consisted of grey clay with lighter patches. Many ‘rootlets’ but no seeds, insects or molluscs.

Sample <40263>
Sample consisted of dark brown clay. Nothing retained on the sieve.

Sample <40413>
Sample consisted of dark brown clay. Nothing retained on the sieve.

Appendix 6

Worked flint post-excavation analysis methods

by Francis Wenban-Smith

INTRODUCTION

The underlying philosophy of the post-excavation lithic analysis was to categorise the artefacts on a technological basis as neutrally as possible, identifying categories such as: core; debitage; flake-tool; and core-tool. This was supplemented by a restricted range of qualitative and quantitative data that it was anticipated would contribute to analysis of the collection. There is a danger in lithic analysis of indiscriminate recording of an over-abundance of superfluous empirical data. This analysis was undertaken with a number of clear objectives in mind, and the recording was focused upon data that were chosen as relevant to these objectives, which were: investigation of knapping strategies and primary technological pathways; tool typology; and investigation of the organisational structure of lithic production and the *chaîne opératoire*.

These data, recorded at the post-excavation stage of analysis, were then combined with site provenance and locational data recorded during excavation to provide the basis for the overall lithic analytical project.

THE LITHIC COLLECTION

The lithic collection was initially divided into two primary groups, each of which subject to fundamentally different approaches to excavation, recording and analysis, namely: (1) artefacts ≥ 20 mm maximum length; and (2) microdebitage < 20mm long. During the excavation, it was not specifically decided to omit recovery and recording of artefacts < 20mm long, but it is certain that the majority of artefacts this size would not have been recovered by the trowelling and mattocking methods applied (Chapter 3), although a few were recovered. Furthermore, it was thought that artefacts of this small size would not usually have been deliberately made in this early period (in contrast, for instance, with the Mesolithic or Neolithic), so there was less value in spending time studying them in detail. However, analysis of the quantity and distribution of microdebitage is of interpretive value in investigating taphonomy and disturbance, so part of the excavation was focused upon a systematic recovery of microdebitage in a selection of the evaluation trenches south of Trench D, by the collection of sediment samples on site that were subsequently sieved through a fine mesh.

Lithic artefacts (≥20mm)

Artefacts ≥ 20mm maximum length were subject to detailed recording, in six distinct data groups:

- Recording referencing
- Packing/storage information
- Site provenance information
- Categorical lithic data
- Quantitative lithic data
- Notes

The details of different data recorded in each of these groups are given below:

Microdebitage (< 20mm)

The microdebitage was divided into two categories: 'chips' and 'spalls'. They are not included in the more detailed technological and typological analyses. There is, however, useful information on the integrity and post-depositional disturbance of an assemblage from: (a) their relative quantities in relation to each other and larger debitage; and (b) their spatial distribution in relation to larger debitage. For ease and consistency of comparison, artefacts <20mm maximum dimension were put through stacked 4mm and 2mm sieves, and those retained in the 4mm sieve were recorded as chips, and those in the 2mm sieve were recorded as spalls.

Comparative data from experimental knapping and sites that are confidently believed to represent complete undisturbed knapping scatters then give a baseline for identifying complete and undisturbed debitage distributions.

RECORDED DATA

There were six main groups of data for artefacts ≥20mm, each of which associated with a range of information to be recorded (Table A6.1), described in turn below. The data were recorded by hand onto a paper recording proforma. This took the form of a landscape format A4 paper sheet with columns for each piece of data to be recorded and 20 blank rows for different artefacts on each sheet. After recording, the paper record was typed into an Excel spreadsheet, which could then be linked with the digital survey data

Table A6.1 Lithic analysis recording proforma

Type of data	*Name*	*Description*
Recording reference	Rec sht	Recording sheet, in number order of recording
	Sht #	Line number on recording sheet
Packing/storage	OA box no.	Box number as originally received
Site provenance data	Δ ID	Unique lithic identifier, small find number
	Context	Taken from finds bag, cross-checked with paper archive
	Area	Area of site: Trenches A-D; Transects 1-3, Strips A-D
	Trench	Evaluation trenches I-XV
	Sample <>	Sample number, for lithic bulk spit-sieved samples
	Spit	Spit-number, for lithics from spits in evaluation trenches I-XV
Categorical data	Cnd	Condition
	C1	Main technological category
	C2	Secondary technological category
	T1	Technology/typology, sub-category 1 (varies acc. C1, C2)
	T2	Technology/typology, sub-category 2 (varies acc. C1, C2)
	T3	Technology/typology, sub-category 3 (handaxes, flake-tools)
	T4	Technology/typology, sub-category 3 (handaxes, flake-tools)
	WhL	Completeness, wholeness (varies acc C1, C2)
Quantitative data	%Cx	Percentage remnant cortex, on dorsal surface of flakes
	DSC	Dorsal scar count, scars from debitage estimated as ≥20mm [not including striking platform, for flakes]
	ML	Maximum length, measured along ventral surface for flakes from point of percussion, mm [*1]
	MW	Maximum width mm, orthogonal to ML[*1]
	MT	Maximum thickness mm, orthogonal to ML
	WtG	Weight grammes
Notes	N	Notes, not usually entered on database but useful on paper record

[*1] ML, MW for debitage — estimate extra for damage/abrasion <20 mm

thus providing the potential to generate site plans and statistics based on the lithic interpretations.

Recording reference

Each sheet was numbered incrementally as it was used, and each row on each sheet (representing separate artefacts) was also numbered from 1-20 down the sheet. Once this data was entered into the digital record alongside the provenance and lithic analytical data, it meant that it was then easy at a later point to go back and investigate the original paper record for any particular artefact. Without this procedure, this would have been a virtually impossible task considering the original paper archive constituted 134 sheets, since the artefacts were not examined in a particular order, other than the context order in which they were provided originally.

Packing/storage

A record was made during the lithic analysis of the box that material was received in. Lithic artefacts were initially put back into the same box they came from after the first examination. This original packing order gradually became more muddled, as it became clear that several artefacts were initially incorrectly numbered or attributed to the wrong context, leading to them being correctly attributed and placed in different boxes. Maintenance of this record of where artefacts were being stored was useful while study was taking place. Later, the material was entirely reorganised to match significant stratigraphic groupings, so this part of the record became redundant.

Site provenance data

Provenance data is usually collected on site and before analysis, and stored in a separate database, before being added later to the analysis data, but there has to be a key field to link the two such as Δ.ID (individual lithic ID) or <SN> (Sample number, eg. for artefact collections from large sieving programmes). At Southfleet Road, stratigraphic provenance and 3-D spatial location data were collected during excavation for the great majority of flint artefacts. A few were recovered from bulk spit-sieve samples, or from excavated spoil of known stratigraphic provenance but uncertain precise location, so did not have full XYZ locational data. The XYZ data was collected digitally using a total survey station, tied in with the artefact find number. The stratigraphic provenance data was collected manually, with the context number (and, if applicable, site area, trench number and spit/sample number) written on the plastic bag into which lithic finds were placed, together with the unique individual find number. This was supplemented by maintenance of a paper find register, which listed the finds numbers used, the stratigraphic context of each find along with notes on the location of the find and its material (at Southfleet Road, almost invariably 'Flint' or 'Bone').

When the artefacts were examined, the provenance information written on the finds bag was recorded on the paper lithic recording proforma. This was subsequently cross-checked with the paper record (which was typed up separately into a different Excel spreadsheet) and any discrepancies investigated and resolved. Six different aspects of provenance were recorded, as specified in the proforma (Table A6.1).

Categorical data

The first categorical attribute recorded was the condition of each artefact, 'Cnd', which was classified as one of five different degrees of damage/abrasion (Table A6.2), ranging from absolutely mint condition, as freshly knapped, to so heavily abraded that virtually a beach pebble. The next two attributes, C1 and C2, relates to the technological category. Seven basic technological categories were recognised (Table A6.3), represented by C1, ranging from natural unworked flint (C1=0) to artefacts interpreted as tools (C1=6). For cores, debitage and tools, the second category C2 represents further more specific subdivisions, for instance irregular waste debitage would be coded as C1,C2 = '5,1', a 'flake-flake' representing a flake removed in course of trimming a flake blank to form a flake-tool would be coded as C1,C2 = '5,4' and a handaxe on a flake would be C1,C2 = '6,2'. The use of numerical codes was found useful as saving time in data entry, and also easier for coding queries for subsequent quantitative analyses investigating the proportions of different types of artefact in different assemblages.

Table A6.2 Lithic condition categories

Grade	*Category*	*Description*
1	Mint	As freshly knapped, razor sharp
2	Sharp/fresh	Sharp to handle, ridges unaffected, but slight abrasion on parts of edges
3	Slightly abraded/rolled	Ridges slightly abraded, edges lightly–moderately battered, smooth to touch
4	Well-abraded	Ridges very abraded, all edges moderately–heavily battered
5	Extremely abraded	Almost a beach pebble, ridges non-existent or vestigial, heavily battered surfaces

Table A6.3 Lithic artefact technological categories

C1	*C2*	*Description*
0 - Natural	-	Not humanly worked, can be interpreted as raw material, can be excluded from database, but if so needs to be quantified
1 - Raw materia	-	No sign of working, but clearly a manuport
2 - Tested nodule	-	Nodule with only a couple of flakes off, no sign of whether a core or core-tool
3 - Chunk	-	Knapped chunk. Uncertain whether core or core-tool, poss. because broken, or not very knapped, or just very ugly
4 - Core	1 - Conventional	Flakes removed, generally reasonably large, from natural lump of raw material and no sign of preferential edge/part for use
	2 - On flake	Debitage used as a core
	3 - On core-tool	Eg if re-used or after breakage
5 - Debitage	1 - Irregular waste	Lump, fragment or shatter; piece bigger than 20mm but not otherwise classifiable, often resulting from knapping frost-fractured pieces; usually show some sign of percussive impact, but in principle can apply to pieces that look completely natural, but are interpreted as resulting from hominin knapping
	2 - Flake, blade	Flakes, or parts of flakes, must have signs of being part of a single removal, else classified as C2=1
	3 - Chip/spall	Flake/irregular waste less than 20mm
	4 - Flake-flake	Debitage from flaking a flake
6 - Tool	1 - Handaxe (core-tool)	Usually evidence of preferential edge/part for use and bifacially worked; attention to straightening, to opposing handle, removal of small shaping flakes of no use in themselves
	2 - Handaxe (on flake)	When a handaxe is made on a blank that shows definite evidence of originally having been a piece of debitage
	3 - Flake-tool	Worked/utilised flake; working can be backing (eg possible interpretation as backed knife), retouching (eg. to form scraping edge) or notching
	4 - Percussor	Evidence of focused battering, can appear on cores/core-tools, can have some working to facilitate handling
	5 - Anvil	Battering on very large pieces, usually would be interpreted as percussors

The next four attribute categories T1–T4 reflect more detailed technological and typological attributions. These varied according to the basic technological category, so for instance, handaxes have a different selection of options than flake tools, and other technological categories lack more detailed T1–T4 options.

For handaxes, a classificatory scheme was applied based upon that developed by Wymer (1968) in his review of the Lower/Middle Palaeolithic archaeology of the Thames Valley, with a different numeric code entered as T1 according to the handaxe shape (Table A6.4). Other handaxe attributes such as the degree of butt-trimming, the presence and knapping direction of tranchet sharpening and the peasants and orientation of a twisted profile are recorded as attributes T2–T4, as shown and described in the respective tables (Table A6.5 – A6.7).

For flake tools, the first two technological/typological attributes T1 and T2 are used to categorise the flake-blank, whether it is a natural scrap (and not realistically

Table A6.4 Handaxe shape categories (T1)

Shape category - T1	*Wymer type*	*Description*
0 - Unspecific	-	Indeterminate, eg. when broken or unclassifiable to other categories
1 - Rough-out/abandoned	-	Pieces which appear to have been abandoned before completion, for instance because of frost-fracturing, persistent failure to achieve thinning, or breakage
2 - Simple	Proto	Includes McNabb and Ashton's 'non-classic' handaxes, simple bifacial or unifacial edges opposed to natural handles
31 - Crude pointed (large)	D	Large (≥100mm) pointed/sub-pointed biface, no soft-hammer, thick, wavy edges, thicker and heavier at butt
32 - Crude pointed (small)	E	Small (<100mm) pointed/sub-pointed biface, no soft-hammer, thicker and heavier butt, thick, wavy edges
4 - Classic pointed	F	Well-made pointed handaxe with clear butt, straightish sides and thinned towards tip, can be any size; butt can be unworked or crudely worked
50 - Sub-cordate	G	Progression from type F with convex sides, often more rounded point, thick/heavy butt, widest part of handaxe well towards butt; butt can be unworked, crudely worked
51 - Sub-cordate (plano-convex)	G	Similar to above but with clear plano-convex profile, cf. Wolvercote Channel
52 - Sub-cordate (twisted)	-	Sub-cordate plan shape, but tip distinctly twisted relative to butt
60 - Sub-ovate	GK	Much more ovate version of sub-cordate; tip is smoothly rounded without any well-defined point, widest part of handaxe is nearer middle of long axis, clear working to shape/thin butt and sides as convex curve, although not as much as for true ovate or cordate
7 - Cordate	J	Cutting edge all round tool with thinning and shaping around butt, centre of gravity near middle, bit more rounded than sub-cordate, but still has clear tip, with widest part of handaxe towards butt
71 - Twisted cordate	-	Cordate plan shape, but tip distinctly twisted relative to butt
80 - Ovate	K	Cutting edge and thinning/shaping all round, centre of gravity near middle, more rounded at base than cordate with widest part of handaxe towards middle, usually one end recognisable as tip by being more elongated from widest part of handaxe and often tranchet sharpened
81 - Twisted ovate	K	Ditto above, but clearly twisted tip
9 - Side-chopper	L	Segmental chopping tool, one knapped bifacial edge or sharper edge opposed by flat edge or natural backing; crucial distinction with cleaver is that business edge is parallel with main longitudinal axis rather than transverse
10 - Classic ficron	M	Very pointed with symmetrical concave sides and well-defined heavy butt, cf. Furze Platt, Cuxton (Wenban-Smith 2004)
11 - Bout coupé	N	Flat-butted cordate, trimmed all round butt, but with distinct corners between gently convex base and sides
12 - Cleaver	H	Key characteristic is straight cutting edge at tip end, transverse to main longitudinal orientation of tool, cf. Cuxton (Wenban-Smith 2004)

Table A6.5 Handaxe butt trimming categories (T2)

T2	*Description*
0	Inapplicable — indeterminate or unknown, eg. when broken
1	Untrimmed butt — entirely cortex or natural fracture
2	Slightly trimmed butt — over 50% cortex or natural fracture
3	Mostly trimmed butt — less than 50% cortex or natural fracture
4	Wholly trimmed butt — all butt and corners trimmed

classifiable as a core-tool), piece of irregular waste or a normal flake (Table A6.8). The last two attributes T3 and T4 then reflect interpretation of the type of flake-tool, with T3 representing the general category of flake-tool, and T4 representing more detailed subdivision (Table A6.9). These subdivisions are not intended to be an exhaustive typological list of the Lower/Middle Palaeolithic, merely to represent basic groupings identified during analysis of the material from the Southfleet Road site. In general, it was not attempted to apply/develop a detailed typology, in light of serious doubts as to whether this would be interpretively meaningful. Rather, it was just attempted to reflect basic technological groupings, and then the range of technical detail exhibited by different technical categories in different assemblages were described and drawn on a case-by-case basis (see Chapters 17, 18 and 20 in particular).

The final categorical attribute recorded was the completeness/brokenness of each artefact. This was coded from 0–4 (Table A6.10), with minor variations of criteria depending upon the different technological categories. As described in the table, broken-off pieces estimated as less than 20mm maximum length were disregarded. For debitage, flake-tools and handaxes, different coding was used to reflect whether the

Table A6.6 Handaxe tranchet sharpening categories (T3)

T3	*Description*
0	Inapplicable — indeterminate or unknown, eg. when broken
1	Absent — no tranchet
2	Left tranchet — struck from left (removal underneath and tip away; can be on both faces, as long as consistently from left)
3	Right tranchet — struck from right (removal underneath and tip away; can be on both faces, as long as consistently from right)
4	Complex tranchet — struck from both left and right (removals from both faces, with face underneath and tip away)

Table A6.7 Handaxe twisting categories (T4)

T4	*Description*
0	Inapplicable — indeterminate or unknown, eg. when broken
1	S-twist, anticlockwise tip-twist when viewed from above, looking down on tip, with tip twisting anticlockwise relative to butt; bifacial edge descending to R across middle of handaxe when profile viewed from side, with tip to R
2	Z-twist, clockwise tip-twist when viewed from above, looking down on tip, with tip twisting clockwise relative to butt; bifacial edge ascending to R across middle of handaxe when profile viewed from side, with tip to R

Table A6.8 Flake-tool blanks, technological categories (T1 and T2)

T1	*T2*	*Description*
0	0	Made on a scrap of natural, eg. frost-fractured, flint
5	1	Made on a piece of irregular waste
5	2	Made on a normal flake

Table A6.9 Flake-tools, typological categories (T3 and T4)

T3	*T4*	*Details*
1 - Notches	10 Single notch	Clear single notch, can be backed by natural cortical handle or blunting/backing retouch
	11 Multi-notched	Two or more notches, scattered around
	12 Linear notches	Two or more notches, aligned on one edge (sometimes to form crude denticulate)
2 - Flake-knives	20 Utilised flake	Use-damaged, evidence of macro use-wear but no retouch
	21 Knife	Blunting/backing retouch opposite/beside natural cutting edge, which can show macro-wear, to facilitate handling and use
3 - Scrapers	30 Gen scraper	General scraping edge/s
	31 "Mousterian" scraper	Convex unifacial scraping edge down one long side of a medium-large flake
4 - Saws	40 Gen saw	Unifacial/bifacial sharpening of edge/edges of flake to form sawing edge on flake
5	50	Point/awl?
6	60	Misc. other; describe on case-by-case basis

Table A6.10 Completeness/breakage codes for different lithic technological categories
[Irregular waste is by definition always whole]

Code	*Core*	*Debitage or flake-tool*	*Handaxe*
0	Broken	-	Broken: piece of core-tool; not clearly butt, middle or tip remaining
1	Whole	Whole — missing bits <20mm	Whole: missing bits <20mm
2	-	20 - Proximal present: missing proximal bit <20mm and distal bit ≥20mm 21 Proximal present: Siret fracture (left), when looking at ventral surface, with strik. plat. upward 22 Proximal present: Siret fracture (right) , when looking at ventral surface, with strik. plat. upward	Butt present: missing butt <20mm and tip ≥20mm
3	-	Mesial present: missing proximal and distal bits both ≥20 mm	Middle present: missing butt and tip, both ≥20mm
4	-	Distal present: missing proximal bit ≥20mm and distal bit <2 mm	Tip present: missing butt ≥20 mm and tip <20mm

proximal, middle part or distal end was present. And for flakes and flake-tools, a slightly more detailed coding was used when the proximal end was present, to identify and distinguish between left and right sides of Siret fractures.

Quantitative data

A relatively restricted range of six quantitative attributes was recorded (Table A6.1), chosen as being particularly relevant to taphonomic/post-depositional interpretation and investigation of the *châine opératoire* and organisation of lithic production. Experimental work by Wenban-Smith (1996) has firmly established that two attributes in particular – percentage cortex and dorsal scar count – are especially useful for categorising the stage of the reduction sequence represented by waste debitage. Therefore these two attributes were recorded here for flakes and flake-tools. The percentage of cortex (or unknapped natural flint surface) on the dorsal surface was categorised by eye as one of 11 grades 0–10 as specified in the accompanying table (Table A6.11). The dorsal scar count was based on the estimated size of the complete removal represented by a dorsal scar, not just the size of the visible remnant, and scars representing removals thought to be less than 20mm maximum length were disregarded. For flake tools, it was attempted to focus on counting scars from flakes removed during the original knapping process rather than from secondary working to form the flake-tool.

The remaining four quantitative attributes recorded were the basic size measurements of length, width and thickness (ML, MW and MT), as well as weight (WTG). There are innumerable variations on the precise way of measuring these apparently straightforward flake-size attributes. Those applied here are illustrated (Fig. A6.1), with the additional factor that broken-off parts less than 20mm were ignored, and measurements estimated to allow for their presence if necessary. This was so that the size data were directly comparable with experimental models based on complete flakes.

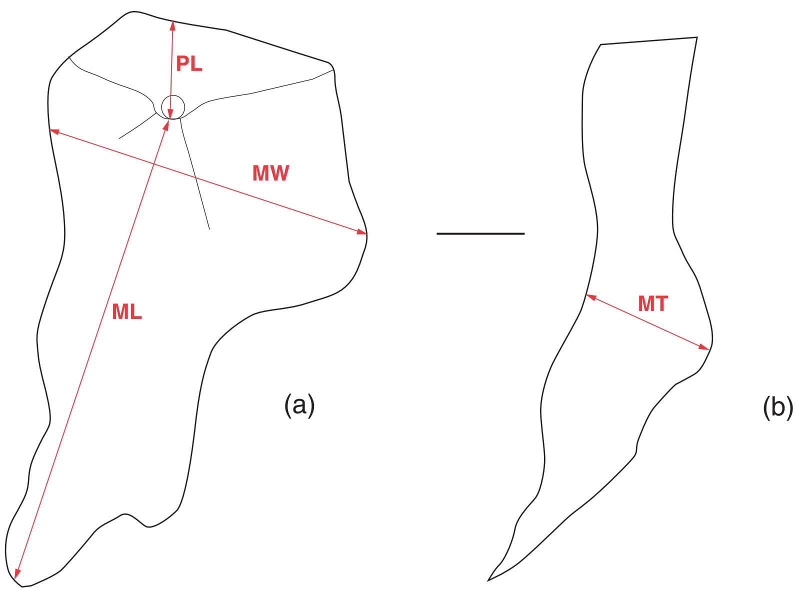


Figure A6.1 Measurement of flake size: (a) maximum length ML and maximum width MW; (b) maximum thickness MT

Table A6.11 Codes for recording amount of cortex present

Code	*Description*
0	0%
1	1–10%
2	11–20%
3	21–30%
4	31–40%
5	41–50%
6	51–60%
7	61–70%
8	71–80%
9	81–90%
10	91–100%

Notes

Finally, various notes and sketches were recorded on the paper archive, drawing attention to anything of interest seen, such as distinctive raw material, unusual knapping strategies or the distribution of fine macro-wear traces on the sharp edges of otherwise unworked flakes. To avoid ambiguity when making these descriptive notes, core-tools are by default oriented butt down, and flakes with striking platform up. When describing working on flakes, 'struck off' refers to the surface bearing the scar/s of any retouch/removals, and 'struck on' refers to the surface hit by the percussor. Hence the normal situation is struck on the ventral surface and off the dorsal surface.

Appendix 7

Thin section data

by Richard Macphail

Reproduced overleaf

Table A7.1 Soil micromorphology: descriptions and preliminary interpretations

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth)* *Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
MFT A1/SMT 1a1, 1a2, 2a1	M40082	290-370mm SM: Heterogeneous with dominant fine and medium sandy SMT 1a1 in lower half, mixing with common fine sandy SMT 1a2 and frequent (fragments/fills) of SMT 2a1 upwards; *Microstructure:* massive with fissures (1.5-2mm wide), 25% voids, fine to coarse fissures, vughs with simple packing voids, (root?) channels traces (0.5-0.7mm). *Coarse Mineral* – C:F (Coarse:Fine limit at 10μm), SMT 1a1=85:15: moderately poorly sorted angular coarse silt/very fine sand-size quartz, feldspar, micas (and opaques including probable haematite), with medium sand-size mainly moderately weathered sub-rounded glauconite (some little-weathered glauconite), fine and medium sandy clay clasts (colourless, 1st order grey birefringence – palygorskite?, relict of Cretaceous), and rare very coarse sand-size rounded clasts of SMT 2a1; SMT 1a2: C:F=60:40, very dominant moderately poorly sorted angular coarse silt/very fine sand-size quartz, etc (as SMT 1a1), with few to frequent medium sand-size glauconite. *Coarse Organic and Anthropogenic: Fine Fabric* –SMT 1a1: cloudy dusty pale brownish grey (PPL), moderately low interference colours (close porphyric to coated grain, speckled and patchily crystallitic, XPL), very pale brown (OIL), rare trace of once-humic iron-staining; SMT 1a2: as SMT 1a1, with close porphyric c/f distribution; SMT 2a1: cloudy and finely speckled pale brown (PPL), moderately low interference colours (open porphyric, stipple speckled b-fabric, XPL), greyish brown (OIL), possible thin humic staining and occasional very fine relict amorphous organic matter. *Pedofeatures: Textural* –occasional void coatings/infillings of SMT 2a1; *Amorphous:* rare ~200μm-thick iron void hypocoatings, associated with thin relict root(?) channels; rare of iron impregnations of possibly once-humic sediment? *Fabric* –many fabric mixing, including v-shaped burrows, some 15mm wide, with broad 2mm thick burrows?? – a long line of later(?) root channel(?)	Context 40057 (Phase 1) South (E) 'Tilted block' Lowermost sequence of site Boundary zone between non-calcareous moderately poorly sorted, coarse silty and fine and medium sandy, glauconite medium sand-rich sediments with little fine material (40057), which upwards become mixed with moderately sorted coarse silts and fine sands, sometimes with fewer glauconite, and mixed with clasts and burrowed-in weakly humic clay (LOI=1.22%). Glauconite is moderately weathered with some little-weathered grains, and opaques include haematite. A relict thin (1.5-2mm) probable root channel is marked by iron hypocoatings; iron staining also affects traces of organic matter. *This is a moderately mixed junction between fine and medium non-calcareous glauconitic sands, and overlying silty glauconitic sands, and clayey silts, probably deposited as alluvium and recording diminishing energy. There has probably been some burrowing and rooting, the latter affected by secondary iron staining, which marks a minor amount of sediment ripening/soil formation. Clayey deposits were probably weakly humic originally. Context 40058 could not be sampled because the sediment monolith was not intact, but apparently clayey inwash into 40057 probably derives from overlying soliflucted 40058.*
MFT E4/SMT 3a3, (3a1)	M40418A	45-125mm 45-70mm SM: Heterogeneous with poorly sorted sands and fine sands (SMT 3a3), with coarse silt and coarsely mixed clay (depleted SMT 3a1); *Microstructure:* massive, finely laminated; 10% voids, fine packing voids and fissures; *Coarse Mineral* –C:F, 80:20, mainly well sorted coarse silts, with patches of less well-sorted fine to medium sands; few glauconite and very few coarse silt-size clay papules present. *Coarse Organic and Anthropogenic: Fine Fabric* – as SMT 3a1 and 3a3. *Pedofeatures – Amorphous*: trace amounts of iron staining and possible Fe-Mn fine nodules. *Fabric* – occasional broad burrows.	Context 40166 (Unit 4?)-40158 (Phase 7/6a) Context 40158 Sediments become less humic and contain less fine detrital organic matter (OM), being clayey deposits, but with marked iron-staining of organic traces.

Table A7.1 (continued 2)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		70-115mm: as MFT C1/SMT 5a1 (M40150B), with few sandy SMT 3a3 115-125: as MFT E3/SMT 6a2 (M40418B)	
MFT E3/SMT 6a2	M40418B	170-250mm SM: Heterogeneous; *Microstructure:* massive, partially laminated, 15% voids, fissures. *Coarse Mineral* – C:F, 60:40 (sandy) and 40:60 humic clays. *Coarse Organic and Anthropogenic* – examples of 5mm long horizontally oriented blackened plant material (eg, 3 thin [20-30µm-thick] monocot? leaf fragments?; occasional fragments and patches of reddish amorphous OM 1-3mm in size; many fine charcoal (100-250 µm). Fine Fabric – SMT 6a2: speckled and dotted brown to dark reddish brown (PPL), moderately low to moderate interference colours (open to close porphyric, grano-striate b-fabric, XPL), brown to dark brown (OIL), humic with very abundant amorphous and very fine charred OM. *Pedofeatures: Textural* – very abundant clayey pans (sedimentary muds) and channel infills (1+mm wide), and associated intercalations and void/matrix coatings. *Fabric:* –many thin burrows. 215-250mm As MFT E2/SMT 3a3, M40418C, below, but with increasing amounts of SMT 6a2 (humic clay containing very fine charcoal) BD (40158): 6.68% LOI	Contexts 40158-40040 (Phase 7/6a) Mainly laminated very humic clayey fine sands and humic clays, with abundant included fine amorphous organic matter and fine charcoal (100-250µm), and few fragments of amorphous peat. An example of a horizontally oriented 5mm long very thin blackened monocotyledonous leaf/leaves fragment occurs. Humic clays sometimes occur as clayey pans and infills. Minor thin burrowing has occurred. Markedly high LOI of 6.68%. *These are laminated peaty clays and peaty sands, horizontally deposited in low to moderately low energy conditions, allowing horizontal deposition of detrital leaves, fragments of pure peat and ubiquitous fine and very fine charcoal. Organic matter shows no sign of being ferruginised. Low energy (seasonal?) minerogenic peat formation associated with burned landscape – wildfires??*
MFT E2/SMT 3a3	M40418C	400-480mm 400-450mm (40158) SM: Homogeneous fine to medium sands (clayey channel fills); *Microstructure* –massive with some relict laminae (1-5mm); 40% voids, simple packing voids, open vughs and channels; *Coarse Mineral* – C:F, 90:10, moderately well sorted very fine, fine sands with medium angular and subangular sands and very coarse silt-size quartz, quartzite and feldspar, very few glauconite. *Coarse Organic and Anthropogenic* – many thin ferruginised amorphous OM stringers? *Fine Fabric* – as SMT 3a3 (iron-stained). *Pedofeatures* – occasional ~1mm clayey 'circular' channel fills. *Amorphous* –abundant ferruginisation, thin ironpan formation, some possibly pseudomorphic of OM. *Fabric* – many 0.5-1mm size thin burrows. 450-480mm (40039)	Contexts 40040-40025-40158 (Strat. Phase 7/6a) Moderately well sorted massive and sometimes laminated very fine, fine sands containing coarse silt and medium sand. Many thin burrows, examples of clayey inwash down fine (1mm) root(?) channels and very thin stringers of ferruginised OM (??) inwash. *Channel fine sands mainly, that were burrowed and rooted, and thus episodically/seasonally exposed. Possibly humic matter from above filtered down and became ferruginised. Clayey sediments above were introduced downprofile along empty relict root channels.*
MFT E1 /SMT 3a3, 3a4		SM – Homogeneous coarse silt-very fine sands (SMT 3a3), with clayey infills (SMT 3a4). *Microstructure* – laminated (0.5-2mm), 35%, simple packing voids, some vughs and fissures associated with laminae. *Coarse Mineral* – coarse silt-very fine sands, with C:F of 90:10. *Coarse Organic and*	Context 40039 Laminated moderately well sorted coarse silts and very fine sands, with patchy 'layer'/infills of clay with occasional ferruginiseed very fine organic matter and phytoliths present. Very thin ironpans associated with sandy laminae appear to be relict

Table A7.1 (continued 3)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		Anthropogenic– occasional very thin 30-50μm ferruginised amorphous layers (peat?) – now thin iron pans. *Fine Fabric* – SMT 3a4: speckled pale greyish brown to brown (PPL), moderately low interference colours (open porphyric, grano-striate b-fabric (textural pedofeatures?), XPL, grey, pale yellow to brown (iron staining – OIL), occasional very fine ferruginised OM and phytoliths present; *Pedofeatures:* Textural – abundant patchy void infills (cf SMT 3a4) and formation of embedded grains/fine sand inclusions; *Amorphous:* abundant ferruginisation of relict amorphous OM, and patchy iron staining of clayey infills. *Excrements* – possible rare very thin organic excrements associated with relict 'peat' laminae, now equally ferruginised.	amorphous OM and can involved very thin relict excrement pseudomorphs. *Fluvial coarse silts and very fine sands; perhaps seasonal (spring) alluviation with winter? period of clay deposition forming infills. Sand laminae also sometimes associated with thin peat formation and its partial working by small invertebrates. Coolish climate? Near channel alluviation.*
MFT D3/SMT 3a1, 3a2, 3a3	M40365A	50-130mm (context 40078-40099 boundary at 110mm) SM – Heterogeneous with mainly poorly iron-stained SMT 3a1, and frequent silty and fine sandy SMT3a3. *Microstructure* –massive (relict laminae/pans), with fine fissuring (medium prisms), 25% voids, fine fissuring and fine to medium channels. *Coarse Mineral*– as M40151B, with example of 2.5mm-size flint and 1.5mm-size quartz. *Coarse Organic and Anthropogenic* – very abundant fine root traces, some ferruginised and some as blackened remains (monocot?); occasional very fine to fine fragments of peat/plant (black and red in PPL, eg 1mm in size) ; *Fine Fabric*– as SMT 3a1 with very thin humic staining, rare to occasional ferruginised and blackened very fine OM. *Pedofeatures: Textural* – many pans, textural intercalations, associated with embedded grains and void coatings and infills (matrans); Depletion: occasional strongly iron depleted zones. *Amorphous*– rare amounts of weak yellowish staining and ferruginised OM; some as poor pseudomorphs of plant material/roots, possibly relict iron/sodium carbonate? *Fabric* –very abundant coarse fabric mixing (rooting disturbance as in monocot peat, mineral junctions, inwash of silty material etc). BD (40078): 2.44% LOI.	Context 40078-40099 transition (Phase 6c/6a) Weakly humic clayey sediment with fine organic fragments and (monocotyledonous?) root traces and common patches of partially bedded silty clay loam (40078) over iron-depleted clayey 40099. 40078 includes blackened relict peat/mocot plant/root fragments, up to 1mm in size (red and black under PPL); overall OM content reflected in 2.44% LOI. Textural intercalations and associated matrix coatings and fabric mixing associated with relict channels and fissures. *Weakly humic remains of putative junction between monocotyledonous peat and minerogenic sediments, with flood wash bringing in silts; hence mixing down along old root channels. Rooting down through waterlogged clayey sediment caused fabric disruption, mixing and intercalations. A period of moderate stasis, with flooding of inwash silts and peat growth?*
MFT B1/SMT 3a1, 3a2	M40365B	220-300mm SM– Moderately heterogeneous with very dominant iron-stained and iron-depleted clayey SMT 3a1 and very few fine and medium sandy SMT 3a3. *Microstructure* – massive, 30% voids (20% intrapedal), fine fissures. *Coarse Mineral* – C:F, as M40151B; more sandy SMT 3a3 can be focused along possible relict root channels. *Coarse Organic and Anthropogenic* – many traces of medium (max 5mm) roots. *Fine Fabric* – SMT 3a1 and 3a3, as M40151B. *Pedofeatures:* Textural – very abundant relict panning (~1mm thick diffuse laminae). *Depletion* – many iron-depleted areas, some	Contexts 40099 (Phase 6c/6a) Mainly iron-depleted clay, characterised by ~1mm-thick clay panning (sedimentation), with silt-rich clay loam along possible relict root channel fills, which are marked by iron staining and relict likely hypocoatings. Relict root features are 3-5mm wide; some show ferruginised traces/oxidised traces of probable pyrite framboids associated with roots. *Waterlogged clay sediments deposited as muddy pans, very low energy alluvial events/flooding. These were rooted by plants, possibly shrubs/*

Table A7.1 (continued 4)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		especially associated with old rooting. *Amorphous* – abundant moderate to strong iron staining.	*woodland(?) and more silty clay loam infilled these on decay.*
MFT B1/SMT 3a1, 3a2	M40365C	310-390mm Sample quite fragmented and also was probably part insect burrowed previously. SM – Heterogeneous with grey clayey SMT 3a1 and iron-stained SMT 3a2. *Microstructure* – massive?; fine fissuring and channels (10% voids?). *Coarse Mineral* – C:F (Coarse:Fine limit at 10μm), as M40151A and B. *Coarse Organic and Anthropogenic* – many traces of (sometime possible woody) roots (now ferruginised) up to 3mm in size. *Fine Fabric* – as M40151A; *Pedofeatures* – as M40151A.	Contexts 40103 (Phase 6c/6a) Central part of site Generally, iron depleted, very weakly humic clay, but with many ferruginised traces of roots, some possibly once-woody(?) up to 3mm in diameter. *Waterlogged lacustrine clay sediments acting as rooting medium for wetland and possible woodland plants.*
D1b/SMT 10a, 10b	M40196	85-165mm 1) Brownish layer: 85-135(155)mm (dominantly SMT 10a) 2) Greyish layer: 135(155)-165mm (dominantly SMT 10b) SM – Heterogeneous. *Microstructure* – massive, with curved horizontal fissuring, 10% intrapedal voids, fine channels and closed vughs. *Coarse Mineral* – as M40195. *Coarse Organic and Anthropogenic* – 1) 2 fire-cracked flint (5mm and 10mm-in size; calcined), strongly rubefied clay ~1mm (opaque, reddish brown under OIL, compared to yellowish orange surrounding iron stained soil), and rare fine rubefied clay/mineral and calcined grains. Fine Fabric – SMT 10a: speckled darkish brown (PPL), moderately low interference colours (open and close porphyric, speckled and grano-striate and uni-striate b-fabric, XPL), orange (OIL), trace amounts of very fine blackened OM/charcoal(?); SMT 10b: speckled greyish brown (PPL), XPL as SMT 10a, grey to pale yellow (OIL). *Pedofeatures* – very abundant textural intercalations, muddy laminae and void (sometimes closed vugh, polyconcave vugh) matrix coatings, also embedding large grains such as clacined flint fragment. *Amorphous* – very abundant iron staining in upper half.	Context 40100 (Phase 6) brownish over greyish This is a brownish clay loam, partially mixed with grey clay loam, and becoming more dominantly grey downwards. The microfabric is characterised by very abundant textural pedofeatures (intercalations, pans and matrix void coatings – and associated closed vughs) and iron staining. Fine channelling and fissuring affected the massive soil-sediment. Two fire-cracked flints (5mm and 10mm-in size; calcined), and an enigmatic embedded strongly rubefied clay clast (~1mm) occurs. Flints are also embedded in the soil-sediment matrix. *This is a muddy mixed clay loam, with mainly iron stained brownish sediment in the upper half of the slide and iron-depleted clay loam below. The upper part also shows mixed grey and brown microfabrics, and the inclusion of probable fire-cracked flints, and possible rubefied clay material, as two ~mm-size fragments and as a scatter of very fine rubefied material. These materials may be relict of a combustion zone, but have been eroded and fragmented by colluvial processes.*
MFT D1a/SMT 9a1 and 9a2 Over MFT D1b/SMT 9a1	M40195	130-210mm SM – Heterogeneous/broadly layered but with SMT 9a throughout, 1) 130-160mm: dusty clayey, 2) 160-185mm: fine clayey with clay clasts (SMT 9a2), 3) 185-210: sandy and gravelly clay. *Microstructure* – massive; 20% with curved planar voids/ fissures, collapsing vughs and planar voids and channels. *Coarse Mineral* – C:F, 1) 30:70, with coarse silt; 2) 50:50, with coarse silt and fine sand and coarse sand to gravel-size angular clay clasts (from CwF?); 3) 80-90:20-10, with coarse silt to very coarse sand and few gravel (max	Context 40100 (sand lens boundaries (Phase 6) This thin section is located along layered junctions between sandy microfacies (coarse silt, fine to very coarse sands with fine [max 5mm flint] gravel) and overlying a moderately, sandy clayey layer containing many fine gravel-size brownish clay clasts (as in M40196 [Context 40100] or Clay-with-Flints like?), and with upwards, a greyish clayey layer where textural intercalations, matrix void coatings and clayey pans are abundant. There is weak

Table A7.1 (continued 5)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		5mm)(ironstone, iron-stained clay also present); both weathered and freshish glauconite is present. *Coarse Organic and Anthropogenic* – possible inclusion of fine angular flakes. Fine Fabric – SMT 9a: dusty to speckled greyish to dark greyish brown (PPL), moderately low interference colours (open to close porphyric, speckled, grano- and striate b-fabric, XPL), pale greyish yellowish brown (OIL), rare very fine blackened/charred OM. SMT 9b (clay clast material): Contains 30% coarse silt and fine-medium sand, dark yellowish brown (PPL), low to moderately low interference colours (close porphyric, speckled, grano- and striate b-fabric, XPL), yellowish orange (OIL), and as 9a. *Pedofeatures: Textural* – occasional textural intercalations, muddy laminae and void (sometimes closed vugh, polyconcave vugh) matrix coatings (150-300µm-thick), increasing to very abundant upwards. *Amorphous* – abundant iron staining, sometimes possibly picking out relict organic fabrics(?).	to moderate iron staining throughout, possibly sometimes picking out relict amorphous organic matter. Both weathered and moderately fresh glauconite is present. Rare fine blackened/charred very fine organic matter occurs. *The thin section records a relatively high energy event/wash compared to the clayey deposits generally, with first sands and fine gravels being deposited, followed by sandy clays containing gravel-size clay clasts (eroded 40100 material [from elsewhere]/ a Clay-with-Flints -like material (Avery et al. 1959)), suggesting a lowering of energy and more muddy colluvial(?) deposition upwards. Lastly, muddy clayey sediments are deposited which are characterised by textural intercalations, matrix void coatings and clayey pans. Generally, this appears to be an upward-fining/decreasing energy sequence.*
MFT C4a/SMT 7a1, 7a3 (7a2)	M40194	320-400mm SM– Heterogeneous with dominant clayey SMT 7a1 (with silty variants), common (pale iron stained) SMT 7a3 and very few SMT 7a2 (speckled with trace amounts of very fine charcoal?). *Microstructure* – massive (coarse prisms?), 10% voids, fine channels and fissures. *Coarse Mineral* – as below; 2.1mm-size quartzite. *Coarse Organic and Anthropogenic* – trace amounts of very fine charcoal; very fine sand size burnt? mineral grains/flint? 2mm-size cracked flint. *Fine Fabric* – SMT 7a1: cloudy and dusty pale grey (PPL), moderate interference colours (open porphyric, speckled, uni-and grano-striate, XPL), pale grey (OIL), very poorly humic with rare very fine amorphous, blackened and charred OM, phytoliths present; SMT 7a2: finely speckled grey (PPL), moderate low interference colours (as 7a1), pale grey (OIL), very poorly humic with rare to occasional very fine amorphous, blackened and charred OM, phytoliths present; SMT 7a3: pale cloudy (ochreous speckled and dotted) yellowish grey brown (PPL), moderate interference colours (open porphyric, speckled, uni-and grano-striate, XPL), pale orange to orange (OIL), many to abundant fine (5-10µm) ferruginised amorphous OM/pyrite pseudomorphs? *Pedofeatures*: Textural –very abundant clayey intercalations; occasional silt concentrations. *Depletion* — occasional strong iron depletion, sometimes including fine fabric SMT 7a2. *Amorphous* – probable oxidised pyrite spheroids?; abundant weak Fe staining and many ferruginised OM/oxidise pyrite? *Fabric* – very abundant mixing of weakly stained/ferruginous microfabric SMT 7a3 (oxidised pyrite) BD (40100): 1.73% LOI, 0.179 mg g 1 phosphate-P.	Context 40100 (stones/artefact inclusions?) (Phase 6) Heterogeneous, massive, compact iron depleted clay and iron-stained clay (containing coarse silt and fine sand) probable 2mm-size fire-cracked flint. Characterised by textural intercalations (associated with uni- and grano-striate b-fabric), sometimes silty clay in nature, and patches and infills of yellow-stained clay with fine (5-10µm) ferruginised amorphous OM? (very fine nodules – possible pyrite pseudomorphs). Trace amounts of very fine charcoal, blackened detrital OM and phytoliths present; examples of possible burned mineral grains. Fabric mixing of two major microfabric types. *Muddy and likely physically disturbed sediment, which was generally iron-depleted (gleyed) but which once had organic sediment mixed in. The latter has been affected by possible pyrite formation (associated with relict OM) and ferruginisation of this material or the fine OM. Possible dung inputs and animal wallow (cf Unit 4u at Boxgrove freshwater pond?).*

Table A7.1 (continued 6)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth)* *Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
MFT C4b/SMT 8a1 and 8a2	M40193A	290-365mm SM – as below. *Microstructure* – as below, with prismatic fissuring – 30% voids (currently); closed vughs. *Coarse Mineral* – C:F, 40-60:60-40, poorly sorted coarse silt to medium, coarse, very coarse sand and example of rounded flint gravel (2.5mm) with bleached rim. *Coarse Organic and Anthropogenic* – root trace. *Fine Fabric* – as below. *Pedofeatures*: *Textural* – very abundant intercalations and associated closed vughs, for example. *Amorphous* – many moderate iron staining, with ferruginised organic very thin excrements in root trace/channel. *Excrements* – trace of organic very thin excrements in root trace.	Context 40100 (Phase 6) (southern end of site?) Similar to below, but more poorly sorted fine to coarse sands and sandy concentrations. Very abundant textural intercalations, with associated closed vugh formation. Fewer (many) and more weakly iron stained fabrics. Example of fine gravel and root trace with ferruginised once-organic very thin excrements were noted. *Muddy trampled(?) water-saturated sediments containing higher amounts of poorly sorted sands, compared to below; perhaps as the result of slightly increasing episodic fluvial activity(?).*
MFT C4b/SMT 8a1 and 8a2	M40193B	370-450mm SM – Heterogeneous, as M40194 with SMT 8a1 and 8a2, with three broad layers of clayey fine sand, centre 20mm characterised by textural pedofeatures. *Microstructure* – massive, 15% voids, fine channels, partially collapsed (?) fissures, vughs. *Coarse Mineral* – C:F, 40:60. *Coarse Organic and Anthropogenic* –400μm-size calcined flint fragment; 8mm-size angular fire-cracked(?) flake with traces of rubefication. *Fine Fabric* – SMT 8a1 (as 7a1) and 8a2 (as SMT 7a3), both with 40% sand-size coarse mineral material. *Pedofeatures* – *Textural*: very abundant clayey infills eg in 3mm wide infills along junction between upper and lower layers, and intercalations throughout. *Amorphous* – very abundant iron staining – weak to strong – especially concentrated in central layer.	Context 40039 lower (Phase 6) (southern end of site?) Similar to M40194 but more sandy, with three c 20-25mm thick layers of clayey fine sand (40% fine sand), with textural clayey intercalations and Fe staining throughout, but concentrated in central layer where there are clay infills up to 3mm wide and an irregular boundary. A 400μm-size calcined flint fragment and a 8mm-size angular fire-cracked(?) flake (traces of rubefication were noted. *Layered muddy fine sand deposition, with for example marked iron staining, clayey intercalations and clayey infills, possibly indicative of trampling. Artefact inclusions indicate human presence.*
MFT C3b/SMT 6a1	M40149	350-430mm As 40099 in M40150A, below, with 2mm-size angular flint fragment (flake?) occurring as an embedded grain; trace amounts of very fine fragments of amorphous OM (max 150μm) in fine channels towards upper part of thin section. SM – Heterogeneous; *Microstructure*: as below, fissured, 30% voids. *Coarse Mineral* –as below. *Coarse Organic and Anthropogenic* – trace amounts of amorphous OM; possible flint flake; *Fine Fabric:* SMT 6a1. *Pedofeatures* – as below. *Textural* – abundant sedimentary clayey intercalations, including 4mm-thick curved layer/fill at 410mm. *Amorphous* – trace amounts of void hypocoatings and OM pseudomorphs. *Fabric* – very broad burrow (?) with collapsed thin excrements.	Context 40078-40099 interface (Phase 6d/6c/6a) 40099 – 6a Iron depleted clay, as below, with abundant sedimentary clayey intercalations, including a 4mm-thick layer/fill at 410mm depth. A possible 2mm-size flint flake is present, as an 'embedded grain'. Near the top, trace amounts of amorphous organic matter inclusions occur in channels. Very weak trace amounts of iron hypocoatings occur. *Continued muddy lacustrine sediment accumulation, with again a possible flint flake fragment occurring as an embedded grain suggesting it sank down under muddy conditions. Inclusions of preserved amorphous organic matter may stem from inwash from overlying contexts (40078?).*
MFT C3a/SMT 6a1	M40150A	220-295mm 220-240(275)mm	Context 40099-40103 transition (Phase 6d/6c/6a); 6c over 40099 - 6a

Table A7.1 (continued 7)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		SM – Homogeneous SMT 6a1. *Microstructure* – massive, fissured, poor prisms, 15% voids, very fine fissures and channels, to medium-size. *Coarse Mineral* – as below, but with 12mm-size angular fragment of flint (flake?). *Coarse Organic and Anthropogenic* – 12mm-size flint flake?; rare blackened root traces (monocot wetland plants?). *Fine Fabric* –cloudy and finely speckled greyish yellow (PPL), moderate interference colours (very open porphyric, speckled and weakly mosaic and striated b-fabric (grano-striate/embedded grains), XPL), pale grey with white areas (clay depleted/weather coatings and infills); very weakly humic with occasional very fine detrital blackened and brown OM, possible trace amounts of charcoal. *Pedofeatures:Textural* – occasional intercalations and rare matrix infills (of collapsed voids?). *Depletion* – very abundant iron depletion throughout; leached/iron depleted fissure and channel hypocoatings (very acid/strong gleying effect). BD (40099): 2.26% LOI, 0.194 mg g 1 phosphate-P.	Iron depleted, very weakly humic clay containing rare detrital fine OM, blackened (organic) monocot? root traces and traces of charcoal. It includes a possible flint flake (12mm). Occasional intercalations and matrix infills, and strongly leached fissure and channel hypocoatings. Bulk analyses record 2.26% LOI, 0.194 mg g 1 phosphate-P; Fe-depleted (SEM/EDS). *Massive iron-depleted lacustrine clay sediments, showing rooting (by wetland plants – blackened organic monocotyledonous root traces), and inclusions of detrtital OM including trace amounts of very fine charcoal. Anomalous 12mm size flint fragment and character suggest it may be a flint flake/of anthropogenic origin; possibly naturally sunk down in muddy sediments. Strong leaching has affected the sediment, hence moderate OM preservation and markedly low phosphate content.*
MFT C2/SMT 5a1		240(275)-295mm Very similar to 40103 in M40150B, with marked concentration of iron staining in uppermost 10mm, as a series and concentrations of 1mm sub-parallel bands (sloping at 45 degrees in thin section sample). These bands and underlying sediment also include very abundant poorly pseudomorphic root traces. In topmost 5mm, 1mm-size rounded clay (soil?) clasts occur with darkish reddish brown finely ganular clay/once-humic soil infilling the voids (often more ferruginous). Iron-stained root traces and mottles possibly pseudomorphic of once-humic (now-ferruginised) soil (burrows and root channels) is present. An atypical 6mm round flint gravel clast is present; trace amounts of very fine charcoal. Pedofeatures – as M40150B, with trace amounts of void matrans forming from textural intercalations. BD (40103 – Fe pan): 3.63% LOI, 1.77 mg g 1 phosphate-P. SEM/EDS : 10 analyses of ironpan and iron depleted zones (Table 5.2)	40103 - 6a As below, but with a (sloping?) concentration of iron staining along uppermost 10mm – forming an iron pan. This is partially made up of a concentration once-humic burrows and channel (fills), and in places 1mm-size 'soil' clasts cemented by infills of sometimes strongly ferruginised (once-humic) fine soil (?). Trace amounts of very fine charcoal and a 6mm example of rounded flint gravel. Marked high LOI (3.63%) and enriched phosphate-content (1.77 mg g 1 phosphate-P); Fe and P-enriched (SEM/EDS). *Possible ripened sediment/soil surface, showing 1) slight truncation in places, 2) traces of rooting and small mesofauna burrowing, 3) very locally eroded and transported ripened soil/sediment clasts, and 4) local inwash of humic fine soil. This appears to be a possible buried ripened soil which may have had short-lived woodland (?) cover, before being affected by inundation and renewed sedimentation (40099). (Gentle inundation caused slaking and structural collapse/formation of intercalations and void matrans, and erosion of local soil/sediments, and inwash.) Buried 'topsoil' interpretation is consistent with LOI and enriched phosphate probably also reflects this and 'geogenic' concentration of P due to groundwater movement.*
MFT C1/SMT 5a1	M40150B	300-375mm SM – Homogeneous SMT 5a1. *Microstructure* – massive, crack and relict prismatic, 25% voids, very fine to medium (1mm) curved planar voids and fissures, fine to coarse (2.5mm) extant and relict channels. *Coarse Mineral* –	Context 40103 (Phase 6d/6c/6a); 6a Massive clay containing small amounts of coarse silt, fine and medium sand. Clay has fissures and relict channels, some with

Table A7.1 (continued 8)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		C:F (Coarse:Fine limit at 10 μm), 20:80; moderately sorted coarse silt to fine to medium sand, as below. *Coarse Organic and Anthropogenic* – occasional (to possibly very abundant?) ferruginised broad and fine woody(?) root traces (0.5-2.5mm). *Fine Fabric* – SMT 5a1: typically pale yellowish brown (PPL; cf. depleted and iron-stained), moderate interference colours (very open porphyric, speckled and occasionally grano-striate ('embedded grain'), XPL), grey to pale yellow (OIL), very weakly humic with trace amounts of phytoliths. *Pedofeatures: Textural* – occasional textural intercalations, rare channel infill of iron depleted clay (plus partial clay destruction). *Depletion* – very abundant iron depletion in matrix and as channel hypocoatings associated with 'roots'. *Amorphous* – very abundant iron impregnation affecting relict roots and forming parallel lines/possible root-like stains. *Fabric* – many apparent slickenslide-like features (clay orientation); *Excrements*: possible rare traces of iron pseudomorphs of very thin excrements in root channels. BD (40103 – Fe mottling): 3.42% LOI, 0.538 mg g 1 phosphate-P	likely ferruginised (woody) root pseudomorphs (0.5-2.5mm; with traces of very thin ferruginised excrements). Sediment is mottled with iron depleted and iron stained areas and other possible root stains. Some channels have iron-depleted hypocoatings; example of channel with leached/iron-depleted clay fill. *'Basal' lacustrine clay sediments, containing scattered small amounts of coarse silt, fine and medium sand – possibly locally blown-in/washed-in. This clay acted as a rooting substrate, possibly for woodland, as suggested by the presence of woody roots (some being dominated by small invertebrate mesofauna). The sediment was also affected by shrinking and swelling (an effect of woodland growth?), marked iron depletion (and possibly clay break down at times) and iron staining – hydromorphic/gleying effects. Enigmatic high measurements of LOI possibly relate to woody root traces, while enhanced P is probably secondary and linked to iron-staining.*
MFT B2/SMT 3a1(3a3)	M40151A	70-150mm (finely cracked dried out sample) SM – Moderately heterogeneous with very dominant iron-stained and iron-depleted clayey SMT 3a1 and very few fine and medium sandy SMT 3a3. *Microstructure* – massive (currently very finely fissured), 30% voids, fine fissures. *Coarse Mineral* – C:F, as M40151B, with 3a1, C:F=30:70 containing fine and medium sand. *Coarse Organic and Anthropogenic* – possible traces of rare thin roots. *Fine Fabric* – SMT 3a1 and 3a3, as M40151B. *Pedofeatures* – *Depletion*: many iron-depleted areas; *Amorphous*: very abundant moderate to strong iron staining, strongest staining describes curved 'fill'(?); possible root stains. *Fabric* – 30mm deep by 4.5mm wide curved 'fill'; very broad burrow fills (focus of sands); possible thin weak iron stained burrows.	Upper-context 40039 (Sub-phase 6a) (Overlying 40103 partially occurs as strongly iron-depleted clay in uppermost 20mm) Massive non-calcareous clay sediments (with few sand inclusions), with marked iron-staining, with a infill features, burrows, once humic peds and excrements, demarcated by strong iron-staining. Sands are only present in rare broad burrow fills. Clays seemingly less humic compared to lower down, and only very fine charred/blackened detrital OM noted. *A minerogenic wetland clayey sediment appears to have developed as a topsoil (hydroseral succession?), with burrows, peds, roots and excrements of relatively humic soil showing marked iron impregnation. Overlying iron-depleted 40103 is probably a flood clay.*
MFT B1/SMT 3a1, 3a2, 3a3	M40151B	320-410mm SM – Heterogeneous with dominant clayey (SMT 3a1), common ferruginous clayey (3a2) and sandy (3a3). *Microstructure* –massive with fissures/crack microstructure (residual bedding and fine laminae); 30% voids, including coarse fissures, but only 20% with fine cracks in matrix; fine channels and vughs. *Coarse Mineral* – C:F, SMT 3a1=10:90 or 30:70 (once laminated silts and clay?), well sorted coarse silt-fine sand quartz, feldspar, mica (opaques include limonite); 3a2, C:F=0/10:100/90 (once-humic?); SMT 3a3, C:F=80/90:20/10, moderately well sorted fine and medium sands; 700 μm –size mica fragment. *Coarse Organic and*	40039 (Sub-phase 6a)(Basal clay etc) Part layered, part coarsely mixed non-calcareous clays, silty clay, fine and medium sands and ferruginised once-organic sediment; silty clays are composed of mixed silt and clay fine laminae. Charcoal as both rare fine (eg. max 800 μm-size monocot charcoal) and occasional very fine material occurs alongside very fine blackened (detrital OM), and phytoliths are present; patches of totally ferruginised organic matter including plant fragment

Table A7.1 (continued 9)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		Anthropogenic – ~350 µm-size charcoal fragments (eg of 800 µm-size monocot charcoal?) and finer, trace in lower part becoming rare alongside occasional upwards alongside very fine blackened detrital material (uppermost clay layer); trace amounts of blackish and reddish brown humified peat including 1mm-size fragment. *Fine Fabric* – SMT 3a1: cloudy very pale brownish grey (PPL), moderately low interference colours (open porphyric, stipple speckled with striated b-fabric, XPL), grey (OIL – iron-stained areas are orange to brown), occasional to many very fine blackened detrital, and charred OM, trace of brownish amorphous OM; phytoliths present. *Pedofeatures: Textural* – many textural intercalations, associated with embedded grains and void coatings and infills (matrans 150-200 µm thick; some stained yellowish – see amorphous). *Depletion* – occasional strongly iron depleted zones; *Amorphous*: rare amounts of weak yellowish staining and possibly associated sand size yellowish, isotropic nodules embedded within same matrix (FeP?); very abundant moderate to strong iron impregnation of fine clayey matrix and once-organic sediment, with fine iron nodules (~30 µm), granular or pseudomorphs? some as poor pseudomorphs of plant material/roots, possibly relict iron/sodium carbonate? *Fabric* – very abundant coarse fabric mixing. BD (40039): 1.88% LOI, 0.556 mg g 1 phosphate-P SEM : 17 analyses of iron-depleted and iron-stained areas (Table 5.2).	pseudomorphs occur (current LOI is 1.88%). Sediments also characterised by textural intercalations and associated matrix embedded grains and matrix void coatings, some stained yellow; rare fine sand-size yellow isotropic nodules/infills are probably iron phosphate formations (see EDS Table 5.2; sediment characterised by slight phosphate enrichment, 0.556 mg g 1 phosphate-P). *Once bedded and laminated weakly humic clays, silts, and occasionally medium sands, with patches (inclusions) of peat(?), now ferruginised with plant pseudomorphs; wetland (marsh) locally burned monocotyledonous vegetation(?). Fabric mixing and associated intercalations, matrix coatings, and yellow staining and nodule formation (FeP), alongside slight phosphate enrichment may infer animal trampling and defecation.*
D2/SMT 4a2	M40323A	0-70mm SM – Homogeneous SMT 4a2. *Microstructure* – massive, diffuse <1mm thick laminae upwards, with embedded/cemented 0.5mm-size subrounded clasts in uppermost 5mm; 10% voids, very thin fissures, channels and vughs. *Coarse Mineral* – as below, but very coarse sand and gravel-free. *Coarse Organic and Anthropogenic – Fine Fabric*: SMT 4a2: speckled and cloudy darkish yellowish brown (PPL), moderate interference colours (close porphyric, speckled and grano-striate b-fabric, XPL), very pale yellowish grey (OIL), generally very weakly humic with rare very fine OM, but upwards 'humic pans'(?) of now-ferruginised; trace amounts of phytoliths. *Pedofeatures: Textural* – as below, with matrix pans upwards associated with laminae; *Depletion* – strongly iron-depleted fine matrix. *Amorphous* – abundant iron impregnation associated with relict fine rooting and once-humic <1mm-thick pans (thin iron panning).	(Context 40039 Upper (Tufaceous channel), Phase 6b/6a); 6a Massive, moderately well sorted clayey fine and medium sand, with in the main strongly iron-depleted fine fabric, which is generally very weakly humic, but appears, upwards, to have a series of thin (<1mm) once-humic (now-iron-replaced) pans. There are trace amounts of phytoliths present. In uppermost 5mm a scatter of 0.5mm-size clay clasts occur. Iron also picks out many traces of probable fine rooting and voids around these clasts. The diffuse boundary to 40070 is marked by intercalated and curved thin ironpans and iron stained burrows; clay infills some burrows and channels. *Moderately low becoming low energy fine and medium sandy colluvial deposition, marked by thin rooting and periodic organic matter accumulation (seasonal very thin peat formation?). Lastly inwash of eroded clay clasts is recorded. This all occurred under waterlogged conditions (hence iron depletion and organic matter panning), perhaps as the channel silted up(?). The sediment was affected by secondary but penecontemporaneous iron staining.*

Table A7.1 (continued 10)

Microfacies type (MFT)/ Soil microfabric type (SMT)	*Sample No.*	*Depth (relative depth) Soil Micromorphology (SM)*	*Preliminary Interpretation and Comments*
		Diffuse boundary from 40039 Upper to 40039 Middle at ~60mm.	The ironpans along the diffuse boundary pick out micro gullying and erosion, typical of some Pleistocene brickearth deposits; clay has washed down from overlying contexts into later burrows and channels. Context 40039 Middle as below in M40323B
MFT D1/SMT 4a1	M40323B	70-130 mm SM – mainly homogeneous fine and medium sandy SMT 4a1, with few subhorizonal intercalations of clayey SMT 4a1. *Microstructure* – massive, with fine bedding laminations and clayey intercalations; 20% voids, fine vughs and channels (root traces?). *Coarse Mineral* – C:F, 80:20, moderately sorted fine and medium sand-size quartz, quartzite, feldspar and mica, with very few coarse sand and gravel (2-2.5mm; quartzite and 3mm flint – trace of clay-coating/embedded grain, traces of rubefication/calcination); very few glauconite. *Coarse Organic and Anthropogenic* – possible traces of burning on flint gravel; Fine Fabric: SMT 4a1, as SMT 3a1 – see M40151B, granostriate b-fabric, with only rare very fine amorphous OM and trace amounts of very fine charcoal. *Pedofeatures: Textural* – occasional clayey intercalations (cf grano-striate), void infills. *Amorphous* – rare iron staining of relict rare very broad burrows/channels (edge only in thin section) and sediment layer hypocoatings. *Fabric* – abundant traces of very broad burrowing (6+mm), with curved infills associated with penecontemporaneous clay inwash.	Context 40039 Middle (Tufaceous channel), (Phase 6b/6a); 6a Massive, moderately well sorted clayey fine and medium sand (very few fine gravel), with relict sedimentary laminae, traces of very broad burrows and penecontemporaneous clayey inwash and intercalation and grano-striate formation. Clayey intercalations may show evidence of rooting – preferential channel formation. Rare iron staining (of edge of very broad burrow?) and sedimentary laminae hypocoatings. *Moderately low energy muddy fine and medium sandy colluvial deposition, with penecontemporaneous very broad burrowing and clayey infilling. Minor secondary iron staining.*

Appendix 8

Site sequence geometry and sub-surface structural geology

by John Hutchinson

The Site

The site is a rescue dig associated with roadworks for the HS1 rail network. It is situated around Grid Ref. TQ 613 732 on the Upper Chalk. The classic Swanscombe Pleistocene exposures lie between 1.2 and 2.5km to the north and north-west.

The 'solid' strata in the vicinity are, in upwards order:

1. The Upper Chalk, which everywhere underlies the site (dip within a couple of degrees of the horizontal)
2. The Thanet Beds, with the Bullhead Bed at their base
3. The Woolwich Beds
4. The Blackheath Beds
5. The London Clay that caps the hill in Swanscombe Park 1km west of the site.

The Quaternary here has not yet been fully logged and worked out. The interim names of units currently used on site (very broadly in upwards order) are:

A. Soliflucted Chalk (Coombe Rock)
B. Reworked Thanet Beds
C. Lacustrine deposits
D. Reworked fine sands and silty clays with a few pebbles, probably derived largelyfrom the Thanet, Woolwich and Blackheath Beds
E. Gravels and sands (apparently little disturbed by the disturbances describedbelow), possibly from a braided river
F. Soliflucted London Clay and associated head

The 1:50,000 geological map shows a terrace of Boyn Hill Gravel about 1.5km NNW of the site and Alluvium at its foot. The relationships of these and the classic sections at Swanscombe to the geological exposures on the Southfleet Road site have yet to be established.

The main exposures seen, from the site office, northwards towards the newly diverted access road are:

a. Small exposure of soliflucted Chalk, overlain by B (above)
b. Rotated block of intact Chalk with contiguous Bullhead Bed and Thanet Beds. Dip of contact (bedding) very steeply (probably 70 to 80O northwards.
c. In cut slope to W, various (unlogged) reworked materials, probably including London Clay
d. In area to the east of c) excellent exposures of a double basin structure, rather fully exhumed , with additional cross trenches. The best exposed basin (to the W) is delineated by a layer of C. Its infill, chiefly D overlain by E, has been largely removed by archaeological excavations. This basin is about 16m across, with a depth (amplitude) of about 3m. The axes of this and the other basin run roughly nort–south. The basins are slightly asymmetrical, with steeper dips on their western limbs. The maximum dips in these approach the sub-vertical. The southern trench allows a good view of the basins in cross section. They are very regular, apart from some secondary undulations, and are virtually unbroken by faults. The deformed clayey layer, C, is continuous across each basin and is underlain by a compact fine sand, probably B. Each basin appears to be elongated in roughly a N-S direction and to peter out at each end. Towards the north end of the eastern basin apparent loading structures were seen. These are of very small scale, around 2m across, in comparison with the two basin structures.
e. We also looked at a new road cutting to the SW of the main site. Soliflucted London Clay is exposed its south face.

No plans, face logs or sections, or drawings showing their general inter-relationships, were seen during the visit; these were currently being produced.

Possible origins of the above features

Dips in the solid geology of the central and eastern parts of the London Basin are very low, generally not exceeding a few degrees. Against this background, the high dips observed in some of the Southfleet Road excavations, both in the Chalk and in the overlying Pleistocene deposits, are remarkable and apparently anomalous.

The main processes in southern England which can produce steep dips are reviewed briefly below:

Tectonics

Dips in the Chalk as high as 55° occur on the southern limb of the London Basin at the Hog's Back (Sumbler 1996) and, further south, approach the vertical on the south side of the Hampshire Tertiary Basin in the Isle of Wight.

The chief features against the double basin at our site being of structural origin is its location in an area of sub-horizontal dip, its very local nature and the apparent absence of hinge structures between the two basins.

Superficial valley disturbances

A wide variety of superficial valley disturbances exists, which is reviewed by Hutchinson (1991; 1992). These can produce local dips of 70° or more in valley bulges and are widely distributed in the Jurassic outcrop of central England and in the Weald (Hutchinson 1992). However, they require the valley to be underlain by a thick argillaceous stratum.

The absence of such a stratum beneath the Southfleet Road site, its location away from the axis of the local valley and the very local nature of the observed anomalous features rule out an explanation depending upon the above mechanisms.

Pingos

Relict pingos, chiefly of open type and generally (but not always) more or less circular or oval in plan, are common in southern England and Wales. Some are reported to have diapiric structures in their lower parts that can result in steep dips. Pingos are frequently found in clusters towards the foot of slopes, particularly if artesian groundwater pressure is present.

While some of these criteria may be fulfilled at Southfleet Road, the continuity of the beds, especially B and C, across the basins and the absence of boggy, peaty infills argue strongly against a pingo origin.

Landsliding

Pressure exerted by the toe of a landslide can produce deformation, folding and faulting of its lower parts and of the resisting ground. An example at Lyme Regis is described by Hutchinson and Hight (1987), but the effects extend no more than about 5m below ground level.

To judge better whether a slide sufficiently deep-seated to affect the area of the basins could have occurred at our site, one should draw a W – E section through areas c and d, picking up the basin structures and the geology and showing as far as possible the original natural ground surface. My impression on site was that, apart from the London Clay, most of the deposits overlying the Chalk are firm and granular and difficult to develop a major slide in which could penetrate down to or below the level of the basins. Furthermore, no slip surfaces were seen there and the basin structures themselves do not correspond to the passive style that one would expect in a slide toe area.

Frost-heave and periglacial solifluction

While both these processes can result in considerable deformation of the ground, they are too shallow to explain the Southfleet Road structures.

Solution of the Chalk

Solution pipes, swallow holes and solution dolines are numerous in the Chalk, especially around the margin of London Clay capped hills (the umbrella effect). The work of Higginbottom and Fookes (1970) and Jones (1981) indicate that the extent and magnitude of solution effects in the Chalk have been underestimated. The former authors report an apparent concentration of solution features on the route of the M40 motorway through the Chilterns, which in some cases are underlain by linear depressions in the Chalk surface as deep as 15m below the general Chalk surface level. The latter author reports particularly severe solution beneath a cover of Blackheath Beds around the southern outskirts of London and a concealed, irregular rockhead on the North Downs and, to a lesser extent, the Chiltern Hills. He concludes that the high, steep-sided pinnacles of Chalk often found beneath the Blackheath Beds and the well-known pipes exposed at Lenham represent rather dramatic examples of solutional forms widely developed on chalklands with a thin cover of superficial deposits. Good reviews of karst development and subsidence on the Chalk outcrop in England are provided by Edmonds (1983; 1988).

Both this background and the detailed local geology point to the solution of Chalk as by far the most likely mechanism producing the exposures b and d. In the former case it is not abnormal to have two solution features adjoining each other or for them to have a linear tendency. It will be interesting to see if this parallels a regional joint direction in the Chalk. In the latter case it is suggested that the exposure represents a fallen karstic pinnacle of Chalk capped by the lower Thanet Beds. The intact nature of the Chalk/Thanet beds contact may indicate that the ground was frozen at the time of collapse (the maximum depth of permafrost here is estimated by Hutchinson (1991) to lie between about 30 and 60m).

If the above conclusions are correct, the surface of the Chalk bedrock should be highly irregular. This should be checked by geophysics and/or closely spaced borings.

Appendix 9

Amino acid dating

by Kirsty Penkman, Victoria Morris and Richard Allen

INTRODUCTION

Advances in Quaternary Science during the past few decades, particularly with respect to absolute dating methods and the correlation of terrestrial stratigraphic sequences with oxygen isotope records (ie major climatic signals) interpreted from the geochemical analysis of deep sea sediment cores, have provided an opportunity to develop a high resolution chronology of human occupation and activity over the past 600,000 years or so. This report details attempts to obtain age estimates using amino acid racemization (AAR).

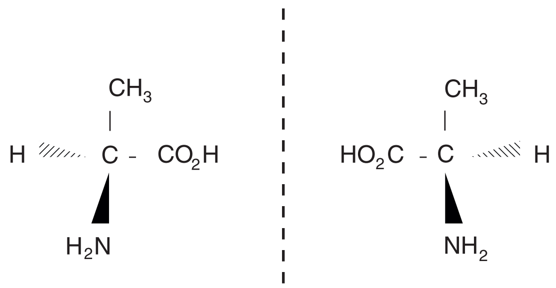
Amino acid analyses were undertaken at the York Laboratory (NEaar) from key horizons. This involves isolating the intra-crystalline protein fraction of two biominerals: the calcitic opercula from the fluvial gastropod *Bithynia tentaculata*, for which an excellent and growing database of protein degradation data has recently been assembled (Penkman *et al*. 2008b). This laboratory has been developing an improved methodology for the technique, and studies are ongoing to calibrate the amino acid data with reference to other dating techniques.

Amino acid racemization geochronology

A new technique of amino acid analysis has been developed for geochronological purposes (Penkman 2005; Penkman *et al*. 2007; 2008), combining a new Reverse-Phase High Pressure Liquid Chromatography method of analysis (Kaufman and Manley 1998) with the isolation of an 'intra-crystalline' fraction of amino acids by bleach treatment (Sykes *et al.* 1995). This combination of techniques results in the analysis of D/L values of multiple amino acids from the chemically-protected protein within the biomineral; enabling both decreased sample sizes and increased reliability of the analysis. Amino acid data obtained from the intra-crystalline fraction of the calcitic *Bithynia* opercula has been found to be a particularly robust repository for the original protein. This has enabled an increased level of resolution and therefore this material has been focused on in this study.

Theory

Amino acids, the building blocks of proteins, occur as two isomers that are chemically identical, but optically different. These isomers are designated as either D (dextrorotary) or L (laevorotary) depending upon whether they rotate plane polarised light to the right or left respectively (Fig. A9.1). In living organisms the amino acids in protein are almost exclusively L and the D/L value approaches zero. D-amino acids are synthesised by some organisms; they are found free in invertebrate body fluids where they play a role in osmoregulation and can occur peptide bound in bacterial peptidoglycan, where part of their function is resistance to proteases. The potential application to geochronology arises from the fact that after death amino acid isomers start to interconvert. This process is commonly termed racemization. In time the D/L value approaches one. The proportion of D to L amino acids is therefore an estimate of the extent of protein degradation, and if this is assumed to be predictable over time can be used to estimate the age of a sample. Other indications of protein decomposition, such as the degradation of unstable amino acids, can also be used to estimate age.



L-Alanine D-Alanine

Figure A9.1 Figure 1: L- and D- amino acid structure

Mechanisms of racemization

The rate of racemization is governed by a variety of factors, most of which have been studied in detail only for free amino acids. North East amino acid racemization (NEaar) analyse the intra-crystalline amino acid fraction and in this way, within a closed environment in which other factors (water content, concentration of cations, pH) are constant, the extent of racemization is a function of time and temperature. Over a small geographical area, such as that represented in this study, it can be assumed that the integrated temperature histories are effectively the same. Any differences in the extent of decomposition of protein within the sample are therefore age-dependent.

Intra-crystalline protein decomposition

The organic matter existing within individual crystals (intra-crystalline fraction) is believed to be a more reliable substrate for analysis than the whole shell (Sykes *et al.* 1995; Penkman 2005; Penkman *et al.* 2008). The initial bleaching step in the recovery of the intra-crystalline fraction removes both secondary contamination and the organic matrix of the shell. This organic matrix degrades and leaches at an unpredictable rate over time, leading to variation in the concentration and D/L of the amino acids. Thus, as appears to be the case in ostrich eggshell (Miller *et al.* 2000), the D/L values of amino acids in the intra-crystalline fraction of shells have been analysed; in the case of ostrich eggshell no bleaching step was used. The molluscan racemization data reported therefore contrasts with previous work that examined D/L values from whole mollusc shells containing both intra- and inter-crystalline material.

This isolation of the intra-crystalline fraction is believed to provide a closed system repository for the amino acids during the burial history of the shell. Only the amino acids within this fraction are protected from the action of external rate-affecting factors (except temperature), contamination by exogenous amino acids and leaching. Amino acids within the whole shell are not protected and can be leached out into the environment. Figure A9.2 shows a schematic of the intra-crystalline fraction with respect to the whole shell. The low level of Free amino acids observed in the inter-crystalline fraction of unbleached samples (Penkman *et al.* 2007) indicates that these have been lost through diagenesis, and as these tend to be more highly racemised than the Total fraction, this loss would lead to a lower than expected D/L for the Total fraction of the whole shell.

Traditionally AAR studies targeted a single amino acid racemization reaction, that of L-isoleucine to D-alloisoleucine (A/I), due to the technical ease of separation and its slow rate of racemization. The approach used in this study diverges from this, as dates are derived from the analysis of multiple amino acids. Whilst racemization rates differ between individual amino acids, they should be highly correlated in a closed system. By linking together different amino acids, and then linking this to a temperature driven model of decay, which includes hydrolysis, racemization and degradation, the extent of protein degradation can be derived. The pattern of decomposition appears to be different between mollusc genera, requiring separate models for each genus or species studied.

Once a closed system inside mollusc shells has been isolated, then the kinetics of protein decomposition are much simpler to predict. In this laboratory the concept of age estimation using the extent of overall Intra-crystalline Protein Degradation (IcPD) has been devised, which links the hydrolysis, racemization and decomposition of all the amino acids isolated by this method. The concept behind the IcPD is to combine multiple information from a single sample to derive an overall measure of the extent of diagenesis of the protein in that fossil. Similar ideas have been used before, although not in such a comprehensive way (Wehmiller *et al.* 2010). Divergence from the normal in a plot of A/I vs Gly/Ala is thought to indicate leaching in molluscs (Murray-Wallace and Kimber 1987). Kaufman (2000)

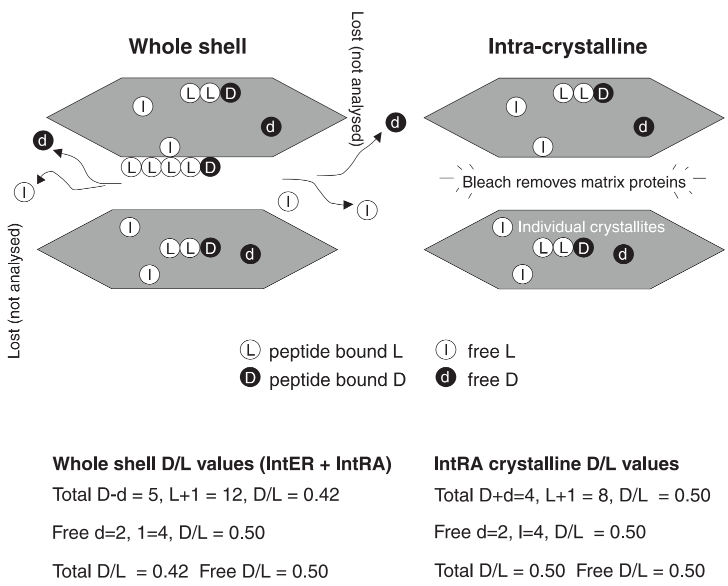


Figure A9.2 Schematic of intra-crystalline amino acids entrapped within carbonate crystallites. Unlike the proteins of the organic matrix between the crystallites, which leach from the shell with time, in a closed 'intra-crystalline' system the amino acids are entrapped. Thus the relationship between the DL ratios of different amino acids and between free (non-protein bound) and total (both free and originally protein-bound amino acids, released by acid hydrolysis) amino acids is predictable. Analysis of the whole shell would result in lower than expected D/L for the total fraction, due to the loss of the more highly racemised frees.

used ratios of Asx to Glx to screen out samples with any unusual values.

In a closed system, it should be possible to predict the relationship between geological time and IcPD increase, using not just racemization but other measures of protein decomposition, such as total and relative concentrations. It follows from the innovations above that, assuming sampling is from an idealised closed system, the pattern of protein decomposition governs the observed racemization of (a) free amino acids and (b) the total system, (c) the percentage of free amino acids and (d) the total concentration of amino acids.

This model can also be used as a method of assessing the internal reliability of each biomineral used and to determine how closely these substrates approximate to a closed system. Subsequently palaeotemperature information can be included and estimates made of the link between degradation and absolute age in environments with fluctuating temperatures. If an accurate temperature model is used, then age estimates can be derived directly from the IcPD data, although the results presented here do not incorporate any palaeotemperature information and are presented simply as a relative dating tool.

MATERIALS AND METHOD

Amino acid racemization (AAR) analyses were undertaken on *Bithynia tentaculata* opercula:

- Two individual opercula from Southfleet Road, context 40078, <40275>, Bulk SV sample (NEaar 6433-4; SFR4Bto1-2)
- Three individual opercula from Southfleet Road, context 40143, <40282/C/0-2>, mollusc subsample from monolith (NEaar 6430-2; SFR3Bto1-3)
- Three individual opercula from Southfleet Road, context 40144, <40295/C>, mollusc subsample from bulk SV sample (NEaar 6435-7; SFR5Bto1-3)
- Three individual opercula from Southfleet Road, context 40144, <40333>, bulk SV sample (NEaar 6438-40; SFR6Bto1-3)
- Eleven individual opercula from Southfleet Road, context 40070, <40315/C>, mollusc subsample from bulk SV sample (NEaar 6424-6, 6606-6613; SFR1Bto1-11)
- Three individual opercula from Southfleet Road, context 40070, <40317/C>, mollusc subsample from bulk SV sample (NEaar 6427-9; SFR2Bto1-3)
- Seven individual opercula from Southfleet Road, context 40070, <40162>, bulk SV sample (NEaar 2041-7; EbABto1-7)
- Two individual opercula from Southfleet Road, context 40103, <40320>, bulk SV sample (NEaar 6441-2; SFR7Bto1-2)
- Two individual opercula from Southfleet Road, context 40025, <40286>, bulk SV sample (NEaar 6443-4; SFR8Bto1-2)
- Two individual opercula from Southfleet Road, context 40025, <40343>, bulk SV sample (NEaar 6445-6; SFR9Bto1-2)
- Fourteen individual opercula from Southfleet Road, context 40062, < 40042>, bulk SV sample (NEaar 6166-7, 6447-9, 6534-6538, 6614-6616; SRA1Bto1-2 and SFR10Bto1-12)

Sample Preparation

Shells were examined under a low powered microscope and any adhering sediment removed. The shell samples were then sonicated and rinsed several times in HPLC-grade water. The shells were then crushed to <100µm. Only bleached samples were analysed.

Bleaching

50µl of 12% solution of sodium hypochlorite at room temperature was added to each milligram of powdered sample and the caps retightened. The powders were bleached for 48 hours with a shake at 24 hours. The bleach was pipetted off and the powders were then rinsed five times in HPLC-grade water and a final rinse in HPLC-grade methanol (MeOH) to destroy any residual oxidant by reaction with the MeOH. The bulk of the MeOH was pippetted off and the remainder left to evaporate to dryness.

Hydrolysis

Protein bound amino acids are released by adding an excess of 7 M HCl to the bleached powder and hydrolysing at 110°C for 24 hours (H*).

20µl per milligram of sample of 7 M Hydrochloric Acid (HCl) was added to each Hydrolysis (‘Hyd’, H*, THAA) sample in sterile 2ml glass vials, were flushed with nitrogen for 20 seconds to prevent oxidation of the amino acids, and were then placed in an oven at 110°C for 24 hours. After 10 minutes in the oven, the caps of the 2ml vials were re-tightened to prevent the escape of vapour. After 24 hours, the samples were dried in a centrifugal evaporator overnight.

Demineralisation

Free amino-acid samples (‘Free’, F, FAA) were demineralised in cold 2M HCl, which dissolves the carbonate but minimises the hydrolysis of peptide bonds, and then dried in the centrifugal evaporator overnight.

Rehydration

When completely dry, samples were rehydrated with 10µl per mg of Rehydration Fluid: a solution containing 0.01 mM HCl, 0.01 mM L-homo arginine internal standard, and 0.77 mM sodium azide at a pH of 2. Each vial was vortexed for 20 seconds to ensure complete dissolution, and checked visually for undissolved particles.

Approximately 20µl of rehydrated sample was then placed in a sterile, labelled 2 ml autosampler vial containing a glass insert, capped and then placed on the autosampler tray of the HPLC.

For each set of sub-samples a blank vial was included at each stage to account for any background interference from the bleach, acid, or rehydration fluid added to the samples.

Analysis of Free and Hydrolysed Amino Acids

Amino acid enantiomers were separated by Reverse Phase High Pressure Liquid Chromatography (RP-HPLC). NEaar uses the method of Kaufman and Manley (1998) using an automated RP-HPLC system. This method achieves separation and detection of L and D isomers in the sub- picomole range.

Samples (2µl) were derivitised with 2.2µl *o*-phthaldialdehyde and thiol *N*-isobutyryl-L-cysteine automatically prior to injection. The resulting diastereomeric derivatives were then separated on Hypersil C_{18} BDS column (sphere d. 5µm; 250 x 3mm) using a linear gradient of a sodium acetate buffer (23 mM sodium acetate, 1.3 mM Na_2EDTA; pH6), methanol, and acetonitrile on an integrated HP1100 liquid chromatograph (Hewlett-Packard, USA).

Individual amino-acids are separated on a non-polar stationary phase according to their varied retention times: a function of their mass, structure, and hydrophobicity. A fluorescence detector is used to determine the concentrations of each amino-acid and record them as separate peaks on a chromatogram. A gradient elution programme was used to keep the retention time to below 120 minutes.

The fluorescence intensity of derivitised amino acids was measured (Ex = 230 nm, Em = 445 nm) in each sample and normalised to the internal standard. All samples were run in duplicate. Quantification of individual amino acids was achieved by comparison with the standard amino acid mixture.

External standards containing a variety of D- and L-amino acids, allowing calibration with the analyte samples, were analyzed at the beginning and end of every run, and one standard was analyzed every ten samples. Blanks which had been subjected to identical preparation procedures were randomly interspersed amongst the standards.

The L and D isomers of 10 amino acids were routinely analysed. During preparative hydrolysis both asparagine and glutamine undergo rapid irreversible deamination to aspartic acid and glutamic acid respectively (Hill 1965). It is therefore not possible to distinguish between the acidic amino acids and their derivatives and they are reported together as Asx and Glx.

RESULTS AND DISCUSSION

In total we conducted 208 analyses, all of which were on bleached samples. The extent of racemization in five amino acids (D/L of Asx, Glx, Ser, Ala and Val), along with the ratio of the concentration of Ser to Ala ([Ser]/[Ala]), are reported for both the Free and Hyd fractions. These indicators of protein decomposition have been selected as their peaks are cleanly eluted with baseline separation and they cover a wide range of rates of reaction. It is expected that with increasing age, the extent of racemization (D/L) will increase whilst the [Ser]/[Ala] value will decrease, due to the decomposition of the unstable serine.

The data obtained from Asx, Glx, serine (Ser), alanine (Ala) and valine (Val) are discussed in detail below. If the amino acids were contained within a closed system, the relationship between the Free and the Hyd fractions should be highly correlated, with non-concordance enabling the recognition of compromised samples (Preece and Penkman 2005). The plot of Free to Hyd data from each sample can also be used as a relative timescale, with younger samples falling towards the bottom left corner of the graph and older samples falling towards the upper right corner, along the line of expected decomposition. The data from the Southfleet Road samples have been plotted in this way below for each of the amino acids, with crosshairs representing the data obtained from other MIS 5e, MIS 7, MIS 9 and MIS 11 sites from the UK with independent geochronology. During hydrolysis the Hyd vials of two of the samples from context 40062, <40042> cracked, and so no Hyd data is available for these two samples

From the majority of horizons, 2-3 individual opercula were analysed, but two horizons were analysed in more detail: Phase 3 (context 40070, <40162>) and Phase 6 (context 40070, < 40315/C>) to test the ability of the opercula samples to resolve between the different phases of the site.

The samples from context 40062, <40042>, were particularly friable, with several disintegrating during the initial rinsing step to clean the opercula. As the figures below show, four of the eleven samples analysed from this horizon showed much lower than expected THAA D/Ls, clear evidence of a compromised closed system. One of the context 40070, <40315/C> samples also showed this behaviour. In the analysis of nearly 500 opercula samples, less than 2% of opercula analysed were compromised, so it is extremely unusual to have so many from one horizon. The friability of the opercula from this horizon indicates that mineral diagenesis has occurred in at least some of these samples. The total data set is shown in the Free vs Hyd plots below, but the compromised samples are removed from the statistical analysis to avoid skewing the data.

Aspartic acid / Asparagine (Asx)

Asx is one of the fastest racemizing of the amino acids discussed here (due to the fact that it can racemise whilst still peptide bound; Collins *et al.* 1999). This enables good levels of resolution at younger age sites, but decreased resolution beyond MIS 7.

The D/L Asx data from Southfleet Road have very similar values to each other, and to those from sites correlated with MIS 9 and MIS 11 (Fig. A9.3). Other than the compromised samples from context 40062, sample 40042, there is one outlying sample from context

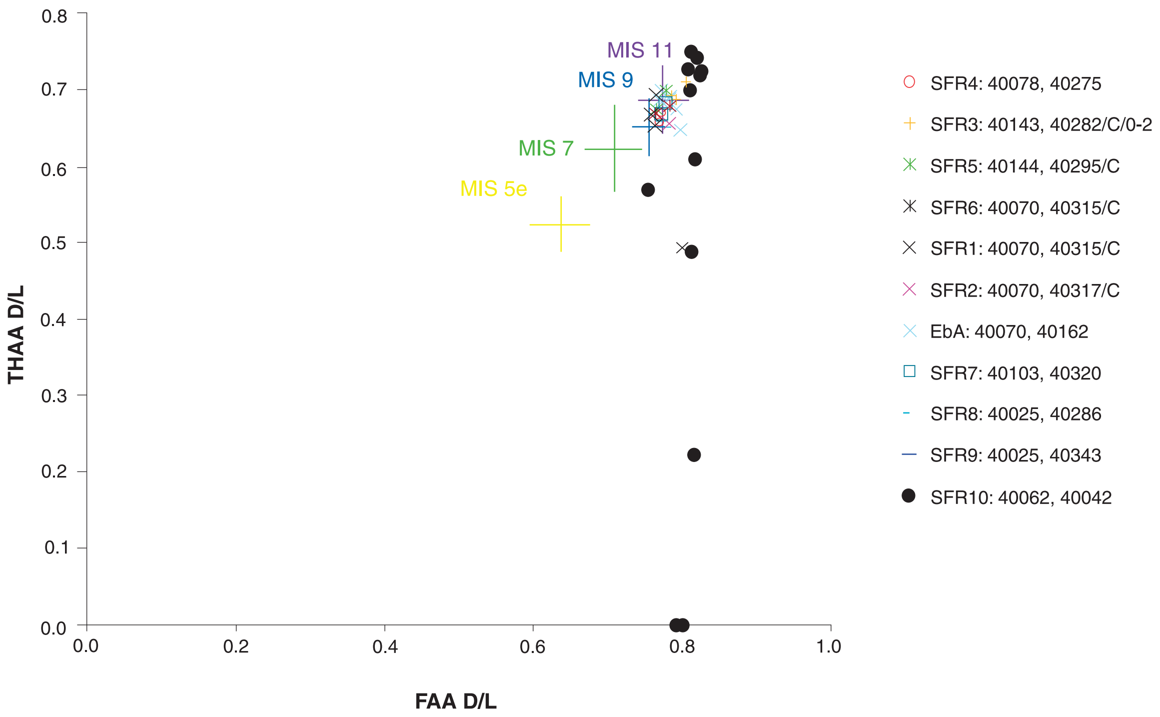
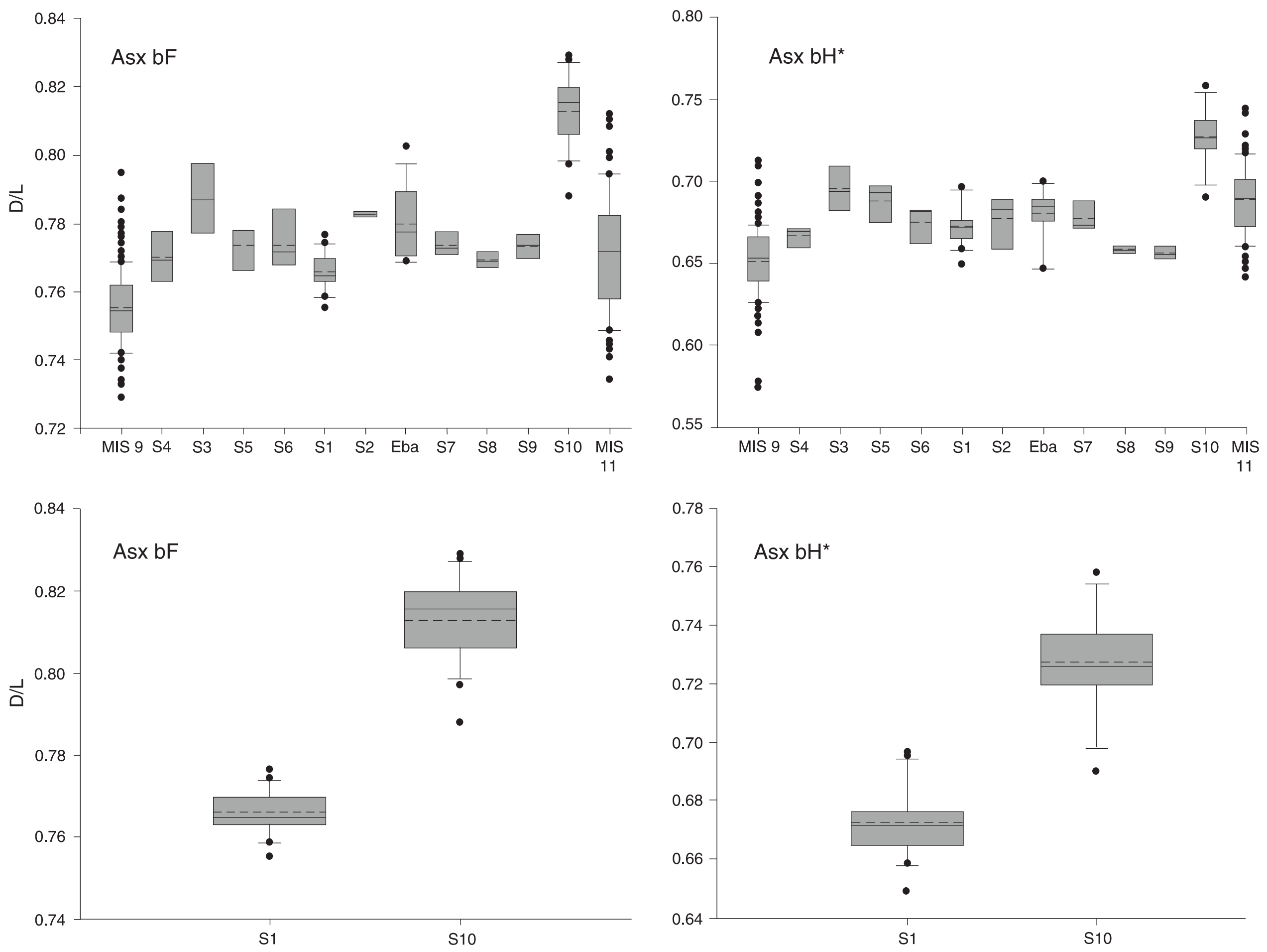


Figure A9.3 D/L Hyd vs D/L Free for Asx in *Bithynia tentaculata* opercula from Southfleet Road. The error bars represent two standard deviations about the mean for data obtained from opercula from sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11.



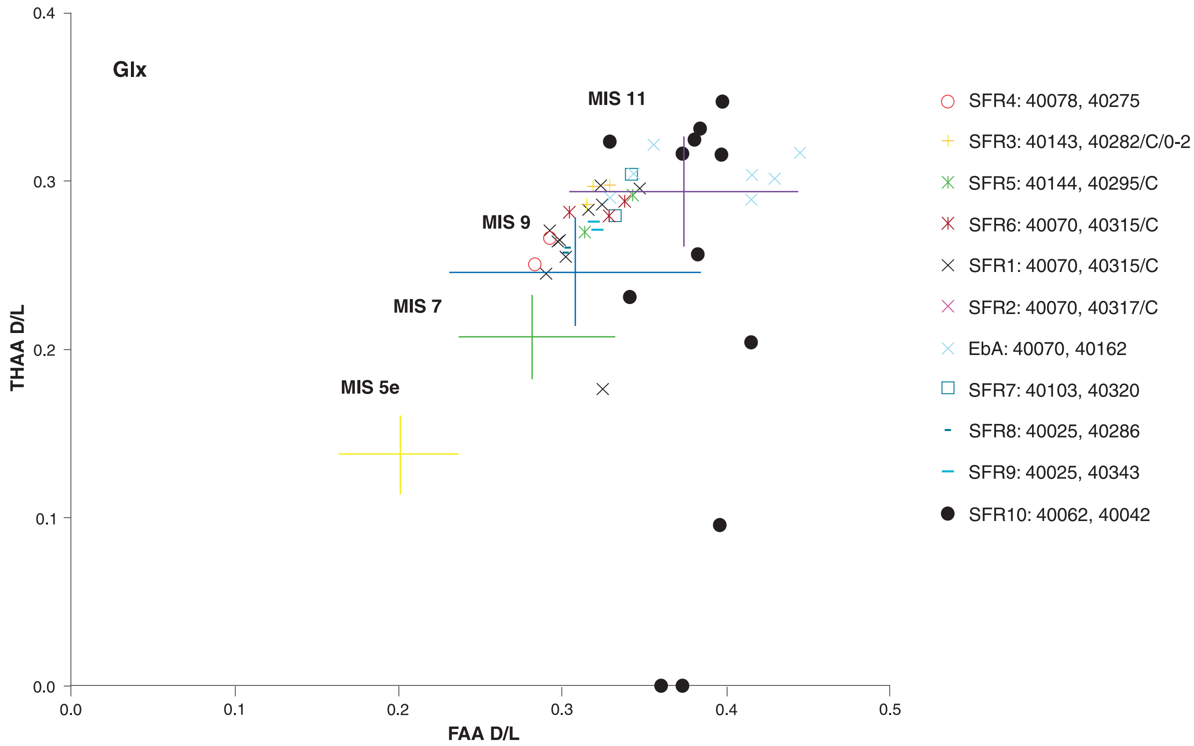


Figure A9.5 D/L Hyd vs D/L Free for Glx in *Bithynia tentaculata* opercula from Southfleet Road. The error bars represent two standard deviations about the mean for data obtained from opercula from sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11.

40070, <40315/C> (NEaar 6612, SFR1Bto10), which falls away from the expected line of decomposition in the Free vs Hyd plot. The amino acid composition of this sample was also divergent, and this sample does not therefore show closed system behaviour.

As the Asx racemization is so near equilibrium, it is surprising that a degree of behaviour consistent with the stratigraphic order is apparent, with the youngest (SFR4; context 40078, <40275>) and oldest (SFR10; context 40062, <40042>) distinguishable (Fig. A9.4). As can be seen from the lower figures, the samples from Phase 3 (context 40062, <40042>) are significantly higher than those from Phase 6 (context 40070, <40315/C>).

Glutamic Acid / Glutamine (Glx)

Glx is one of the slower racemizing amino acids discussed here and so the level of resolution from young sites is less than that seen with faster racemizing amino acids such as Asx. However, the low levels of racemization do help discriminate between material of Middle Pleistocene age. It is noteworthy that Glx has a slightly unusual pattern of racemization in the free form, due to the formation of a lactam (see Walton 1998). This results in difficulties in measuring Glx in the Free form, as the lactam cannot be derivitised and is therefore unavailable for analysis.

The Glx D/L values from Southfleet Road show values within the range of those expected from sites of MIS 9 and MIS 11 age (Fig. A9.5). Sample SFR1Bto10 also shows divergent behaviour in this amino acid.

While the Free Glx D/L is very variable in the EbA samples (context 40070, <40162>), this amino acid does show some increase in extent of racemization in concordance with the stratigraphy (Fig. A9.6), again enabling resolution between S1 (Phase 6) and S10 (Phase 3).

Figure A9.4 *(facing page)* Free (left) and Hyd (right) D/L for Asx in *Bithynia tentaculata* opercula from Southfleet Road, plotted in stratigraphic order. For each group, the base of the box indicates the 25th percentile. Within the box, the solid line plots the median and the dashed line shows the mean. The top of the box indicates the 75th percentile. Where more than 9 data points are available, the 10th and 90th percentiles can be calculated (shown by lines below and above the boxes respectively). The results of each duplicate analysis are included in order to provide a statistically significant sample size The lower figure shows the data for the two horizons studied in greater detail: S10 from Phase 3 (Context 40062, sample 40042) and S1 from Phase 6 (Context 40070, sample 40315/C). Note different scales on the y-axes.

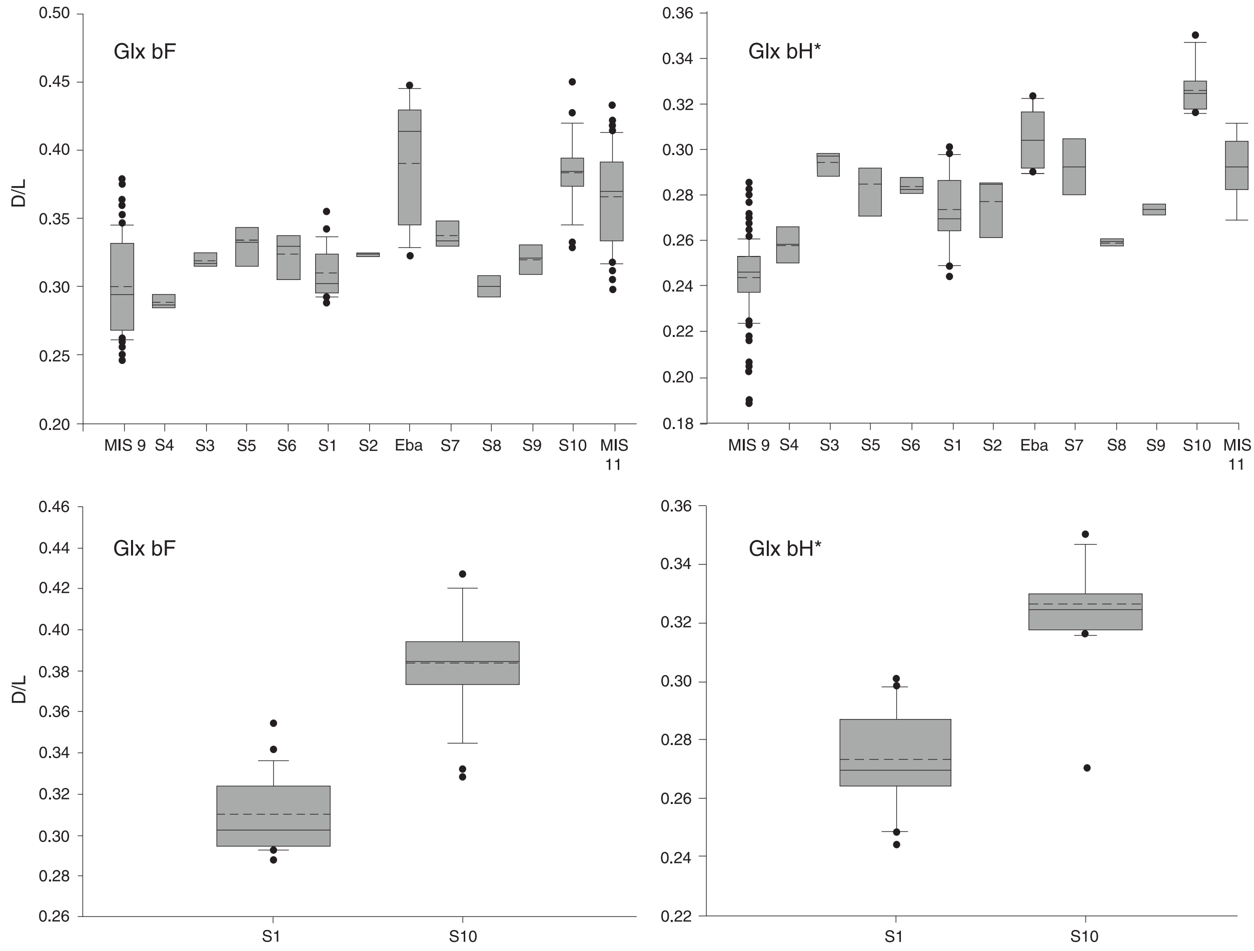


Figure A9.6 Free (left) and Hyd (right) D/L for Glx in *Bithynia tentaculata* opercula from Southfleet Road, plotted in stratigraphic order. For the full legend see Figure A9.4.Note different scales on y-axes

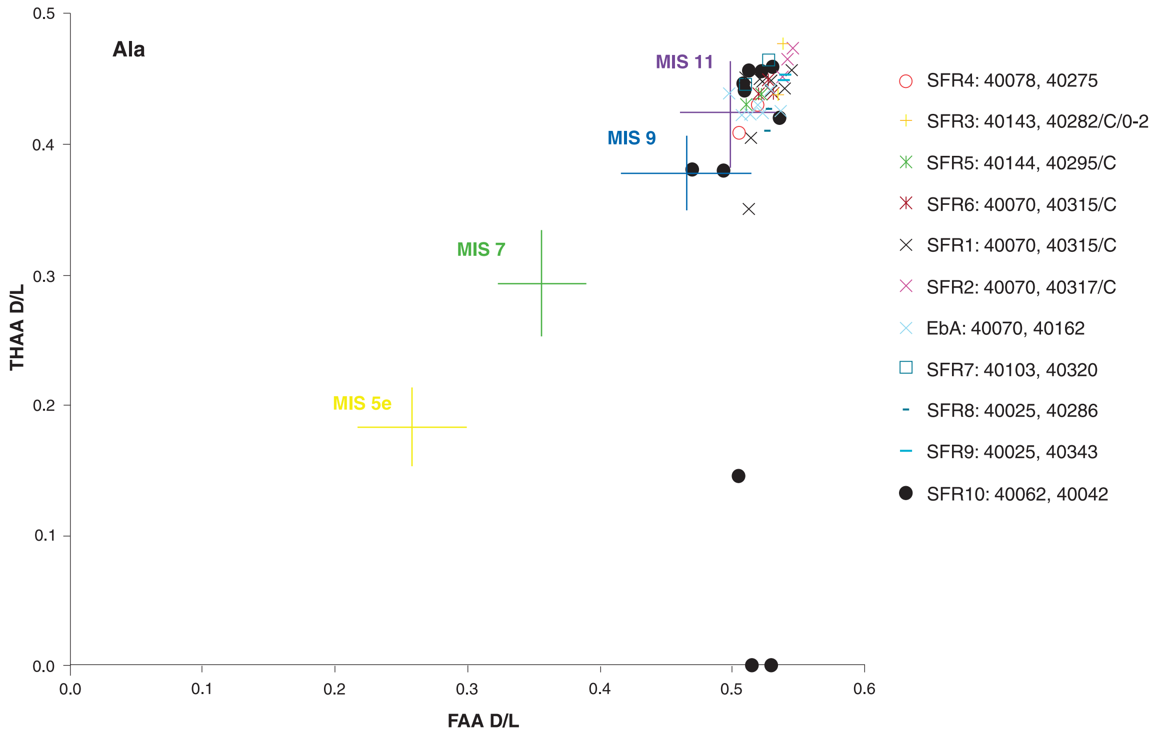


Figure A9.7 D/L Hyd vs D/L Free for Ala in *Bithynia tentaculata* opercula from Southfleet Road. The error bars represent two standard deviations about the mean for data obtained from opercula from sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11.

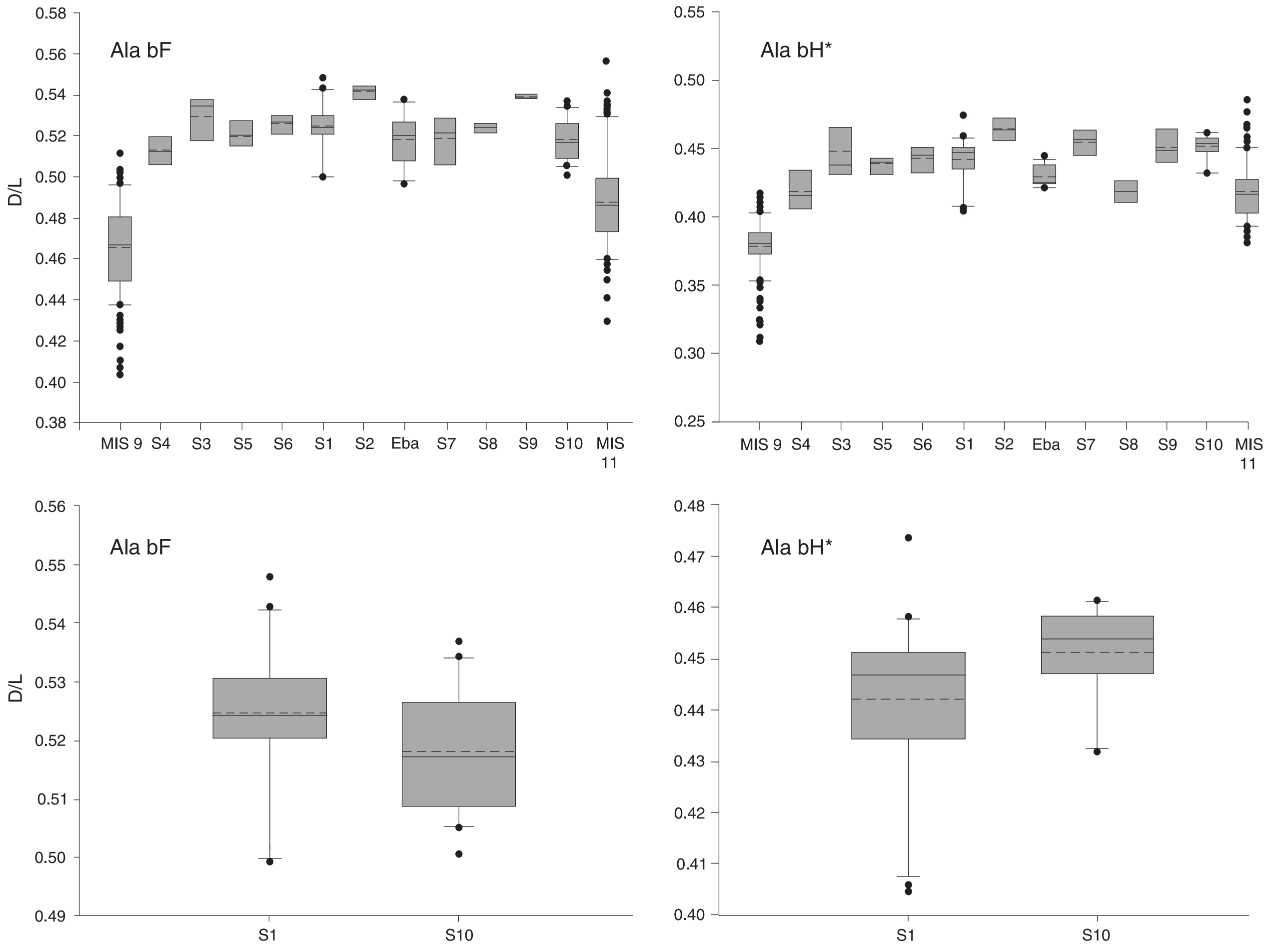


Figure A9.8 Free (left) and Hyd (right) D/L for Ala in *Bithynia tentaculata* opercula from Southfleet Road, plotted in stratigraphic order. Note different scales on y-axes

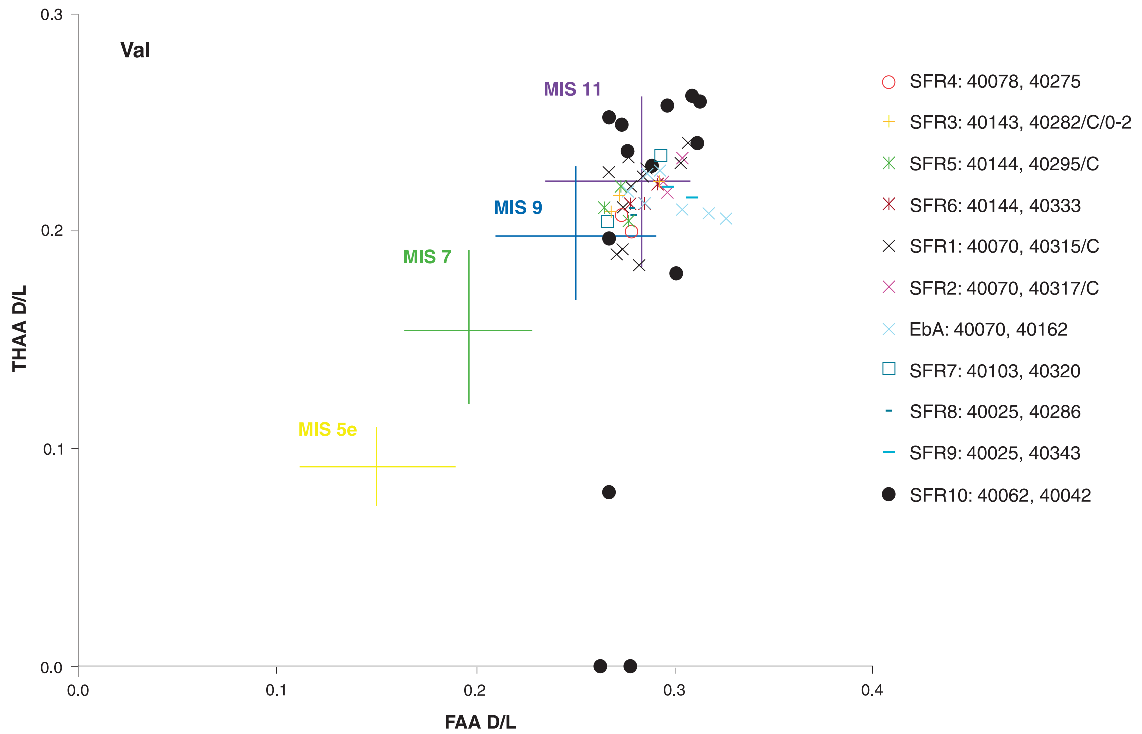


Figure A9.9 D/L Hyd vs D/L Free for Val in *Bithynia tentaculata* opercula from Southfleet Road. The error bars represent two standard deviations about the mean for data obtained from opercula from sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11

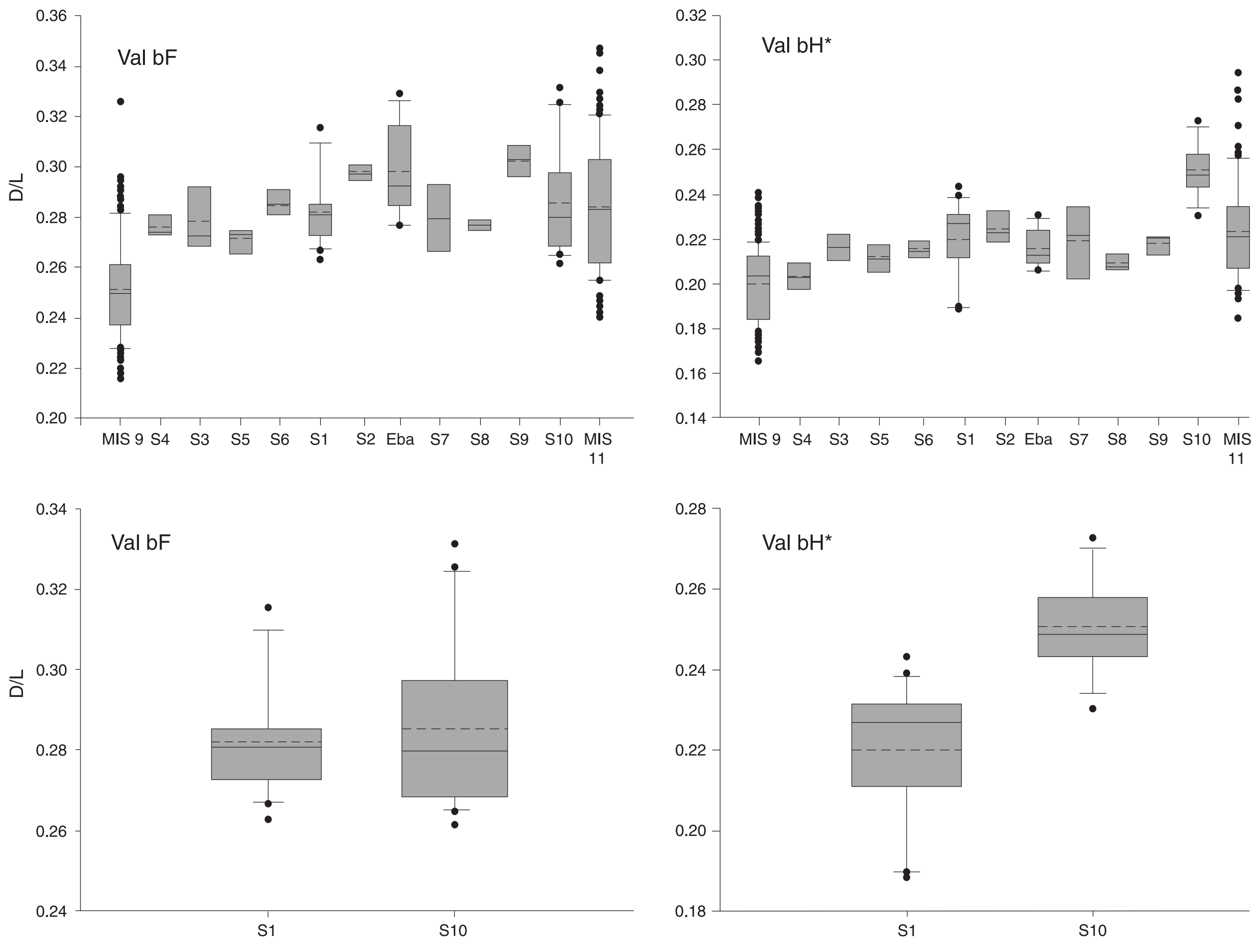
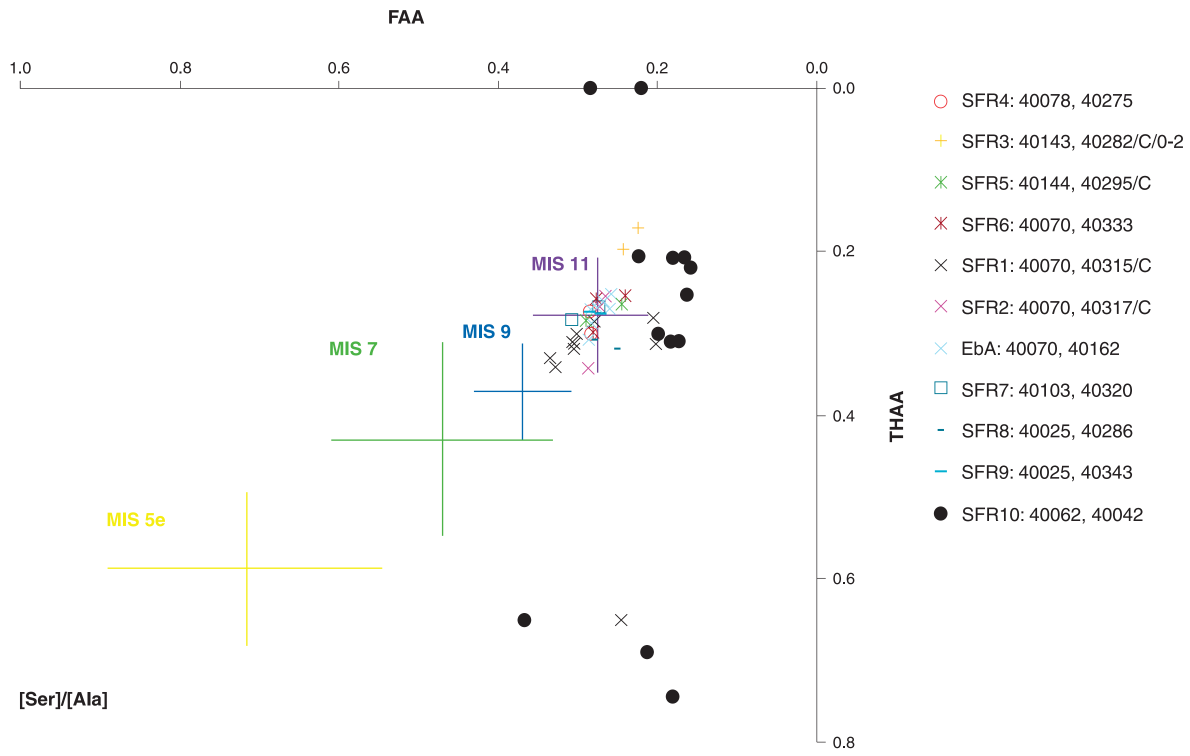


Figure A9.10 Free (left) and Hyd (right) D/L for Val in *Bithynia tentaculata* opercula from Southfleet Road, plotted in stratigraphic order. Note different scales on y-axes



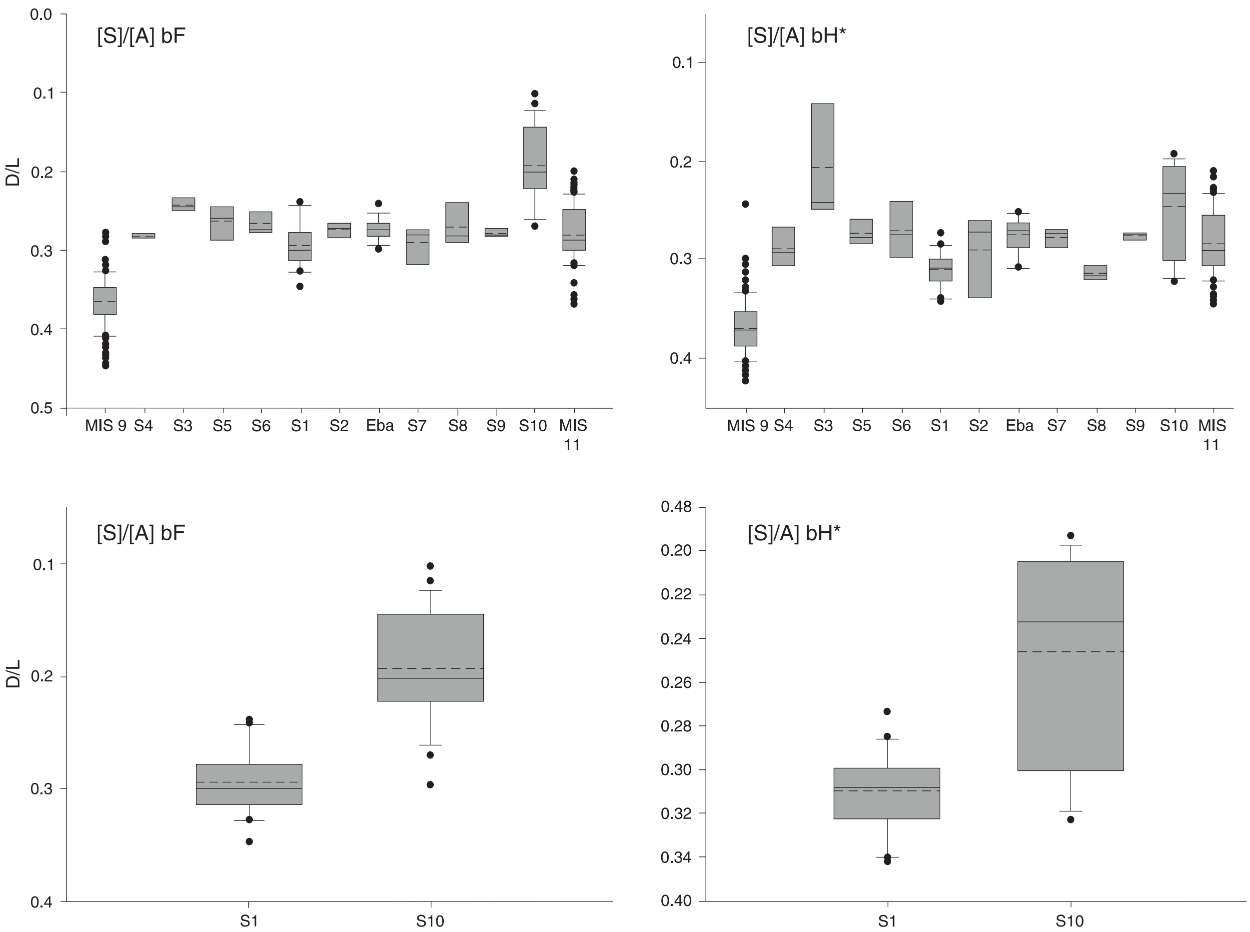


Figure A9.12 Free (left) and Hyd (right) [Ser]/[Ala] in *Bithynia tentaculata* opercula from Southfleet Road, plotted in stratigraphic order. As the [Ser]/[Ala] value decreases with increasing protein decomposition, the axes of this plot has been reversed so that the direction of protein decomposition is the same as that for the D/L graphs. Note different scales on y-axes

Alanine

Alanine (Ala) is a hydrophobic amino acid, whose concentration is partly contributed from the decomposition of other amino acids (notably serine). Ala racemises at an intermediate rate, so is one of the most useful amino acids for distinguishing samples at these timescales. The Ala data shows a tight clustering of data, consistent with a correlation with MIS 11 (Fig. A9.7) clearly enabling discrimination from sites of MIS 9 age. The two samples from S10 which fall within the MIS 9 cluster are those that show clear evidence in the other amino acids of being compromised. There is however little discrimination within the site using this amino acid (Fig. A9.8).

Valine (Val)

Valine has extremely low rates of racemization, and as the concentration of Val is quite low, the difficulty of measuring the D/L accurately results in higher variability. It does however still prove useful for age discrimination within material of Middle Pleistocene age. The Val D/L in the Free and the Hyd fractions again support the other amino acid data (Fig. A9.9). Only in the Hyd fracton is discrimination within the site possible using Val (Fig. A9.10).

[Serine]/[Alanine]

The ratio of the concentrations of serine and alanine provides an extremely useful tool for age estimation.

Figure A9.11 *(facing page)* [Ser]/[Ala] Hyd vs Free in *Bithynia tentaculata* opercula from Southfleet Road. The error bars represent two standard deviations about the mean for data obtained from opercula from sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11. As the [Ser]/[Ala] value decreases with increasing protein decomposition, the axes of this plot has been reversed so that the direction of protein decomposition is the same as that for the D/L graphs, with younger samples falling to the bottom left corner and older samples falling to the top right corner of the graph

Serine is a very unstable amino acid, and it can degrade via dehydration into alanine (Bada *et al.,* 1978). As the protein within a sample breaks down, the concentration of serine will decrease with an increase in the concentration of alanine, thus the [Ser]/[Ala] value will decrease with increasing time. In order to ease the interpretation, the y-axes in Figure 11 are plotted in reverse, so that the direction of increase in protein degradation is the same as for the racemization graphs.

The [Ser]/[Ala] of the Southfleet Road samples are again consistent with an age in MIS 11, but the level of discrimination is not particularly high (Fig. A9.11). The variability in the data precludes any definitive within-site stratigraphy from the amino acids alone, but the samples from context 40062, <40042> (SFR10) do show the highest levels of protein breakdown.

DISCUSSION

Comparison with other sites

The analysis of the closed system of protein within shells allows a new concept of age estimation to be developed, which incorporates multiple amino acid data to give a single measure of the overall extent of protein breakdown within a sample. This measurement, the Intra-crystalline Protein Degradation value (IcPD, formerly DMK) simplifies the presentation of the data to two compound values for each sample, one for the Free and one for the Hydrolysed amino acids. As these should be highly correlated, they can be cross-plotted, giving an aminostratigraphic framework with younger samples lying at low values and older samples with higher values, given a similar temperature history for all the sites. A study has been undertaken of interglacial sites within the UK that has allowed the tentative correlation of the aminostratigraphic framework to the marine oxygen isotope stage (MIS) record (Penkman 2005; Penkman *et al.* 2013).

On the basis of the relative D/L values and concentrations, the amino acid data from the opercula from Southfleet Road are very similar to the IcPD from UK sites correlated with MIS 11, including Hoxne, Barnham, Swanscombe, Beeches Pit, Elveden and Clacton.

CONCLUSIONS

In this study the amino acid data has been used as a relative dating technique to present an aminostratigraphy for the area in question. The conversion of relative sequences into absolute dates and accurate correlation between different areas is currently being undertaken, but preliminary correlations have been made to the MIS record.

The samples from Southfleet Road are consistent with an assignment within MIS 11. The samples from Phase 3 (context 40062, <40042>) show the highest levels of protein breakdown within the sequence and are statistically distinguishable from those of the Phase 6 deposits. The samples from context 40078, <40275> (SFR4) generally shows the lowest levels of IcPD.

GLOSSARY

18MΩ water: The water has a resistivity of 18MΩ/cm, indicating a lack of ions.

HPLC grade water: In addition to low ion content, HPLC grade water has a low organic content (typically < 2 ppb).

Amino acids: the building blocks of proteins and consist of an alpha carbon atom (C) which has four different groups bonded to it: an amino group ($-NH_2$), a carboxyl group (-COOH), a hydrogen atom (-H), and a side chain, (often called an R group). About 20 amino acids normally occur in nature and some of these can undergo further modification (eg, the hydroxylation of proline to hydroxyproline). The amino acids are commonly known by three letter codes (see below, Abbreviations). They exist free in the cell, but are more commonly linked together by **peptide bonds** to form proteins, peptides, and sub-components of some other macromolecules (eg bacterial peptidoglycan).

Amino acid isomers: amino acids occur as two stereoisomers that are chemically identical, but optically different. These isomers are designated as either D (dextro-rotary) or L (laevo-rotary) depending upon whether they rotate plane polarised light to the right or left respectively (Fig 6). In living organisms the amino acids in protein are almost exclusively L and the D/L ratio approaches zero. Two amino acids, isoleucine and threonine, have two chiral carbon atoms and therefore have four stereoisomers each. As well as racemization, these two amino acids can undergo a process known as epimerization. The detection of the L-alloisoleucine epimer (derived from L-isoleucine) is possible by conventional ion-exchange chromatography, and was thus the most commonly used reaction pathway in geochronology.

Asx: Measurements of aspartic acid following hydrolysis also include asparagines, which decomposes to Asx. This combined signal of aspartic acid plus asparagine (Asp +Asn) is referred to as Asx (Collins *et al,* 1999).

D-amino acid: dextrorotary amino acid, formed following synthesis of the protein as it degrades over time (remember as 'dead amino acid').

IcPD: Conventional racemization analysis tends to report an allosioleucine / isoleucine (A/I or D/L ratio). This amino acid ratio has the advantage of being relative easy to measure and also sufficiently slow to be used to 'date' sediments in the European Quaternary.

Our IcPD approach utilises multiple amino acids. However we have avoided trying to give a whole series of D/L values for each amino acid in each sample. Instead we are using a theoretical model of protein degradation. The model outputs are then used to compare observed D/L values of any amino acid against the A/I value at the same stage of protein decomposition. The relative rate of racemization of any amino acid (its DL ratio) is then reported as an A/I equivalent – which as a working title we have named the Intra-crystalline Protein Degradation value (or IcPD) (Penkman, Collins and Kaufman in prep).

Instead of getting a single A/I ratio we obtain a series of (IcPD) values, currently $IcPD_{Asx}$, $IcPD_{Glu}$, $IcPD_{Phe}$, $IcPD_{Ala}$, $IcPD_{Val}$, and a (pretty unreliable) A/I ratio ($IcPD_{A/I}$ = A/I). Other ratios, notably $IcPD_{Ser}$, are not currently of implemented in the model – ie we don't have a good degradation model for this amino acid yet.

Because each amino acid has its own particular characteristics, only in a well behaved system will $IcPD_{Asx} = IcPD_{Glu} = IcPD_{Phe} = IcPD_{Ala} = IcPD_{Val}$ = A/I. If an amino acid has an unusually low ratio (due to modern contamination) or unusually high racemization (due to inclusion of bacterial cell wall contaminants) either some or all of the amino acids will no longer fit to the idealised degradation model. Indeed we can use elevation of $IcPD_{Asx} = IcPD_{Glu}$ and = $IcPD_{Ala}$ to provide a bacterial contamination index. We have not done so in this case as there was no evidence of contamination.

IcPD values: Intra-crystalline Protein Degradation value, a summary value obtained from multiple amino acid D/L values from a single sample all normalised to a common model of protein degradation and racemization.

Enantiomers / optical isomers: mirror image forms of the same compound that cannot be superimposed on one another.

Epimerisation: the inversion of the chiral -carbon atom.

Free amino acid fraction: The fraction of amino acids directly amenable to racemization analysis. Only amino acids which have already been naturally hydrolysed (over time) are measured. These are the most highly racemised

Hydrolysis: A chemical reaction involving water leading to the breaking apart of a compound (in this case the breaking of peptide bonds to release amino acids).

L-amino acid: levorotary amino acid, the constituent form of proteins (remember as 'living amino acid').

Peptide bond: an amide linkage between the carboxyl group of one amino acid and the amino group of another.

Racemization: the inversion of all chiral carbon atoms, leading to the decrease in specific optical rotation. When the optical rotation is reduced to zero, the mixture is said to be racemised.

Stereoisomers: molecules of the same compound that have their atoms arranged differently in space.

Total amino acid fraction: The extent of racemization of all amino acids in a sample, determined following aggressive high temperature hydrolysis with strong mineral acid, which has the effect of breaking apart all peptide bonds so that the total extent of racemization in all amino acids both free and peptide bound are measured.

Zwitterion: A dipolar ion containing ionic groups of opposite charge. At neutral pH the ionic form of amino acids which predominates is the zwitterions

IcPD = Glx not aIle / Ile?

Due to the problem of being unable to accurately measure A/I in our current system, we have switched to a version IcPD which is normalised for Glutamic acid. Although D/L Glu A/I, we have not yet fully established this relationship.

What does the date estimated from IcPD mean?

The date is our best estimate based upon the temperature history of the site. If we wanted to constrain this further we would need reliable independent dates. There are considerable differences in racemization rates between different molluscs. This reflects differences in rates of decomposition of proteins within the shell – the so-called species effects (Lajoie et al, 1980).

Past Use of Amino Acid Racemization Dating.

The presence of proteins in archaeological remains has been known for some time. Nearly fifty years ago Abelson (1954) separated amino acids from subfossil shell. He suggested the possibility of using the kinetics of the degradation of amino acids as the basis for a dating method (Abelson 1955). In 1967 Hare and Abelson measured the extent of racemization of amino acids extracted from modern and sub-fossil *Mercenaria mercenaria* shells (edible clam). They found that the total amount of amino acids present in shell decreased with the age of the shell. The amino acids in recent shell were all in the L configuration and over time the amount of D configuration amino acid increased (Hare and Abelson 1967). However, even after 35 years this method of dating is still subject to vigorous debate, with the application of AAR to date bone being particularly controversial (Bada 1990; Marshall 1990). Major reviews of AAR include: Johnson and Miller (1997), Hare, von Endt, and Kokis (1997), Rutter and Blackwell (1995), Murray-Wallace (1993), Bada (1991) and Schroeder and Bada (1976). Racemization is a chemical reaction and a number of factors influence its rate (Rutter and Blackwell, 1995). These include: amino acid structure, the sequence of amino acids in peptides, pH, buffering effects, metallic cations, the presence of water and temperature. To establish a dating method the kinetics and mechanisms of the racemization (and epimerization) reaction of free and peptide bound amino acids need to be established. To this end various workers in the late 1960s and the 1970s studied free amino acids in solution and carried out laboratory simulations of post mortem changes in the amino acids in bone (Bada 1972) and shell (Hare and Abelson 1967; Hare and Mitterer 1969). Attempts have also been made to relate the kinetics of free amino acids, with those in short polypeptides and the proteins in various archaeological samples (Smith and Evans 1980; Bada 1982).

The ability of this technique to be used as a geochronological and geothermometry tool has led to its use in many environmental studies. Goodfriend (1991; 1992) analysed terrestrial gastropods. Other studies have looked at bivalves (Goodfriend and Stanley 1996), foraminifera (Harada *et al* 1996), ostrich egg shells (Miller *et al.* 1992; 1997) and speleothems (Lauritzen 1994). Early methods of chemical separation, using Ion-Exchange liquid chromatography, are able to separate the enantiomers of one amino acid found in proteins, L-isoleucine (L-Ile, I), from its most stable diastereoisomer alloisoleucine (D-aile, A). By analysing the total protein content within non-marine mollusc shells from UK interglacial sites, an amino acid geochronology was developed using the increase in A/I, with correlations made with the marine oxygen isotope warm stages (Bowen *et al.* 1989).

Abbreviations used in this report

Abbrev	*1-letter code*	*number of chiral centres*	
Ala	A	1	Alanine
Arg	R	1	Arginine
Acn			acetonitrile
AA			Amino acid(n)
Asn	N	1	Asparagine
Asp	D	1	Aspartic acid
Asx			Asparagine + Aspartic acid + succinimide
Asu			Succinimide
Cys	C	1	Cysteine
DCM			Dichlormethane
GABA			γ-Aminobutyric acidγ
Gln	Q	1	Glutamine
Glu	E	1	Glutamic acid
Gly	G	0	Glycine
His	H	1	Histidine
HPLC			High-Performance Liquid Chromatography
Hyp			Hydroxyproline
IBD(L)C			N-Isobutyryl-D(L)-Cysteine
Ile	I	2	Isoleucine
Leu	L	1	Leucine
Lys	K	1	Lysine
MeOH			Methanol
Met	M	1	Methionine
Nle			Norleucine
OPA			ortho-Phthaldialdehyde
Orn			Ornithine
Phe	F	1	Phenylalanine
Pro	P	1	Proline
Ser	S	1	Serine
Thr	T	2	Threonine
Trp	W	1	Tryptophan
Tyr	Y	1	Tyrosine
Val	V	1	Valine

Appendix 10

The bird remains

by John R. Stewart

INTRODUCTION

The bird remains were identified by means of modern comparative material of the author. Avian anatomical description follows the terminology described in Baumel (1979). Stewart and Hernández Carrasquilla (1997) published a review of literature which aids in the identification of bird skeletal remains. Woolfenden (1961) has been consulted for the identification of the Anseriformes as a whole, Woelfle (1967) for ducks, Stewart (1992) for the Turdidae. Comparative metrical data used in the identifications and measurement protocols come from the above publications. The size categories follow Harrison and Stewart (1999).

DESCRIPTION OF THE SOUTHFLEET ROAD BIRD REMAINS

Context 40070

Sample <40162>
1. Os carpi ulnare
   Passeriformes (< Blackbird size)
2. 1. Os carpi ulnare
   Passeriformes (< House sparrow size)

Sample <40035>
1. Proximal (L) ulna
   Small bird – cf. Passeriformes (House sparrow size)

Sample <40307>
1. Phalange, proximal end with shaft, distal end damaged.
   Small bird – cf. Passeriformes (Blackbird – House sparrow size)

Sample <40314>
1. Proximal (R) ulna.
   Passeriformes (Blackbird size)
2. Coracoid (R) fragment – region of the procoracoid
   Passerine (Blackbird size)

Sample <40315>
1. Humerus (R) shaft
   Passeriformes (< Blackbird size)
2. Distal (L) tibiotarsus
   Small bird – cf. Passeriformes (< House sparrow size)

Sample <40317>
1. Proximal (L) carpometacarpus
   Passeriformes (House sparrow size)
2. Proximal (L) tarsometatarsus
   Passeriformes (House sparrow size)
3. Distal tibiotarsus (L/R?) – Immature as no articulation
   Small bird – cf. Passeriformes (< House sparrow size)

Sample <40318>
1. Distal (L) tibiotarsus
   Passeriformes (Blackbird size)

Sample <40329>
1. Tibiotarsus (L) shaft (broken into 2 fragments)
   Anatidae (Mallard size)
2. Scapula (R) articular end with ca. 2cm of corpus present (broken into 2 fragments)
   Anatidae (Mallard size)
3. Distal (R) humerus
   Passeriformes (House sparrow size)
4. Distal (L) humerus
   Passeriformes (House sparrow size)
5. Distal (L) tarsometatarsus
   Passeriformes (House sparrow size)
6. Distal (L) tarsometatarsus – trochlea missing
   Passeriformes (House sparrow size)

Sample <40033X>
1. Distal (R) ulna
   Small bird cf. Passeriformes (Blackbird size)
2. Phalange of pes
   Not Anatidae? (Mallard size)
3. Distal tibiotarsus (R)
   Small bird (House sparrow size)
4. Proximal (R) ulna
   Small bird cf. Passeriformes (House sparrow size)

Sample <40330>
1. Distal humerus (L)
   Passeriformes (Backbird size)
2. Distal (L) ulna
   Small bird – cf. Passeriformes (House sparrow size)
3. Thoracic vertebra
   Small bird (Blackbird size)
4. Possibly a bird distal carpometacarpus fragment

Sample <40331>

1. Proximal (L) humerus (Bp: 8.1 mm).
   Turdus cf. *philomelos* / *iliacus*. The morphological characters that can be used to distinguish *Turdus* from *Sturnus* (Stewart 1992, 2007) were applied.
2. Carpometacarpus (R) (GL: 18.0)
   Turdus / *Sturnus*. The morphological characters that can be used to distinguish *Turdus* from *Sturnus* (Stewart 1992; 2007) were not applied due to damage to proximal articulation. Based on modern measurements this would be *T. philomelos* / *iliacus* (Stewart 1992; 2007).
3. Distal (R) ulna
   Anatidae (Mallard size?)
4. Sternal extremity of coracoid (L)
   Small bird – cf. Passeriformes (Blackbird size)

Sample <40335>

1. Proximal ungual phalanx fragment – tip broken off
   Small bird (House sparrow size)
2. Distal tibiotarsus (L/R?) – Immature as no articulation
   Small bird (House sparrow size)
3. Phalange of pes
   Medium sized bird?

Sample <40347>

1. Tarsometatarsus (L) shaft
   Anatidae (Mallard size) – immature as has grainy texture to shaft
2. Proximal (L) carpometacarpus
   Passeriformes (House sparrow size)

Sample< 40381>

1. Os carpi radiale (?)
   Anatidae (Mallard size)
2. Ungual phalanx
   Small bird – cf. Passeriformes (House sparrow size)