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PRoSWeB

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THE PALAEOLITHIC RIVERS OF SOUTH-WEST BRITAIN

(PNUM 3847)

Final Report (Phases I & II)

Prepared for

English Heritage
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by

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EXECUTIVE SUMMARY

This project report summarises the desktop resource assessment, the geoarchaeological fieldwork undertaken in the Axe, Otter and Exe valleys, and at Doniford, and the outreach/dissemination activities undertaken and resources produced during Phase I and Phase II of the Palaeolithic Rivers of South-West Britain Project (PNUM3847).

The report is organised into five sections:

- Section 1 (the project and the ALSF): an overview of the implications of the project's key conclusions and outputs for the ALSF criteria, including the mitigation of past and future aggregates extraction. *Of key significance were the Axe valley fieldwork implications for the nature, distribution, antiquity, and archaeological potential of the Axe's fill terrace fluvial deposits; the implications of the Exe and Otter valleys fieldwork for the nature, distribution, antiquity, and archaeological potential of the Exe and Otter's strath terrace fluvial deposits, and their contrasts with the Axe valley to the east; and the enhancement of the county HERs to support future management and conservation strategies*.

- Section 2 (introduction and background): an introduction to the project background and a summary of the results from the first phase resource assessment. *The project was initiated in light of distinctive aggregates threats in the south-west region (including small, sometimes episodically exploited, quarry sites, prohibition order sites, and borrow pits), the absence of a geochronological framework for Pleistocene fluvial landforms and deposits, and recognition of an 'invisible' component to the region's Palaeolithic archaeological record. The phase one resource assessment indicated that the Pleistocene fluvial landscape resource is more substantial than previously recognised, and that there is a substantial 'invisible' component to the Palaeolithic archaeological record in the south-west region*.

- Section 3 (report on the geoarchaeological fieldwork): a summary of fieldwork activities. *These included sedimentary (section) logging; clast fabric and lithological analysis; terrace deposit mapping; OSL sampling programme; organics sampling; and ground penetrating radar (GPR) surveys. The fieldwork has generated sedimentary logging records, clast fabric and lithology data, photographic archives, and terrace mapping data for fluvial terrace deposits in the Axe, Otter and Exe valleys, and also for the deposits of the palaeo-river Washford at Doniford Cliffs. OSL sampling has produced age estimates for a series of terrace deposits in the Axe, Otter and Exe valleys, and also for the palaeo-Washford deposits at Doniford.*

- Section 4 (project outreach and dissemination): a summary of the outreach and dissemination activities and resources. *These included school activity days; Palaeolithic Geoarchaeology walks; lithic artefact identification days; museum displays and mobile exhibitions; seminars and workshops (Regional Palaeolithic Networking Meeting and Regional Palaeolithic Geoarchaeology Workshop); and further outreach and dissemination activities. The outreach and dissemination programme has introduced and highlighted the Lower and Middle Palaeolithic archaeology and Pleistocene fluvial terrace resources of the south-west region, to school, archaeological/historical/ geological groups, and to the general public through a range of activities and mechanisms.*

Section 5 (summary): a summary of the key results and implications from the fieldwork programme; and the response to the outreach activities. *This project presents for the first time a partial chronology for river terrace formation in South-West England, including the strath-style terrace staircases of the Exe and the Otter. The sequence has implications for understanding the distribution of Palaeolithic archaeology in south-western England and managing the archaeological resource of both disused and working quarries. The contrasting models of terrace formation and modification imply different degrees of archaeological potential, while the OSL sample ages suggest that the palaeogeography of the south-west region may have undergone a major transformation during the late Middle Pleistocene. The positive response to the project outreach has highlighted the existence of public interest within the region, and the potential for promoting sustained interest, recognition, and reporting of Palaeolithic finds and/or Pleistocene fluvial deposits beyond the timescales of the project. The fieldwork has indicated key deposits and locations, and this information is being disseminated to the HERs and ADS for consideration in the future planning and mitigation of aggregates extraction.*

1. ALSF IMPLICATIONS OF THE PALAEOLITHIC RIVERS OF SOUTH-WEST BRITAIN PROJECT

The outputs of the Palaeolithic Rivers of South-West Britain project (PRoSWeB) support both core areas of the ALSF criteria (English Heritage n.d.):

- Developing the capacity to manage aggregate extraction landscapes in the future (hereafter ALSF-A).
- Promoting understanding of the conservation issues arising from the impacts of aggregates extraction on the historic environment (hereafter ALSF-B).

The project outputs also support the following headline objectives (English Heritage n.d.):

1. Research to enhance the understanding of the scale and character of the historic environment in current or likely future aggregate producing areas in order to provide the baseline information necessary for effective future management (hereafter referred to as ALSF-2.1).
2. Supporting the operation of the planning system through assistance with excavation, analysis and dissemination of unexpected discoveries subject to English Heritage's normal conditions (including support for evaluation and survey work on sites with outstanding planning permissions granted before the implementation of PPG-16) (hereafter ALSF-2.4).
3. Support for the development of management and conservation strategies for the historic environment in current or likely future areas of aggregate production (hereafter ALSF-2.2).
4. Local education, interpretation, outreach and community involvement, and capacity building which raise awareness of conservation issues, communicates the knowledge gained through the extraction process, and raises the profile of the positive benefits of extraction to communities living in current extraction areas where this work is demonstrably beyond that required by the planning system (partnership projects with industry where this goes beyond the legal obligations on industry would be particularly welcome) (hereafter ALSF-2.5).
5. Training and professional development: programmes to raise awareness of and promote best practice to industry, historic environment professionals and other stakeholders (hereafter ALSF-2.3).
6. Local education, interpretation, outreach and community involvement, and capacity building associated with past extraction which raises awareness of conservation issues and communicate knowledge gained through the extraction process (hereafter ALSF-3.1).
7. Dissemination and assimilation of ALSF-funded and other related work to stakeholder groups (hereafter ALSF-2.6).

The principal outputs of the Palaeolithic Rivers of South-West Britain project are:

- Geochronological OSL frameworks for the fluvial terrace deposits of the Axe, Exe, Otter, and Doniford river systems.
- Investigation of the Axe, Exe, Otter and Doniford fluvial system, including modelling of system evolution and terrace formation and development.
- Re-assessment of the Lower and Middle Palaeolithic archaeological record in the south-west region (as defined by this project).

- Enhanced public awareness of the Palaeolithic rivers of the south-west region, through outreach and dissemination activities.

The project outputs have been principally disseminated by:

- Delivery of GIS and HER-compatible resources with associated metadata (and underlying database resources) to the Cornwall Devon, Dorset and Somerset County Council Historic Environment Records. These will include details of the project fieldwork (including OSL and palaeoenvironmental sampling) and the archaeological findspot/artefact re-assessment. The project GIS/database resources will be cross-linked to the final project report and the project's academic papers (digital copies will be supplied to the HERs as they are completed/published). HERs will also receive a digital and hard copy of the final project report.
- The project reports (see also above), documenting the project fieldwork results and fluvial system models (Basell *et al.* in prep.) and the OSL dating programme (Toms 2007).
- Academic papers (see also above), presenting the project fieldwork and fluvial system models (Basell *et al.* in prep.), desktop evaluation of the archaeological resource (Hosfield *et al.* 2006), and the OSL dating programme (Toms 2007; Basell *et al.* in prep.).
- Two project workshops/seminars (the Regional Palaeolithic Networks Meeting and the Regional Palaeolithic Geoarchaeology Workshop).
- Schools events and teaching packs (hard copies of the teaching packs were distributed to Dartmoor National Park Authority, Cornwall Library and Information Service, and Royal Albert Memorial Museum and Art Gallery (Exeter), and were also made available as digital copy on the project website and publicised through the project website and contacts database).
- Project website resources (http://www.rdg.ac.uk/palaeorivers/).
- Public events (Palaeolithic artefact identification days and Palaeolithic Geoarchaeology walks), Ice Age Devon exhibition (Exeter Museum) and travelling library posters (through the Cornwall and Devon Library Services), project literature (project booklet and flyer distributed to project mailing list members), and local journal/newsletter contributions.

1.1 PRoSWeB Outputs & ALSF Criteria

The relationships between the project outputs, delivery methods, and ALSF criteria are summarised visually in Figure 1.

With regards to the ALSF main areas (summarised above):

- ALSF-A (managing aggregate extraction landscapes) is principally supported by the project fieldwork at the active aggregates extraction site at Chard Junction:
    - o Lithostratigraphic logging and OSL sampling indicated the fill terrace nature of the sediments and the contrasting deposit types through the sequence at the Hodge Ditch location: debris flow in the upper part, capping fluvial deposits below. Fine-grained channel deposits (bedded sands and silts) were identified in the sequence, and organic samples were recovered.
    - o The similarity of the Chard Junction OSL dates to those from Kilmington (see below) and, less clearly, to Broom (Toms *et al.* 2005) suggest that

extensive thicknesses (up to 15m at Chard and Broom) of fluvial, colluvial and debris flow deposits may be present throughout much of the Axe valley. Such thick deposits could potentially be of interest to the aggregates industry, particularly in light of their low-lying nature (the Broom deposits extend beneath the surface height of the current floodplain).

    - However the results of the project fieldwork indicate that any future management plan should acknowledge the potential for significant Palaeolithic artefactual material within the Axe valley deposits. Any artefact assemblages could date between *at least* OIS-8 (potentially as far back to OIS-10/11 at Chard) and early OIS-6 (assuming an OIS-6 to OIS-4 abandonment of Britain). The fill terrace nature of the Axe valley gravels is more likely to preserve fine grained units in which artefacts may be concentrated with minimal reworking, while the deposits are less likely to be exposed to reworking and erosion than thin strath terrace deposits. The association of artefacts with fine-grained and/or organic channel deposits would potentially improve the time resolution and spatial integrity of any data.
    - Any future management plan should also acknowledge the potential for palaeoenvironmental evidence (particularly from organic and/or fine-grained deposits) associated with the fill terrace deposits of the Axe.
- ALSF-A is secondarily supported by the results from the Exe, Otter and Washford, and other parts of the Axe. The project results have indicated:
    - Deposits in other parts of the Axe valley (e.g. at Kilmington) display a similar character (i.e. a fill terrace system) and chronology to those at Chard Junction. Such deposits may therefore be appropriate for future aggregates extraction, although it is also likely that they may contain deposits and artefacts of archaeological importance (see also comments above).
    - The landforms and deposits from the Exe and the Otter river valleys are characterised by strath terrace systems, with relatively thin (in comparison with the Axe terraces) individual deposits, which have also been significantly cryoturbated and/or truncated in some locations. Such deposits are unlikely to be of high priority interest for aggregates extraction.
    - In the case of the Exe and Otter deposits it is also likely that any archaeological materials will have been subject to disturbance and/or reworking (reflecting the shallow depth of the deposits, the evidence for cryoturbation/truncation, and erosion/reworking processes associated with a strath terrace system).
    - The palaeoriver Washford deposits exposed at Doniford highlight the potential for the terrace 2 deposits of the River Tone to date to either the Late Pleistocene (OIS-3/2) or earlier (assuming a model of extensive re-working). Any future aggregates extraction plans for those deposits should acknowledge the potential for both artefactual and faunal evidence.
- ALSF-B (promoting understanding of conservation issues) is supported by the overall results of the project, specifically the new information provided with regards to the Pleistocene gravels (chronology), landscapes (evolution), and Palaeolithic archaeology ('hidden' resources) of the south-west region. This knowledge has also been actively disseminated to the general public over the

course of the project, through a range of outreach methods (events, exhibitions, website resources, papers: see Section 4 for further details).

With regards to the ALSF headline objectives:

- ALSF-2.1 (enhance understanding of historic environment) is supported by the results of the geochronological OSL dating programme, the field-based fluvial deposit investigations, and the Lower and Middle Palaeolithic archaeological assessment, all of which have improved current understanding of the scale and character of the historic (Palaeolithic and Pleistocene) environment in one current extraction area (Chard) and potential future extraction areas in the Axe (although Kilmington is apparently to be returned to agricultural land and/or reinstated, this has yet to occur, and there is also the possibility of an inert landfill usage). In particular this improved understanding focuses upon the ages of the deposits, the distributions and extents of key deposits, and presence/absence of archaeological artefacts. Full reports and discussion of this material are included in Sections 3 & 5, but the key implications are summarised here:
    - The majority of OSL dates sampled from the river terrace deposits are younger than OIS-9 (one of the Chard samples exceeds this age). While it would appear that several of the OIS-3 ages reflect cryoturbation of older deposits, the general impression is that the modern fluvial drainage patterns of the Exe, Otter and potentially the Axe (essentially north–south) are relatively recent, post-dating a major re-alignment of palaeo-drainage systems. This also implies that any artefactual material originally associated with pre-OIS-9 terrace deposits have the potential to have been substantially re-worked (see also comments below). Such re-working would be likely to disperse material, resulting in single artefact and/or low concentration findspots. Material may also have been re-worked into the marine zone. While the younger deposits (post-OIS-9) retain potential for larger concentrations of material (e.g. as at Broom in the Axe valley), it should be noted that Palaeolithic Britain from early OIS-6 to OIS-4 remains apparently abandoned.
    - Evidence for extensive cryoturbation in the shallower terrace deposits suggests both intensive cold-climate conditions, associated by OSL dating with OIS-3 (and probably OIS-6), and potential re-working of older deposits (and archaeology contained within them).
    - Field investigation of terrace gravel deposits in the Exe valley has indicated that at least some of the terraces (e.g. terrace 6 at Yellowford Farm) are composed of relatively thick (3–4m) gravel deposits, in contrast to thin, ‘draped’ deposits which may be associated with less fluvially concentrated periglacial outwash flows. These thicker and more substantial deposits may be suggestive of a different type of fluvial depositional environment and/or differential incision activity.
    - The Exe and Otter rivers show a marked contrast in terrace formation with the river Axe to the east. The former rivers are marked by clearly distinguished staircase (“strath”) terrace systems, while the Axe is a fill terrace system. This contrast may reflect an abundant supply of sediment from the weathered Cretaceous and Tertiary materials of the Blackdown Hills and insufficient discharge to remove the material and incise, although it is possible that local variations in uplift rates may also play a role.

    - The geochronological framework, cryoturbation evidence, terrace formation models, and archaeological assessment suggest that the recorded distribution of artefacts in the deposits of the Palaeolithic rivers of the south-west region is not necessarily representative of the spatial and/or chronological distribution of Middle and Late Pleistocene hominins. The observed distribution represents a series of taphonomic factors: the greater concentration of artefacts in the Axe valley (principally at Broom) may at least partially reflect the fill-nature of the Axe terrace system (although this does not fully explain the *current* paucity of artefacts in other substantial deposits of the Axe, such as at Chard Junction and Kilmington). The apparent paucity of artefacts to the west does not seem to be due to a paucity of deposit exposures (particularly beneath the town of Exeter in the Exe valley), but rather due to re-working of older strath terrace deposits (as indicated by cryoturbated deposits and OIS-3 ages for these disturbed sediments), which may have eroded, dispersed and re-worked any artefact assemblages (potentially into the maritime zone).
- ALSF-2.2 (develop management/conservation strategies) is supported by the delivery of GIS and HER compatible resources with associated metadata, to the ADS and the county HERs and therefore available to be utilised within the development of management/conservation strategies for the historic environment within current or future areas of aggregates production. These resources are underpinned by the project fieldwork and desktop evaluations. The key implications of the GIS/database resources for the development of future strategies are (see Section 5 for further details):
    - The contrast between the terrace formation processes in the Exe and the Otter (strath terraces) and the Axe (fill terraces) highlights the relative difference in the archaeological signature of the aggregates deposits from the different river valley systems.
    - It should also be noted however that the fill terrace deposits of the Axe offer greater potential both for fine-grained and/or organic channel deposits and palaeoenvironmental remains, and significant archaeological assemblages.
- ALSF-2.3 (training and professional development) is supported by the distribution of the GIS and HER compatible resources with associated metadata to the county HERs, with the new resources providing education for HER staff with regards to the nature and structure of Palaeolithic archaeology and Pleistocene fluvial geology resources and data. This has also been supported by the attendance of HER staff and county archaeologists at project outreach events, activities, and workshops/seminars (see also below).
- ALSF-2.4 (operation of the planning system) is supported by the status of the currently operating aggregates quarry at Chard Junction, and the results of the project fieldwork. Chard Junction (Hodge Ditch) is currently working under extant permissions, following an inspector's recommendation adopted by the Planning Committee. Permissions for working at Hodge Ditch were granted in 2002, and continued working and disruption is anticipated for as long as there are economically viable reserves in the permissions area. The deposit ages sampled during the course of this project have underpinned new understanding of fluvial deposit formation in the Axe Valley, and the implications of the work to date have highlighted the importance of negotiating future access for an ongoing watching

brief, with the potential for further dating and sampling (in particular of the deepest deposits in the fluvial sequence at Chard) as appropriate.

- ALSF-2.5 & ALSF-3.1 (education, interpretation, outreach, and community involvement) are supported by the outreach activities (artefact identification sessions, Palaeolithic Geoarchaeology walks) and dissemination resources (websites, literature, exhibitions) produced by the project (see Section 4 for further details). These activities and resources have raised awareness about the importance of river gravels for our understanding of Pleistocene landscape evolution and the distribution and nature of Palaeolithic archaeology in the south-west region. They have also communicated knowledge to the public gained through old (e.g. at Kilmington) and current (e.g. at Chard Junction) aggregates extraction processes.
- ALSF-2.6 (dissemination and assimilation to stakeholder groups) is supported by the hosting of the project seminars/workshops (July 2005 and July 2006), which were attended by aggregates company staff, English Heritage and English Nature staff, County Council archaeologists and HER staff, museum staff, BGS staff and RIGS representatives, and academic staff. Discussion themes at the project seminars/workshops included 'working with the aggregates industry' and 'post-project outreach'.

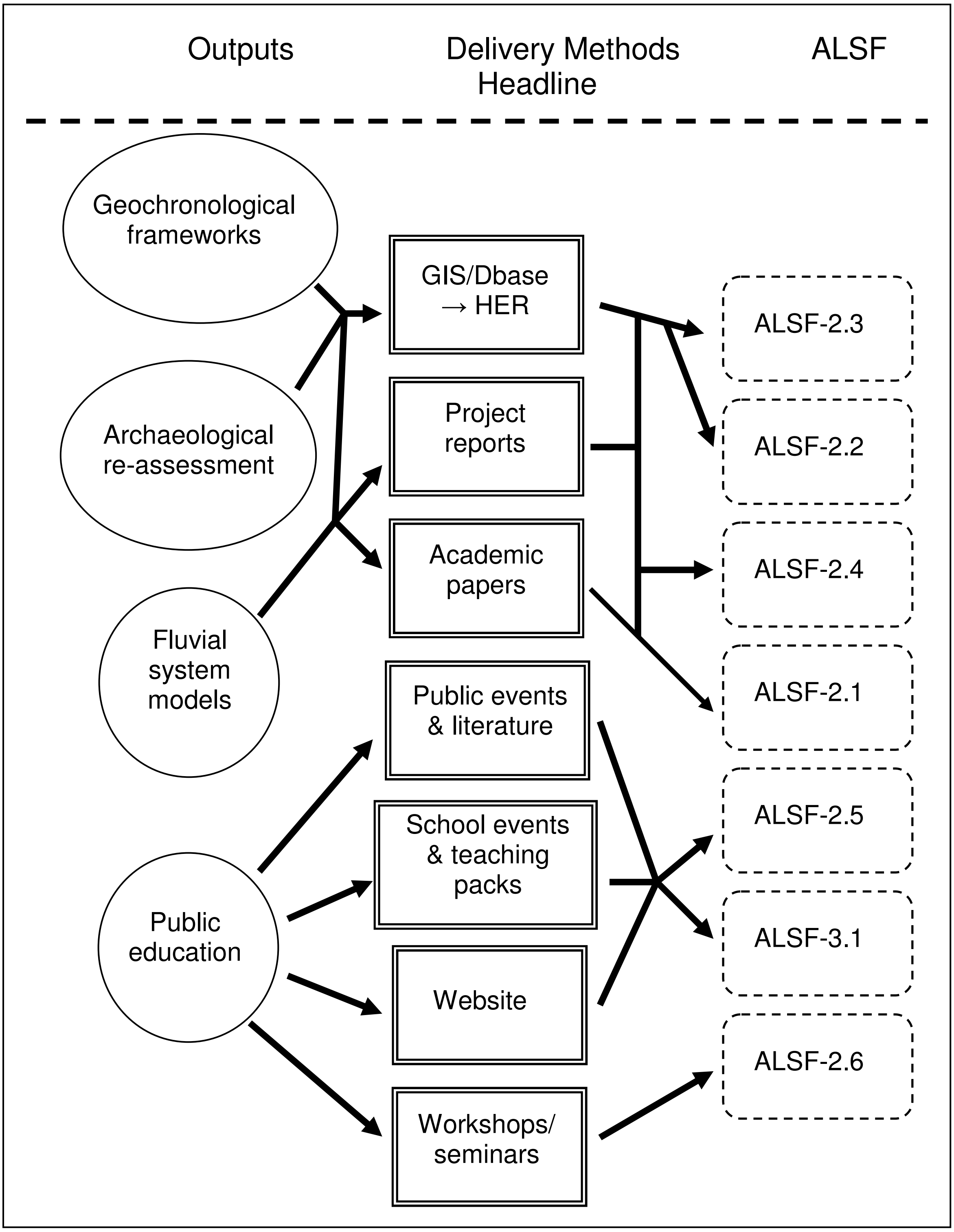

Figure 1: PRoSWeB project outputs, delivery methods, and ALSF criteria

2. PROJECT BACKGROUND & PHASE I RESOURCE ASSESSMENT

This section summarises the project background and rationale (Sections 2.1–2.6), and the results of phase one of the project, which undertook a resource assessment of the Lower and Middle Palaeolithic archaeology and Middle and Late Pleistocene fluvial (river terrace) geomorphology of the south-west region of Britain (Sections 2.7–2.9). The project background discusses the instigation of the work in light of potential threats to the aggregates resource of the region (Section 2.1) and contemporary developments in Palaeolithic archaeological and Pleistocene geological research (Sections 2.2–2.5).

The goals and objectives of the resource assessment phase of the project were as follows:

- Identification of all river systems in the south-west region where past aggregates extraction has taken place, where aggregates extraction currently occurs, and where mineral planning has identified Areas of Search in each of the local authorities within the study region.
- Assessment (including field verification) of the Palaeolithic geoarchaeological potential of the river systems of the south-west region, with regard to the presence/absence of: (i) terrace landforms containing coarse- and/or fine-grained fluvial sediments of Pleistocene age; (ii) sediments appropriate for the application of optically stimulated luminescence dating (OSL); (iii) Palaeolithic archaeological material, either stone tools or organic artefacts; and (iv) biological material appropriate for palaeo-environmental reconstructions (e.g. pollen assemblages).
- Collation of extant and 'invisible' records documenting the Lower and Middle Palaeolithic archaeology (findspots and artefacts) associated with the fluvial landscapes of the south-west Britain region.

2.1 Potential Threats to Aggregates Resources in the South-West

In the counties of Cornwall, Devon and Somerset there is no large scale aggregates extraction from post-Tertiary sands and gravels (Brown 2004). The majority of existing and future aggregate provision is, and will be, met by hard rock sources, particularly from the Mendips (Somerset CMLP), and Cenozoic and Mesozoic sands and gravels (Cornwall CCMLP & Devon CMP). However, this has not always been so and there is some both current, and potentially future, small-scale extraction in the region. The soft aggregate resource in south-west England has never been fully evaluated, yet geological mapping has shown that the major valleys including the Axe, Exe, Tone, Taw, Torridge and Tamar, and smaller valleys in Cornwall, contain gravel terraces or suites (Brown 2004). The archaeology associated with these deposits has been largely unknown and yet is under threat from a variety of directions:

- Continued small-scale sand and gravel extraction (including the re-working of old permissions). Examples include the active sand and gravel quarry at Chard Junction (RMC Group) in the Axe Valley, the Kilmington site in the Axe valley, and the pit at Trewint Marsh, Bodmin being worked by the Bodmin Alluvial Sand and Gravel

Company, which is not even *recorded* in the Cornwall Minerals Local Plan. Many farmers also episodically use small pits which are rarely (if ever) recorded.

- Several sites now come under the aggregate tax due to secondary production of sand and gravel. These are sites where the primary economic mineral is not sand and gravel but typically ball clay or kaolinite and these resources frequently lie underneath Quaternary sand and gravel deposits. If they sell sand and gravel they now come under the tax. This includes the kaolinite sites at Petrockstowe Basin and in the Bovey basin, both of which contain Quaternary gravels, and the ball clay sites in the Bovey basin.
- Prohibition order sites. These are sites which are presently dormant (for more than two years), but which retain full permissions, and therefore applications can be made for these workings to be re-activated.
- The neglect and/or infilling of old quarries. In particular the flooding or infilling of quarries with inert materials renders the aggregates and archaeological resource inaccessible and effectively sterile.
- Borrow pits. These are temporary mineral workings that are required to supply aggregate materials (often over the short-term) for use in specific constriction projects. Borrow pits tend to be local to the projects, and the prohibition order sites described above would be candidates to be utilised in this capacity.

These varied threats illustrate that although the aggregate archaeology resource in south-west England is different to that in many other regions of the UK, it is under threat and, critically, there has traditionally been virtually no data regarding the types of archaeology and palaeo-landscape evidence that are present and the quantities that are being threatened. These are clearly issues of aggregates resource management covered by the ALSF criteria, and a key goal of the overall project is the provision of new data to assist in the current and future management of the resource.

2.2 Academic Context

The wider context for this ALSF-funded assessment of the Lower and Middle Palaeolithic archaeology, Pleistocene fluvial landscapes, and hominin occupation of south-west Britain covers a range of factors: (i) the paucity of Palaeolithic studies undertaken in the south-west region, particularly over the last twenty years, despite other developments such as Campbell's (1998) review of the Quaternary of south-west Britain; (ii) the limited understanding of the Palaeolithic archaeology of this marginal region at the north-western fringes of the Acheulean world (e.g. Wessex Archaeology 1993; Wymer 1999); (iii) the development of complementary regional studies and national studies of the British Quaternary and Palaeolithic archaeology, which have contributed to the continuing development of a dynamic, national research framework; (iv) recent advances in the understanding of the evolution of the English Channel, particularly with respect to the palaeogeography of the Channel River and its tributaries (e.g. Antoine *et al*. 2003; Bates *et al*. 2003; Gibbard & Lautridou 2003; Lericolais *et al*. 2003; Reynaud *et al*. 2003), and their relevance to the processes of hominin colonisation and movement in the northern France/English Channel 'landscape'/southern Britain region; and (v) recent recognition of the archaeological potential of secondary contexts (Hosfield & Chambers 2004), and the importance of assessing the fluvial, secondary context component of the south-west's Palaeolithic archaeological record (i.e. assemblages of derived stone tools occurring in fluvial sands and gravels, which at a national level represent 80–90% of Britain's known Palaeolithic heritage (Wymer 1999)), alongside its better known cave deposits (Campbell & Sampson 1971; Straw 1995, 1996; Wymer 1999).

2.3 Pleistocene Fluvial Geology of the South-West

The rivers of the south-west region are beyond the limits of the Anglian (OIS-12) glaciation as traditionally defined (Figure 2). However the Clevedon exposures (a buried channel filled with glacial out-wash) and a glacially striated boulder at Kenn Pier in Somerset suggest that the Anglian, or possibly an OIS-16, glaciation did extend southwards beyond the Bristol Channel (Wymer 1999: 182). The probable line of the ice limit in Devon and Somerset on the basis of this evidence is therefore also indicated here (Figure 2). Nonetheless, it is clear that the Pleistocene fluvial deposits of the majority of the south-west region's rivers have not been subject to direct glacial modification, although the potential impacts of indirect glacial processes (e.g. pro-glacial lake overflows) have been the subject of discussion (e.g. Stephens 1974, Green 1974).

The Pleistocene geology of the south-west region is highly variable and complex, reflecting a combination of factors: (i) the considerable thicknesses of gravels in the Axe valley are poorly understood, since a potential explanation of pro-glacial lake overflow (creating the Chard Gap and supplying 'catastrophic' quantities of gravel into a previously minor Axe valley) is not supported by the absence of glacial erratics in the River Axe gravels (Wymer 1999: 183); (ii) westwards of the River Exe, river gravels are typically poorly preserved, reflecting the steep profiles of the rivers in their descent from the Dartmoor and Exmoor plateaux to the sea, and their resultant cutting of narrow, gorge-like valleys in which Pleistocene-age deposits are often poorly preserved; and (iii) the age of the well preserved terrace gravels of the River Otter and the Doniford Head gravels remains unknown.

2.4 Archaeological Background

With respect to its Palaeolithic archaeology the south-west region is typically renowned for its caves and rock shelters: Somerset Limestone Quarry, Westbury-Sub-Mendip, Somerset (Bishop 1975; Andrews *et al.* 1999); Kent's Cavern, Torquay, Devon (Campbell & Sampson 1971, Straw 1995, 1996); Windmill Cave, Brixham, Devon; Rhino Hole, Wookey, Somerset; Hyena Den, Wookey, Somerset (Tratman *et al.* 1971); and Somerset Uphill Quarry, Weston-Super-Mare, Somerset (Harrison 1977). These sites have yielded archaeological materials dating to both the pre-Anglian (OIS-12) period (Westbury-Sub-Mendip and Kent's Cavern) and the Middle Palaeolithic (Kent's Cavern, Rhino Hole and the Hyena Den, and the Uphill Quarry).

It is clear from recent syntheses however (Wessex Archaeology 1993; Wymer 1999) that the south-west region also contains Palaeolithic archaeological materials (stone tools) associated with surface deposits (e.g. clay-with-flints) and fluvial contexts (e.g. river terrace gravels), alongside the better known caves and rock shelter archaeology. However, it is also noted that the numbers of Palaeolithic artefacts are small, especially in south Somerset and Cornwall. Moreover, the majority of recorded deposits and artefacts are currently undated (*c.f.* the Broom assemblage (Hosfield & Chambers 2002; Hosfield & Chambers 2004; Toms *et al*. 2005)). Finally, the majority of the stone tools and other artefacts recovered from fluvial contexts are also derived, and are often recovered from Holocene alluvium deposits into which they have been re-worked over time.

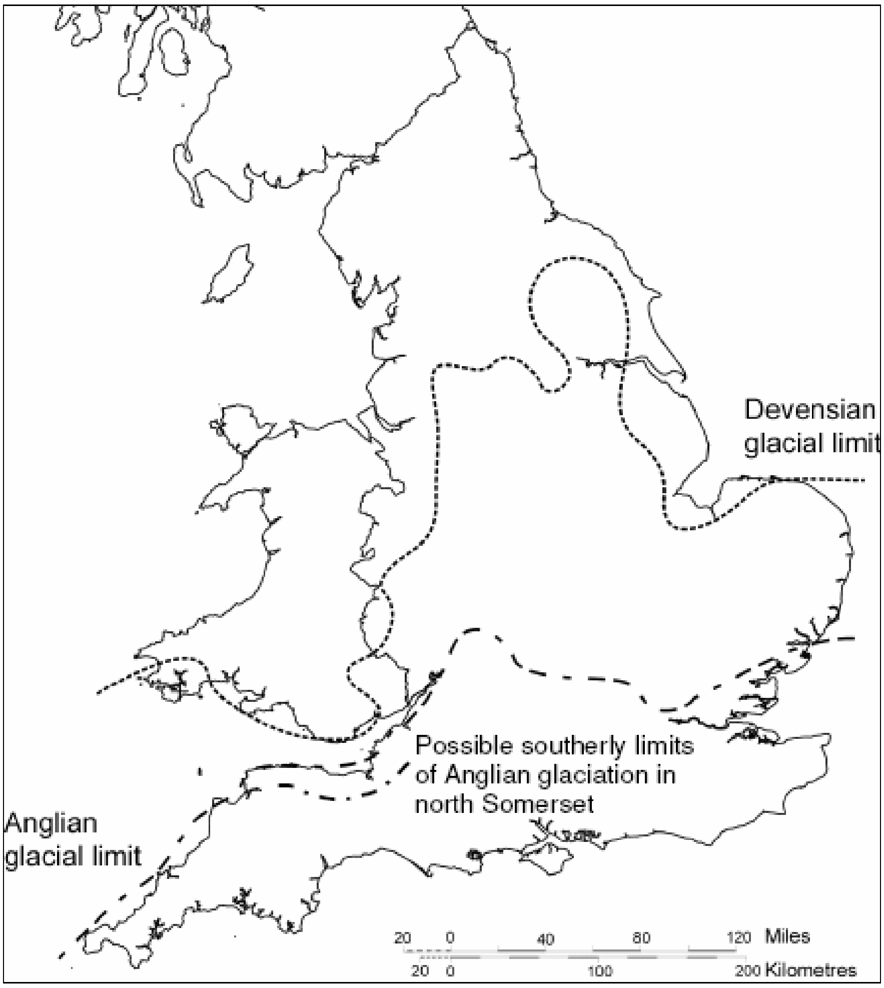

Figure 2: Southerly extents of the Devensian and Anglian glaciations (after Wilkinson 2001: Figure 1; Wymer 1999: Figure 43)

The question of how Palaeolithic hominins accessed the south-west region remains unresolved. This reflects both the poor understanding of the archaeology of the region, and wider issues regarding the Palaeolithic occupation of Britain. Current dating of the British Palaeolithic indicates a complete abandonment of Britain between OIS-6 and OIS-4/3 (Wymer 1999), a trend traditionally linked to the severe glacial climates of OIS-6 and the high sea-levels (preventing access from continental Europe) of the Ipswichian interglacial (OIS-5e). Moreover, recent models (White & Schreve 2000; Ashton & Lewis 2002) have proposed detailed cycles of Palaeolithic colonisation, occupation and abandonment, associated with the glacial/interglacial phases of the Middle and Late Pleistocene. It is against the background of those models that the colonisation and occupation of the south-west region must be explored. Wymer (1999: 181) has suggested: (i) entry along the southern side of the Severn Estuary into the northern zone of the south-west region; (ii) entry along a corridor lying between the headwaters of the River Kennet and the Hampshire Avon, and the Bristol Avon; and (iii) entry into the River Axe valley system through the South Dorset Downs. All of these routes stem from the more intensively occupied Palaeolithic regions in central southern and eastern England (e.g. the Thames valley and the Solent River system), which ultimately link into the continental river networks (e.g. the Thames/Rhine system in the southern North Sea basin and the Solent River/Channel River/Seine system in the central English Channel basin).

However, recent investigations into the Pleistocene Channel have highlighted the complex palaeogeography of this region during periods of low sea-levels. The distribution of the Channel River and its tributaries indicates the potential for landscape connections between the south-west region, the Channel region (during glacial phases and low sea level) and, further to the south, north-western continental Europe (especially the Normandy and Brittany regions of France). These potential links also require assessment with regard to possible routes for hominin access into the south-west region.

2.5 Previous Archaeological & Geological Research

There has been relatively little investigation of the Lower and Middle Palaeolithic archaeology of the south-west region, particularly with respect to the open-air 'sites' (i.e. not cave deposits) associated with fragmented fluvial landscapes. Wymer (1999: 181–188) provides the most recent and comprehensive review, documenting the artefact finds from the river gravels exposed in the Broom, Chard Junction and Kilmington pits (the River Axe valley); the artefacts exposed in the Doniford Head Gravels at Watchet (see also Wedlake & Wedlake 1963); and the surface sites (on clay-with-flints and Upper Greensand bedrock) and other poorly provenanced finds both to the east (including Whitestaunton, Wambrook, Membury, Chardstock, Tatworth, Lyme Regis, Shute, Seaton, Weymouth, Portland and Bere) and to the west (including Kingsteignton, Haccombe with Combe, Teignmouth, Tiverton, Thorverton, Budleigh Salterton, Sidmouth, Ladock and St Buryan) of the River Exe. A sample of the data from Wymer (1999: 181–188, derived from Wessex Archaeology 1993) is summarised in Table 1, indicating both the scope (and limitations) of the existing data.

Location (where given)	Site NGR (where given)	Archaeological & geological information
Thorncombe	ST 341045	-
Chard Junction Pits	ST 345044	*c*. 10 handaxes; “several others” with Chard provenance, including 2 Levallois flakes
Broom Gravel Pits & Hawkchurch	ST 328025 & ST 326020	Minimum 1800 handaxes; 1 Levallois core & 2 flakes; deposit thickness & divisions; assemblage origins
Axminster	-	-
Wyke District	-	-
Kilmington & Kilmington Pit	SY 277982 & SY 275980	*c*. 10 handaxes
Whitestaunton	-	Surface sites on Clay-with-flint-and-cherts; mostly individual handaxes
Membury		
Wambrook		
Chardstock	-	Surface sites on Upper Greensand; mostly individual handaxes
Tatworth		
Lyme Regis	General provenance only	Mostly individual handaxes
Shute		
Seaton		
Weymouth		
Charmouth	-	One handaxe, possibly from river gravel
Portland	-	Two handaxes; found on Portland Beds
Bere	-	Two handaxes
Watchet	ST 090432 – ST 115434	Artefacts on beach, derived from head gravel (Doniford Gravel) on top of cliff; minimum 24 handaxes, 29 cores, 148 flakes, 1 Levallois flake
Watchet	-	Single handaxes; found in Doniford Gravels
Williton	-	-
Bradford-on-Tone	-	Two palaeoliths; from edge of alluvium in valley of River Tone
Taunton	-	Surface finds from hills south of Taunton
Exeter (Magdalen Street)	-	One handaxe; in River Exe gravel (*in situ*)
Thorverton	-	Derived handaxe(s?); found near bottom of river coombe
Kingsteignton	-	Single handaxes; recovered from alluvium
Haccombe with Combe		
Teignmouth		
Tiverton	-	Two handaxes; found on surface of river gravel
Halberton	-	8 handaxes and fragment of another; on surface of Palaeozoic rocks
Wigginton	-	One handaxe; on edge of terrace gravel
Budleigh Salterton (Tidwell Mount)	-	One handaxe; on edge of Terrace 5 gravel

Sidmouth (Mutters Moor)	-	One handaxe; on Head gravel
Newton Poppleford	-	Single handaxes; found on Palaeozoic rocks
Harpford, Woodbury		
Budleigh Salterton		
Brent Moor	-	Single handaxe; surface site
Constantine	SW 730303	Single handaxe; very worn & stained
Grade Ruan	SW 768186	
Landewednack	SW 695135	
St. Buryan	SW 405276	
Ladock	SW 893505	Broken handaxe (pointed end); from riverbank
-	SW 704129	Broken handaxe; very worn & stained
Lanhydrock	SX 077636	Broken handaxe; very worn & stained
-	SW 679129	Tip of handaxe; very worn & stained
-	SW 707129	Bifacial fragment; very worn & stained
St. Keverne	SW 725205	Single handaxe, bifacial fragment and 8 flakes; very worn & stained
Higher Polcoverack Farm	SW 769188	Struck Levallois core; very worn & stained

Table 1: Lower Palaeolithic data for the south-west region, synthesised from Wymer (1999)

However, it is also clear from discussions with regional archaeological staff (e.g. Chris Webster and Dr Frances Griffith) that the south-west also has an 'invisible' Palaeolithic resource, consisting of findspots and artefacts (often held in local and regional museums and private collections) which is not documented either in the Southern Rivers Palaeolithic Project (SRPP; Wessex Archaeology 1993) or in Wymer's (1999) recent synthesis. Moreover, the recent EH-funded syntheses (Wessex Archaeology 1993; Wymer 1999) provided little or no detail regarding artefact typology (e.g. biface types) and/or the physical condition of the material, and were restricted in the south-west region to summaries of numbers of artefacts from findspots and their division into very broad categories (e.g. bifaces (handaxes), cores, and flakes). Finally, the EH syntheses were also limited (reflecting the scope of those projects and the periods in which they were undertaken) in terms of geochronological data.

Although the cave and rock shelter sites of the region have been well documented, the only major investigation of an open air assemblage has occurred for the Broom pits in the River Axe Valley (Reid Moir 1936; Shakesby & Stephens 1984; Green 1988; Marshall 2001; Hosfield & Chambers 2002, 2004). These studies have documented the archaeology as a late Acheulean (*c.* 250,000–300,000 BP) biface-dominated assemblage in secondary context (fluvial river terrace gravels and sands); although Hosfield & Chambers (2004) argue that the stone tools have been principally derived from local rather than regional sources. The richness of the Broom biface assemblage highlights one of the major academic research questions associated with an investigation of the Lower and Middle Palaeolithic archaeology of the south-west: *does the rich archaeology of the River Axe valley represent a 'western' frontier in terms of the British Lower and Middle Palaeolithic, beyond which Palaeolithic occupation of the south-west region was highly* *sporadic? Or is the apparent paucity of archaeology to the west of the Axe valley due principally to issues of taphonomy and sampling?*

In contrast to the limited suite of archaeological investigations, there have been a wider range of geological studies with respect to the Pleistocene geology of the south-west region (Salter 1899, 1906; Ussher 1906; Woodward 1911; Green 1947; Stephens 1970a, 1970b, 1974, 1977; Green 1974; Shakesby & Stephens 1984; Campbell 1998; Brown *et al.* in prep.). These studies have also been augmented by the recent re-mapping of the Exeter region by the British Geological Survey. Alongside the mapping of the major Pleistocene deposits of the region, these studies have also highlighted two issues whose further research is critical to the interpretation of the south-west region's Lower and Middle Palaeolithic archaeology:

- The absence of robust geochronological frameworks for the Pleistocene fluvial deposits (with the recent exception of the Middle Pleistocene sands and gravels exposed at Broom in the Axe Valley).
- The limited understanding of the processes of terrace development in the south-west region, which appear to be markedly different to those documented for the Thames valley and the Solent River in south-east and southern England (e.g. Bridgland 1994, 2001; Maddy *et al.* 2001).

Recent investigations of the River Axe valley's Palaeolithic archaeology, principally the assemblage from the Broom pits (Hosfield & Chambers 2004), developed theoretical models of secondary context assemblage formation and artefact re-working in fluvial systems. The field testing of these models against the Palaeolithic fluvial landscapes of the south-west region is central in developing an improved understanding of two key elements of the regional archaeological record:

- Why is the distribution of derived artefacts in the River Axe valley so heavily biased towards Broom, particularly in light of the major gravel exposures at Kilmington and Chard Junction?
- Do the isolated artefact finds from the south-west region (especially to the west of the River Exe) genuinely represent a minor archaeological presence or are they the remnants of larger assemblages whose identification has been hindered by the poor preservation of river terrace deposits in the steep-gradient valleys?

2.6 Background Summary

Building upon the state of knowledge summarised above, the phase one resource assessment addressed the issues of the distribution and potential of the fluvial landscapes of the south-west and the nature of their threats (Section 2.7), and the scope of the Lower and Middle Palaeolithic archaeological resource in the south-west region, both visible and invisible (Section 2.8).

2.7 Assessment of Geoarchaeological Potential

2.7.1 The impacts of climatic change on the south-west during the Pleistocene

Ice cover, changing sea levels and uplift have all had a significant impact on the fluvial systems and Quaternary landforms of south-west Britain; particularly the formation of river terrace systems, which are the primary focus of this report. Currently, the earliest evidence of glaciation in south-west Britain is *c*. 600 kya BP, though the dating evidence is insecure. At Kenn Pier in Clevedon, a channel fill with fossils, and estuarine deposits known as the Yew Tree Formation, is indicative of temperate conditions. These deposits overlie members of the Kenn Formation, which has been interpreted as glacial outwash and till. Amino acid racemization (AAR) dates have suggested the Yew Tree Formation can be correlated with OIS 15, which in turn suggests a pre-Anglian age for the underlying deposits (Campbell 1998). The Oxygen Isotope record suggests a major climatic deterioration and very large ice volumes during OIS 16, so an association of the Kenn Formation with this OIS does not seem unreasonable (Campbell 1998). Evidence for such early glaciations is rare elsewhere in Britain, although Lee *et al*. (2004) have suggested an OIS 16 age for the Happisburgh glaciation in eastern England. With regard to the Kenn Pier deposits, other authors tend towards an Anglian or more recent cold event association (e.g. Kellaway & Welch 1993). As shown in Figure 3 however, it is possible that the maximum extent could be as old as OIS 16, and could also be the source of the glacial erratics found on the coasts of Devon and Cornwall (Campbell 1998). There is evidence to suggest the ice extended southwards beyond the Bristol Channel, but it is unlikely that it covered more than the very fringe of the North Devon landmass, and probably terminated in the Bristol Channel. Deposits such as the Fremington Clay, previously thought to be associated with ice-cover, are better interpreted as having formed in a glacio-lacustrine environment (Campbell 1998). The age of the Fremington Clay formation is as controversial as its history of interpretation, but it is possible it dates to OIS 12 (Campbell 1998).

Irrespective of whether the maximum extent of glaciation is associated with the Anglian (*c*. 478–423 kya BP) or OIS 16 (*c*. 600 kya BP, part of the Cromerian Complex), south-west Britain lay at the limits of the ice sheets. This means that most of the study area was spared the consequences of direct glacial erosion. Instead, it has been strongly affected by periglacial processes. These include denudation and the formation of thick "head" deposits (discussed further below), which characterise large areas of the south-west. During the Last Glacial Maximum (OIS 3 at *c*. 18 kya BP), also shown in Figure 3, ice cover has been argued to only extend as far south as South Wales (Campbell 1998), although Scourse (1987, 1991a, 1991b, 1996, 1998) has identified deposits on the Isles of Scilly linked to an Irish Sea glacier, and has suggested that this glacier may also have clipped the coast of north Cornwall. Irrespective of the extents of this glacier however, periglacial processes would have destroyed, masked, or re-worked many of the features associated with earlier glaciations, though certainly not all of them, across the south-west region. Essentially then, because the study area was not glaciated, fragments of Quaternary landscapes predating the Last Glacial Maximum have been preserved. Terraces in the lower reaches of the valleys, and estuaries associated with several major drainages, are also preserved, but because of the rise in sea levels since the Last Glacial

Maximum these are now submerged (e.g. Edwards & Scrivener 1999; Antoine *et al.* 2003).

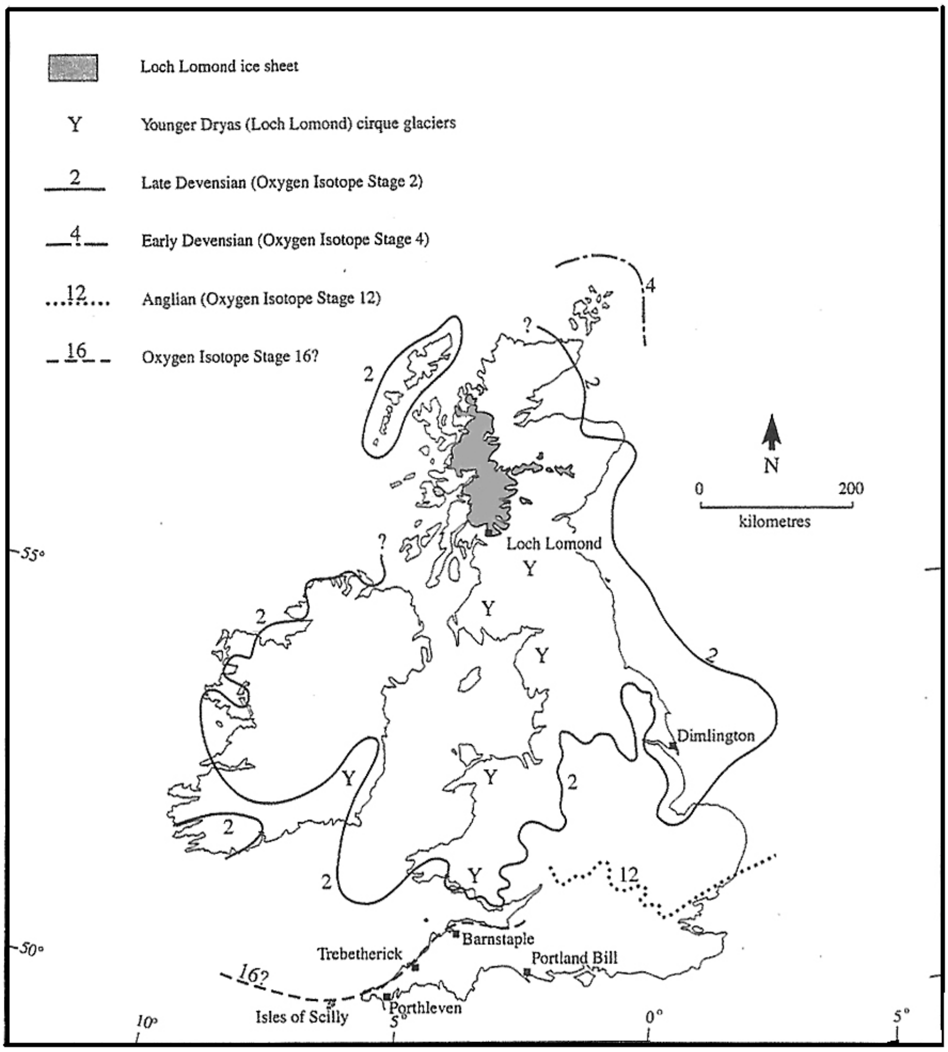

Figure 3: Reconstructed Pleistocene maximum ice limits adapted from Campbell (1998: Figure 2.3)

2.7.2 Rivers, Terraces and Archaeology

The earliest known occupation of the British Isles by hominins is represented at sites such as Boxgrove (*c*. 500 kya BP (Roberts 1994)), Swanscombe (*c*. 400 kya BP (Stringer & Hublin 1999)), and Kent's Cavern, where recent re-dating and re-examination of the sequence suggests correlation of the artefact-bearing breccia with OIS 10 (*c*. 380–339 kya BP) or earlier (Proctor *et al*. 2005). Therefore, evidence for the occupation of the British Isles by hominins occurs during the latter part of the Pleistocene from the Cromerian onwards (see Table 2).

The cave sequences of the south-west region are comparatively well documented, and this project has been concerned with finds from "open" sites of the south-west, and particularly those associated with river terrace deposits. As noted by Wymer (1999) *"…the great majority of the evidence for the Palaeolithic occupation of Britain comes from river deposits"*; and in general these are the river terraces of south-east Britain. Because these are so extensive, they have been widely exploited as a primary aggregate resource, and a far greater proportion of archaeological material has been retrieved from them. They have been well studied, and have formed the basis for the development of widely accepted models of climate-driven terrace formation (e.g. Bridgland 2000; Maddy *et al*. 2001), as summarised in Figure 4.

OIS	Quaternary name		Age years BP	Archaeological Periods
1	Holocene		10.5 K-present	Mesolithic-Modern
2	Late Devensian		12.5 -10.5 K	Late Palaeolithic (Upper Palaeolithic)
3	Middle Devensian		50-12.5 K	Middle Palaeolithic
4	Early Devensian		70-50 K	
5a			110-70 K	
5b				
5c				
5d				
5e	Ipswichian *sensu stricto* (T)		130-110 K	
6	Wolstonian 3		186-130 K	
7	Ilfordian	Stanton Harcourt (T)	245-186 K	
8	Wolstonian 2		303-245 K	
9	Wolstonian1/2		339-303 K	Lower Palaeolithic
10	Wolstonian 1		380-339 K	
11	Hoxnian (T)		423-380 K	
12	Anglian (C-G)		478-423 K	
21-13	Cromerian Complex		c. 500 K	

Table 2: A Pleistocene Chronology, adapted from Brown (forthcoming)

River terraces are most easily defined as past floodplains which have been abandoned by river incision and so now exist as landforms above the present river and floodplain. Their archaeological significance comes from both the attraction of floodplains for many human activities (hunting, fishing, plant and rock gathering) and the inevitability of human interaction with rivers (crossings and transport). The open game-rich character of Palaeolithic floodplains has always been associated with open-air scatters such as knapping sites, butchery sites and camps. Once abandoned through river incision terraces remain attractive to hominin settlement due to close proximity to the river and floodplain resources but less risk of flooding (Brown 1997). Terraces may form *"by any environmental factor which causes river incision into the old floodplain, including climatic change, changes in sediment availability, changes in catchment hydrology, tectonic activity and base level change"* (Brown 1997). Such floodplains may be divided into cold, glacial, periglacial or cold temperate conditions, and generally consist of gravels with few organic remains, or under interglacial, or interstadial conditions, finer sediments with organic-rich channel fills. For the vast majority of the Pleistocene however, gravels in SW Britain would have been formed under periglacial conditions.

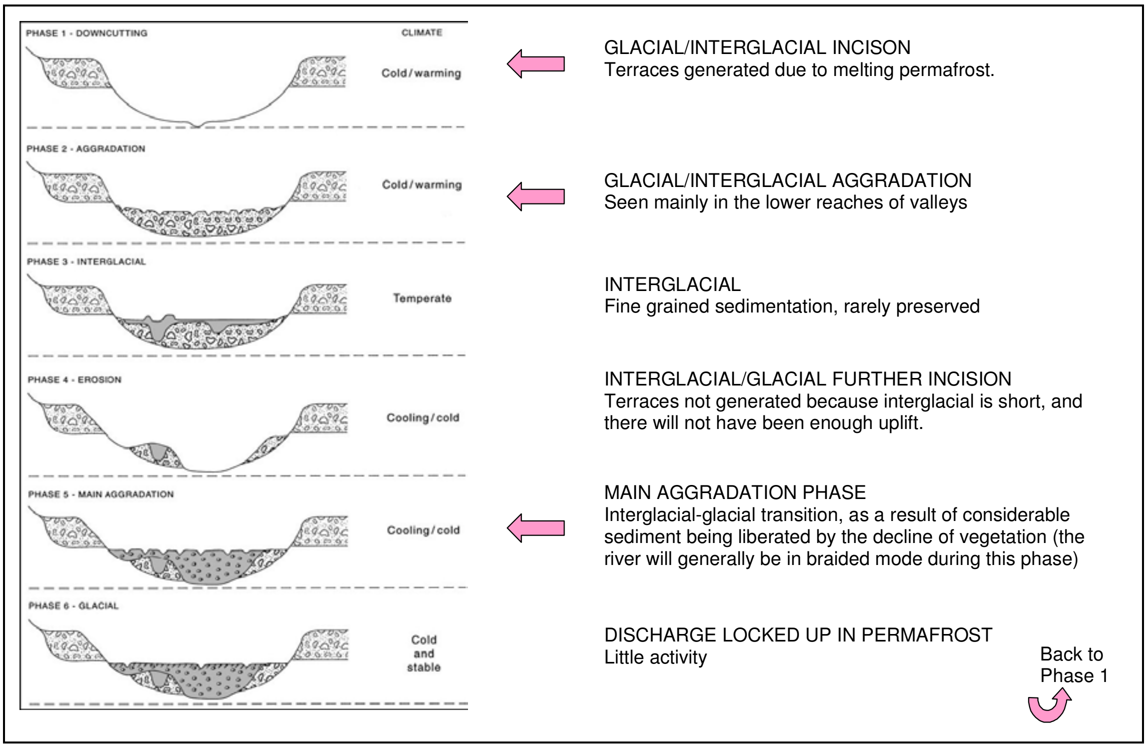

Figure 4: Major Terrace Formation Periods: Bridgland's Cyclic Climatic Fluctuation Model, adapted from Bridgland (2000: 1295 & Figure 1)

In contrast to the impressive "staircase" sequences associated with the Middle Thames for example (Bridgland 1998), very little attention has been paid to the terrace sequences of south-west Britain. Although it cannot be denied the river terrace deposits are not as widespread as in the east of the country, this does not mean they are unimportant or not at risk from extraction. The cave sites clearly show hominins were present in this area of the country and provide an excellent sequence into which palaeo-landscape reconstructions could be tied. It is most important then that the research bias with respect to the river terraces is redressed. These river terraces are one of the few sources of information we have about the palaeo-landscapes inhabited by the earliest occupants of Britain.

That river terrace deposits exist in the area and that some of these could be of considerable antiquity has been known for many years (e.g. Ussher 1876). The only study that has considered Palaeolithic archaeology in relation to these deposits in the south-west was conducted by Wessex Archaeology some ten years ago (Wessex Archaeology 1993, Wymer 1999). He identified a number of findspots in the south-west region, and contrasted the considerable thicknesses of gravels in the Axe valley, with the more fragmentary terraces to the west. He wrote, *"…westwards the geology is very different and terrace gravels are non-existent or very poorly preserved. The Exe, the Teign, and the Dart all have their sources on high land on Exmoor or Dartmoor between 450 and 500m OD. Thus they have very steep gradients in their descent to the sea and correspondingly cut narrow gorge-like valleys. The result is that as such rivers cut down, they leave nothing of their previous deposits"* (Wymer 1999). This is in part true. The bedrock geology is an important consideration in terrace formation, as is the base level gradient (Brown 1997), but Wymer considerably overstates the fragmentary nature of the terraces. This is largely due to the lack of research that has been conducted on them. Their landscape morphology does differ from the terraces found further to the east, but exactly why, is something that needs further investigation and is unlikely to be related solely to the bedrock geology. As discussed further below, considerable swathes of terrace deposits exist in the south-west region particularly in association with the Exe, Otter, Taw, Torridge, Tamar, Bristol Avon, and at Doniford in association with the palaeo-river Washford. In recent re-mapping by BGS, river terraces are better differentiated from other gravel deposits, as well as altitudinally (discussed further below), which was not the case in the 1990s (e.g. Wessex Archaeology 1993). Where rivers lack terraces, or have a restricted staircase, this is not necessarily related to bedrock, base level or preservation, but to the fact that the drainage course may be a relatively recent phenomenon — for example the River Sid, or the Honiton branch of the River Otter.

Beyond this, very little is known about the south west terraces. We do not understand how the considerable thicknesses of gravels in the Axe valley formed, since a potential explanation of pro-glacial lake overflow (creating the Chard Gap and supplying 'catastrophic' quantities of gravel into a previously minor Axe valley) is not supported by the absence of glacial erratics in the River Axe gravels (Wymer 1999). Pre-Devensian terraces (such as the Doniford gravels, and the terraces associated with all the drainages listed above) remain undated (though see discussion below). The major exception to this is the date of *c*. 250–300 kya BP obtained by Dr Robert Hosfield and Dr Philip Toms for the terrace deposits at Broom by OSL (Toms *et al*. 2005). In contrast to the deposits of the south-east none of the terraces have been named, and no members, units, or sub-divisions between or within terrace systems have been defined. As this report will show, such differences do exist, but no comprehensive study or work has been conducted on these in the south-west region. Further study of these deposits provides an excellent opportunity to:

- Contextualise the Palaeolithic hominin occupation of Britain.
- Ascertain the likelihood of Palaeolithic artefacts being recovered from specific terrace deposits.
- Gain a much clearer understanding of mid–late Pleistocene landscape evolution and palaeolandscape configuration in the south-west region (including the possibility of gaining a handle on differential uplift rates).
- Understand differences and similarities in the morphology of terrace deposits in the south-west in comparison to the south-east of Britain.
- Provide information on palaeoclimatic change and palaeoenvironmental conditions and intra-terrace differentiation.
- Ultimately, gain an idea of what the landscapes inhabited by hominins actually looked like through the employment of visualisation techniques.

2.7.3 Methods

This section describes the methods and data sources used to produce the geoarchaeological assessment of potential: the results, discussion and conclusions are then presented in Sections 2.7.4 and 2.7.5.

Acquisition and analysis of South-West Region Historic Environment Records

Following the results of the assessment of the BGS maps and memoirs (discussed below), for the purposes of phase one, Devon was chosen as a primary focus area to supplement the wider-ranging assessment of HER and museum data undertaken by Dr Simon Hounsell (see Section 2.8). The purposes of this task were to:

- Assess whether more finds were represented than discussed in the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993; Wymer 1999).
- Put the data into a coherent digital format.
- Display the data in a GIS database.
- See what patterns were generated when the HER records were displayed against the geological data.

HER records for all find spots/sites recorded as having a Palaeolithic component were acquired from the relevant sources (Devon County Council, Torbay Council and Plymouth Council). Records entered as “Prehistoric” were also requested and searched. A detailed Access database was built purely for Devon, which fully incorporated all the relevant HER data, and data from the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993). The database accommodates general site information, geological and archaeological data in a series of linked tables displayed as forms to facilitate data entry. The geological data was derived from the HERs and from studying the BGS map sheets and memoirs described below. Data was split into numerous separate categories to aid a) querying the data, and b) entering a similar resolution of data for the other counties in the study area should this be required at a future date.

Once the original Access database for Devon had been built and the data entered, it became apparent that ArcGIS is limited in the number of characters that can be displayed for a findspot. Consequently, a pared down version of the database was prepared solely for use with ArcGIS (see below), where data entries were shorter and several categories of data were removed entirely. The coding of findspots corresponds with the original, more detailed database, which can be consulted if more information is required about a site by the GIS user. A check box was added to the GIS-linked Access database to show whether further information on the site/findspot is available in the independent, more detailed Access database. The database for GIS display had one further additional category specifying the accuracy of the grid reference to 1000m, 100m or 10m. This allows the accuracy of findspots as defined by grid reference to be displayed visually in GIS. The Southern Rivers Palaeolithic Project's (Wessex Archaeology 1993) accuracy categorisation was not employed, because there were more find spots than identified by that study and the information used to define these accuracy categories was not readily available for all of the new findspots.

Literature review

The literature review has been ongoing throughout phase one, and many of the texts consulted are referenced in this report. Probably the single most important text dealing with Quaternary landforms in the south-west was Campbell (1998), while the Southern Rivers Palaeolithic Project for the south-west region (Wessex Archaeology 1993; Wymer 1999) provided an excellent foundation to build on. A bibliographic Endnote database of the texts consulted was also constructed.

Analysis of BGS maps sheets and memoirs

The purpose of this was to:

- Determine which areas of the study area were mapped in detail, and when.
- Ascertain the extent and location of the terrace deposits.
- Identify which areas should be purchased for the GIS database.
- Learn what information was available on the terraces from the memoirs.

Geological solid and drift maps exist for the whole of the south-west at a scale of 1:50,000. All the most recent maps covering the study area were studied. A catalogue was created in Microsoft Excel that noted number of terraces mapped on each sheet, the river they were related to, and how much head was shown. Coverage of solid and drift maps for the study area at a scale of 1:10,000 varies and is shown in a BGS catalogue. Obviously more detail is shown on maps at this scale, but of particular use is that selected borehole data is also presented alongside the map, and shown on it. A limited number of these 1:10,000 maps were consulted at BGS Exeter. The Exeter Sheet was purchased because: the area had been recently re-mapped in great detail; a considerable number of terraces associated with the River Exe are present in this area; the degree of development made it very difficult to identify the exact extent of terraces and location of boreholes at a scale of 1:50,000. Selected memoirs and technical reports were also consulted for map sheets where significant quantities of terrace deposits were shown.

Analysis of BGS borehole data

Borehole data is useful because it can record limited, localised information on the depth of river terrace deposits, and the material they consist of, without large-scale excavation or exposure. Borehole data coverage for the south-west can be viewed online through the BGS website at http://www.bgs.ac.uk/geoindex/home.html. This website provides basic information: the borehole type, location, precision, date of borehole code and which company conducted the work. The majority of boreholes are drilled prior to housing/industrial development or road construction, which is demonstrated very clearly by viewing the borehole distributions in relation to major roads, towns and cities. There appear to be a large number of boreholes, but the relevance of these to clarifying the depth, constituent materials and dating potential of possible river terrace deposits is extremely variable. Bennett (forthcoming PhD thesis) has put this data to excellent use across a section of the River Exe, using a series of records from boreholes drilled prior to road construction. This enabled her to create profiles of the river valley and its terrace deposits in an area that is now developed.

Only a fraction of the boreholes shown on the web site are located on areas mapped as terrace deposits, and on closer examination of the paper records which has been possible at BGS Exeter and larger scale maps, many of these are of little use. Where 1:10,000 coverage of an area is available, selected borehole records are detailed in the map legend, but the most useful information comes from studying the original paper logs. Some borehole records are classified, and not available for study without express permission from the company who conducted the work. (No such records were examined for this phase of the project). For others, the detailed log data is "missing" though the grid reference of the boreholes is known. The data shown on the paper records varies according to the type of borehole, the reason for drilling it, the date of the work, the company that was involved, the level of recording detail and the experience of the person interpreting the sequence. Of particular interest are those records where more than one person has interpreted the data retrieved, as these demonstrate the diversity of possible interpretations. Frequently, the solid (bedrock) deposits are of primary interest to the company conducting the work, and the superficial (drift) deposits retrieved from boreholes are ignored or only cursorily described. Where superficial deposits such as terrace river gravels are described, the detail given can vary from extremely general: e.g. "Terrace deposit" to more specific: e.g. "Medium dense red/brown, sandy, well-graded gravel". More detailed records may provide good descriptions for several strata, which are then collectively interpreted as river terrace deposits. Such records are extremely useful. They allow one to assess the accuracy of the interpretation as remnant terrace rather than as head for example, and whether it contains materials suitable for dating, e.g. sand or silt lenses or beds in the deposit suitable for Optically Stimulated Luminescence (OSL) dating. Where river gravels lie directly on bedrock, such detailed descriptions also make it much easier to distinguish the depth at which terrace deposits end and regolith begins.

In order to calculate the depth of a possible terrace deposit, the most useful records are those where the ground level O.D. is given. Some borehole records provide a good borehole log, but only an approximate ground level. Where none is given at all, an approximate level can be estimated by looking at the nearest contour, or by re-locating the site and working out the present day ground level O.D. This is not ideal, particularly if the borehole was drilled some time ago or construction has occurred since the borehole was drilled. The most useful records then, are those that contain strata interpreted as river terraces, where the logs provide some detailed descriptions of the deposits, and where both the ground level O.D., and the depths and/or levels of the various strata are recorded. Whilst time consuming, by careful selection of specific boreholes and close examination of the data in their logs, it has proved possible to examine the differences between the river terraces associated with the River Exe and its tributaries.

Consultation meeting (curatorial and minerals planning staff) and analysis of Local Authority MLPs and OMPs

Meetings with the relevant Minerals Planning Staff from Devon, Cornwall and Somerset County Councils were conducted. Communication and discussion of the project with Dorset County Council has only been possible through telephone conversations and e-mails. The purpose of this was to discuss aggregate extraction and waste management policies, and to assess how this research might be most usefully employed by the Minerals Planning Authority Staff and also served to identify areas particularly at risk. The published Minerals Local Plans from each of the relevant counties were acquired and examined with the same goals in mind.

Field verification of digital and desktop data

Several field trips were conducted during Phase 1 with the primary purposes of:

- Examining of locations where dating has been achieved.
- Identifying exposures potentially suitable for dating and fieldwork in phase two.
- Learning to use the differential GPS and conducting survey to ascertain to what degree terraces are altitudinally separated.
- Examining some of the sites where river terrace deposits have been/are being exposed, and removed.

The first visit was to examine areas mapped as river terrace deposits, head deposits and the influence of the solid geology on the River Exe and its tributaries. One trip focussed primarily on the terraces 1 to 4 of the River Exe. A second trip (LB and Dr Richard Scrivener (BGS)) focussed on the higher-level terraces and head deposits. Two further days were spent learning to use the differential GPS and then surveying river transects. One transect was conducted across the River Exe, and the other across the River Culm. Visiting Corfe Mullen, a site that has yielded numerous handaxes from terrace deposits associated with the River Stour, to look at old quarry faces re-exposed by Dr Robert Hosfield and Dr John McNabb provided an extremely useful example of the different nature of terrace deposits east of the River Axe. A day was spent conducting survey at Broom using the differential GPS to resolve some inconsistencies between three previous surveys of the area. Another trip examined some of the higher-level terraces associated with the River Otter to look at their landscape form, accessibility and potential for dating. A further day was spent with Dr Raemus Gallois (BGS) visiting Kilmington Gravel Pit, Broom, and Blackhill Quarry to examine the river gravel exposures in these areas, and in the higher terrace exposures associated with the Otter in the cliffs at Budleigh Salterton.

GIS/database construction, data entry, data checking and data correction

On the basis of the preliminary research, Devon and Dorset were identified as the areas of highest potential (as discussed below), and the geological digital data for Devon and Dorset was purchased. To minimise file sizes, and speed up display, only the superficial deposits have been incorporated in the initial GIS model, though for example data files showing solid deposits (bedrock) and faults could be added to this very quickly. The geological data can be clicked on and associated data displayed, or labels added. The former method of display was chosen for clarity. The data from the Access database from Devon, described above was then added to the GIS database so that each of the find spots/sites could be viewed and when clicked on, a list of associated data displayed. Cave sites as recorded in the Devon HER were also added, but only the name, grid reference and HER number is displayed. Ordnance Survey data for Devon was downloaded from Digimap, and can be displayed as a backdrop to the superficial geological deposits. Finally, all the quarry sites and prohibition order sites listed in the Devon Minerals Local Plan are also shown, but again only their name, grid reference, and MLP reference number are associated with each point. It would be possible to add further information to these data points and to the cave location points.

2.7.4 Results

The following section highlights recent findings about the Pleistocene fluvial deposits in the south-west as a result of the work undertaken by the assessment project (Phase 1). It should be noted from the outset that Devon was swiftly identified as the county with the most potential for expanding our knowledge in this respect. While it would be possible to discuss the other counties in the south-west region in some detail, this would largely replicate discussions presented in Campbell (1998) and Wymer (1999), and the BGS memoirs and reports. As far more, little-known data was identified for Devon, what follows is biased in favour of that county. However, it should be noted that the potential exists for similar data to be generated in the future, through targeted fieldwork in Cornwall and Somerset. These data will also complement work being undertaken in adjacent regions to the Palaeolithic Rivers of South-West Britain study region (e.g. Bates & Wenban-Smith's (2004; Bates 2005) research into the Pleistocene deposits of the Bristol Avon area).

Mapped Terrace Differentiation and Head Deposits

Four key questions were addressed:

- What terrace deposits are there and where are they?
- How and to what degree are the terraces differentiated laterally and altitudinally on the BGS maps?
- What is the actual degree of altitudinal separation between some of these features on the ground?
- What do we know about the structure and material that makes up the terraces?

Examination of the BGS maps at a scale of 1:50,000, the associated memoirs and discussions with staff at BGS Exeter, shows that there is considerable variability in the level of detail shown. Factors such as the skill and experience of the field-cartographer, time and resources all play a role in this. Several areas have recently been re-mapped (e.g. Exeter Sheet (British Geological Survey 1995)) and comparing the old and new versions of the same sheet, or the level of differentiation between the new sheet and older adjacent sheets, these differences are clearly shown. There are five sheets in particular which are currently being re-mapped, or which are difficult to interpret. These sheets are: Tiverton, Wellington, Ivybridge, Tavistock, and Dartmoor Forest (pers. obs.; Dr R. Scrivener, pers. comm. to LB). It is clear from studying the maps that while terraces are present across the whole of the south-west region, Devon has some of the largest exposures of terrace deposits, several recently mapped sheets cover some of these deposits, and the greatest degree of differentiation between terraces occurs here.

More recently mapped areas tend to show greater terrace differentiation between areas mapped as river gravels, and between head and terrace deposits. The number of terraces/gravel deposits defined and the major drainages are shown in Table 3.

Numbers are used to differentiate terraces on the basis of altitudinal separation, but correlation between adjacent map sheets does not always occur. On more recent maps, "plateau gravels" are commonly re-defined as higher level terraces as this separation was related primarily to their topographic positions, and not to any difference in the structure of the deposit. An example of very high-level terraces overlying the Budleigh Salterton Pebble Beds, can be seen at Blackhill Quarry in Devon (Nicholas 2004). Today, these deposits fall on the catchment boundary between the Rivers Exe and Otter. This demonstrates that the river that formed those deposits existed in an environment and drained an area very different to the one we see today.

COUNTY	NUMBER OF TERRACES/GRAVELS DEFINED
Devon	
Exe	U and 1 to 8
Otter	U and 1 to10
Dart	U
Axe	U and 1
Teign	U and 1
Torridge	U and 1 to 9
Sid	U
Taw	1 to 10
Erme	U
Petrockstow	1 to 4
Somerset and Bristol	
Parrett	U
Avon (Bristol)	U and 1 to 3
Tone	U
Cornwall	
Fal	U
Neet	U and 1
Tamar	U and 1 to 8
Fowey	U
Camel	U
Dorset	
Axe	U and 1
Frome	U and 1
Piddle	U and 1

Table 3: Number of terraces/gravel deposits differentiated for the major drainages of the south-west region according to the most recent BGS 1:50 000 maps available. Note: When the digital superficial data was received, it was noted that large numbers of terraces (c. 15) have now been differentiated in association with the Frome and the Piddle.

Examination of the memoirs and discussion with the staff at BGS, has also shown that the higher-level terraces (formerly "plateau gravels") differ from lower terraces in their landscape form. They tend to "drape" over the landscape rather than form reasonably sharp breaks of slope evident in the lower terraces. This point has been made specifically in relation to the River Exe, terraces 5 and above (Edwards & Scrivener 1999). It may be that this difference of form is related to the generation of the terrace through periglacial outwash. As no dates have been obtained on the upper terraces and no sedimentology has been conducted, it is currently impossible to verify or refute this possibility. It is also important to note that in many diagrams of terraces, the base of gravels is portrayed as flat, but this is a gross simplification. As with any deposit associated with dynamic processes, the forms the terraces take are variable.

Areas previously mapped as "valley gravels" are often re-defined as "head" deposits, or "head and colluvium". Because different processes generate them, terraces differ from head deposits in their structure, and clast morphology (see above for "river terrace definition" and below for discussion of "head"). However, as terraces are effectively defined by a *"break of slope separating two relatively flat surfaces"* (Brown 1997) it can be difficult in the absence of exposed sections, exposed ground, or borehole data to separate head deposits slumping down from higher ground, from terrace deposits in some areas (Dr Richard Scrivener and Dr Raemus Gallois pers. comm. to Laura Basell).

However, all these features considered when mapping is undertaken by BGS, so differentiation between head and terrace deposits is reasonably good.

The term "head" was first used in the geological literature by De la Beche in 1839 (Edwards & Scrivener 1999). It has been employed in different ways, but today, generally refers to masses of locally derived rubble of weathered surface material (regolith) in clay and sand moved downslope in periglacial conditions by solifluction and freeze-thaw processes (Scrivener 1984; Selwood *et al*. 1984). These deposits are widespread across the south-west. They are so common on some (usually earlier) BGS maps, the cartographers chose not to map them at all (particularly where they were thin and patchy (Kellaway & Welch 1993)). Campbell (1998) points out that many head types can be recognised, and where exposed in coastal sequences, these are generally divided into Upper and Lower Head. A Wolstonian (Saalian) age is preferred for the Lower and a Devensian age for the Upper on the basis of their relationships to raised beach deposits. Dates have been achieved on the Upper Head deposits at Boscawen in Cornwall suggesting an age of no older than 30 kya BP, or a "Late Devensian" attribution (*ibid*.). The age of the Lower Head deposits remain unknown but could relate to a number of Pleistocene cold phases, such as OIS 4 or 6.

Inland, less is known about the age of head deposits. Depending on their stratigraphic context and the material from which they are composed however, they may be used to suggest the age of related features. For example, in the Bristol district, the large head deposits *"which mantle the exposed Triassic marl supporting the patch of Terrace Gravel at Sheephouse Farm, Easton-in-Gordano [808 774], postdate the formation of the nearby terrace...and predate deposition of the Estuarine Alluvium. Since the extensive belt of head at Easton-in-Gordano was formed by the degradation of all the younger Terrace gravels as well as the Triassic bedrock, it must also be Devensian in age"* (Kellaway & Welch 1993). This example shows clearly that it is currently only through the focussed study of specific drainages that it is possible to gain a handle on relative ages of these landforms, and landscape evolution. It also highlights the most important point that because head deposits are derived from locally derived material, this may include old terraces. On some maps, (e.g. Sidmouth (British Geological Survey 2004)) where further localised differentiation occurs, different head types are distinguished (e.g. as on the Sidmouth sheet where a contrast is drawn between soliflucted deposits restricted to valleys ('Valley Head and Colluvium'), and 'Other' head deposits).

In order to clarify the extent to which terraces are altitudinally separated, two cross-valley transects were conducted using differential GPS over the lower terraces associated with the Rivers Exe and Culm. The Exeter sheet has recently been re-mapped so the actual altitudinal differences could be related to the differentiated mapped deposits. The results from these transects are shown in Figures 5 & 6 below. The differences between terraces 1–3 are clear, but relatively small. Between terraces 3 and 4 there is a significant separation. This suggests terrace 4 is associated with a major event; and given its structure and the dates on terrace 3 discussed below, this could be a cold event such as OIS 4 or 6. However, more dates and study of the sedimentology is necessary to confirm this. Analysis of the borehole data further supports these differences, as it shows basal separation between the deposits. These findings are important as they show *contra* the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993; Wymer 1999; which drew on the work of Kidson) that although the terraces are different those in the south-east, they can be defined as separate, altitudinally separated entities, which is in keeping with Bridgland's models of terrace formation.

Dated river terrace deposits and sites yielding environmental information

Key questions asked here included:

- What do we know about the age of the river terraces?
- What can we tell about past catchments?
- Are there any associations with particular terraces and archaeological finds?

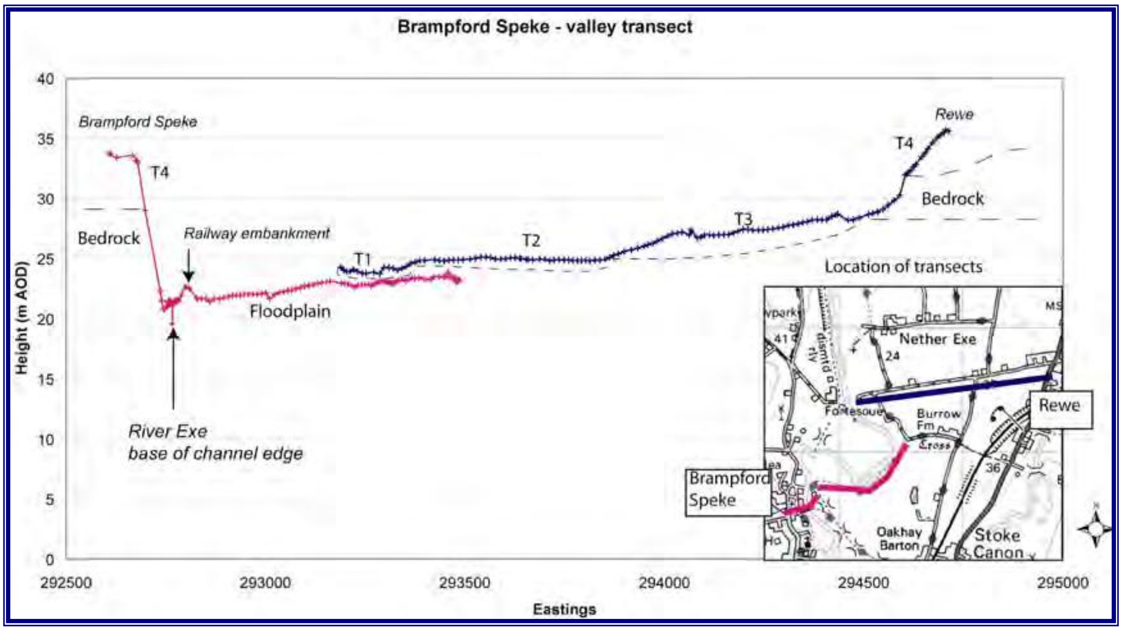

Figure 5: Terrace separation at Brampford Speke, River Exe. Results of differential GPS survey conducted by L. Basell & J. Bennett. Results drawn up into this diagram by J. Bennett. Unpublished PhD research.

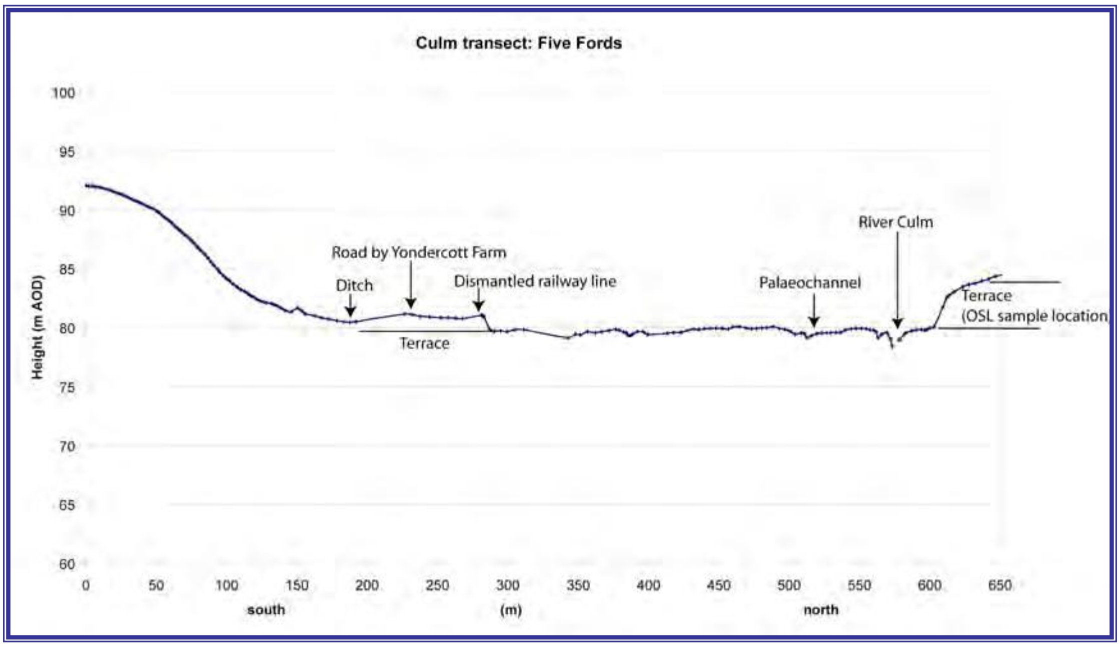

Figure 6: Terrace separation at Five Fords, River Culm (Exe Tributary). Results of differential GPS survey conducted by J. Bennett and L. Basell. Results drawn up into this diagram by J. Bennett. Unpublished PhD research.

In addition to the dates achieved at Broom on terrace material associated with the River Axe, mentioned above (Toms *et al*. 2005), some pollen data has also been recovered from the clays and silts at Kilmington. This is interpreted by Scourse (Shakesby & Stephens 1984; Campbell 1998; Scourse pers. com.) as indicating boreal forest. However the relationship between the gravels at Broom, Kilmington, and the supposed cold stage accumulation at Chard Junction Pits (Campbell 1998) remains unresolved, and can only be clarified by further dating, sedimentological analysis and sampling. Otherwise no dates or environmental information is available in any other terrace deposits in the south-west. Dates have been achieved on raised beach deposits in the area, and on the Burtle Beds in Somerset, frequently suggesting an OIS 5e correlation (Campbell 1998), but no connections between these deposits and the river terraces have been made, beyond speculation, with one exception.

During the construction of the Honiton bypass in 1965 a *"mossy peat"* deposit was revealed which included organic material, and bones originally thought to have been embedded in the peat, but that were possibly remobilised in mud flow and moved a short distance during the Last Glaciation (Turner 1975). Mammal remains from 17 individuals included *Hippopotamus amphibious* (which earned the site its name of the "Honiton Hippo Site"), *Palaeoloxodon antiquus, Cervus elaphus* and *Bos primigenius* (hippopotamus, elephant, giant ox and red deer). Samples of the peat taken from both the surrounding peat material and from inside the animal bones was analysed. Sparse tree pollen from a range of species was represented, and a high representation of herb pollen. A list of macro-fossil remains was also compiled. The general picture obtained from the analysis of this site was of a rich marsh flora and grass landscape occupied by grazing herbivores. It is now commonly attributed to OIS 5e (e.g. Edwards & Scrivener 1999). On the old BGS Sidmouth sheet, these deposits were mapped as undifferentiated river terrace deposits associated with the River Otter. On the most recent map, they were remapped as head. This is in keeping with Turner's original interpretation that the peat and its contents had been "remobilised" during the Last Glaciation. Though the fauna is likely to be 5e (Tuner 1975), this does not give us any clue to the age of any extant landform, as head deposits by their very definition are made up of reworked material, and no terraces are now mapped in the immediate vicinity of the findspot. Indeed north of Alfington, no terraces are mapped in association with the Otter.

Recently however, two dates have been achieved on terrace deposits associated with the River Exe. These have not yet been published. At Five Fords by the River Culm (a tributary of the River Exe), an OSL sample on a sand deposit in the terrace shown in Figure 7 has yielded a date of 39,450 ± 2,930 BP (work conducted by Prof. Tony Brown). This geological sheet is currently being remapped by BGS, so the terrace remains undifferentiated. However it is likely to be degraded Terrace 3 (Dr Richard Scrivener, pers. comm. to Jenny Bennett).

At Washfield by the River Exe a further unpublished date obtained by OSL on bulk sample from the terrace shown in Figure 8, has yielded a date of 27, 500 ± 240 BP. Ms J. Bennett conducted this work as part of her PhD research. The site lies on the Exeter map sheet, recently been re-mapped in great detail by BGS. This site is defined as Terrace 3.

These dates are extremely important. They demonstrate the potential antiquity of the higher terraces associated with the Exe, which is entirely in keeping with the archaeological associations with Terrace 5 (see below), and more dates of this kind could provide a means of judging regional uplift.

Field trips to exposed sections and areas mapped as terrace deposits in farmland areas, associated with the Rivers Axe, Exe and Otter have led to the identification of several sites which will be suitable for fieldwork and for dating. These include the undifferentiated deposits of the Axe, and some of the higher-level terrace deposits of the Exe and Otter which appear to be associated with Palaeolithic finds (see below). In addition, current excavations at the Princesshay development in Exeter should penetrate gravels defined as terrace 6, associated with the River Exe. Preliminary discussions have been held with Exeter Archaeology Unit regarding this matter.

Figure 7: Dated terrace at Five Fords

Figure 8: Dated terrace at Washfield

Work on the terraces will also help us to determine whether significant catchment changes have taken place in the Palaeolithic. For example it has been assumed that because most of the peninsular was not glaciated the Exe catchment would have persisted throughout the Pleistocene. However, the shape of the basin (planform) and the existence of high-level terraces on internal interludes and the mis-match between terrace distribution and present river size suggests that at some point in the Pleistocene the Exe catchment has changed, probably by capturing northerly drainage and by loosing easterly drainage areas. This is potentially important for the environment and routeways of early hominins in south-west England. The terraces are also cut by the many pronounced blind-dry valleys which on present evidence may not have existed at all in the Lower and Middle Palaeolithic.

Perhaps the most striking feature of the rivers in the region is the dominance of a north–south trend in their flow. While this is clearly related to the bedrock geology, which influences the drainage, there are some strong indications, that not all rivers have always followed this course. The course of the River Torridge today flows eastwards, and then turns sharply northward. This is odd, and suggests that it once drained south, and was later captured by the Okement.

Paired terraces (i.e. where terrace deposits that broadly correspond in terms of altitude above the floodplain, are found either side of the current river or a dry valley) are evident on many of the rivers in the south-west region — for example the River Axe. These are especially important because they indicate that that particular section of the river has not shifted laterally by any great amount since the terraces were formed. In effect then, the limits of these areas represent landscape remnants, potentially of great antiquity. Not only do they provide a clue to the size of the river and past drainage patterns, but importantly suggest that these areas are of higher archaeological potential in terms Palaeolithic artefacts. It is envisaged that these will be a focal point of the Phase two fieldwork. Finally, buried channels at river mouths (e.g. Exe, Teign) are also a feature associated with low sea levels and although undated most probably date to OIS 3–2, although they may have been older exhumed and infilled features perhaps associated with OIS 12.

Palaeolithic findspots from terrace deposits in Devon

More than 80 open locations in Devon have yielded finds attributed to the Palaeolithic. This is considerably more than the number of findspots represented in the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993), a finding supported for the rest of the study area by Dr Simon Hounsell's work. As most of the find spots have yielded only single finds, this does not significantly increase the number of known Palaeolithic artefacts in Devon, but does suggest the potential for such finds. A number of these open findspots are close to rivers and about 13 lie within a kilometre of areas mapped as river gravels.

The level of detail recorded in the HERs for Devon varies considerably between find spots. Because the majority of open Palaeolithic find spots in Devon are surface finds, the findspot location is often very general and the context from which the find was recovered is not always recorded. Several queries have been run on this data, revealing a number of interesting patterns. One of these shows that just under half (41) of the HER findspots for Devon correspond with the sites studied by the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993). Of the remaining findspots/sites recorded as containing Palaeolithic archaeology from open contexts, two are faunal remains, and some refer to Upper Palaeolithic finds, but there are not many of these. This shows that the Southern Rivers Project (Wessex Archaeology 1993) did not incorporate all Lower and Middle Palaeolithic finds in Devon. Interestingly, where the date of discovery was recorded for Devon (which was not very frequently), the distribution of discoveries over time was very even.

Of the archaeological data, four separate sites are accurately located within or directly on top of river terrace deposits in Devon. Where these deposits are numbered on sheets covering the Rivers Exe and Otter, they are named as Terrace 5 which occurs *c*. 30 metres above flood plain. On the Tiverton sheet where terrace differentiation has not been mapped, height above floodplain was calculated and is the same as Terrace 5. These sites include Friars Gate and Tidwell Mount at Wiggaton (Smith 1933–1936), the Magdelen Street hand axe from Exeter (Pickard 1933–1936) and findspots near the River Lowman (Exe Tributary) which were discovered during fieldwalking by Tiverton Archaeology Group.

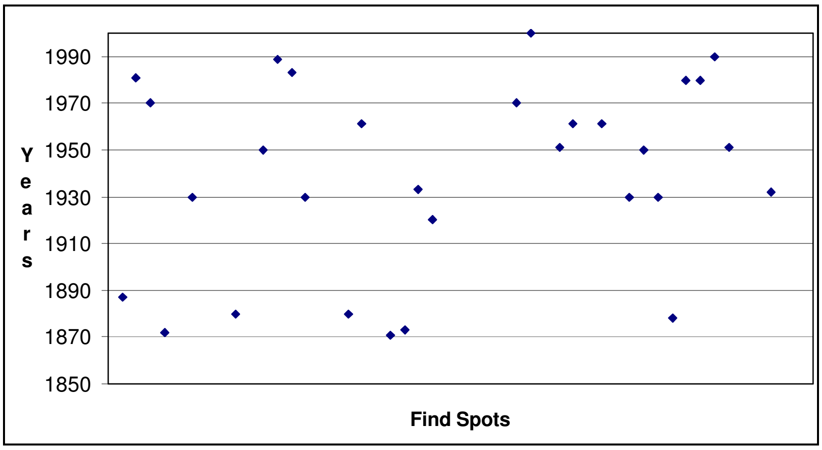

Figure 9: Discovery dates of Palaeolithic finds in Devon (where recorded in the HERs)

2.7.5 Discussion and Conclusions

The geographical difference in the distribution of Palaeolithic finds is more likely related to history of aggregate extraction than a difference in patterns of the hominid occupation of Britain. Since The Southern Rivers Palaeolithic Project (Wessex Archaeology 1993; Wymer 1999), further work and re-mapping has better distinguished between terrace and head deposits in association with the rivers of the south-west region. Work conducted during Phase 1 for Module 1 has shown that:

- The principal terrace distributions are located in the east of the study area and most of the rivers with a significant amount of terrace differentiation occur in Devon.
- In contrast to the south-east, although there is superficial differentiation between terraces, there is no data naming members or different features within terraces; although preliminary examination of the borehole records and exposed sections at sites such as Broom show that such differentiations do exist.
- It is possible to date river terraces, and dates obtained so far suggest some of the high-level terraces may be of significant antiquity.
- Dating the terraces also provides dates on associated and relevant features such as dry valleys, where the stratigraphic relationship between such features and the terraces has been studied in a specific drainage.
- Terraces are altitudinally separated both superficially and basally.
- More Palaeolithic archaeological finds are present in Devon than previously thought.

- Five unequivocally Palaeolithic finds in Devon have come from four sites directly associated with river gravels of the same height above the floodplain, in association with the River Otter, the River Exe and the Lowman (one of its tributaries). Where mapped this terrace level is distinguished as Terrace 5.

Tentative links have been made between the higher-level terraces of both these rivers. Both areas have recently been re-mapped and have a large number of differentiated terraces. As a result of this work, three areas stand out as being of particular importance, and as having high potential for the targeted fieldwork envisaged for Phase two. These are the Rivers Axe, Exe and Otter. The River Axe is already known as an important area, but our understanding of this area needs to be improved as the drainage and its terraces are anomalous when considered in relation to other drainages in the immediate vicinity.

Developing the study from the Axe westward is logical. It works from:

The *Axe* which:
- Is an area of prolific archaeological finds in association with terrace deposits. As Campbell (1998) writes *"Some sites and areas are recognized as internationally important…the Palaeolithic site at Broom aspires to this level of importance on archaeological grounds alone"*
- Is geomorphologically anomalous in comparison to all the drainages immediately surrounding it in that it has large amount of undifferentiated terraces with one or two very small patches of terrace one, rather than numerous altitudinally separated terraces.
- Has a long history of terrace exploitation for aggregates as a primary aggregate source.
- Has been successfully dated by OSL, but yielded dates, which raise interesting questions about the terraces and the archaeology that could be resolved by further study.
- Has only "undifferentiated" and "terrace 1" deposits defined.
- Has been recently re-mapped by BGS.
- Remains under threat from extant permissions, and backfilling.
- Remains poorly understood in terms of terrace and palaeolandscape evolution.

Via the *Otter* which:
- Has a large number of terraces in direct contrast to the River Axe.
- Has a small number of Palaeolithic finds in its immediate vicinity, some of which are directly associated with Terrace 5.
- Is a misfit river with few tributaries.
- Has terraces that have been correlated with the River Exe.
- Has exposures of terrace deposits suitable for dating.
- Has a number of dry valleys.
- Has been little studied and never been dated.
- Runs through geology that differs from both the Axe and the Exe.

To the *Exe* which:

- Is a large River with numerous tributaries.
- Due to development in the area over the last 20 years, a large amount of borehole data is available.
- Has two dates on its lower terraces which indicate high potential for further successful dates and clarification of the terrace sequence.
- Has upper terraces (6–8) that may indicate periglacial outwash.
- Has a number of dry valleys.
- Has been contrasted with the Axe in terms of the quantity of Palaeolithic finds retrieved from its terraces, but nonetheless has finds from within terrace deposits high above its floodplain.

The overwhelming impression from the work undertaken during Phase one is that the landscapes of the south-west were not just marginally different to the landscapes we see today; it is not the case that the Quaternary in the study area saw a few slight changes in the course of one or two major drainages, accompanied by fluctuations in sea level. Rather the period covered by the human occupation of Britain has witnessed in the south-west (as in the south-east) dramatic changes in drainage, topography, vegetation and fauna. We know very little about these changes; but one of the single most useful sources of information that remains are river terrace deposits. While these are not as extensive as in other parts of southern Britain, they are under threat from aggregate extraction policies. Indeed their lesser extent makes them more valuable in terms of their status as a potential source of information. Once they are gone, the opportunity to contextualise the Palaeolithic archaeological artefacts found both within the gravels, and in non-terrace contexts, through landscape reconstruction will be severely diminished.

2.8 The Lower and Middle Palaeolithic Archaeological Resource in South-West Britain

2.8.1 Introduction

The relative paucity of Palaeolithic studies undertaken in the south-west region, particularly during the last twenty years has limited the understanding of the Palaeolithic archaeology of this district. This has important ramifications with regard to the understanding of hominin migration and colonisation in an area at the very north-western fringe of the Acheulean world. Consequently the resultant need for focused research into the Palaeolithic archaeological/Pleistocene geological resources in the south-west region has been at the heart of this project's aims and objectives, particularly given the relative wealth of Palaeolithic archaeological and Pleistocene geological research associated with surrounding regions such as the Avon valley and the Bristol region (e.g. Oriel 1903; Davies & Fry 1928; Lacaille 1954; Fry 1955; Donovan 1964; Roe 1974; Bates 2003; Bates & Wenban-Smith 2004) and the Solent River (e.g. Allen & Gibbard 1993; Bridgland 1996; Wenban-Smith & Hosfield 2001).

The aims of the resource assessment of the Lower and Middle Palaeolithic archaeology of the south-west region were as follows:

- Collation of the extant Lower and Middle Palaeolithic archaeological records, through analysis of the regional Historic Environment Records (HERs), and museum records, as appropriate.
- Visual assessment of the extant Lower and Middle Palaeolithic archaeological stone tool assemblages, based on the analysis of museum artefact collections.

2.8.2 Aims & Methodology

During the first phase of the project (module 2) attention was placed upon the clarification and documentation of the level of known and unknown or "invisible" (e.g. artefacts and findspots not collated in major published works such as Roe (1968), Wessex Archaeology (1993), and Wymer (1999)) Palaeolithic archaeological material, originating from fluvial, and typically secondary, contexts within the defined study area of the south-west region. This was achieved by:

- Firstly collating the existing records from extant syntheses of the region's Palaeolithic archaeology (principally from the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993) to provide a baseline of current knowledge.
- Once this had been established consultations were set up with staff from the regional Historic Environment Record (HER) offices (Cornwall, Devon, Dorset, Plymouth, Somerset and Torbay and Bath) and the archaeological curators from the main regional museums (Royal Cornwall museum, Royal Albert Memorial museum (Exeter), Devizes museum, Dorset County museum (Dorchester), Somerset County museum (Taunton), Plymouth museum, Torquay museum, Bristol City museum, and Cambridge Archaeology & Anthropology museum). The purpose of these meetings was to identify the 'invisible' resources present in their records, and those collections appropriate for inclusion in this resource review and assessment.
- Further to this, the opportunity was taken to undertake an artefact-sampling programme of the material held in the regional museums. The aim of this aspect of the project was to generate morphological, typo-technological and physical condition data on each artefact. The artefact recording procedures followed the methodologies established by Roe (1968) for artefact dimensions, and Wymer (1968) for artefact abrasion and typo-technology. The data generated included the following categories:
    - Maximum artefact length (mm).
    - Maximum artefact thickness (mm; handaxes only).
    - Artefact weight (grams).
    - Level of abrasion (using the 'mint', 'fresh', 'rolled/slightly rolled', 'very rolled' and 'extremely rolled' categories of Wymer (1968)).
    - Artefact breakage (yes/no).
    - Artefact provenance.
    - Artefact typology (including distinguishing features).
    - Bibliographical information.
    - Photographic archive.

  The recording criteria for use in this project was developed in collaboration with, and with due awareness of, the recording being done on *The Lower and Middle Palaeolithic Occupation of the Middle and Lower Trent Catchment* project and the *Medway Valley Palaeolithic Project*. This ensured that all the recorded artefact data in these related ALSF-funded Palaeolithic research projects is of a consistent standard and format, enabling inter-project data transfers and collaborations and the production of consistent resources for future HER enhancement.

By following this programme of research it has been possible to significantly develop understanding of the Lower and Middle Palaeolithic resource in the south-west region, with reference to those artefact findspots associated with fluvial landforms, sediments and depositional contexts. Specifically, understanding has been developed with reference to:

1. The spatial distribution of Lower and Middle Palaeolithic archaeological findspots throughout the south-west region, and its implications for our understanding of: (i) future management of both the archaeological and aggregates resources in the region; and (ii) the hominin occupation of the region.
2. Morphological, typo-technological and physical condition patterning in the handaxe assemblages of the south-west region.
3. The representation of non-handaxe Lower and Middle Palaeolithic lithic artefact types in the region (handaxes predominate in the extant syntheses for this region).

The resource assessment has also generated new resources for the interpretation and management of the Lower and Middle Palaeolithic archaeological resource:

- An updated findspots database, combining the documented records from the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993) with the 'new' findspot records recorded during the resource assessment from the HERs and the museum records. A digital copy of the findspots database (PRSWB_Findspots.mdb) has been distributed with this document, and the database contents are summarised in Section 4.4 below.
- An artefact database, documenting records of the artefacts examined from the regional museums during the resource assessment. A digital copy of the artefacts database (PRSWB_Artefacts.mdb) has been distributed with this document, and the database contents are summarised in Section 2.8.4 below.

2.8.3 The Lower and Middle Palaeolithic Resource

The literature review undertaken as part of the resource assessment focused upon the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993; also Roe 1968; Wymer 1999), as the most comprehensive and up-to-date source of Lower and Middle Palaeolithic sites and findspots from fluvial contexts in the south-west region. The Southern Rivers Palaeolithic Project volume (Wessex Archaeology 1993) lists 152 findspots from within and around the margins of *The Palaeolithic Rivers of South-West Britain* project study area, and provided the baseline resource for the project.

The pattern of recorded findspots in the extant literature shows that there are Lower and Middle Palaeolithic findspots distributed in a number of distinct zones across the entire south-west region (Figure 10). In particular findspots are focused in:

- The Axe valley, Devon/Dorset/Somerset (e.g. the findspots at Broom, Kilmington and Chard Junction).
- The Otter valley, Devon (e.g. the findspots at Budleigh Salterton and Otterton).
- The Exe valley and the Teign valley, Devon (e.g. the findspots at Exeter, Tiverton, and Bishopsteignton).
- South and west Somerset (e.g. Bradford-on-Tone, Watchet and West Quantoxhead).
- South Cornwall, in the areas of St. Buryan and St. Keverne (e.g. the findspots at Coverack, Higher Polcoverack Farm, and Lower Leah Farm).

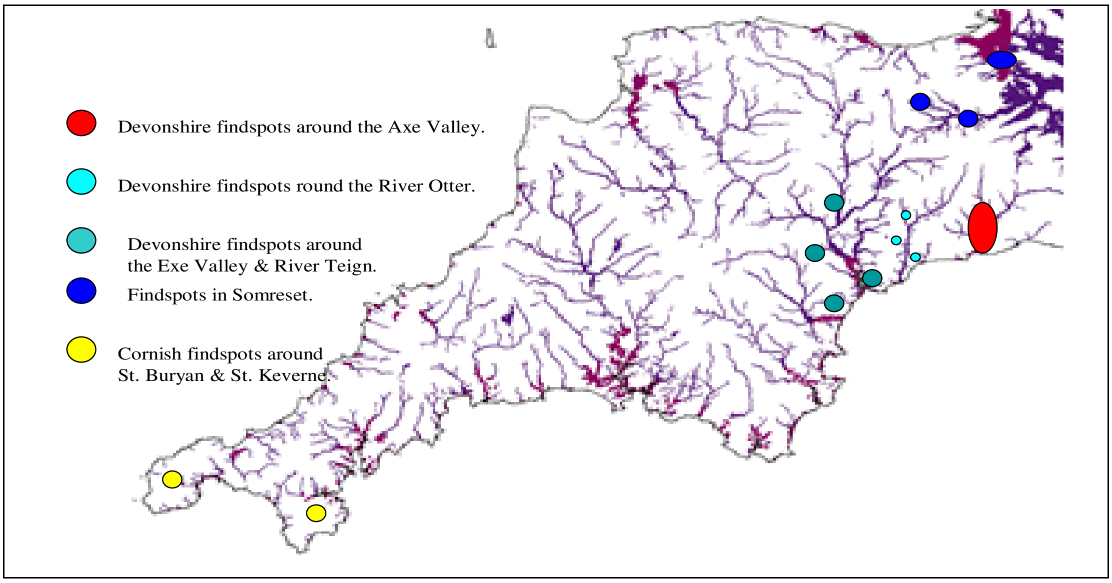

Figure 10: Distribution of Lower and Middle Palaeolithic Findspots in the South-West Region

However, within these patterns the two most significant areas (in terms both of numbers of findspots and numbers of artefacts) are the River Axe and the River Exe valley.

In the River Axe valley region 25 findspots occur, from the mouth of the river at Beer in the south, along the length of the river (*c.* 11–12 km) up to Chard Junction, including the locales of Cloyton, Kilmington, Hawkchurch and Thorncombe. This is an area well known for its Palaeolithic richness, with the commercial aggregates excavations at Broom having yielded *c.* 1,800 handaxes (Hosfield & Chambers 2004).

The River Exe valley region has 23 findspots, which are distributed over the longer extents of the Exe (*c.* 500km^2), although the majority of the findspots are located below Tiverton (*c.* 14–15 km above the mouth of the Exe). Key locales include those at Tiverton, Thorverton, Upton Pyne, and Exeter).

The county of Cornwall has the fewest number of findspots recorded (11), although whether this is an accurate depiction of the county's Palaeolithic record or a sampling bias is as yet unknown (and will be addressed in the third phase of the project). However, what is clear is that where discoveries have been made they have always been in the far south of the county. Without exception the Palaeolithic archaeology of Cornwall is located either on the "Lizard" at places such as St. Keverne and Landewednack or on the extreme south-western peninsula in areas such as St. Buryan.

The recorded findspots in Somerset are distribution throughout the county, with no areas of particular concentration. Findspots are located in the north around the Cheddar area (e.g. at Shipham and Priddy), in the west (e.g. at Watchet, Doniford, and West Quantoxhead), in the south (e.g. at Pitminster, Taunton, and located around the River Axe valley region, at Crewkerne and Chard), and centrally (e.g. at Middlezoy). No finds have as yet been documented from the eastern area of Somerset.

During the research undertaken in this project however it became clear that the published record of Lower and Middle Palaeolithic archaeology from fluvial contexts in the south-west region of England (summarised above) is incomplete. The short resource assessment undertaken in phase one of the project has indicated that many more findspots exist than have so far been recognised in the published literature. As stated the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993) lists 152 findspots in the south-west region, this number can now be increased to 224, an addition of 72 new findspots (a 48% increase) from the "invisible" record (Figures 11, 12 & 13).

The majority of these 'new' findspots (n=49, 67%) come from the county of Devon. Many of these are located in east Devon, in districts already well known as Palaeolithic "hotspots" such as Thorncombe in the Axe valley region. Such records however remain of value despite the well-documented richness of the area, as they serve not only to confirm the areas importance, but also add a further level of understanding of spatial patterns in hominin occupation histories. Of potentially greater importance in Devon however are the new findspots identified in areas where little evidence has been previously documented, such as the discoveries around the River Otter at Gittisham, Otterton, and Sidmouth. The new findspots are indicated in the attached database (PRSWB_Findspots.mdb).

Finally, a significant number of these novel findspots are located in areas of relatively low archaeological occurrence, such as locales to the far west of the region in southern Cornwall (n=5, 7%). Whilst these findspots follow the same distribution pattern for that county (i.e. they are distributed across the south-western margins of Cornwall) they remain of importance as they increase our knowledge of hominin landscape use within the region as a whole. Similarly in Somerset the 15 new findspots (21%) repeat the distribution pattern of those already recorded, with a roughly even distribution across the central, southern, northern, and western county, although again with no finds in the east.

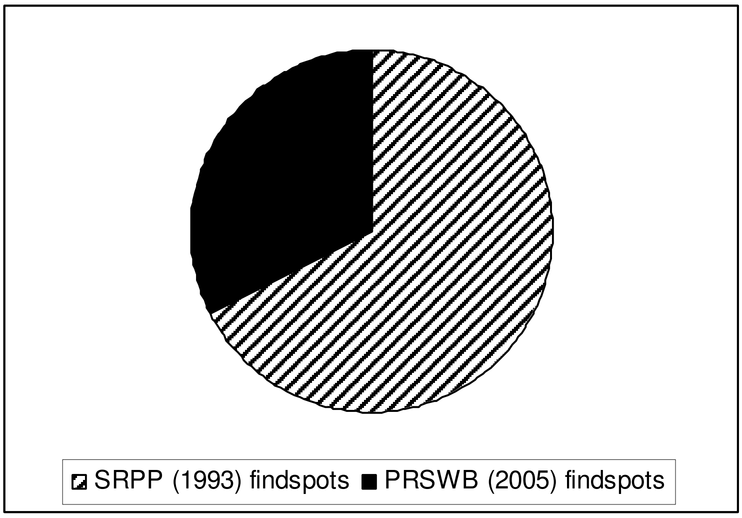

Figure 11: Lower and Middle Palaeolithic findspots from South-West Britain, as recorded by the Southern Rivers Palaeolithic Project & the Palaeolithic Rivers of South-West Britain project (the "invisible" record)

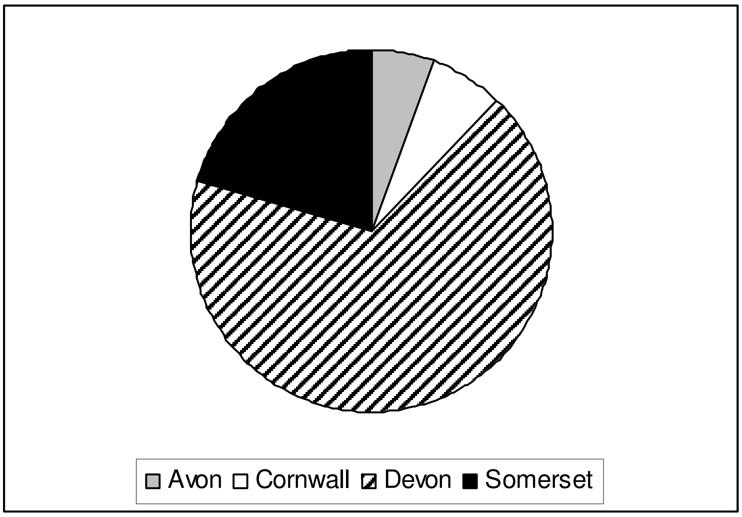

Figure 12: Distribution of 'new' Lower and Middle Palaeolithic findspots in South-West Britain by county

Table 4 (below) documents the 'new' Lower and Middle Palaeolithic findspots in south-west Britain, as identified by the current project, with a summary of findspot co-ordinates, county, location, context, artefact(s) type(s), and additional comments where available/relevant.

Co-ordinates	*County*	*Location*	*Context*	*Artefact type*	*Comments (verbatim from HER records)*
SW 403253	Cornwall	Pendrea, St Buryan	Surface find	Core	Found in ploughed field by Mr P. Pearman 1988.
SS 214057	Cornwall	16 Hawthorn Ave, Bude	Found in garden	Handaxe	Found in 1975.
SW 751198	Cornwall	Field in Kerrier, St Keverne	Surface find in field	Retouched flake	Found by Mr P. Steele 1988 while field walking.
SW 636439	Cornwall	Raskajeage Downs, Illogan	Surface finds	Miscellaneous finds	Found by Mr H.J. Berryman over 15 year period. Only 3 artefacts from Upper Palaeolithic with no listing as to what types.
SW 513308	Cornwall	Marazion Beach, Penwith	Surface find	Handaxe	Found by Mr J. Matthews 1997, identified by C. Thorpe of CAU. Stone not native to Cornwall. Handaxe (?) possibly brought in ships ballast. Possible derived from Palaeolithic forest deposits.
SX 460570	Devon	Brickfields Devonport, Plymouth	Slope of fields	Handaxe	Deposits of widely separated ages. Scatter.
SX 470560	Devon	Ford Park, Stoke Damerel, Plymouth	/	Handaxe	Worked flints found during building operations. Scatter.
SX 464572	Devon	Greenslade Park, Beacon Park, Plymouth	Garden	Flake, core	/
SX 465581	Devon	Penycross, Plymouth	Found in soil heap	Handaxe	Raised by bulldozer making new road to serve Burringdon industrial estate.
SX 479537	Devon	Plymouth Hoe	/	Handaxe	Found during works on Marine biology lab, tools accompanied by teeth of Ox and Boar. Scatter.
SX 506521	Devon	Field at Higher Hooe near Plymouth (not precisely located)	/	Handaxe	Quartzite axe.
SX 874686	Devon	Aller Brook, Teignbridge, Kerswells	Found in sandy gravels 1.22m thick overlying ball clay	Miscellaneous finds	Clactonian, found opposite zigzag quarry near 50 ft contour.
SX 98-79-	Devon	Dawlish Warren, Teignbridge	/	Handaxe	Flint implements.
SX 921820	Devon	Haldon, Teignbridge, Kenton	Found on disturbed surface	Flake	Clactonian, near ruined barrow.
SY 099875	Devon	Pin Beacon area, Otterton	/	Retouched flake, scraper, blade	In Hutchinson collection, possibly Palaeolithic.
SY 119869	Devon	Jacobs Ladder, Sidmouth	Found in cliff fall	Chopper/core	Rough possible chopper on Broom flint.
SY 226879	Devon	Beer Head	/	Handaxe	Miscellaneous collection of tools including Neolithic.
SY 216995	Devon	Beer head plateau, Beer	Surface & excavated finds	Handaxe	Excavations took place in 1920's, thousands of artefacts found, span period from

					Palaeolithic, Mesolithic & Neolithic.
SY 235898	Devon	Beer to Seaton road, Seaton	*In situ*	Handaxe	Layer may be correlated with upper boulder clay glaciation of East Anglia & upper tumbled gravel at Broome Pit. Mousterian or Clactonian.
SY 254927	Devon	North of Colyford station, Colyton	/	Handaxe	Worked flints similar to those found on Beer head plateau (NSA-6/3)
SX 899739	Devon	Market garden near Wolfsgrove, Bishopsteignton	Surface	Handaxe	Found by Mr Rogers. Includes Neolithic finds. NGR not particularly near Wolfsgrove.
SX 86-73-	Devon	Broadway, Kingsteignton	/	Handaxe	Retained by Mr Gill of Ashburton.
SX 458546	Devon	Brickfields, Devonport, Plymouth	/	Handaxe	Found in 1933 (possible duplicate of NSA-4/9)
SX 629541	Devon	Clenmeads, Ermington	/	Handaxe	Handaxe of vesicular spilite.
ST 230036	Devon	Stocklands little camp, Stockland	/	Handaxe	Mesolithic axe also found here unsure if there are two separate entries.
ST 23-03-	Devon	Corry Brook or Millstream, near Millhayes, Stockland.	Found in waterways	Handaxe	/
ST 257083	Devon	River Yarty, Yarcombe	Found in waterway	Miscellaneous finds	Found by Mr C.T. Shaw in 1930's possibly Palaeolithic.
SY 275980	Devon	Gammon's Hill Quarry, Kilmington	/	Handaxe	/
SY 246940	Devon	Near Colyton.	/	Handaxe	May have come from ballast gravels at Broom.
SY 24-91-	Devon	Manor Pit, Seaton	Gravel pit found on 50 foot terrace	Handaxe	/
SX 48-74-	Devon	Tavistock	/	Handaxe	Made on Broom chert.
SY 12-88-	Devon	New cemetery, Sidmouth	Surface find	Miscellaneous finds	Found by Mr H. Ede 1878.
ST 265015	Devon	Beekford bridge, River Yarty, Stockland	Found in waterway	Handaxe	/
SS 998120	Devon	Halberton	/	Handaxe	Organised fieldwalk, miscellaneous artefacts from all periods including Palaeolithic. Scatter.
SS 983131	Devon	Tiverton	/	Handaxe	Fieldwalking. Miscellaneous finds including Mesolithic/ Neolithic/early Bronze age. Handaxe found by Mr S. Bush. Scatter.
SS 990114	Devon	Rowridge Farm, Halberton	/	Handaxe	Found by Mr M. Britton. Evidence of multi-period activity. Scatter.
ST 257052	Devon	Membury	Surface finds	Handaxe	Collected from field by N. Pearce. Scatter.
SS 42-29-	Devon	Westward Ho! Northam	Raised beach	Miscellaneous finds	Worked stone possibly Palaeolithic/Mesolithic.
ST 04-08-	Devon	Kentisbeare	/	Handaxe	Also Mesolithic axe from same area.
SY 241903	Devon	18 Seaton Down Rd.	Found in	Handaxe	/

		Seaton	garden		
SY 143996	Devon	Route of SWW pipeline, Gittisham	/	Handaxe	Handaxe of probable Palaeolithic date.
SY 244939	Devon	Colyton	/	Handaxe	Found during evaluation at stonewalls representing residual material incorporated into deposits of a later date. Felt to date to around 35 kya.
ST 480527	Somerset	Northeast of Carscliff Farm, Cheddar	/	Flake, scraper	Found by V Russett 1983. No period given.
ST 376411	Somerset	South of Newclose Drove, Chilton Polden	/	Retouched flake, flake	Found in 1971. No period given.
ST 352368	Somerset	Mount Close Batch, Chedzoy	/	Flake	Burnt flake found in molehill. No period given.
ST 349367	Somerset	Mount Close Batch, Chedzoy	/	Retouched flake	Found after ploughing. No period given.
ST 423373	Somerset	Greylake, Middlezoy	/	Handaxe	"Probable prehistoric date".
ST 418402	Somerset	Skinners Wood, Shapwick	/	Handaxe	Prehistoric finds.
ST 482554	Somerset	East of Piney Sleight Farm, Cheddar	/	Handaxe	Flint scatter.
ST 43- 16-	Somerset	South Petherton	/	Handaxe	/
ST 080413	Somerset	Long street, Williton	Dug up in garden	Handaxe	Ovate, similar to those in Broom gravels.
SS 93-43-	Somerset	Wootton Courtenay	/	Scraper	Found by Mr L. Ketting 1966
ST 23-14-	Somerset	Otterford	Bed of Yarty Stream	Scraper, Levallois flake, core	Found by T. Leslie & St Gorge Gray family 1902 & 1915.
ST 166219	Somerset	West of Hetherton Park, Bradford-on-Tone	Clay embankment of stream	Handaxe	Found by Mr A. Discombe. Taunton museum bout coupe Handaxe Accession No. 84-AA-11
ST 334047	Somerset	Lower Hurtham, South Chard, Tatworth	/	Handaxe	Found in spoil heap from shallow trench. Handaxe, tip broken.
ST 343072	Somerset	The Drift, east of Forton	/	Handaxe	Found on surface of tracks, probably imported to site as bricks etc… form surface here.
ST 504153	Somerset	Odcombe	Dug up in garden of Odcombe rectory	Scraper	/
ST 600500	Avon	Clutton	Found besides stream	Miscellaneous finds	Found by H. Strachey 1928.
ST 635704	Avon	Keynsham, Bath & Northeast Somerset	Found on surface of ploughed field	Handaxe	Artefacts destroyed in war.
ST 660657	Avon	Burnett, Compton	/	Handaxe	Localised concentration of

		Dando			flints. Very patinated retouched flake may be axe resharpening flake.
ST 563560	Avon	East Harptree	/	Handaxe	Widespread flint scatter. Possible prolonged use of site.
SY 79----	Dorset	Woodsford, West Dorset	/	Handaxe	/
ST 623119	Dorset	Near Lillington Beacon, West Dorset	Found in field	Miscellaneous finds	Worked ochreous flint.
SY 37-99-	Dorset	Lamberts Castle (?) Marshwood	/	Handaxe	Unfinished roughout handaxe
ST 342044	Dorset	Gravel pit Thorncombe	Dug up in gravel 14 ft down	Handaxe	Found by Mr G. Osborne 1955. Ovate handaxe.
ST 339043	Dorset	Westford Farm Gravel pits, Thorncombe	Dug up in gravels	Miscellaneous finds & handaxe	Palaeoliths, including handaxes.
ST 344045	Dorset	Thorncombe quarry	Found below screening plant & spoil heap	Handaxe, flake	Found by J Wymer in 1974. Handaxe & flakes.
ST 344049	Dorset	Thorncombe quarry	Found on surface	Handaxe	Found by C. Waller 1986.
ST 347048	Dorset	Hodge Ditch Thorncombe	1m below surface during ditch digging	Handaxe	Found by Mr. D. Waller in 1988.
ST 343045	Dorset	North side of present quarry, Thorncombe	/	Handaxe	Abraded, twisted ovate handaxe (flint) found by J. Wymer 1959.
ST 339042	Dorset	Thorncombe gravel pit	/	Handaxe	Findspot. Palaeoliths found by G. Osbone 1–5m depth.
ST 340042	Dorset	Thorncombe gravel pit	/	Miscellaneous finds & handaxe	Implements including handaxe found by W.G Larcombe, north side of road opposite Batehams Farm.

Table 4: 'New' Lower and Middle Palaeolithic findspots documented during project phase one resource assessment

As indicated in Table 4, a number of additional patterns were also apparent in the newly identified and documented findspots:

- Although all of the 'new' findspots are believed to have originated from an 'open landscape' context (there is no indication that any of the findspots are cave deposits), information regarding the specific geological and/or depositional context was scarce. Location evidence indicated that 11 (15%) of the findspots were associated with pit or quarry sites (Brickfields, Devonport, Plymouth; Gammon's Hill Quarry, Kilmington; gravel pit and/or quarry at Thorncombe; Manor Pit, Seaton; north side of present quarry, Thorncombe; Westford Farm gravel pits, Thorncombe), while 'gravel', 'river gravel' or 'floodplain gravel' were indicated as the probable geological context for an additional four of the findspots. Geological information was generally rare (n=6, 8%), with 'loam and clay' and (rather ambiguously) 'chert with clay content' recorded as the contexts for two other findspots. There were also records relating to the circumstances of discovery (Table 5), although unfortunately those suggesting a river gravel context (n=5, 7%) all related to findspots where a gravel pit location was already known (see above).

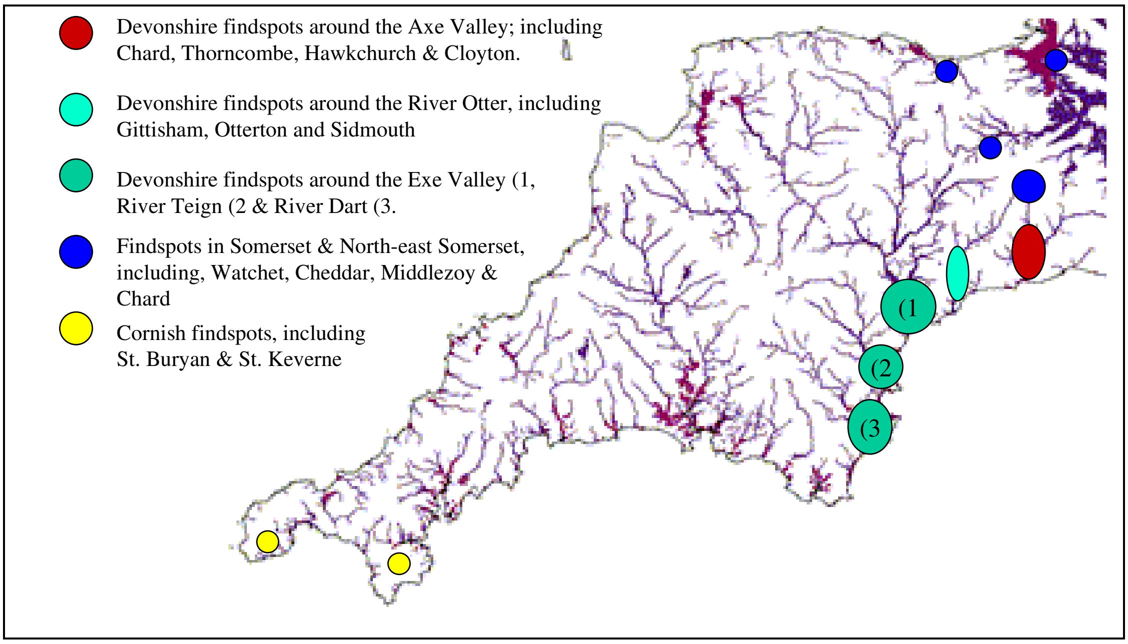

Figure 13: Location of selected 'new' Lower and Middle Palaeolithic findspots in South-West Britain, as identified in the project phase one resource assessment

Discovery context	No. of findspots
Surface finds	13
Unspecified excavations	7
Modern watercourses	6
Gravel pits/quarries	5
Miscellaneous (including cliff-fall, raised beach & boulder clays)	3
Total	**34**

Table 5: Generalised discovery contexts for 'new' findspots identified during the phase one resource assessment

- Data relating to the accuracy of the findspot location was rare (n=7, 10%), reflecting the nature of the records, although in all cases where it was recorded the findspots were classified as 'accurate' (i.e. to within 100m).
- Data relating to the number of artefacts from each findspot was of variable quality, since in a significant number of cases (n=28, 39%) references were made to 'artefacts', 'implements' etc without further details being supplied. In the remaining instances however, single artefact finds (n=35, 49%) were dominant, with smaller numbers (n=9, 12%) of single figure artefact finds (Figure 14).

- The artefacts identified by type (Figure 15) were dominated by handaxes, which were definitely present in 25 (35%) of the findspots. Of these, 23 findspots (32%) were single handaxe finds, with one instance of a 'handaxe with flakes', and one instance of two handaxes found on a single findspot. This is perhaps unsurprising given the nature of the findspot discoveries described above. The other artefact categories were present in far fewer of the findspots.

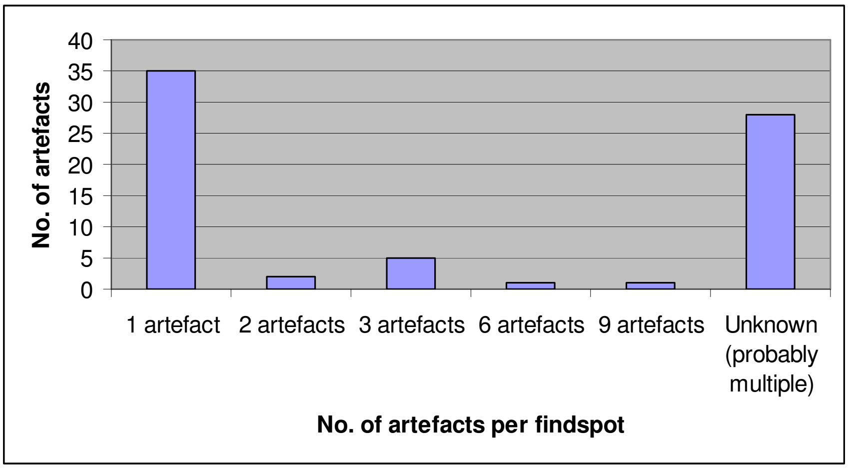

Figure 14: Number of artefacts per findspot

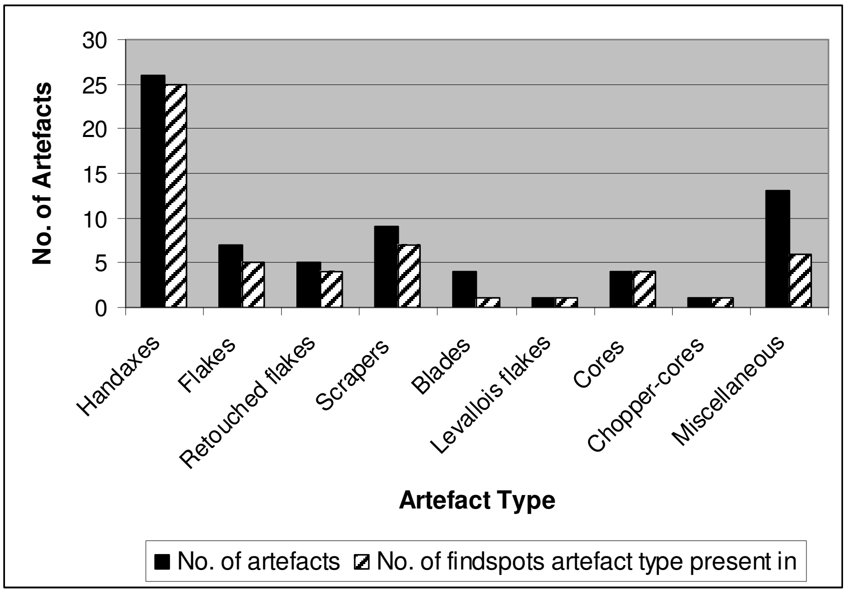

Figure 15: Finds by artefact type

In general the evidence from the resource assessment indicated a number of small artefact discoveries documented in the HER records, but which had been absent from the major syntheses. These tended to be single/single figure artefact finds, both from aggregates pit and quarries and also from non-industrial excavations and surface finds.

The second aspect of data collection within the Lower and Middle Palaeolithic resource assessment concerned the specific artefact sampling programme. Artefact data was recorded from collections housed in all of the major regional museums in the south-west (including the Royal Cornwall museum, Royal Albert Memorial museum (Exeter), Devizes museum, Dorset County museum (Dorchester), Somerset County museum (Taunton), Plymouth museum, Torquay museum and Bristol City museum), as well as those from the Cambridge Archaeology & Anthropology museum stores.

364 artefacts were recorded (Table 6). However, in many cases it was difficult (and in some cases impossible: see comments below) to link individual artefacts in the collections with their specific findspot records (whether extant (e.g. Wessex Archaeology 1993) or 'new' findspots), and therefore it is not currently possible to assess what proportion of the identified findspots' artefacts have been recorded (this issue will be addressed during the phase three project synthesis). Nonetheless, where provenancing information was available it was clear that the provenance locations of the artefacts broadly followed the distribution patterns outlined in the findspot data, with the great majority (n=202; 55%) originating from the Axe Valley region in Devon/Dorset/Somerset (and therefore suggesting that these artefacts are associated with the documented findspots), and the bulk of these coming from the gravel pits at Broom (n=166, 46%). Similar distribution patterns as to those outlined above are also found in each of the other counties studied (i.e. artefacts in Cornwall were predominantly recorded from the southern margins of the county).

It is stressed that many of the artefacts recorded have probably been documented previously, be Roe (1968), Wessex Archaeology (1999) and Wymer (1999). Unfortunately, knowing which artefacts have, and which have not, is difficult. This is partly due to the quality of the baseline knowledge upon which the resource assessment is based. The lack of museum accession numbers in Roe (1968) and the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993; Wymer 1999) has inevitably made the cross-correlation of individual artefacts in museum collections with those already listed in the extant literature extremely difficult. This was further compounded by the level of detail in the records associated with the artefacts, particularly those regarding their provenance. In almost every case there was no information concerning the context in which the artefact was found or, in many cases, the person who found the artefact. This lack of detail can of course largely be ascribed to the age of the records/collections, with many being deposited at the turn of the last century. These factors, together with the paucity of cross-referencing between individual artefacts or groups of artefacts and the HER records meant that very few of the palaeoliths recorded during this phase of the project can be identified as either:

- Artefacts which are already known; *or*
- 'New' artefacts from the "invisible" record.

The implications of these difficulties are discussed in more detail below.

Nonetheless, the resource assessment did provide a range of new data which develops previous records (Roe (1968) and the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993) simply listed types and numbers of artefacts: reflecting the scope and goals of those projects). This project's resource assessment has generated a limited range of new data (e.g. typological, morphological, and photographic) for a significant component of the south-west region's Lower and Middle Palaeolithic artefacts. However, in the light of the difficulties in provenancing individual artefacts to findspots (discussed above), patterns within the artefact sample are only discussed in general terms.

Artefact Type	**No. of artefacts**
Blades	7
Chopper/cores	1
Cores	11
Flakes	24
Handaxe (including fragments)	291
Handaxe Roughouts	3
Levallois cores	2
Miscellaneous (including chunks, shatter, 'worked' flints, & implements)	22
Retouched flakes	1
Scrapers	2
Total	**364**

Table 6: Artefact types recorded during phase one resource assessment

Nonetheless, certain factors and patterns were clear during this artefact analysis stage of the data collection process:

- *The type of artefacts being recovered*: In all of the museum collections visited handaxes made up the overwhelming majority of the known Palaeolithic artefacts (n=294, 81%). This is to be expected given the high visibility of these tools (reflecting their size and distinctive morphology), and their status as a diagnostic artefact (enabling them to be assigned with relative ease to either the Lower or Middle Palaeolithic periods). This is a key point particularly with regard to fluvial contexts and deposits, since artefacts recovered from these secondary contexts have been re-worked and it is therefore extremely difficult to assign un-diagnostic pieces (e.g. débitage flakes) to a particular period. Moreover, smaller/lighter artefacts (e.g. flake tools) are also more vulnerable to destruction/damage beyond the point of recognition during transportation and re-working in fluvial environments, while the larger sized artefacts such as handaxes were more prone to be spotted and recovered by gravel workers/collectors in the context of aggregates quarries and pits. These factors almost certainly explain the prevalence of handaxes in Palaeolithic museum collections, rather than any unusual hominin behaviour (e.g. the introduction of handaxes from outside the region and their sole discard, with all other lithic material culture removed from the region by the hominins).

- *The types of raw materials employed by hominins in the region*: The overwhelming majority of the raw material used is that of chert (n=296, 81%), while the rest of the artefacts are made on flint (n=64, 18%) with the exception of one handaxe from Mill Hayes, Stockland in Devon which was made on igneous rock (unfortunately weathering and abrasion of the artefacts prohibited identification of the igneous rock type during this assessment).
- *Artefact condition*: Similarly it is possible to assess the general physical condition of the artefacts (Figure 16), following the Wymer (1968) classificatory scheme based on flake scar ridge abrasion. None of the artefacts were classified as mint, 24% (n=88) were classified as sharp, 49% (n=177) as slightly rolled, 23% (n=84) as rolled, and 4% (n=15) as very rolled. These preliminary results suggest that the majority of the sampled artefacts had been subject to fluvial transportation and were extremely likely to have been recovered from fluvial gravel (probable secondary) contexts.

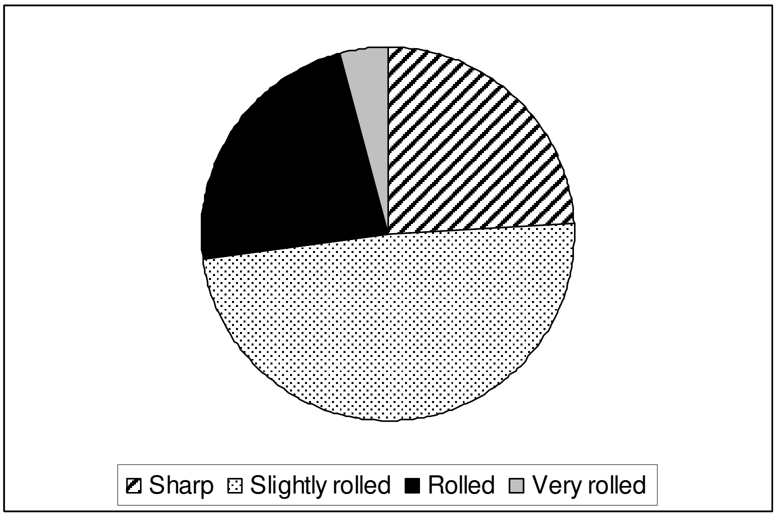

Figure 16: Lower and Middle Palaeolithic artefact abrasion (after Wymer 1968)

The individual artefact data is available in the resource assessment database (PRSWB_Artefacts.mdb).

2.8.4 Interpretation
The resource assessment has indicated that the Lower and Middle Palaeolithic fluvial context findspot and artefact record for the south-west region is greater than that which is already known and has been previously reported. This is clearly true both in terms of identifiable findspots (a c. 48% increase) and individual recorded artefacts (this is more difficult to demonstrate at the current time but is a logical extension of the previous statement).

However, it is important to note that whilst the data gathered from the regional HERs is complete, the artefact data from the region’s museum collections thus far consists of that from only the larger, regional museums. This simply reflects the quantity of material identified at those museums and the time constraints on the first phase of the project. The larger museums sampled included Bristol City museum, Taunton museum, Devizes museum, Cambridge Archaeology and Anthropology museum, Dorset County museum, Plymouth museum, Torquay museum, The Royal Albert Memorial museum (Exeter) and the Royal Cornwall museum (Truro). While this sampling programme has identified a significant quantity of Palaeolithic material, we suggest that further relevant data will be gained by visits to, and examinations of, those collections held by the smaller, local museums within the region, and also recording of those private collections where artefacts may be housed which have not yet been included in the literature. Therefore in order to provide a complete picture of the Palaeolithic archaeology from the south-west region, the second phase of the project will include an additional sampling programme to cover the museums and private collections identified above.

The data provided through the resource assessment also has implications with regard to the archaeological interpretation of the south-west region (and the south of England as a whole) during the Middle and Late Pleistocene. The main archaeological question posed by this project concerns the extent to which the south-west region was occupied, and how this is represented in the current interpretation of the region's Palaeolithic archaeological record. This can be summarised with the question:

Does the rich archaeology of the River Axe valley represent a 'western' frontier in terms of the British Lower and Middle Palaeolithic, beyond which Palaeolithic occupation of the south-west region was highly sporadic? Or is the apparent paucity of archaeology to the west of the Axe valley due principally to issues of taphonomy and sampling?

The data collected in the resource assessment highlights a number of potential avenues for addressing the above question. Overall it can be seen that many of the 'new' findspots recorded in this project lie in areas of well documented Palaeolithic activity within this "western" frontier, for example the Axe valley region in Dorset & Devon. This pattern confirms the interpretation of Pleistocene occupation in this region (i.e. that the Axe valley was a key foci for hominin occupation, *at least* during the late Middle Pleistocene (Toms *et al*. 2005). However, several of the 'new' findspots lie further west and south of this area, suggesting some form of occupation beyond this boundary. Such findspots include the recent discovery of a handaxe at Marazion Beach, Penwith in Cornwall in 1997 and the Levallios flake in Otterford, Somerset. Whilst evidence of occupation in these areas had been previously documented, the number of findspots prior to this project was far lower than in the east of the study region. Consequently the addition to these locations of 'new' findspots is of significance as it reinforces the idea of hominin occupation beyond the region of the Axe valley. Furthermore these findings have been combined with BGS geological survey maps of the Devon region (Section 3) in order to produce Palaeolithic archaeological findspot/Pleistocene terrace deposit location maps where locales suitable for further investigation have been identified.

2.8.5 Discussion & Conclusions

During the implementation of the resource assessment programme several limiting factors have occurred with some frequency:

- The most major of these has concerned the resolution of the available data, regarding previous documentation of artefacts and archaeological findspots. In order for a clear picture to be built as to what is already known of the Palaeolithic of south-west England, it is fundamental to be clear as to which records have (or have not) been cited. Without this information subsequent research must necessarily start from a position of ignorance as to which dataset is associated with particular artefacts and findspots. Fortunately much of the data provided by the regional HER offices included whether the record had been included in previous studies, and if so which ones. However, this was not the case when gathering data from museum collections. In practice there were no records as to whether any of the artefacts recorded had been included in previous studies. This obviously created problems when trying to identify 'new' artefacts from the "invisible" record. Leading on from this it was also apparent that there is little correlation between the HER records and museum collections, again this creates difficulties in establishing which records have already been catalogued, thus increasing the possibility of duplication.
- The Palaeolithic material housed in many of the south-west museums is underused as a resource, with handaxes constituting the vast majority of the *documented* artefacts in any collection, and other possible Palaeolithic material simply being boxed, and often ignored. Whilst this is understandable given the secondary context origins of the findspots (handaxes are both likely to over-represented in individual collections and are also 'easier' to interpret when dealing with disturbed and re-worked findspots), it does mean that often previous research in these areas have simply "gone over old ground", in that the handaxe assemblages tended to repeatedly be the focus of research. This is not to say that further material is lacking however. In almost all of the museums visited during the resource assessment non-diagnostic artefacts of possible Palaeolithic age were present (often in abundance). However, there was little or no information as to the assemblage's provenance, and therefore the chronological affiliation of the material is rarely known. Unfortunately this means that without a much more detailed analysis of the artefacts very little pertaining to their origins can be inferred at the current time.

It is important to stress however that the difficulties outlined above are not viewed as insurmountable obstacles to Lower and Middle Palaeolithic research in the south-west of England. Indeed, the 'new' findspots and artefact information gathered by the resource assessment illustrate that gainful data from this period can be collected. In particular the project databases developed as part of this resource assessment have:

- Documented artefact museum accession numbers (where known) and linked them with specific findspots (using either the Southern Rivers Palaeolithic Project (Wessex Archaeology 1993) findspot codes or the new findspot codes generated as part of this project: these will be disseminated to the HERs at the end of phase one).

Furthermore, bringing such complications to the forum allows them to be addressed more readily. Such issues were the subject of a workshop discussion at the Regional Palaeolithic Networks meeting held on the 16th of June 2005. The outcome of this discussion demonstrated the interest of HER & museum staff members, local enthusiasts and regional archaeological societies for further research into the Palaeolithic of the region. Discussion also took place as to how best these individuals and organisations could tackle the issues outlined above, and also expand the level of research being carried out. The need for further training and education into artefact and river terrace identification was highlighted as an important factor. This would be a clear advantage to further research in the area. Not only would it increase the probability of additional findspots coming to light via fieldwalking and the knowledge of local enthusiasts, but also it would help to resolve some of the issues concerning artefact identification in extant museum collections. Similarly it was agreed that sessions should be held to outline the role of non-flint raw materials for artefact production in the south-west Palaeolithic record. Much of the lithic assemblages from the south-west region are produced on flint and chert (both siliceous materials). However it is now being recognised that an increasing amount of stone tool production used non-siliceous rocks such as quartzite. The fracture dynamics of such materials is very different to that of flints and cherts, and therefore the identification of palaeoliths made on this material can be difficult. These sessions will be run as part of project phase two, with arrangements already having been made to work in partnership with other regional Palaeolithic research initiatives (such as the National Ice age Network in Birmingham).

Overall the key conclusions of the resource assessment of the Lower and Middle Palaeolithic archaeology of the south-west region are as follows:

1. The findspot record for the region is richer than had previously been documented in the over-arching, national syntheses.
2. It is assumed that the artefact record for the region is richer than had previously been documented in the overarching, national syntheses: however, this has not yet been fully demonstrated because of the difficulty of linking all of the individual artefacts to their specific findspots.
3. New artefact data (typo-technological, morphological, physical condition) has been generated, enabling provisional patterns to be identified and acting as a baseline resource to support future artefact research.
4. There is both a need and an enthusiasm for future training in the identification, reporting and recording of Palaeolithic artefacts, both among amateur/public and professional archaeologists.

2.9 Key Conclusions of the Phase I Assessment

1. There are a series of threats to the aggregates resources of the south-west region, and currently a paucity of strategy information concerning the potential and value of the different landforms, deposits and sequences to inform our understanding of the Pleistocene archaeology of the region.
2. The Lower and Middle Palaeolithic findspot (and by implication artefact) record in the south-west region is significantly more substantial than previously suggested in key extant synthesis works. The ‘new’ findspots identified through the regional HERs occur both in areas and regions with well documented Palaeolithic heritage (e.g. the Axe valley), but also in areas (e.g. the extreme south-west of Cornwall and the

Plymouth region) where Palaeolithic archaeology has previously been given a very low profile, particularly in the national literature.

3. Due to the quantity of Lower and Middle Palaeolithic artefacts present in the south-west regional museums, artefact recording and analysis during the first phase of the project was limited to the regional museums.
4. The Pleistocene fluvial landscape resource (e.g. terrace landforms and deposits) in the south-west region is more substantial than has previously been argued in key extant synthesis works. Recent re-mapping of the Exe region has indicated that altitudinally-distinct terrace landforms are present, while OSL applications have indicated Devensian ages for the lower terraces. The rivers of east Devon (e.g. the Axe, Exe, and Otter) provide the most substantial fluvial terrace resources, although deposits and landforms of Pleistocene age occur across the extents of the south-west region (although they are more fragmented and sporadic in the west).
5. There are very few robust geochronologies for the fluvial landscape deposits and landforms in the south-west region, resulting in a Palaeolithic archaeological resource which is severely de-contextualised.
6. There is a need, and support, for training in Palaeolithic artefact and Pleistocene fluvial landform identification, to support both reporting, and curation, of the resource in the future.

3. FIELDWORK & GIS MODEL

This section reports on the fieldwork undertaken during phase two of the project, and on the updates to the GIS model. The main text provides an overview discussion of the fieldwork and its implications: the fieldwork data and specialist dating and pollen reports are included in the Appendices.

3.1 Summary of Fieldwork Objectives

The core fieldwork objectives in Phase 2 were to:

- Conduct extensive mapping, sampling and dating of the Exe, Otter and Axe valley systems (Figure 17) including initial calibration of ground penetrating radar (GPR) techniques in the Axe valley.
- Conduct targeted monitoring, sampling and dating (where appropriate) of fluvial sedimentary exposures in other parts of the south-west region as opportunities arise (Figure 18).
- Complete a desktop evaluation of the Axe system using IFSAR and GIS methodologies.
- Enhance the county HERs and develop the existing GIS model resources and disseminate the information to the HERs.

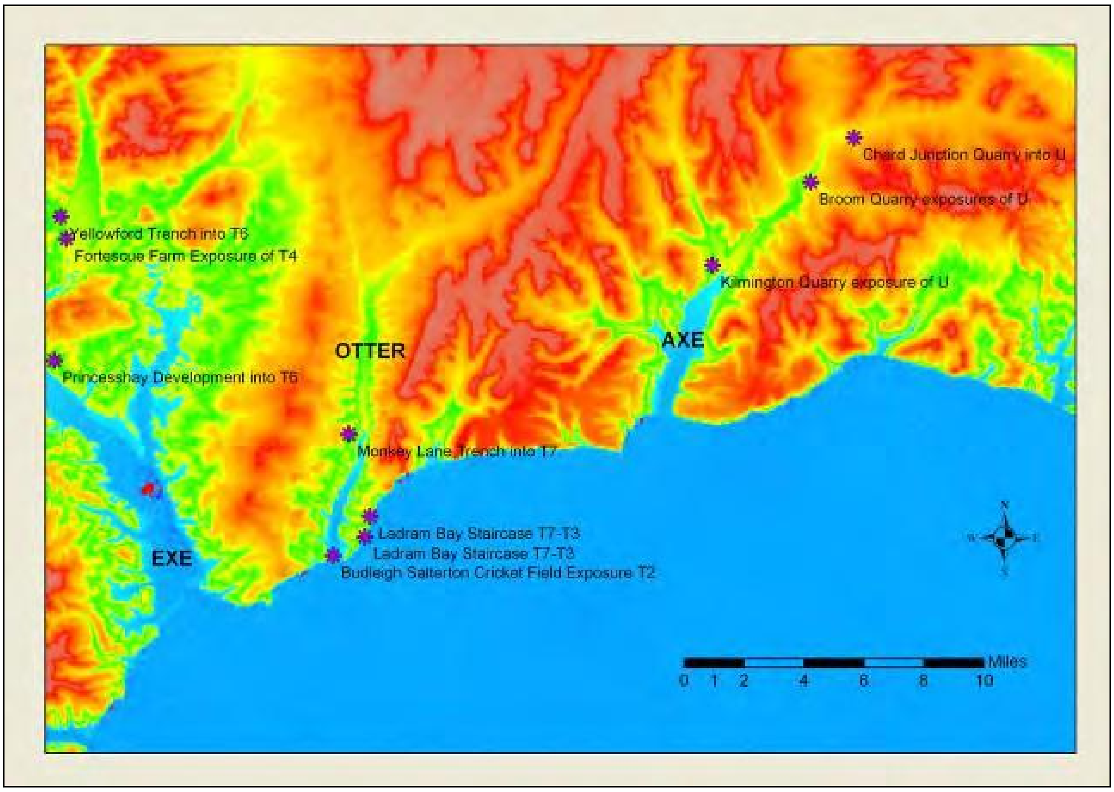

Figure 17: Key fieldwork sites associated with the Rivers Exe, Otter and Axe, and discussed in the text. DEM backdrop is derived from Integrated CEOS European Data Server data (http://iceds.ge.ucl.ac.uk/). Rivers and place names are derived from Digimap Carto (Strategi) data licensed to Exeter University. Figure created in ArcGIS by L Basell.

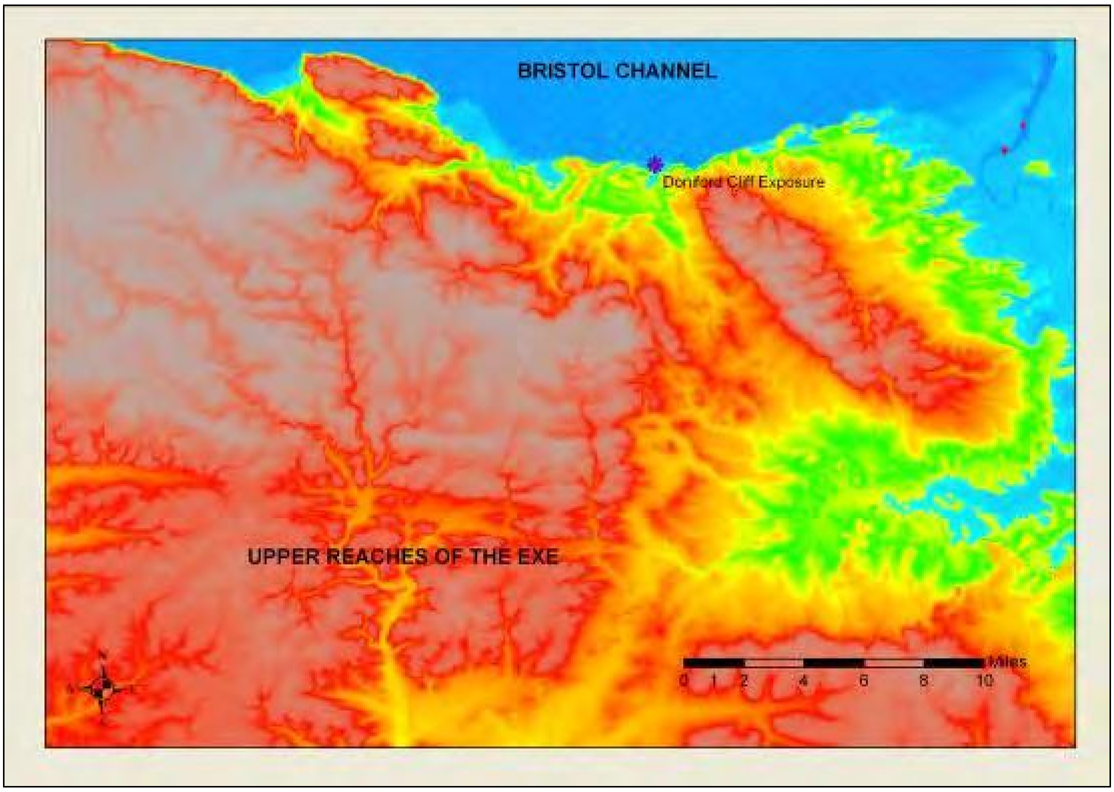

Figure 18: Location of the Doniford cliff exposure, discussed in the text. DEM backdrop is derived from Integrated CEOS European Data Server data (http://iceds.ge.ucl.ac.uk/). Rivers and place names are derived from Digimap Carto (Strategi) data licensed to Exeter University. Figure created in ArcGIS by L Basell.

3.2 Fieldwork Summary: River Exe

3.2.1 Background

Following the phase one evaluation, the most pertinent points regarding the Exe terraces may be summarised as follows:

- Eight terraces have been differentiated in association with the Exe (Scrivener, 1984).
- Palaeolithic archaeological artefacts have been found in direct association with terrace 5.
- The higher-level terraces appear to drape over the landscape and it has been suggested by Dr R. Scrivener that this is related to periglacial outwash (Scrivener, 1984 and pers. comm. to Laura Basell (LSB)).
- There is altitudinal separation between the terraces.
- There are OSL dates on the terrace 3 deposits at:
    1. Five Fords, River Culm (Exe tributary): 39,450 ± 2,930 BP (unpublished work conducted by Prof Tony Brown).
    2. Washfield, River Exe: 27,500 ± 240 BP (work conducted by J. Bennett as part of her unpublished PhD research).
- There are very few exposures of any of the terraces, and particularly the higher-level terraces.
- No sedimentological studies have been conducted on them.

During Phase 2, fieldwork has been completed at 3 separate terrace locations in the Exe Valley.

3.2.2 Princesshay: Terrace 6 (Appendix 5: Section 1)

This site lies in the centre of Exeter, and is the location of a major development (NGR 292229, 092760; Figure 19). Prior to construction, Exeter Archaeology conducted extensive excavations, during which exposures of superficial geology (river terrace 6) and bedrock geology (Whipton Formation and Basalt) were revealed. According to the site geologist, D. Jordon of Terranova, the bedrock geology slopes gently south west (i.e. slopes towards the present-day course of the Exe). The river terrace deposits exposed at the site occurred at heights of between 40 and 42 m OD. Unfortunately some of the best exposures of terrace deposits at this site occurred prior to the fieldwork phase of the Palaeolithic Rivers of South-West Britain project.

Exeter Archaeology took two slides of these exposures, and noted the extent of the gravel spreads, but no little further detail on them. According to information from Exeter Archaeology there was a considerable difference between the exposure in the east of the site and the west of the site (C. Barnes, pers. comm. to LSB). In the former the clasts were quite small (~10 cm), appearing as in thin spreads over the site and surviving only in hollows. In the latter, they were larger (up to ~20 cm) and the deposits exposed were deeper and survived as a more general spread. Small exposures of gravel were still visible in November 2005 when LSB visited the site. These were in the central section of the area indicated on Figure 20. No exposure was greater than 1m in depth, because the river terrace deposits have been truncated by later human activity.

Some shallower deposits were accessible, and these have been recorded through drawings and digital photographs. The best exposure was in a pit interpreted as a night soil pit (Figure 21). The pit fill contained finds of Saxon (597–1066 AD) affinities, providing a minimum age for the pit cut. All exposures exhibited significant cryoturbation and the small clast size of ~10 cm is in keeping with the easterly exposures noted by C. Barnes. A sand deposit, related to the terrace was sampled for OSL dating by Dr Phil Toms (PT). At the time of sampling it was interpreted as being re-worked Whipton formation and this remains the most likely interpretation. Preliminary dates are surprisingly recent from terrace 6 in the Exe (in light of the terrace 3 dates sampled by Brown and Bennett: see above): 43,000 ± 5,000 BP and 44,000 ± 4,000 BP (Appendix 7). These dates probably reflect disturbance of the deposit through cryoturbation during Oxygen Isotope Stage (OIS) 3, rather than the age of the terrace's deposition.

A further briefly exposed section not far from the Civic Centre was logged by C. Barnes (pers. comm. to LSB). This describes an exposure (indicated on Figure 20) to the north east of the dated samples examined by LSB (discussed above). The top of the gravel had again been truncated, but an exposure of river gravels was revealed to a depth of 1.10 m with a band of manganese staining at the base. The log describes sub-horizontally bedded gravels with some variation in the roundedness of the clasts and matrix, but no mention of cryoturbation features. This does not necessarily mean they were not there, but is in keeping with the findings at Yellowford Farm (see below) where the upper part of the terrace deposits were cryoturbated, but lower deposits did not exhibit any cryoturbation features. As all the exposures have been truncated, some caution must be exercised. However, it is possible that the thinner, more westerly, spreads of heavily cryoturbated gravel represent the margins of a deeper channel which is represented by the thicker, more easterly deposits of crudely bedded material. It is probable that similarly cryoturbated deposits once formed the top of the easterly material, but that later anthropogenic processes have truncated these.

That the River Terrace 6 has been reworked through cryoturbation has important implications both for the palaeoenvironment of the Exe, and for the archaeology found within terrace 6, and other terraces pre-dating OIS 3 elsewhere in the Exe catchment. If the river gravels are being reworked by freeze thaw processes, then artefacts already within the deposit could also become reworked, and potentially more recent artefacts that were lying on the surface could also become incorporated. This is a particular problem when dealing with Palaeolithic artefacts were much of the material is either non-diagnostic or only dateable to extremely large time spans (e.g. 100,000s of years).

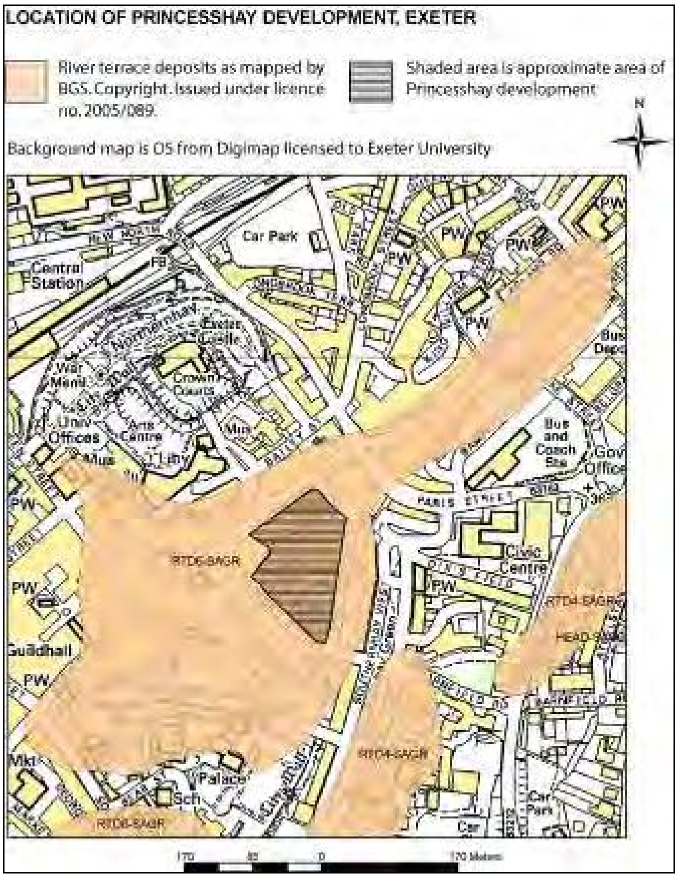

Figure 19: Location of Princesshay Development, Exeter. Figure created in ArcGIS by L Basell.

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Figure 20: Location of specific gravel spreads at the Princesshay Development, Exeter courtesy of Exeter Archaeology. Yellow areas in area B/C were examined by LSB in November 2005. Blue area marked "Here" represents exposure recently logged by C. Barnes. Pink is Basalt Bedrock.

3.2.3 Yellowford Farm: Terrace 6 (Appendix 5: Section 2)

The terrace 6 deposits at Yellowford Farm lie to the north of Exeter, between the villages of Brampford Speke and Thorverton (NGR 292573, 100491).

Following the excavation of a 20 m trench, clast analysis was conducted on selected units within the gravels; samples were taken for organics; and clasts were taken to BGS for lithological identification. Dr R. Scrivener and Dr B. Leveridge of BGS were also consulted. A photographic archive was compiled and sand units from three separate locations were sampled for OSL dating. The site was backfilled, and is now under crop.

In contrast to Princesshay the river terrace deposits here were not truncated and were in fact more substantial than expected. Rather than the very thin drape of gravel anticipated by Dr R. Scrivener, thought to be associated with periglacial outwash (Hosfield *et al*. 2005: 26), roughly 3.5 m of gravel were discovered beneath a variable amount of topsoil, but generally ~35-45 cm. Whilst these gravels may still represent periglacial outwash, the depth of deposit is greater than previously suspected. Most of the gravels were clearly cryoturbated (in concordance with the Princesshay deposits) with the exception of gravels in the deepest part of the pit. An ice-wedge cast was also revealed in two sections at 90° angles to each other (Figure 23). The regularity of the feature, the nature of the deposit, and the fact it appeared in both sections supports this interpretation over it being a root or burrow feature. The depth of the cryoturbation in the exposure at Yellowford indicates the deposit has probably been repeatedly cryoturbated over several different glacial cycles and implies a significant antiquity for the deposit.

Figure 21: Pit with truncated river gravels exposed. Arrow shows location in deposit underlying river gravel that was sampled for dating purposes. Below that is Whipton Formation solid geology. November 2005. © L Basell.

The clast analyses data very clearly distinguish the heavily cryoturbated area from less cryoturbated areas (See plots in Appendix A1.2). Where there is less cryoturbation, clustering is coarse, but clear, possibly giving some indication of palaeoflow directions. Some clasts were up to ~30 cm in size, demonstrating the river that deposited the gravels was at least intermittently high energy. The rock types represented include material derived from Exmoor (BGS staff pers. comm. to LSB) and probably from the Hangman Formation. Ternary Sneed and Folk diagrams completed for Yellowford allow comparison of clast shapes within the terrace unit, and between terraces of specific catchments. As clast shape is related both to fluvial and taphonomic processes and to lithology, this can be used to identify/clarify major differences between units. For example, at Yellowford the diagrams show a slight variation between the two units on which clast analysis was conducted with the very heavily cryoturbated unit showing clasts to be more elongate (slab/rod) rather than blocky. This may be related to frost shatter. As the sample size is small, this interpretation should be treated cautiously, but it supports the interpretations of other data, and observations made in the field. Comparison of the Yellowford and Fortescue ternary plots of clast shape, do not show any major differences.

OSL samples were taken from three areas. Two features apparently associated with, but considered during fieldwork to post-date, the gravels were sampled. A further small sample from an uncryoturbated unit at the very base of the gravels was also taken. The preliminary dates received are 15,000 ± 3,000 and 12,000 ± 2,000 on features sampled that cut into the gravels, and 78,000 ± 23,000 on the small sample taken from the uncryoturbated area at the base of excavation (Figure 22). This latter date is far more recent than expected and the error margins are extremely large. This means the date could range from OIS 5 to 3, and Dr Toms believes this is a minimum estimate (see Appendix 7):

"Both the accuracy and precision of this sample's age estimate are influenced by two factors. First, the age is based on a limited number of measurements owing to a low mass of datable material. Second, the Shute sandstone may have some influence on the spatial heterogeneity (accounting for age imprecision) and temporal stability of dose rate (accounting for age underestimation through gradual migration towards the sample of relatively high radioactive U and Th bearing material sourced from the Shute sandstone)".

(Toms, pers. comm.)

This is important as, as it demonstrates a methodological limitation of OSL in certain areas of the Exe catchment (see Appendix 7).

Figure 22: Basal, non-cryoturbated unit suitable for OSL dating at Yellowford Farm. © L Basell.

Figure 23: Ice wedge feature at Yellowford Farm, 2006. © L Basell.

3.2.4 Fortescue Farm: Terrace 4 (Appendix 5: Section 3)

This site (NGR 292875, 099298) lies close to Brampford Speke and Yellowford Farm, and exposes terrace 4 deposits (Figure 24). The exposed section was cleaned and logged. Further excavation was undertaken in an attempt to reveal the junction between the terrace deposit and bedrock and ascertain the total river terrace deposit thickness. The junction was not revealed, but a further exposure of Terrace 4 deposits downstream at Brampford Speke (surveyed during Phase 1) showed the gravel thickness to be ~4 m. The total depth of exposed section at Fortescue was 3.7 m, including ~3.3 m of river terrace deposits. The base of the gravels was not reached, but several distinct units were logged. The section was logged at ~3 m intervals along a well-exposed section of ~20 m. These varied between cryoturbated, chaotically orientated gravels, and sub-horizontally bedded units with no clear evidence of cryoturbation. This suggests that like Yellowford, the river terrace deposits have undergone repeated cryoturbation over different glacial stages. Clast analysis was completed on all the major units (Appendix 3 & 4). The altitudinal separation of this terrace from the lower three terraces (1–3; Figure 25) suggests that the cutting and deposition of the terrace 4 landform and deposits was associated with a major climatic event, and given the dates already known from Terrace 3 this is likely to be OIS 4.

Clasts were again taken to BGS for lithological identification and, as for terrace 6 at Yellowford, include material derived from the Hangman Formation or the Pickwell Down Sandstone on Exmoor (Dr B. Leveridge pers. comm. to LSB). Their shape as expressed in the Sneed and Folk ternary diagrams (Appendix A2.1) does not differ significantly from those measured at Yellowford. Of particular interest however is the very clear increase in the roundedness of the clasts between the terrace 6 at Yellowford, and terrace 4 deposits at Fortescue from "Sub Rounded" being dominant at Yellowford, to "Rounded" being dominant at Fortescue in all units (Appendix A4.2). In addition there is nearly a 40% reduction in clast size between terraces when clast sizes across all units (at each terrace respectively) are considered (Appendix A4). These patterns could be interpreted as representing local changes in fluvial processes.

However, in combination with the other data and given that the lithology is the same, an alternative interpretation is that the terrace 6 deposits have been reworked probably into terrace 5 and then again into terrace 4, resulting in increasing rounding of the material. This concept has important implications at a more general level for our understanding of terrace formation; particularly as this reworking is a factor that is not expressly incorporated in the Bridgland's widely used model of terrace formation (Bridgland 2000). Stereograph plots of clast dip and orientation from all the units at Fortescue show a range of patterns (Appendix A1.1). However, the dominant orientation clusters on all plots suggest a broadly similar orientation, probably representing a dominant palaeoflow direction that differs little from that observed today. As for the stereograph plots drawn up for Yellowford, badly cryoturbated units stand out clearly on the plots (Appendix A1.2), with points clustering towards the middle indicating a high dip angle. Heavily cryoturbated units also show a greater range of variability in clast orientations.

Figure 24: Exposed section at Fortescue Farm, 2006. © L Basell.

Figure 25: Terrace 4 landform at Fortescue Farm, 2006. © L Basell.

3.3 Fieldwork Summary: River Otter

3.3.1 Background

Following the phase one evaluation, the most pertinent points regarding the Otter terraces may be summarised as follows:

- Palaeolithic archaeological artefacts have been found in direct association with terrace 5.
- There appears to be altitudinal separation between the terraces.
- There are very few exposures of any of the terraces, and particularly the higher-level terraces.
- No absolute dates have ever been achieved on the terraces associated with the Otter.

- There are nine terraces differentiated by BGS mapping, and a higher terrace noted overlying the Budleigh Salterton Pebble Beds at Blackhill Quarry which has not been mapped by BGS but is recorded in the Geodiversity Audit (Nicholas, 2004).
- No work has been done on the sedimentology of the terraces, although attention has been paid to the hanging dry valleys in the catchment (Gregory, 1971).

During Phase 2 fieldwork was completed at two locations in the Otter Valley, and samples of all mapped terrace fragments in the southern half of the catchment were visually examined during the identification of practical fieldwork sites.

3.3.2 Budleigh Salterton Cricket Field: Terrace 2 (Appendix 5: Section 4)
Discussions with BGS indicated that only three exposures of terrace deposits (other than those visible in cliff sections south of Ladram Bay) existed when mapping of the Sidmouth sheet was conducted. One of these exposures is at Budleigh Salterton Cricket Field where there is an exposure of terrace 2 about 2.5 m in thickness (Figure 26). Logging and sampling for OSL dating has been completed at the site. Two sand lenses were sampled; one within the gravels and one at the base of the gravels at the junction with the Otter Sandstone. These samples have been processed and generated dates of 75,000 ± 9,000 BP and 99,000 ± 10,000 BP. These are however minimum estimates (see *Appendix 7*). No clear cryoturbation features were observed though there is some root disturbance from the trees growing above the section. In general the gravel exhibited crude sub-horizontal bedding; there is considerable variability in clast size and imbrication of clasts is clearly visible. No channel features were clear, but this is unsurprising as the exposure is small. The sand lenses also exhibited clear horizontal bedding. The lithology is overwhelmingly dominated by clasts from the Budleigh Salterton Pebble Beds with occasional flint and chert clasts, as for Terrace 7 at Monkey Lane (see below).

Figure 26: Terrace 2 Exposure at Budleigh Salterton, 2006. © L Basell.

3.3.3 Monkey Lane: Terrace 7 (Appendix 5: Sections 5 & 6)
A 20m trench was excavated in Terrace 7 at Monkey Lane south of Newton Poppleford. On-site consultations were carried out with Dr R. Gallois (who mapped the Sidmouth area for BGS). Gravels were exposed overlying weathered Otter Sandstone, along with a raft of clay derived from the Mercian Mudstone occurring at the junction between the gravels and the Sandstone. The form and size of this mudstone indicates that it was transported as a frozen block. The gravels were clearly truncated, and did not exhibit cryoturbation features as seen at the Exe valley sites,

although a clear tree throw feature, and palaeochannels were observed (Appendix 5: Sections 5 & 6). The maximum gravel thickness across the trench was ~1 m 40 cm, but is likely to be thicker in other areas of Terrace 7. The gravel at Monkey Lane is truncated, and would therefore have been a thicker unit in the past. The site is high and exposed, and historically this field has undergone significant episodes of erosion, which has caused a change in the land management patterns ("Home Farm" Staff, pers. comm. to LSB). Sections were logged at regular (~2 m) intervals, digitally photographed. Clast analysis was conducted on the main units. The site was backfilled and the grass re-sown.

Clast analysis shows no variation in lithologies between the main units at this site (Appendix A3). The clasts are completely dominated by locally derived chert and quartzite with very occasional pieces of flint and sandstone. The stereographic plots (Appendix A1.3) show some variability, probably related to different channel flow directions. Three separate sand lenses were sampled for OSL dating. The first of these yielded a date of 116,000 ± 17,000 BP, but showed some slightly anomalous behaviour (PT, pers. comm. to LSB; Appendix 7). Dr Toms believes this to be a minimum estimate. As the date stands however, it places the site within Oxygen Isotope Stage 5d.

Following excavation, a survey was conducted over the terrace fragment (Figure 27) using differential GPS. The data has been post processed (accuracy resolved to 10mm vertically and 20 mm horizontally using RINEX data and Leica GeoOffice software), and 3D modelling of this data completed (Figure 28). This data indicates a second break of slope within the terrace mapped as a single unit. This shows a greater complexity to the formation of the terrace than can be seen from the mapping, and indicates that two terraces are represented here. Two GPR transects were also completed across the terrace (Appendix 8). These detected the base of gravels and highlighted variation within them. Of particular interest were anomalies to the east of the site, which may show an additional terrace feature, potentially supporting the GPS model. The fieldwork has shown the gravel to be of significant antiquity. The GPS and GPR surveys support each other in showing that a gravel body previously mapped as a single unit appears to contain two distinct units. The block of Mercian Mudstone (Figure 29) bears witness to conditions very different from those seen in the valley today, although on the whole the palaeoriver Otter was clearly deriving its bedload from local sources as it is today. In addition, structure within the terrace has been preserved showing palaeochannels, and the clast analyses can be used as indicators of palaeoflow directions.

Figure 27: Terrace 7 at Monkey Lane

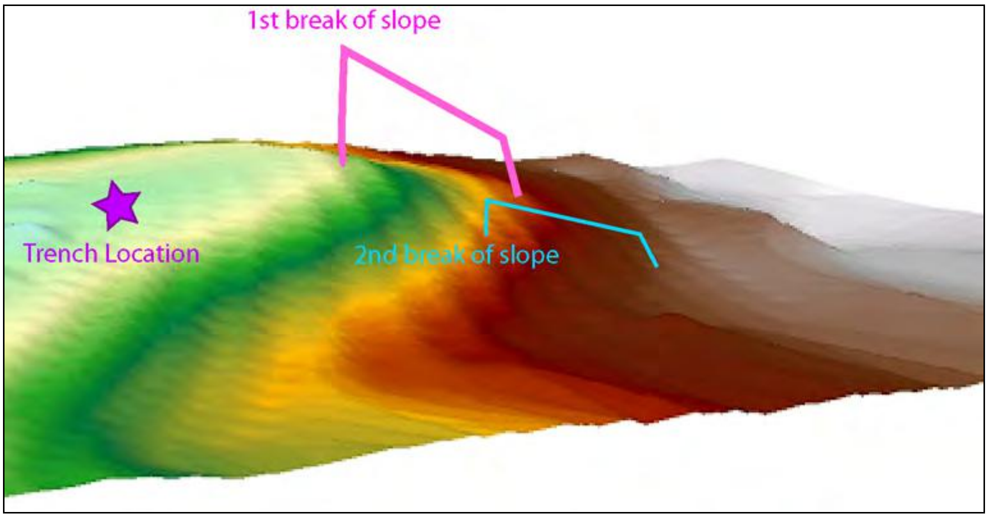

Figure 28: Terrace 7 modelled on GPS data in ArcGIS and ArcScene by LSB. Annotated to show clear breaks of slope which are not especially clear on the ground, and particularly when vegetation is high.

Figure 29: Terrace 7 at Monkey Lane showing Otter Sandstone at base, raft of Mercia Mudstone in the right hand section between the Otter Sandstone and overlying Gravel, River Terrace Deposits and minimal Topsoil. © L Basell

3.3.4 Ladram Bay Staircase Sequence

Some of the terraces in the area to the west of the river Otter lie very high above the current floodplain and must be of considerable antiquity. Terraces 3, 4, 5, and 7 to the north of Brandy Head are clearly stepped topographically (Figure 30 & Figure 31). Although the area is of high geomorphological potential (extensive areas of river terrace deposits are preserved) unfortunately the land proved inaccessible.

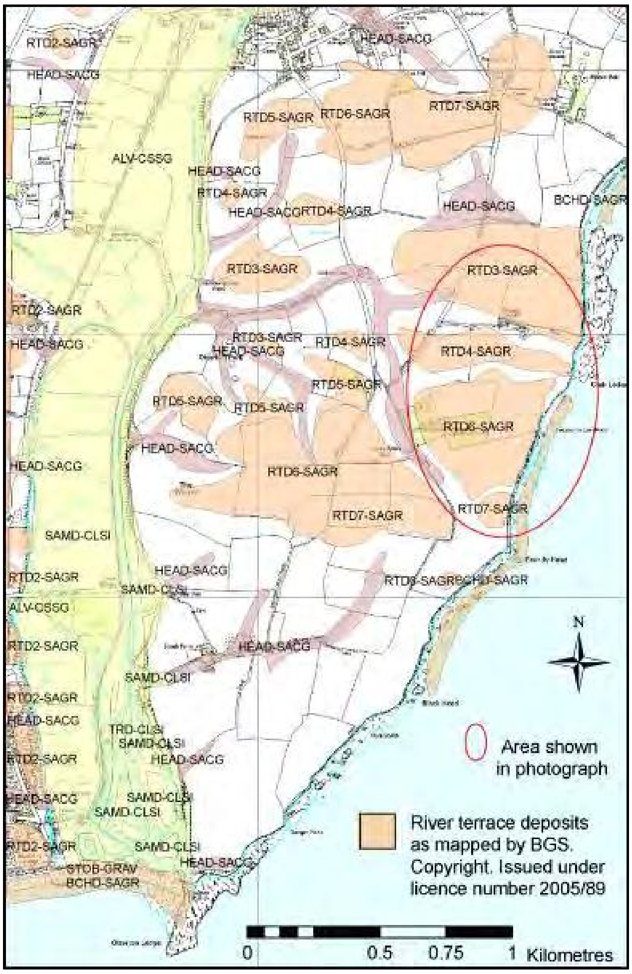

Figure 30: Terrace deposits to the south of Ladram Bay. Background map is OS data from Digimap licensed to Exeter University. Figure created in ArcGIS by L Basell.

Figure 31: View (to the south-east) of terrace staircase sequence on the coast to the south of Ladram Bay annotated to show terraces. © L Basell.

3.4 Fieldwork Summary: River Axe

3.4.1 Background

Following the phase one evaluation, the most pertinent points regarding the Axe terraces may be summarised as follows:

- Palaeolithic archaeological artefacts have been found in abundance at Broom.
- Single findspots of Palaeolithic material are found at a number of other locations in the catchment (e.g. Chard Junction and Kilmington), but artefacts are found in nowhere near the same quantities as at Broom.
- The terrace sequence is anomalous when considered in relation to the terrace sequences to the east and to the west. The area has been mapped recently, yet only undifferentiated terraces and terrace 1 are found in association with the River Axe. However, some of these terraces are extremely deep, up to ~15 m at Chard Junction for example.
- The gravels of the Axe valley have been more extensively quarried than any of the other terrace deposits under study in the Palaeolithic Rivers of South-West Britain project and continue to be actively quarried at Chard Junction.
- A series of dates have been achieved on the terraces associated with the Axe at Broom. These dates ranged between c. 250000 – 300000 BP (prior to Bayesian modelling), and were obtained by Rob Hosfield and Phil Toms for the terrace deposits at Broom by OSL (Toms *et al*. 2005).
- Limited work has been conducted on the sedimentology of the terraces away from Broom.

3.4.2 Kilmington (Appendix 5: Section 7a–10b)

Work was conducted at Kilmington, which was identified as a major area of interest in Phase I. All areas of past working at Kilmington Pit were examined, although large areas of previously open worked ground have now been backfilled. Section drawing and logging has been completed at Kilmington Quarry (grid reference 327530 097885) where there are large exposed sections through the terrace deposits. The lower half of these sections are generally slumped and vegetated (Figure 33), but the upper halves are well-exposed, "clean" faces. The quarry is now disused and quite overgrown, but whilst it was a working pit, two Acheulean bifaces and several flakes attributed to the "Palaeolithic" were recovered. Much of the area originally worked has been backfilled and is used as farmland.

Only the southern, western and eastern faces are made up of *in situ* gravels. Much of the northern face is backfill. The non-backfilled faces have slumped considerably, leaving a total section exposure of ~9 m. This must originally have been closer to ~14 m. A section 21 m long section was cleaned and drawn in detail (Figure 32), and digitised (*Appendix 5, section 7a, 7b, 10a, 10b*). Clast analysis was completed on major units seen in the 21 m section. A further five stratigraphic logs were taken along an additional 122.5 m of the southern and part of the western section including the OSL sample location points and digitised (*Appendix 5, section 8a , 8b & 9*). A dumpy level traverse was conducted to ascertain the height OD, and sediment samples have been taken for pollen analysis. The quarry edges were GPS surveyed (*Appendix 5, section 9*) and levels were taken across the site.

There are clear cryoturbation features in the uppermost units (heaves and clusters), while the lower units tend to exhibit some horizontal bedding and imbrication. Manganese and iron staining occurs in patches throughout. Within nearly all the main gravel units are discontinuous sand, silt and clay lenses of varying sizes. Some of these have been disrupted by cryoturbation, and some show bedding and cross bedding. The deposits show channel and bar features and the variation in the composition of the sedimentological units are clearly indicative of different flow rates and fluvial processes. All units exhibited the same basic lithology dominated by chert. The stereographic plots of dip and orientation were particularly successful. Aligning the stereographs with the section drawings at the appropriate sedimentological unit different palaeoflow directions can be clearly distinguished.

Two of the four extant sections contained sand lenses suitable for OSL sampling (Figure 34). Four samples were taken and processed by Dr Toms. These have yielded dates of 309,000 ± 26,000 BP, 273,000 ± 26,000, 179,000 ± 18,000 BP and 154,000 ± 19,000 BP (Appendix 7). The dates fall into two groups and are stratigraphically contiguous, with one exception. They appear to date two major units. On receiving the dates, the location of the exceptional sample was re-examined and the sample location was found to be within a large block of sediment slumped from the upper unit. This means the lower part of the gravel exposure is dated to OIS 8 and the upper part of the exposure dated to OIS 6.

Unfortunately we do not know which unit the artefacts came from. If it was the lower unit, then this makes the Kilmington artefacts similar in age to those at Broom (and perhaps even dating to the same general phase of occupation in the Axe valley). The dates of ~309,000 BP and ~273,000 BP fall into late OIS-9 and mid OIS 8 so it is certainly possible that the artefacts are actually older than the dates on the gravels and represent a human presence in OIS 9. If they come from the higher unit, with the dates of ~179,000 BP and ~154,000 BP then they could reflect a human presence in early OIS 6 or OIS 7.

Geomorphological mapping of the paired terraces in this region has been completed by Jenny Bennett (JB; Figure 35; Appendix 6). Significant geomorphological features were revealed through this survey. Although the area has been mapped by BGS as Undifferentiated terraces, there are clearly altitudinal differences between discontinuous terrace patches. On specific swathes of terraces several large breaks of slope have been mapped by JB. This confirms there is much greater complexity to these deep gravel deposits than can be gained simply from examination of the BGS mapping, as for their purposes it was only necessary to note the limits of the terrace form, and not variability within it such as these additional breaks of slope. It should also be noted that smaller tributary valleys, which must post-date the formation of the terraces, repeatedly cut across and through the river terraces as they flow into the modern floodplain.

Figure 32: Part of 21 metre section at Kilmington, looking west (left), January 2006. General shot of quarry, looking southeast, with the southern section clearly visible (right), January 2006. © L Basell.

Figure 33: Slumping and vegetation on the old quarry faces at Kilmington: southern section, viewing to the east, January 2006. © L Basell.

Figure 34: Cross-bedded sand lens, Kilmington, being sampled for OSL dating, January 2006. © L Basell.

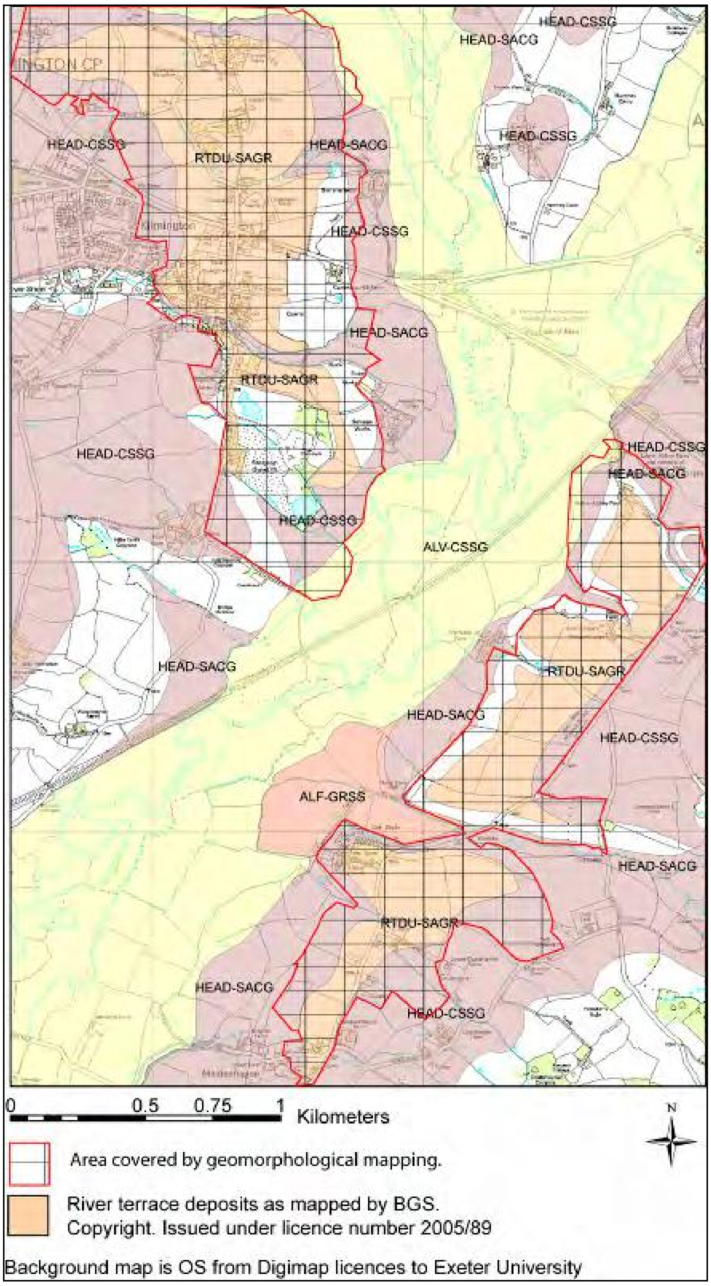

Figure 35: Terrace deposits in the Axe valley. Background map is OS data from Digimap licensed to Exeter University. Figure created in ArcGIS by L Basell.

3.4.3 Chard Junction (Appendix 5: Sections 11–13)

Permission was obtained to work in this pit, from the quarry managers and with full agreement from Bardon Aggregates, and their cooperation is gratefully acknowledged. This is an active pit which continues to extract river terrace deposits in the Hodge Ditch Farm area (NGR 335135, 104735). The late John Wymer found a biface at the pit some years ago whilst on a QRA/INQUA trip (Wymer 1977; C. Norman pers. comm. to LSB), and several other bifaces are recorded in the HERs as having come from Chard Junction Pit. The site is ideal as it has only recently been opened so it has been possible to record all the major units before they have been removed. OSL samples were taken from three separate sections and at different depths and locations in the active pit. A further sample was taken from the base of an extant section in an area now being used as a silt pond. Two long sections were logged, sketched, and photographed (*Appendix 5: Sections 11 & 12*). These covered the locations of OSL samples CHAR01 and CHAR03. The sections (one of 110 m and one of 21 m) were both logged at 5 m intervals. The locations of the other two OSL samples (CHAR02 and CHAR04) were photographed and their height OD surveyed in (*Appendix 5: Section 13*). Examination of the records shows that there are effectively two major units currently visible at the Hodge Ditch location. The uppermost unit most closely resembles a debris flow deposit, whilst the lower is clearly fluvial. Cryoturbation features are visible to varying degrees throughout these units. These include heaves, clast clusters and ice cracks (Figure 36). There is considerable lateral and vertical variability in the composition of the major units at the pit. Channel features run through the deposits with sand/silt fills, as well as gravel showing imbrication. Many of the sand/silt deposits exhibited superb bedding structures and several sarsen stones have also been recovered from Hodge Ditch. Samples of organics were also taken (see *Environmental Assessment Document*) but clast analysis was not undertaken due to the complexity of the stratigraphy and size of the working. Lithologies were noted and were dominated by chert and flint. Judging by the orientation of the channel features and imbrication, the dominant palaeoflow direction was similar to that observed in the Axe Valley today, although the multiple channels indicate a braided stream environment so some variability in the flow directions is naturally apparent.

The gravels at Chard Junction extend to a maximum thickness of 15 m, which is an unusual amount for Pleistocene terraces in the British Isles. The series of OSL dates are of similar antiquity to the Kilmington and Broom dates. The first dates are on the junction between the upper debris flow deposits and then lower fluvial deposits, and are statistically within the same time range. They are 98,000 ± 8,000 BP and 94,000 ± 9,000 BP, dating the top of the fluvial unit to OIS 4. At the very base of the currently exposed deposits, a second date of 174000±18000 BP was achieved. A further date of 274000±74000 BP was obtained from the sample taken from the base of the silt pond section in the former workings. The examination of large lateral extents of gravel is particularly informative about the conditions under which the gravel accumulated and the post-depositional processes which then affected it. The excellent series of stratigraphically contiguous dates fall in line with those from Kilmington and Broom. It is now possible to resolve the relationship between these sites. As the deepest deposits exposed at Chard so far are yielding dates within OIS 6, it seems quite feasible that the remaining ~8 m of gravel known to exist at Chard Junction will be even older than the deposits observed already. Given the time ranges covered it is possible and indeed probable that interglacial deposits may be preserved and there is a possibility of further archaeological finds from this site.

Figure 36: Ice crack feature in bedded sands at Chard Junction. OSL sample location also indicated. © L Basell.

3.4.4 Broom (Appendix 8)

As a considerable amount of work has previously been conducted at Broom by other projects (e.g. Hosfield & Chambers, 2004: Ch. 3-4), no work was planned here during Phase 2 except to "test" the GPR. One GPR transect was run across the Railway Pit (T1; Figure 37). Examination of the GPR transects shows some interesting anomalies, but could not distinguish the base of gravels. The anomalies suggested that the GPR is picking up crude sedimentological variation within the gravels, but problems were encountered due to the high water and made ground. Given the depth of gravels now known from the Chard Junction borehole data (Bardon Aggregates pers. comm. to LSB), and the gravel thickness visible in the extant faces at Kilmington and Broom it is unsurprising that the base of gravels could not be detected. Workings at Broom Railway Pit were quite extensive, but only reached the base of the Middle Beds, so a considerable body of gravel (some of which lies below the water table) is likely to remain in this area.

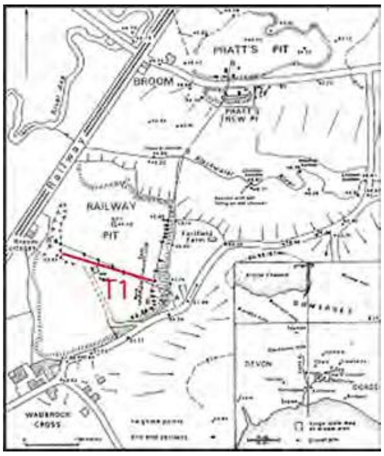

Figure 37: Location of GPR transect T1 conducted at Broom (T1 and T2). Background map from C Green & R Shakesby (unpublished).

3.5 Fieldwork Summary: Palaeoriver Washford

3.5.1 Doniford (Appendix 5: Section 14)

This site was mentioned as being of importance in the Phase 1 project design (Hosfield & Brown, 2005), as it is one of the most westerly sites in the UK where Palaeolithic finds have been retrieved from a stratified deposit. This SSSI site has yielded bifaces and mammoth remains (Figure 39). The site lies in Somerset (grid reference 308701 143172), extending the coverage of the Phase 2 fieldwork beyond Devon and Dorset. These finds came from river terrace deposits associated with the palaeo-river Washford. Discussions with Mr R. Wedlake (son of A.L. Wedlake, who discovered the artefacts) indicated that there has been considerable erosion at the site in recent years. The last work conducted on the sedimentology was in the 1960s (including some clast analysis), and the cliff is thought to have eroded at a rate of approximately 1m/year since then. Photographs at the museum showing gun mounts some distance inland from the cliff edge support this, as these now lie on the beach (Figure 38). The major units of a 150 metre section of the cliff were drawn and the OSL sample locations were recorded (*Appendix 5, Section 14*). Photographic logs were also taken. The height of the section above sea level was ascertained by a dumpy level traverse. Organics were found in some of the gravel units and were sampled (see *Environmental Assessment Document* in Appendix 9).

The deposits at this site are complex. Some units are very disturbed by cryoturbation and contain clasts that have been split in situ by freeze/thaw processes (congelifraction). Other units are bedded and not affected by cryoturbation. OSL samples were taken from five locations along the section. Five good OSL samples were taken and results received from PT of 51,000 ± 4,000 BP, 49,000 ± 5,000 BP, 45,000 ± 5,000 BP on the basal gravels, and 25,000 ± 3,000 BP higher up the sequence (see *Appendix 7*). The dates support the idea that the river deposits were reworked several times, and obviously date the latest reworking rather than the depositional event associated with the formation of the terrace deposits. It is highly likely that the Doniford artefacts were originally lying on a terrace level in the Washford Valley that may have corresponded to the present day Terrace 2 of the River Tone, from which similar artefacts have been found. Over several climatic cycles the terrace deposits (and the archaeology) have been eroded and eventually re-deposited by the periglacial palaeo-Washford in their current location.

Figure 38: Doniford cliff section with Phil Toms undertaking OSL sampling. © L Basell.

Figure39: Sample of Doniford Palaeolithic artefacts and Pleistocene faunal material on display in Watchet museum. © L Basell.

3.6 Organic Sampling

Many of the sites mentioned above were sampled for organics. All samples have been processed and pollen was poorly preserved in all cases (needs reference to data and at least a summary of the results). Where pollen grains could be identified, cold species were represented, but in no case was the quantity statistically significant, or enough to warrant further comment. See *Environmental Assessment Document* (Appendix 9) for full details.

3.7 Future Fieldwork Recommendations

The fieldwork phase of the project highlighted six locations which, although inaccessible over the duration of the project, would be potential sampling locations for future research investigating the Pleistocene terraces of the Exe and Otter:

- Terrace 5 near Broadclyst (River Exe).
- Terrace 5 at Hayne Barton (River Exe) and near Newton St Cyres (River Exe).
- Terrace 4 Hayes Farm Quarry (River Exe, grid reference 299300 094400). The importance of this quarry, where terrace 4 sand and gravel deposits have been recently removed, was discussed in the Phase 1 report (Hosfield *et al*. 2005: 54). The altitudinal separation of terrace 4 from the lower terraces and the terrace landform morphology suggest it is associated with a major event (also discussed in the Phase 1 report (Hosfield *et al*. 2005: 27)). The site is currently dormant, but the possibility of future extraction remains, provided the correct permissions are obtained.
- Terrace 2 south of Monkey Lane, in the river cliff section by the River Otter.
- Blackhill Quarry (Rivers Exe and Otter). The geodiversity audit recorded gravels here, high on the interfluve between the Otter and the Exe, though they were not mapped by BGS. Suitable deposits are present in the river gravels, overlying the Budleigh Salterton Pebble Beds.
- Honiton Hippo Site (River Otter).

3.8 Collections Analysis

Following a recent article in PAST (the Newsletter of the Prehistoric Society) LSB visited BGS Keyworth to examine several small collections of artefacts, which were collected by geologists in the south-west region. These were examined along with the collectors' notebooks, and photographs and notes were taken. In addition, C. Norman invited LSB to examine and discuss some of the Palaeolithic finds from Somerset and to examine the river terraces in the Taunton region following communication with S. Minnett. Many of the lithics were quite fresh suggesting they have not moved significant distances or been exposed for long periods since deposition. Both assemblages consisted of bifaces, but also included cores, flakes and occasional retouched pieces. On the basis of this, LSB then returned with TB to visit the sites at Cotlake Hill and Norton Fitzwarren with Mr Norman: the artefacts from Norton are clearly associated with Terrace 2 of the River Tone.

3.9 GIS & Digital Survey Data

During phase two the GIS model and database developed during phase one of the project for Devon was updated and refined. The IFSAR data and orthorectified aerial photographic data, like the geomorphological mapping, clearly shows the considerable complexity in the terraces previously mapped as undifferentiated and terrace 1 in the Axe Valley (Figure 40).

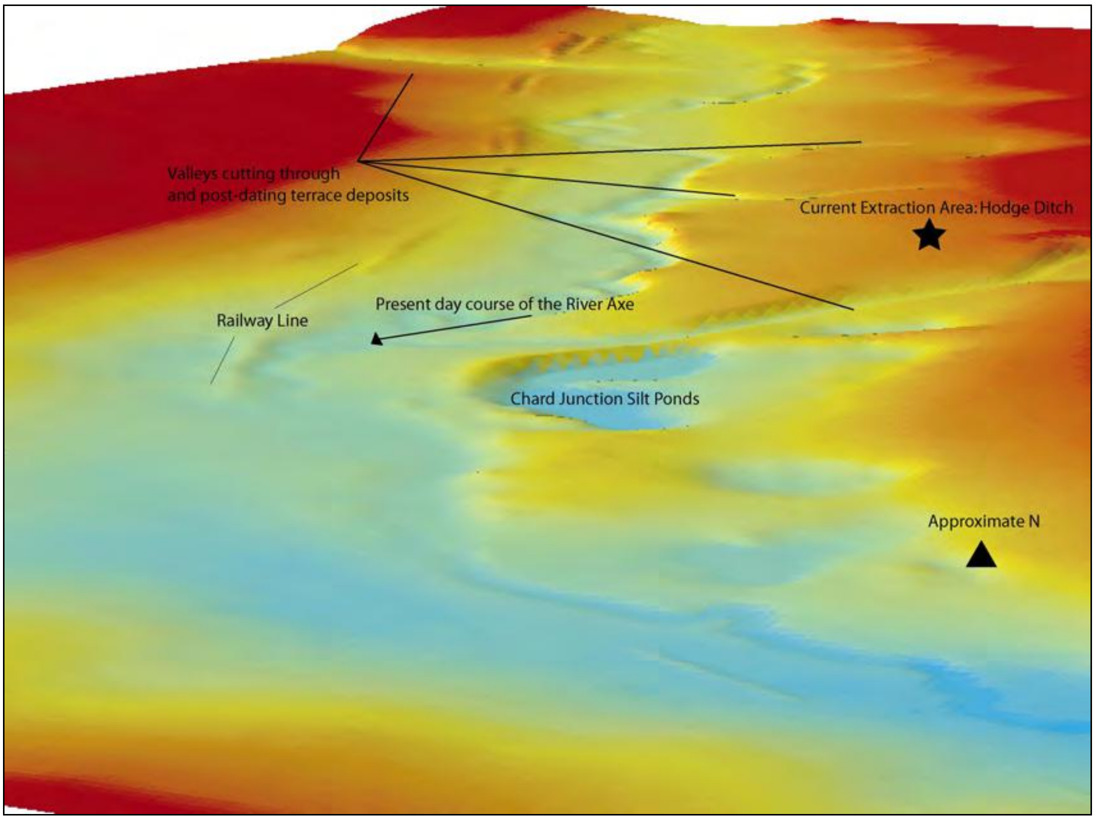

Figure 40: Example of view generated in Arc Scene using shading but no vertical exaggeration to highlight topography and geomorphology in the Axe Valley around Chard Junction by LSB.

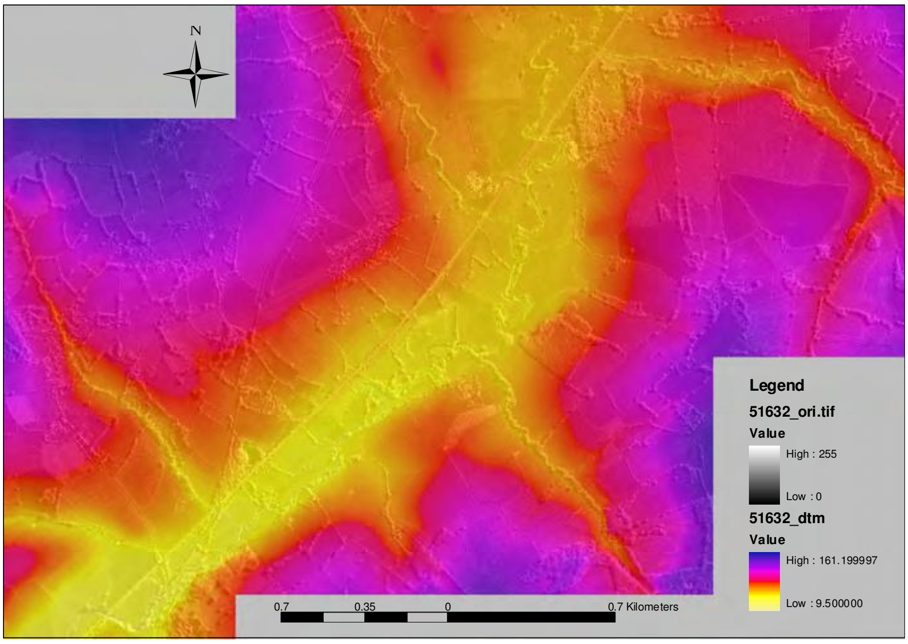

Figure 41: Drape of orthorectified aerial imagery view over digital terrain model generated in ArcGIS by LSB.

3.10 Fieldwork Conclusions

The fieldwork and dating programmes have been successful and extensive, and have provided an expanded chronological framework for the hominin occupation of south-west England. The project fieldwork has enhanced the county HERs through the provision of new data. Analysis of the fieldwork data has enabled the refinement of these models and outputs, ultimately providing an interpretation of palaeolandscape evolution in the south west region over the last ~500 000 years (see Section 5 and forthcoming papers by Basell *et al*. and Brown *et al*.).

Edwards (Edwards & Scrivener, 1999: 135) wrote of the terraces associated with the Exe: *"There is no good evidence for dating the terraces"*. Other than the two unpublished dates on terrace 3 of the Exe and the dates from Broom, no chronometric dates were previously available for any terrace systems in the south west region. The dates reported here (above and see *Appendix 7*) provide the basis for a chronological framework for the river terrace sequences of the south-west and their associated archaeological artefacts. These show terrace deposition from as early as OIS 9 and demonstrate reworking of deposits during OIS 3. This suggests that significant revision of previous relative chronologies is required.

All these dates have implications for the archaeology and hominin occupation of the south west. For example, the dates from Kilmington and Chard Junction support the previous evidence from Broom in suggesting a hominin presence in the area by at least 300,000 BP, although such a presence is somewhat younger than the earliest occupation suggested by the new dates from Kent's Cavern (Proctor *et al*. 2005). The finds from Doniford have finally been contextualised and show that episodes of reworking may have been very important in the accumulation of Palaeolithic archaeological material in the south-west. The types of processes suggested by the sedimentology at all sites dated to OIS 3, shows that these reworking episodes could technically mix older archaeological material with more recent artefacts. At Doniford there was no evidence for this. Rather, the reworking and deposition occurred episodically, forming a series of deposits with stratigraphic integrity, where the oldest deposits occur at the base and the youngest at the top. The number of dates indicating OIS 3 cryoturbation/disturbance/reworking also demonstrates how dynamic palaeolandscape evolution has continued to be, including the Late Pleistocene periods associated with the Upper Palaeolithic and *Homo sapiens*. Resolving the differences between supposedly cold stage gravels at Chard and the other Axe sites was a key project goal, and the excellent dates from Chard and Kilmington have indicated a clear association between parts of the sequences at all three major exposures (Broom, Kilmington, and Chard Junction).

The fieldwork has reinforced the point made during project phase one that there is significant inter-valley variation. A much better understanding of the causes of this variation has been gained showing that one of the principal causal factors is geological/geomorphological processes. Importantly this work demonstrates that while the Rivers Exe and Otter are clear staircase strath terrace systems, the Axe is a fill terrace system. The gravels here are made up of different units as recorded in the sedimentological logging, and both the geomorphological mapping and the modelling show there are altitudinal differences, and features within units mapped as a single terrace. This demonstrates that their evolution is multiphase (i.e. that they are compound terraces). The difference between these fill terraces and the Exe and Otter where staircases are forming must be related to an abundant local supply of clasts from the weathered Cretaceous and Tertiary material from the Blackdowns; but a lack of main channel discharge capable of removing this material and incising. That is until the downcutting that occurred when last glacial sea level was reached.

Collectively then the methods of analyses employed during the fieldwork have supported analysis of terrace formation, thereby contextualising the archaeological material with which they are associated. This formation of the gravels has affected the spatial and temporal patterning of the intra-gravel archaeological record. A key implication of these preliminary findings is therefore that the inter-valley geological variation must be better understood in order to allow any archaeological evaluation of the Palaeolithic record. Clast and sedimentological analyses in the Otter and Exe valleys in combination with the dates also suggest factors such as lateral erosion of the valley floor and reworking of terraces to be important. This supplements Bridgland's model of terrace formation.

Conducting the fieldwork has emphasised how significantly different the landscapes of the south-west region must have been during the Palaeolithic/Pleistocene. Take for example Figure 41 which is a map of superficial deposits against a basic OS map of the Nether Exe Basin. The main river channels today are shown in blue, and the alluvial deposits in yellow, probably representing deposition from late Stage 2 onwards. The red areas represent paired terrace 7, lying on the 50 m contour line. If one assumes that all areas below terrace height today were at or below floodplain height at the time of terrace deposition and there has not been significant neotectonic movement in the area, then it is possible to fill in the areas that would have been the previous floodplain (the green area in Figure 42). This shows where was far less topographic relief in the past as represented by the green fill. These would have been wide stretches of braided rivers, which certainly supported different faunas. In combination with the dates, it seems the majority of these changes have occurred over approximately the last 500000 years, which in geological terms rapid. Even though the pollen data from the samples collected were not well preserved, the fieldwork results already indicate that the landscapes in the south west over the last 500000 years have been altered dramatically. Analysis of the fieldwork data will allow us to assess at what times the area would have been amenable to hominin occupation.

Figure 42: Superficial deposits in the Nether Exe Basin, overlying OS mapping

Figure 43: Theoretical modelling of terrace 7 floodplain extents in the Nether Exe Basin

4. OUTREACH & DISSEMINATION

4.1 Introduction

One of the key goals of the project was to engage the public of the south-west region with the subjects of Palaeolithic archaeology and Pleistocene (fluvial) geology, and to communicate the results of the project research. It was also an important element of the project to establish resources which could potentially support interest in those topics beyond the life-span of the project. This was achieved through a series of activities and resources, discussed below.

4.2 School Activity Days

School activity sessions were organised to introduce school pupils to British Palaeolithic archaeology and Pleistocene geology, with particular reference to the resources of the south-west. The session activities were targeted towards the national curriculum (Table 7) after discussions with the History advisors for Devon, Cornwall, and Somerset.

The school activity days were advertised through the Somerset Information Exchange (web resource) and the website of the Specialist Schools Trust (which advises schools on curriculum development):

http://www.schoolsnetwork.org.uk/Article.aspa?PageId=235705&NodeId=223

Specialist School Advisors in the south-west region provided guidance with regards to specific schools appropriate for targeting. The Historical Association included an announcement of the school activity days in their February e-news to primary and secondary teachers, and the CBA circulated a preliminary announcement to their school and education contacts.

Two activity sessions for school groups were run at Doniford Cliffs, north Somerset on the 2nd May 2006 (Figure 44). 26 seven–nine year olds from Cleve School, Washford attended the morning session and 27 ten–eleven year olds from Robert Blake School, Bridgwater, attended the afternoon session. Activities included:

- A general introductory session, covering archaeology and geology (‘what are they?’), the Palaeolithic (‘what and when is it?’), and general site health and safety (**Introduction** in Table 7).
- A ‘walk through time’/timeline exercise to illustrate Palaeolithic chronology, dates for key events (e.g. the first art), and the cyclical nature of Pleistocene climate change (**Timeline** in Table 7).
- Animals and plants of the ice ages, which introduced different species of Pleistocene flora and fauna, highlighted the relationship between specific plant/animal species and specific climatic/habitat conditions, and the role that particular animal species can play as chronological markers (**Animals of the Ice Ages & Interglacials** in Table 7).
- Palaeolithic artefact handling (Figure 44), using replica artefacts (in both resin and flint) to discuss aspects of Palaeolithic stone tool technology, including flint knapping, tool functions, and typology (**Tools Handling** in Table 7).

- Ice Age (Pleistocene) landscapes, which introduced different types of deposits (principally fluvial gravels and sands) and sedimentary processes (principally rivers) with reference to the Doniford cliff section, and included a cliff section drawing component (**Sediment Analysis** in Table 7).
- Demonstration of fluvial processes using a simple flume, which introduced concepts of entrainment, transportation and deposition, and was related to the fluvial sedimentary sequences evident in the lower part of the cliff at Doniford (**Sediment Analysis** in Table 7).
- A general summary session, reviewing the activities and the topics and issues covered, and including a short oral quiz (**Round-up** and **Quiz** in Table 7).

All students were given a brief guide to the 'Ice Ages' (copy in Appendix 10.1) and the teaching staff were provided in advance with an information pack containing key references and links to the National Curriculum (copy in Appendix 10.2). Selected resources used during the activity sessions (including the resin replica artefacts) were adapted during the remainder of the project to produce self-contained teaching resource boxes (see Section 4.8 below).

Saltash School were originally scheduled for an activity session on Wednesday 3rd May 2006 but cancelled due to staffing issues. Feedback from teachers and students was good, particularly from the morning session on Tuesday 2nd May. The teacher's questionnaire response for the morning session (copy in Appendix 10.3) noted particularly that students were kept moving between activities, that the artefact handling opportunities were appreciated, and that the level of content and interaction was "about right". The sessions have been featured in the Somerset press and in editions of both schools' newsletters.

Figure 44: School Activity Day, Doniford Beach, May 2nd 2006. Photograph © D. Perry.

The level of take-up of the activity days was slightly disappointing but appeared to reflect issues of travel distances, staffing issues, lack of direct relevance to the National Curriculum (no prehistory is taught in the National Curriculum, although links to History/Geography were stressed in the teachers' information packs: see

Subject	Topic	Teaching/Learning Goals & Outcomes	Activities meeting Learning Outcomes
History	Chronological understanding	Pupils should be taught to: • Place events, people and changes into correct periods of time. • Use dates and vocabulary relating to the passing of time, including ancient, modern, BC, AD, century and decade.	Introduction Timeline Round-up
	Knowledge and understanding of events, people and changes in the past	Pupils should be taught: • To identify and describe reasons for, and results of, historical events, situations, and changes in the periods studied.	Introduction Sediment Analysis Animals of the Ice Ages & Interglacials Round-up
	Historical interpretation	Pupils should be taught to recognise that the past is represented and interpreted in different ways, and to give reasons for this.	Sediment Analysis Tools Handling Animals of the Ice Ages & Interglacials Round-up
	Historical enquiry	Pupils should be taught: • How to find out about the events, people and changes studied from an appropriate range of sources of information, including ICT-based sources [for example, documents, printed sources, CD-ROMS, databases, pictures and photographs, music, artefacts, historic buildings and visits to museums, galleries and sites]. • To ask and answer questions, and to select and record information relevant to the focus of the enquiry.	All Sessions All Sessions Quiz
	Local history study (for local schools)	A study investigating how an aspect in the local area has changed over a long period of time, or how the locality was affected by a significant national or local event or development or by the work of a significant individual.	All Sessions, particularly Introduction
Geography	Geographical enquiry and skills	In undertaking geographical enquiry, pupils should be taught to: • Ask geographical questions [for example, 'What is this landscape like?', 'What do I think about it?']. • Collect and record evidence [for example, by carrying out a survey of shop functions and showing them on a graph]. • Analyse evidence and draw conclusions [for example, by	Introduction Sediment Analysis Round-up Quiz

		comparing population data for two localities].	
		In developing geographical skills, pupils should be taught: • To use appropriate fieldwork techniques [for example, labelled field sketches] and instruments [for example, a rain gauge, a camera]. • To use secondary sources of information, including aerial photographs [for example, stories, information texts, the internet, satellite images, photographs, videos].	Sediment Analysis Introduction
		Pupils should be taught: • To identify how and why places change [for example, through the closure of shops or building of new houses, through conservation projects] and how they may change in the future [for example, through an increase in traffic or an influx of tourists].	Round-up
	Knowledge and understanding of patterns and processes	Pupils should be taught to: • Recognise and explain patterns made by individual physical and human features in the environment [for example, where frost forms in the playground, the distribution of hotels along a seafront]. • Recognise some physical and human processes [for example, river erosion, a factory closure] and explain how these can cause changes in places and environments.	Sediment Analysis
	Themes	In their study of localities and themes, pupils should: • Carry out fieldwork investigations outside the classroom.	All Sessions
Citizenship	Developing good relationships and respecting the differences between people	Pupils should be taught: • To think about the lives of people living in other places and times, and people with different values and customs.	All Sessions, particularly Tools Handling
		During the key stage, pupils should be taught the knowledge, skills and understanding through opportunities to: • Meet and talk with people [for example, people who contribute to society through environmental pressure groups or international	Children will have the opportunity to ask archaeologists and palaeogeographers

			aid organisations; people who work in the school and the neighbourhood, such as religious leaders, community police officers].	questions throughout the day.

Table 7: Links to curriculum for Key Stage 2

Appendix 10.2 and Table 7), and timing (the planned dates, which reflected the availability of project staff) were close to school examinations periods). Six schools expressed interest in a follow-up visit from project staff (although these were cancelled due to the absence of a project phase three): Strode College, Somerset; Saltash Community School, Cornwall; Bideford School, Devon; Richard Huish School, Taunton, Somerset; Blue School, Wells, Somerset; and Looe School, Cornwall. Egbbuckland Community College, Cornwall expressed interest in receiving teaching resources. All these schools were contacted with details of the digital teaching resources available through the project website (see Sections 4.8 and 4.9 below).

The event was run in partnership with NIAN and a NIAN Project Officer (Alastair Brown, University of Southampton) was one member of the activity session staff (along with Hosfield, Young and Bennett from the Palaeolithic Rivers of South-West Britain project). NIAN staff (A Brown, Dr J Chambers, and Dr B Silva) also assisted in the preparation of resource materials for the sessions.

The school activity sessions replaced the planned school participation in fieldwork events (Hosfield *et al*. 2005: Section 5.2.1.3). This change reflected logistical difficulties in scheduling the project fieldwork and the need for early notification of the schools with regards to event dates and/or locations.

4.3 Geoarchaeology Walks

Guided geoarchaeology walks introducing the Palaeolithic archaeology and fluvial geomorphology of the Otter and Exe river valleys were run over the weekends of the 6th/7th May 2006 and the 13th/14th May 2006 respectively. 42 individuals participated in the Otter valley walks (35 adults and seven children), while the Exe valley walks attracted 34 (28 adults and six children). Participants came from:

- Devon Archaeological Society
- North Devon Archaeological Society
- Geologist's Association (West England group)
- Devon Association (East Devon branch)
- Sidmouth College (mature A-level archaeology students)
- Caradon Adult Education College
- Devon Young Archaeologists
- Dillington House (Somerset County Council's residential centre for professional development)
- Brampford Speke residents (Exe valley)
- English Heritage
- Environment Agency

Two hour guided walks (Figure 45) were followed by (for the Otter valley walks) or preceded by (for the Exe valley walks) an opportunity to handle original and replica stone artefacts, to view a small poster display presenting various aspects of Palaeolithic archaeology, Pleistocene climate and environments, and examples of English Heritage (ALSF)-funded Palaeolithic projects (the *National Ice Age Network*, the *Palaeolithic Archaeology of the Sussex/Hampshire Coastal Corridor* project, and the *Medway Valley Palaeolithic Project*), and to discuss Palaeolithic archaeology/Pleistocene geology issues with project members and NIAN staff officers. All participants were provided with an information pack and field guide (copies in Appendices 10.4 and 10.5) listing the points of interest on the walk, summarising basic background information, and defining key terms. A flint knapping display (by Alastair Brown and Dr McNabb) took place after each walk, including a discussion of the diagnostic features of worked stone artefacts and artefact handling opportunities.

Figure 45: Palaeolithic Geoarchaeology Walk at Ottery St Mary (May 2006)

21 archaeological/heritage and geological/natural history/geographical societies in Dorset, Somerset, Devon, and Cornwall were contacted to advertise the walks. All schools and colleges teaching ‘A’ level archaeology in Cornwall, Devon and Somerset, and the Workers Educational Association (WEA) were contacted regarding the walks, but take-up from the schools and colleges was very low. Informal feedback indicated that the walks coincided too closely with the start of the examination period (the dates were selected due to staff availability) and that both staff and students were reluctant to attend events on a Saturday (Saturdays were however originally selected on the basis of earlier informal feedback that students couldn’t be taken out of school at this time). There was however significant post-walk interest in follow-up visits to archaeological, heritage and geological societies by project staff, principally from participating societies, resulting in a talk to the Bristol Naturalists Society (Geology Section) in January 2007.

Questionnaire responses and written feedback have been very positive (examples in Appendices 10.6 and 10.7), unanimously indicating that the duration, archaeological content, field guide, and Palaeolithic information displays were directed at an appropriate level. The majority of respondents said they now had a much better understanding of the Palaeolithic period and its archaeology. Particularly positive comments were made about the walk leader's (Dr Hosfield) commentary and ability to judge the knowledge level of the group.

The field guides were adapted and made available as digital resources through the project website (see also Section 4.9).

These events were run in conjunction with NIAN and a NIAN Project Officer (Alastair Brown, University of Southampton) took part in all events, while Dr John McNabb (University of Southampton & NIAN) provided flint knapping demonstrations on the weekend of the 13th/14th May.

The walks replaced the planned open access fieldwork events (Hosfield *et al*. 2005: Section 5.2.1.3). This change also reflected logistical difficulties in scheduling the project fieldwork and the need for early notification of the potential participants with regards to event dates and/or locations.

4.4 Lithic Artefact Identification Days

Three lithic artefact identification days were organised and held in Cornwall (Truro) and Devon (Exeter and Plymouth) on the 1st July 2006, 8th July 2006, and 17th February 2007 respectively. The days included knapping demonstrations (by Dr Jenni Chambers at Truro and Plymouth, and Mr Michael Miller (Figure 46) at Exeter), artefact handling and identification sessions (Figure 47), and general presentations. The events were advertised and promoted by email to Finds Liaison Officers (FLOs) from the Portable Antiquities Scheme, commercial archaeological units, HER staff, county archaeologists, and museum staff (and other curatorial archaeologists) from the south-west region, as well as to contacts established through other events. The response from Finds Liaison Officers in particular was encouraging. A promotional leaflet was produced (Appendix 10.8) and sent to contacts from other events, regional and local museums, key tourist information centres, National Park offices, libraries, colleges teaching archaeology, and regional aggregates industry contacts, alongside all those groups (e.g. the FLOs) discussed above. The numbers of attendees at the three events were 12 (Truro), 39 (Exeter), and 42 (Plymouth).

These events were organised in conjunction with NIAN (promotion, contacts and staffing), the Royal Albert Memorial Museum and Art Gallery, Exeter and Plymouth City Museum (who loaned samples of their artefact collections for the events), Cornwall Archaeological Society and the Plymouth and District Archaeological Society (promotion) and the Royal Cornwall Museum and Plymouth City Museum (use of their premises).

A previously undocumented Palaeolithic handaxe (from Budleigh Salterton) was identified and recorded through the Exeter artefact identification day. Other artefacts, which were non-Palaeolithic (typically Mesolithic or Neolithic), brought to the attention of the project through the lithic identification days were evaluated on the day, and the owners were strongly encouraged to take them for full recording through the Portable Antiquities Scheme's Finds Liaison Officers so they would be entered in the relevant HERs.

Figure 46: Knapping demonstration by Michael Miller at the Exeter Lithic Artefact Identification Day (July 2006)

Figure 47: Artefact handling at the lithic artefact identification day at the Royal Cornwall Museum, Truro (July 2006)

4.5 Ice Age Devon Exhibition

The Royal Albert Memorial Museum and Art Gallery, Exeter (RAMM) offered the project an opportunity to mount a two month display during July and August 2006 in their Giraffe Gallery. Although this was not originally scheduled in the phase two UPD (Hosfield *et al*. 2005: Section 5.2.1.3) it was felt that this was an excellent opportunity to develop one of the project's stated goals of outreach and public education concerning the Palaeolithic archaeology of the south-west region.

The display (*Ice Age Devon*) was prepared in consultation with RAMM staff, and in collaboration with NIAN. Display cases included artefacts and faunal material from the Lower Palaeolithic sites of Broom and Kent's Cavern. Ten display boards were produced on a series of core Palaeolithic archaeology and Pleistocene geology/climate/habitat topics (Figure 48):

Figure 48: 'Ice Age Devon' exhibition at the Royal Albert Memorial Museum & Art Gallery, Exeter (July & August 2006)

- What was life like during the Ice Ages in Britain?
- A timeline of the Ice Ages
- Ice Age tools: Introduction
- Ice Age tools: Making and using tools
- The climate of the Ice Ages
- Animals and plants of the Ice Ages
- Humans of the British Ice Ages
- Important questions about Ice Age humans in Britain
- Ice Age archaeology in the south-west
- The Palaeolithic Rivers of South-West Britain project, the National Ice Age Network, and the Aggregates Levy Sustainability Fund

Digital copies of these exhibition boards are included on the enclosed *Outreach* CD.

Oliver Blackmore (RAMM) communicated that the museum was visited by 40,015 visitors during July and August 2006, when the exhibition was on display in one of the key museum galleries (from 8^{th} July to 26^{th} August). The exhibition was also accompanied by copies of the National Ice Age Network's lithic and faunal remains identification sheets and copies of the Palaeolithic Geoarchaeology walk field guides for the Exe and the Otter.

4.6 Mobile Exhibition

A digested version of the RAMM exhibition (Section 4.5 above) was produced and two copies were exhibited in Devon and Cornwall through the Devon and Cornwall Library Services respectively. Each copy of the display (*The British Palaeolithic*) consisted of three A0-size posters (digital copies enclosed on the *Outreach* CD) and presented the following aspects of Palaeolithic archaeology and Pleistocene archaeology, with particular reference to the resources of the south-west region:

- What is the Palaeolithic (including an introduction to the Palaeolithic, hominin species, and stone tools).
- Life in the Ice Ages (including ice age climate, plants and animals, and diet and using tools).
- The Palaeolithic of the South-West (including questions and evidence, Palaeolithic sites in the south-west, and the Palaeolithic Rivers of South-West Britain project).

The poster exhibition was accompanied by copies of the National Ice Age Network's lithic artefact identification leaflet. Distribution of the exhibition around the libraries of Devon and Cornwall was controlled by the respective Library Services.

4.7 Booklets & Flyers

Summaries of the project research and results were publicised through the production of a project flyer and project booklet (digital copies are included on the enclosed *Outreach* CD and hard copies in Appendix 10.9). Both the flyer and booklet were intended for a general audience, and were targeted at attendees of the Palaeolithic Geoarchaeology walks (Section 4.3 above), lithic artefact identification days (Section 4.4 above), and the project seminars/workshops (Section 4.10 below), at regional archaeological and geological societies, and at schools/colleges who attended/ expressed interest in the school events.

The flyer provided a brief overview of the project and the Lower and Middle Palaeolithic periods, and a map of the south-west region highlighting key rivers systems and Lower and Middle Palaeolithic archaeology. The booklet provided an introduction to river terraces and Palaeolithic archaeology, a summary of the goals of the project and the fieldwork methods utilised, and a review of the key fieldwork results and their implications for current understanding.

To date 253 copies have been distributed by mailing list, and further copies have been distributed through public events such as the lithic artefact identification day at Plymouth (Section 4.4 above), and distribution will continue beyond the completion of the project through the digital copies of the flyer and booklet available on the project website (see also Section 4.9 below).

4.8 Teaching Resource Boxes

The Teaching Resource Boxes were compiled during phase two of the project. One of the key goals of the resource boxes was to provide a maintainable resource which could promote interest in the Palaeolithic archaeology and Pleistocene geology of the south-west region beyond the completion of the project.

The teaching resources boxes consisted of:

- 13 replica Palaeolithic stone tools. These resin reproductions were cast from genuine archaeological artefacts (background details were given on the artefact bags and on an enclosed contents list), and were produced by GeoEd. Limited.
- Examples of flint and chert (two commonly used raw materials for the production of stone tools in Britain during the Palaeolithic), accompanied by appropriate health and safety advice for handling these materials.
- 12 resource cards. These were divided into six topics (Palaeolithic stone tools; Palaeolithic hominins; Palaeolithic chronology; Pleistocene climate, flora and fauna; Pleistocene landscapes; and Palaeolithic lifestyles and behaviour), with a 'Basic' and 'Advanced' card for each topic. The cards were written so that the 'Advanced' cards expand upon the issues and themes introduced in the 'Basic' cards. Each card included a range of information, key terminology (including definitions of scientific terms, and short descriptions of key archaeological sites), three short quiz questions (an 'answers' card was also enclosed), further website resources, and related images and/or tables as appropriate (all images were copyrighted to Dr R Hosfield (University of Reading), and/or Dr J Chambers (NIAN, Birmingham University): a wider range of images were also available through the listed website resources).

There was no pre-defined method for using the cards: teachers and/or students can use as much or as little of the material from as few or as many of the cards as they choose, although it was recommended that users at least review the 'Basic' card before moving onto the 'Advanced'. There is also no set order for using the cards, although the order given above is recommended as one possible approach. The cards were not written with a specific audience in mind (in order to not limit their potential appeal): it was hoped that the materials, used partially or in their entirety, can be tailored by teachers for students ranging from grade 7 to adult learners.

It was also not the intention of the resource boxes to provide comprehensive information about the British Palaeolithic. Those seeking further details and information were directed to a list of recommended books and the website links (on the individual resource cards).

To encourage long-term potential use of the resources and their sustainability Dr Hosfield was listed as a point of contact for future queries regarding the resource box, its contents, or its use.

Three hard copies of the resources boxes (including the replica Palaeolithic artefacts) were distributed to Dartmoor National Park Authority, Cornwall Library and

Information Service, and Royal Albert Memorial Museum and Art Gallery (Exeter) (due to cost implications additional hard copies of the resource boxes were not produced), and encouraging feedback has been received (included in Appendix x.10). Digital copies of the teaching box resources are available through the project website, and these resources were highlighted to those schools/colleges were attended/expressed interest in the school events (Section 4.2 above). The teaching resource boxes were also publicised to teachers through the Devon Curriculum Services via David Weatherly. Digital copies of the resource cards are included on the enclosed *Outreach* CD and hard copies are included in Appendix x.10.

4.9 Project Website

The project website was utilised to distribute digital copies of the project's outreach resources were appropriate. These included:

- Copies of the project booklet and flyers (see Section 4.7 above).
- Copies of the teaching resource box resource cards (see Section 4.8 above).
- Copies of the Palaeolithic Geoarchaeology walk field guides (see Section 4.3 above). These were accompanied by notes regarding issues of access and use where appropriate.
- Copies of the project poster (summarising key Lower and Middle Palaeolithic archaeology in the south-west region: a copy is also included on the enclosed *Outreach* CD).

The project website will continue to be maintained on the University of Reading website by Dr Rob Hosfield beyond the completion of the project.

4.10 Project Workshops & Seminars

The two project seminars/workshops were central to the dissemination of the project goals and results, and the promotion/development of informal Palaeolithic archaeology/Pleistocene geology networks and contacts in the south-west region.

The Regional Palaeolithic Networks meeting was held at Exeter University on 16th June 2005. The meeting consisted of morning presentations (by project and NIAN staff, Chris Webster (SWARF), and Victoria Bryant (Worcestershire HER): a copy of the meeting programme is included in Appendix 10.11) and round table discussion sessions in the afternoon, focusing on a series of topics including Pleistocene fluvial landscapes, Palaeolithic networks, and Quaternary data & the HERs. There were 35 attendees, including academics, HER officers, county archaeologists, non-professional archaeologists, archaeological and geological society members, English Heritage staff, BGS staff, and curatorial staff.

The Regional Palaeolithic Geoarchaeology workshop was held at Exeter University on Thursday 13th July 2006. The workshop consisted of morning presentations (by project and NIAN staff: a copy of the workshop programme is included in Appendix 10.11) and discussion workshops in the afternoon, focusing on a range of topics including the relationships between Palaeolithic archaeology/Pleistocene geology and the aggregates resource/industry, strategies for promoting and sustaining the long-term reporting of Palaeolithic artefacts and/or Pleistocene geological exposures/sections within the south-west region, and a demonstration of the GIS models and database resources developed by the project to date. There were 52 attendees, including academics, HER officers, county archaeologists, Mineral Planning Officers, archaeological and geological society members, English Heritage staff, curatorial staff, and representatives from the aggregates industry.

4.11 Project Literature

A series of short notes and letters were published during the course of the project to disseminate the goals and aims of the project to a general archaeological readership (digital copies are enclosed on the included *Outreach* CD):

- A short research note to *PAST: The Newsletter of the Prehistoric Society* (Hosfield *et al*. 2005)
- An article to the Devon Archaeological Society (DAS) newsletter, focusing primarily on the Budleigh Salterton biface, but also discussing wider implications of the project
- An article to the Cornwall Archaeological Society (CAS) newsletter.
- An article to the Dartmoor National Parks Community News quarterly.
- A short note to the Historical Association newsletter (also available on-line at http://www.history.org.uk/news.asp)

A PDF copy of the phase one paper published in the Ussher Society journal *Geosciences in South-West England* (Hosfield *et al*. 2006) is also included on the enclosed *Outreach* CD.

4.12 Project Talks

During the course of the project, dissemination and outreach was also promoted through a series of project presentations and talks:

- The English Heritage (ALSF) *Current Work on the Palaeolithic and Pleistocene* seminar at Peterborough (22nd March 2006).
- The CBA *Archaeology and Geography* seminar (9th March 2006).
- The Ussher Society's *Geoscience in the South West* conference (January 2006).
- The *Geoarchaeology* conference (Exeter University, September 2006).
- Devon Archaeological Society's *Archaeology in Devon* day conference (24th June 2006).
- The CBA (South-West) symposium "*Global Cooling": The Ice Ages in SW Britain* (4th November 2006).
- Bristol Naturalists Society (Geology Section) in January 2007.

Project staff also attended the following meetings:

- The English Heritage *Outreach Work in Progress* seminar (Rachel Young).

4.13 Conclusions

The project has included a variety of outreach components, all of which have promoted the Palaeolithic archaeology and the Pleistocene fluvial geology of the south-west region. It is hoped that these events and resources will result in a sustained post-project interest in these topics, in particular through those resources available via the project website, and as a result of the project booklet and flyer, and the mobile exhibition.

5. PROJECT IMPLICATIONS

This section summarises the key project implications. In light of the completion of the project after phase two, only preliminary (pre-publication) implications are presented here. For full details see the forthcoming published papers by Brown *et al*. and Basell *et al*.

5.1 Project Results Summary

This project presents for the first time a partial chronology for river terrace formation in South-West England. The oldest dates have come from the River Axe (Kilmington, Broom, and Chard Junction) where fill-style gravels underlying the major valley terrace have given ages suggesting deposition during marine isotope stage (MIS) 10/9, and continuing to accumulate through MIS-8 and MIS-6. This is a remarkable sequence and has implications for both Palaeolithic archaeology in southern England and managing the archaeological resource of both disused and working quarries. These implications include an enhanced understanding of which aggregate units or terraces are most likely to contain archaeological resources and so may warrant curatorial and management interest under PPG-16. A second implication is the provision of new data to support strategic research planning, as currently occurring through the South West Regional Research Framework (SWARF).

The project has also provided the first framework for a chronology of the strath-style terrace staircases seen in the Exe and Otter Valleys, and by extension and correlation for other terrace staircases in south-west England. The dates on the first altitudinally separated terrace on the Exe (BGS No. 4) suggest an MIS-4 age which is in line with dates from the lower inset terraces of MIS-3 & 2 and confirm that the mid and upper terraces (characterised by cold-stage gravels) predate MIS-5. A similar sequence has also been demonstrated for the River Otter, including MIS-4 dates for the lowest altitudinal terrace (BGS No. 2) and, crucially, an MIS-6 date on BGS terrace No. 7. In general, attempts to date the upper terraces have been less successful than those for the lower terraces and it is not fully understood why at this time. However, several dates do suggest periods of intense reworking of these upper terrace gravels in MIS-4 and 3.

Work on the terrace deposits exposed in the cliffs at Doniford (north Somerset) has also provided a remarkably consistent stratigraphy spanning from the late Middle Devensian (MIS-3) up to shortly prior to the Last Glacial Maximum (*c*. 25 kyr BP), and then recommencing in the Late Devensian/Early Holocene. This work is important in showing how both reworked Middle Palaeolithic elements such as lithics and faunal remains from substantially different time periods can be combined in aggregate bodies.

The chronological studies and associated sedimentological analyses have important archaeological implications. Firstly the contrasting models of terrace formation and modification between strath/staircase terraces and fill-style terraces offer different and complimentary degrees of archaeological potential. Secondly there is scope for future research: (i) testing fluvial terrace archaeology chronologies against the cave chronologies of the south-west region; (ii) recognising and evaluating the role of terrace reworking; and (iii) mapping and interpreting the extant archaeological records against an enhanced palaeoenvironmental context framework. The results of the fieldwork, in particular the ages from the OSL samples, also suggest that the palaeogeography of the south-west region may have undergone a major transformation during the late Middle Pleistocene (*c*. MIS-6). This has clear implications for the apparent paucity of Lower and Middle Palaeolithic artefact finds from the remnant terrace deposits to the west of the Axe valley.

The positive response to the project outreach has also highlighted the existence of public interest within the region, and the potential for promoting sustained interest, recognition, and reporting of Palaeolithic finds and/or Pleistocene fluvial deposits beyond the timescales of the project.

Overall, the geomorphological and chronological findings of the project are critical to a contextual understanding of the Lower and Middle Palaeolithic archaeological evidence from the region, and combined with the resource assessment data from phase one of the project provide the basis for a new synthesis of the Pleistocene hominin occupation of the south-west Britain region. The fieldwork has also indicated key deposits and locations, and this information is being disseminated to the HERs and ADS for consideration in the future planning and mitigation of aggregates extraction.

5.2 A Terrace Model

The results of the project, combined with earlier research in the region, are supporting a new interpretation of fluvial activity and terrace formation. Please note that the material discussed below will be published fully in Brown *et al.* (in prep) and represents a preliminary interpretation.

Most of the models of terrace formation proposed in recent years privilege the role of climatic change as expressed through cyclic changes in discharge and sediment supply (e.g. Bridgland 1999, 2000). Whilst cyclical changes, along with regional uplift (Maddy *et al.* 2001), are certainly dynamic forces behind both fluvial deposition and incision, the Bridgland models are essentially single dimension models. Recent attempts to model terrace evolution have shown however that a key element is the lateral erosion which creates the strath onto which the terrace sediments are deposited (Hancock & Anderson 2002). Lateral erosion therefore creates the accommodation space for terrace gravels, as is illustrated by the enhanced lateral development of terrace staircases within basins (such as the Netherexe Basin) which are underlain by relatively soft bedrocks (this was also noted by Bridgland (1985)).

This process can be seen today on the lower Otter, and more frequently within the gorge sections of most major rivers. After the creation of a wide strath and deposition of gravels (most frequently as bars in a braid-plain complex), incision occurs as predicted in the Bridgland (e.g. 2000) and Vandenberghe (e.g. 1995) models. This is due to high discharges from melting permafrost at glacial–interglacial transitions. However, once incision has occurred subsequent lateral erosion has to remove both the preceding floodplain thickness of gravels *and* the bedrock to the depth of the incised thalweg. Therefore even if the discharges at the end of a cold cycle were greater than those in the preceding depositional phase, lateral erosion is unlikely to exceed the width of the previous strath terrace due to the greater material erosion required to create the same accommodation space.

This emphasis on the lateral component of terrace formation and the strong positive feedback implicit in incision and deposition cycles suggests that some assumptions about staircases sequences may need to be re-evaluated. It has for example become common to assume that the terrace deposits themselves, especially if not composite, represent very short aggradational periods with incision taking place over the majority of Pleistocene time. This is generally reinforced by the temporal clustering of dates in vertical sequences from single quarry faces. Few studies have compared sequences from the same terrace in a lateral sequence and it has been assumed that longitudinal diachrony occurs as a result of the downstream migration of sediment or complex response.

The importance of lateral erosion is also clear in the reworking of terrace gravels from one terrace to another. In most soft-rock basins the bedrock is too easily weathered and fragmented to form a substantial part of the clast lithology and is reduced to providing the matrix. This is common in the Exe where the Shute and Dawlish Sandstones and Cadbury Breccia provide the matrix for the gravels along with shillet which is derived from eroded Bude Formation mudstones. It is therefore commonly assumed that the resistant clasts have been derived from the headwaters of the catchment, mostly Exmoor in the case of the Exe. However, simple volumetric calculations suggest that this may not be the case and that the majority of lower terrace deposits are simply the reworked components of the previous terrace gravels with no doubt an incremental downstream flux.

There are several independent observations that support this hypothesis. Firstly the upper terraces of the Exe (8–6) are far richer than the lower terraces in flints and chert and the most likely source for this material is the erosion of the Tertiary flint gravels now only remaining as interfluve fragments on the Haldon Hills. Secondly it is very common to note an overall increase in roundness down terrace staircases, until there is an overall reduction in clast size. This can be observed between the adjacent fragments of terraces 6 and 4 (Yellowford and Fortescue) along the edges of the Netherexe Basin. Thirdly it has increasingly been realised that not only have many, if not most intra-gravel lithics been transported (Wymer 1999) but that they may have been inherited from a previous terrace deposit (e.g. Ashton & Lewis 2002).

An additional element of the lateral erosion model is that as incision occurs there is an emergent topography created. The small valleys of the lowland tributaries and in some cases small sub-catchments appear as terraces are eroded, in order to grade to the base level created by main channel incision. This also created the interfluve terrace capping common in the lower Exe Valley and in time confines tributary junctions reducing junction mobility.

5.3 Implications for Palaeolithic Archaeology

The project results from the fieldwork and the desktop resource assessment have raised a number of issues relevant to the understanding of the Lower and Middle Palaeolithic occupation of the south-west region.

The beginnings of a chronology for the Exe, Otter and Axe gravels have some of the most significant implications for the Palaeolithic archaeology of south-west England (and potentially more widely). The project OSL dates permit the approximate dating of those artefacts from the terrace gravels of the Exe (including the slightly abraded biface at Magdalene Street in Exeter, and the examples from Pyne Corner and Thorverton (terrace 5)); and the Otter valley (examples include the bifaces found both on, and in, the gravels at Wiggaton (terrace 5), Greenham and Tidwell (terraces 3 or 5), Landram Bay (terrace 7), and Budleigh Salterton (terrace 2)). These finds confirm at least the occasional use of the Exe and Otter floodplains during the Middle Palaeolithic period and probably prior to OIS 6, as is the case with the artefact-rich Axe valley landscape to the east during OIS-8 and 9, and possibly earlier. These patterns are of course also in line with the Lower and Middle Palaeolithic cave archaeology of the region.

Any artefact assemblages associated with the Axe valley fill terrace deposits could date between *at least* OIS-8 (potentially as far back to OIS 10 at Chard) and early OIS-6 (assuming an OIS-6 to OIS-4 abandonment of Britain). The fill terrace nature of the Axe valley gravels is also more likely to preserve fine grained units in which artefacts may be concentrated with minimal reworking, while the deposits are less likely to be exposed to reworking and erosion than thin strath terrace deposits: this may well explain the rich findspot at Broom. The association of artefacts with fine-grained and/or organic channel deposits would potentially improve the time resolution, spatial integrity, and palaeoenvironmental context of any data.

However, in the case of the Exe and Otter strath terrace deposits it is likely that any archaeological materials will have been subject to disturbance and/or reworking (reflecting the shallow depth of the deposits, the evidence for cryoturbation/truncation, and erosion/reworking processes associated with a strath terrace system). This may explain the general paucity of findspots (and the small numbers of artefacts) found in this area, as such re-working would be likely to disperse material, resulting in single artefact and/or low concentration findspots. Material may also have been re-worked into the marine zone. More generally, the majority of OSL dates sampled from the investigated river terrace deposits (the Axe as well as the Exe and Otter) are younger than OIS-9 (one of the Chard samples exceeds this age). While it would appear that several of the OIS-3 ages reflect cryoturbation of older deposits, the general impression is that the modern fluvial drainage patterns of the Exe, Otter and potentially the Axe (essentially north–south) are relatively recent, post-dating a major re-alignment of palaeo-drainage systems. This also implies that any artefactual material originally associated with pre-OIS-9 terrace deposits have the potential to have been substantially re-worked. Such re-working (in both strath and fill terrace systems) would be likely to disperse material (perhaps catastrophically), resulting in occasional single artefact and/or low concentration findspots (as are typically found in the Exe and the Otter systems), or even dispersal offshore. While the younger deposits (post-OIS-9), especially in fill terrace systems, retain potential for larger concentrations of material (e.g. as at Broom in the Axe valley), it should be noted that Palaeolithic Britain from early OIS-6 to OIS-4 remains apparently abandoned.

It is apparent that the recorded distribution of artefacts in the deposits of the Palaeolithic rivers of the south-west region is not necessarily representative of the spatial and/or chronological distribution of Middle and Late Pleistocene hominins. It is likely that the observed distribution represents a series of taphonomic factors: the greater concentration of artefacts in the Axe valley (principally at Broom) may at least partially reflect the fill-nature of the Axe terrace system. The apparent paucity of artefacts to the west does not seem to be due to an absence of deposit exposures (terrace deposits were exposed beneath Exeter for example), but rather due to re-working of older strath terrace deposits (see also comments below). The original Palaeolithic artefact record in this area may therefore have been somewhat richer at one time.

5.4 Conclusions & Discussion

There are both methodological and general conclusions that have arisen from this first systematic study of river terrace deposits in the Palaeolithic rivers of the south-west.

The terrace staircases recognised by the BGS in both the Exe and the Otter valleys contain gravels with significant variation in form, sedimentology and clast lithology, and similar variability in fluvial deposits is found in the thicker fill terraces of the Axe valley. Gravel thicknesses of up to 3.5m were excavated in the Otter and the Exe, and shown in the case of terrace 6 of the Exe and terrace 7 of the Otter to be complex: being made up of at least two members. Terrace fragments were frequently heavily truncated, as at Princesshay and Monkey Lane and all showed varying degrees of cryoturbation. In the Axe valley the fill terraces contained deposits of considerable thickness (up to 15m) in certain locations (e.g. Chard Junction). These sequences were chronologically extensive (see also below), and contained a mixture of fluvial, colluvial and debris flow deposits.

The OSL dating programme had variable results in the Exe and the Otter, with more extraneously reliable results for the lower terraces. One problem identified was that high dose rates in the Middle Exe area can cause saturation of the OSL signal making dating beyond 70,000 years problematic. However, the first OSL-based estimates are that the lower four terraces of the Exe were deposited during the Devensian, with terraces 4 and 3 pre dating the LGM (terrace 4 in the early Devensian (OIS-4) and terrace 3 in the Middle Devensian (OIS-3)), and the inset terraces 2 and 1 after the LGM in the Late Devensian. The marked incision between terraces 4 on the Exe (and 3 on the Culm) and the lower inset or floodplain terraces would appear to be associated with the LGM climatic event. The higher terraces are more problematic but the Early Devensian (OIS-4) would provide a minimum age for terrace 5 and above on the Exe, while in the Otter valley, OSL dating of terrace 7 at Monkey Lane suggests deposition in the Wolstonian (OIS 6). The OSL ages for the Axe valley at Chard and Kilmington were comparable, suggesting that fluvial deposition has been occurring since OIS-9 at the earliest, and persisting through to OIS-8 and OIS-6.

The form, extent, sedimentology, and clast lithological properties of the Exe terraces have been combined to produce an evolutionary model for the Lower Exe. This model emphasises the importance of lateral erosion (see also above) and the incorporation of higher level, largely preceding, terrace gravels into lower terraces. The lateral emphasis of this model has important implications. Firstly it would appear that the topography under *c.* 140 m above the floodplain of the lowland part of the Exe catchment is probably Middle–Late Pleistocene in age including many landscape features such as the dry-valley systems which grade to the main valley, small tributary valleys, emergent interfluves (some gravel capped), and the confinement of river junctions. In particular the steep dry valleys typical in and around the City of Exeter bisect terraces 5 and 4 but grade onto and contain solifluction deposits (head) resting above terrace 3 gravels, implying a Late Devensian date for both their erosion and the deposits contained within them.

Palaeolithic artefacts are known to be associated with terraces 5 of the Exe, 2 and 5 of the Otter, and the fill terraces of the Axe. The survey undertaken during the resource assessment stage of the project has significantly increased the known number of findspots in Devon and Cornwall above those reported in Wymer (1999), although the overall numbers are still small in comparison with south-east England. Nonetheless it is evident that there is a Lower Palaeolithic occupation in the Axe valley and a Middle (and probably also a Lower) Palaeolithic occupation of South-West England west of the River Axe. The pattern still suggests a concentration around the river valleys, both those draining to the English Channel (Exe, Otter, and Axe) and to the Bristol Channel (the Tone and the palaeo-Washford). It also suggests that many of the lowland artefacts recovered from between terrace fragments are residual and once were deposited on these braidplains (as White and Jacobi (2002) have noted, many authors have assumed that because artefacts were found on the modern surface they are relatively young in age (i.e. Devensian), but this is clearly not necessarily the case in south-west England). This reinforces the theory that these floodplains were important routeways in between upstanding upland blocks, which during warm periods were probably thickly wooded. The extensive nature of the gravel terraces and strath benches in both the Exe and the Otter and the model described above re-emphasises that the landscapes Palaeolithic hominins moved in were of lower relative relief than those of today, with wide, inter-linking, flat, gravelly floodplains and shallow multi-channel rivers, particularly during the cold–warm transitional periods that may have been most favourable for human/hominin migration into the British Isles.

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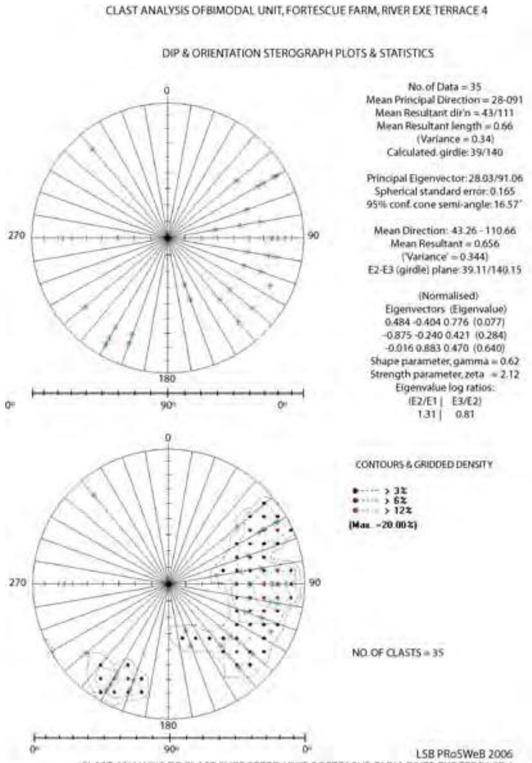
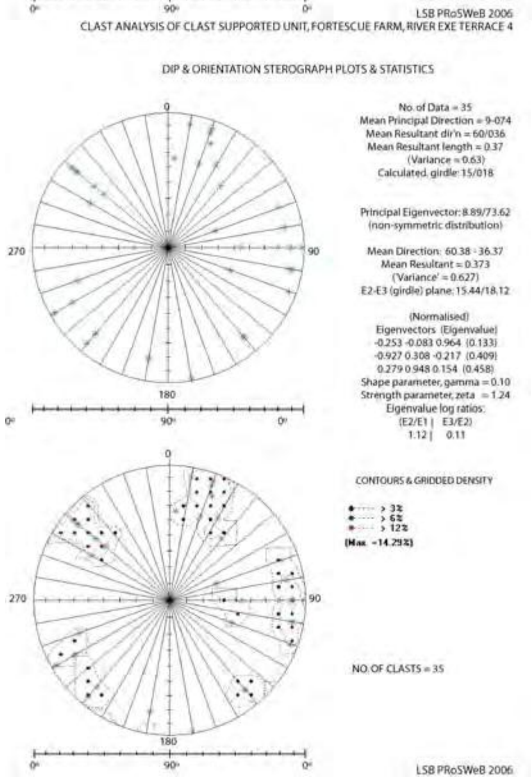
APPENDIX 1

A1 Stereographic Plots

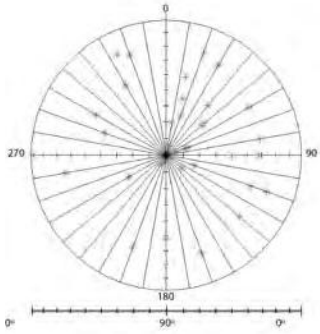
A1.1 Fortescue Farm





CLAST ANALYSIS OF DISRUPTED UNIT, FORTESCUE FARM, RIVER EXE TERRACE 4

DIP & ORIENTATION STEROGRAPH PLOTS & STATISTICS

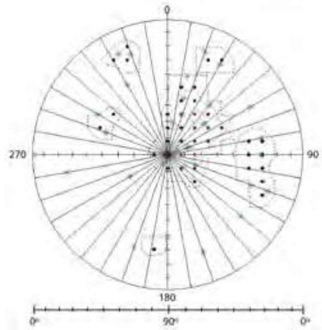


No. of Data = 35
Mean Principal Direction = 68-051
Mean Resultant dir'n = 74/044
Mean Resultant length = 0.70
(Variance = 0.30)
Calculated. girdle: 68/040

Principal Eigenvector: 67.62/51.08
Spherical standard error: 0.186
95% conf. cone semi-angle: 18.77°

Mean Direction: 74.47 - 44.27
Mean Resultant = 0.700
('Variance' = 0.300)
E2-E3 (girdle) plane: 68.03/39.53

(Normalised)
Eigenvectors (Eigenvalue)
-0.715 -0.590 0.374 (0.186)
-0.657 0.751 -0.071 (0.240)
0.239 0.296 0.925 (0.574)
Shape parameter, gamma = 3.38
Strength parameter, zeta = 1.13
Eigenvalue log ratios:
(E2/E1 | E3/E2)
0.26 | 0.87



CONTOURS & GRIDDED DENSITY

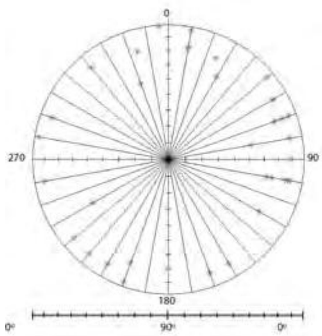
> 3%
> 6%
> 12%
(Max. =17.14%)

NO. OF CLASTS = 35

LSB PRoSWeB 2006

CLAST ANALYSIS OF UNIT 2, FORTESCUE FARM, RIVER EXE TERRACE 4

DIP & ORIENTATION STEROGRAPH PLOTS & STATISTICS

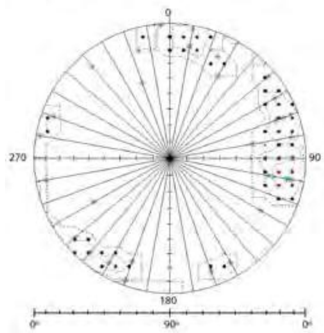


No. of Data = 35
Mean Principal Direction = 8-061
Mean Resultant dir'n = 50/073
Mean Resultant length = 0.34
(Variance = 0.66)
Calculated. girdle: 9/084

Principal Eigenvector: 8.46/61.47
(non-symmetric distribution)

Mean Direction: 50.11 - 73.41
Mean Resultant = 0.342
('Variance' = 0.658)
E2-E3 (girdle) plane: 9.14/83.99

(Normalised)
Eigenvectors (Eigenvalue)
-0.017 -0.158 0.987 (0.082)
-0.881 0.469 0.060 (0.376)
0.472 0.869 0.147 (0.543)
Shape parameter, gamma = 0.24
Strength parameter, zeta = 1.89
Eigenvalue log ratios:
(E2/E1 | E3/E2)
1.53 | 0.37



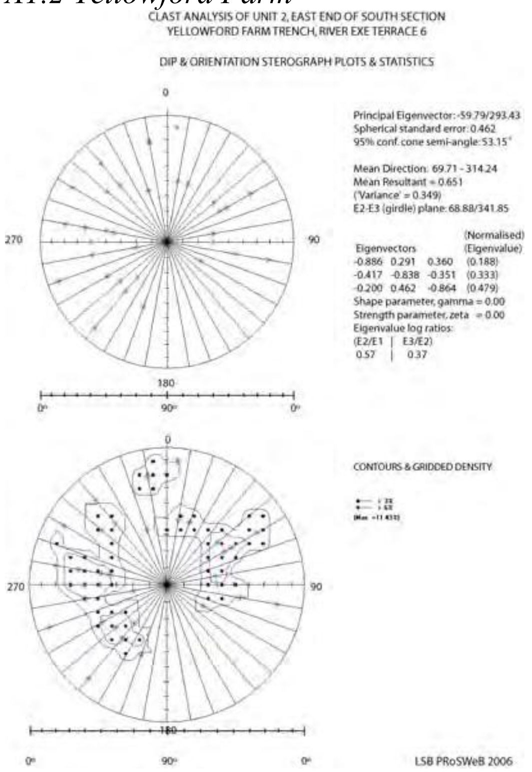
CONTOURS & GRIDDED DENSITY

> 3%
> 6%
> 12%
(Max. =17.14%)

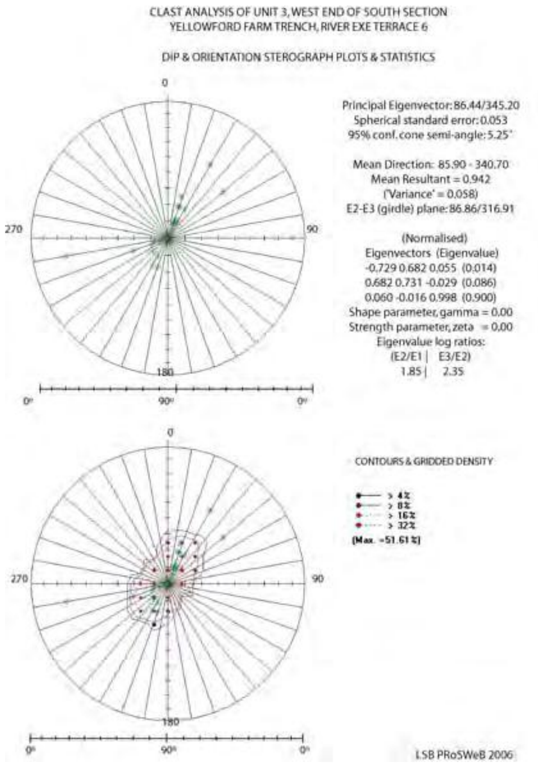
NO. OF CLASTS = 35

LSB PRoSWeB 2006

A1.2 Yellowford Farm

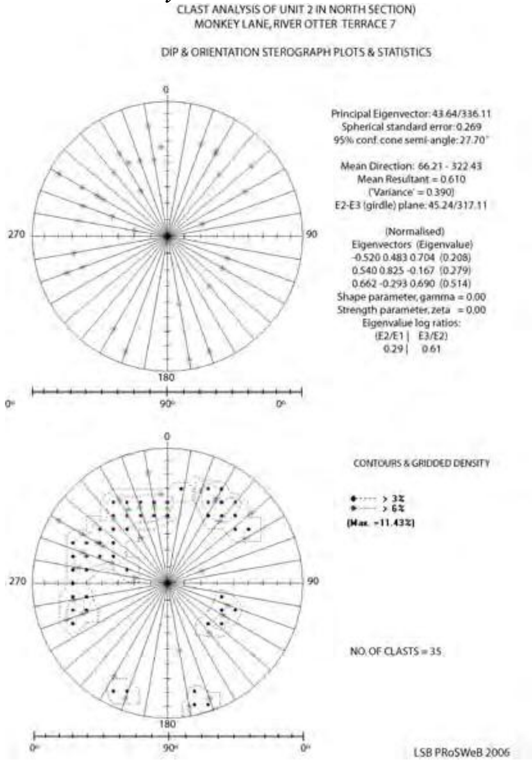


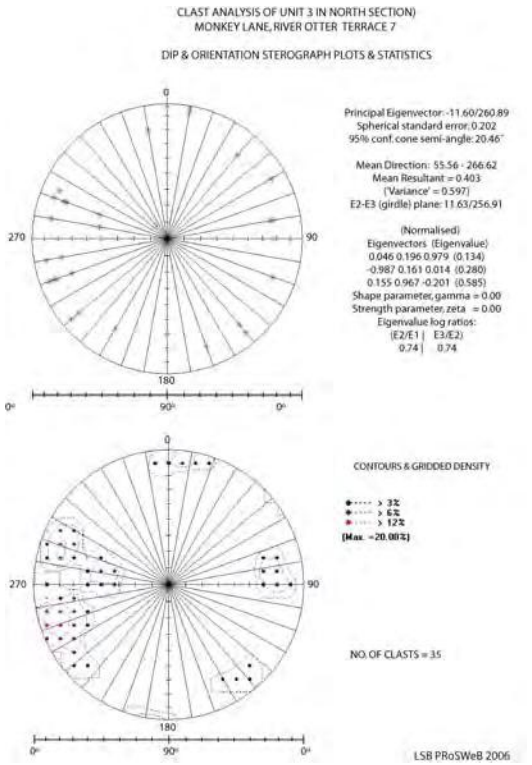
Unit 2 at Yellowford

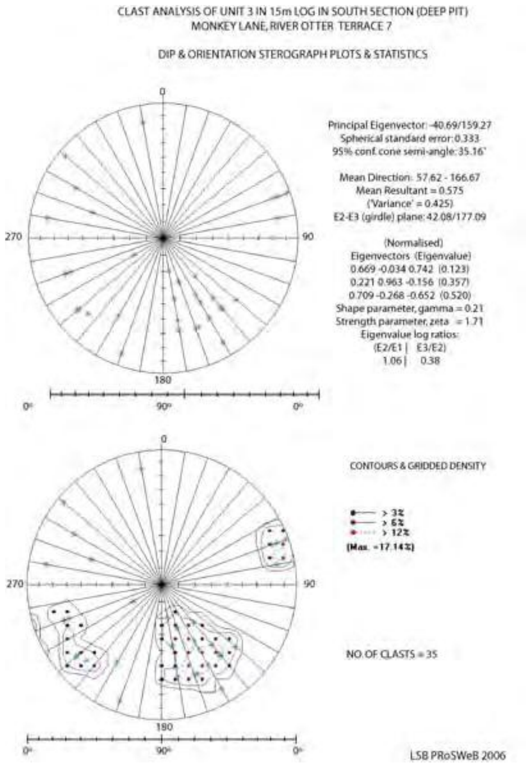


Unit 3 at Yellowford (Heavily Cryoturbated which results in the clustering in the centre as the clasts have a high dip angle)

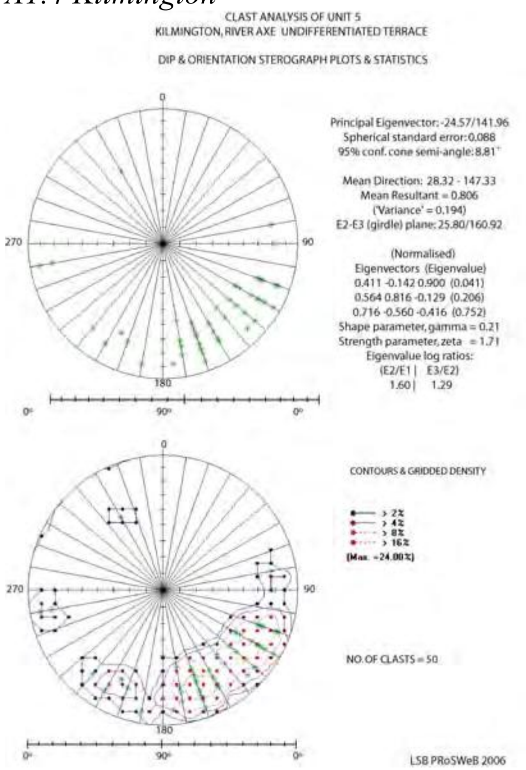
A 1.3 Monkey Lane





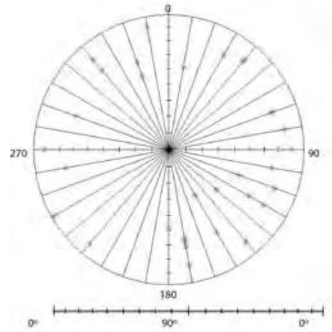


A1.4 Kilmington



CLAST ANALYSIS OF UNIT 6
KILMINGTON, RIVER AXE UNDIFFERENTIATED TERRACE

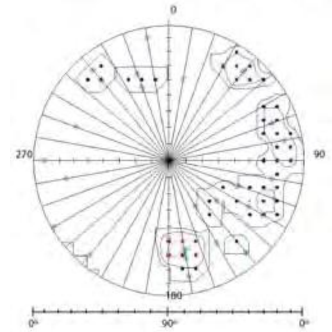
DIP & ORIENTATION STEROGRAPH PLOTS & STATISTICS



Principal Eigenvector: -21.14/118.19
Spherical standard error: 0.685
95% conf. cone semi-angle: 90.00°

Mean Direction: 61.51 - 100.69
Mean Resultant = 0.458
('Variance' = 0.542)
E2-E3 (girdle) plane: 21.34/109.78

(Normalised)
Eigenvectors (Eigenvalue)
0.123 -0.342 0.931 (0.158)
0.889 0.455 0.050 (0.372)
0.441 -0.822 -0.361 (0.470)
Shape parameter, gamma = 0.21
Strength parameter, zeta = 1.71
Eigenvalue log ratios:
(E2/E1 | E3/E2)
0.85 | 0.24



CONTOURS & GRIDDED DENSITY

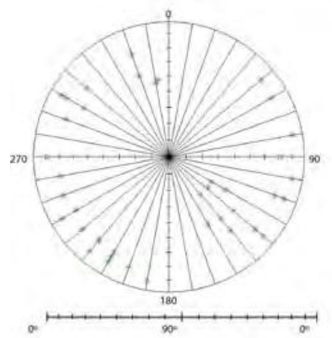
> 3%
> 6%
> 12%
(Max. = 14.29%)

NO. OF CLASTS = 35

LSB PRoSWeB 2006

CLAST ANALYSIS OF UNIT 10
KILMINGTON, RIVER AXE UNDIFFERENTIATED TERRACE

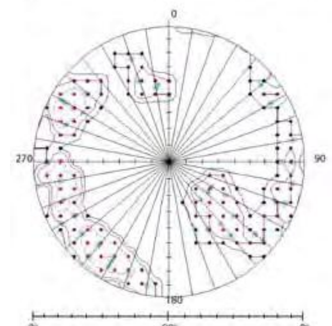
DIP & ORIENTATION STEROGRAPH PLOTS & STATISTICS



Principal Eigenvector: 7.53/269.60
Spherical standard error: 0.380
95% conf. cone semi-angle: 41.08°

Mean Direction: 54.72 - 227.67
Mean Resultant = 0.451
('Variance' = 0.549)
E2-E3 (girdle) plane: 18.71/202.56

(Normalised)
Eigenvectors (Eigenvalue)
0.296 0.123 0.947 (0.153)
0.955 -0.045 -0.293 (0.351)
-0.007 -0.991 0.131 (0.496)
Shape parameter, gamma = 0.00
Strength parameter, zeta = 0.00
Eigenvalue log ratios:
(E2/E1 | E3/E2)
0.83 | 0.35

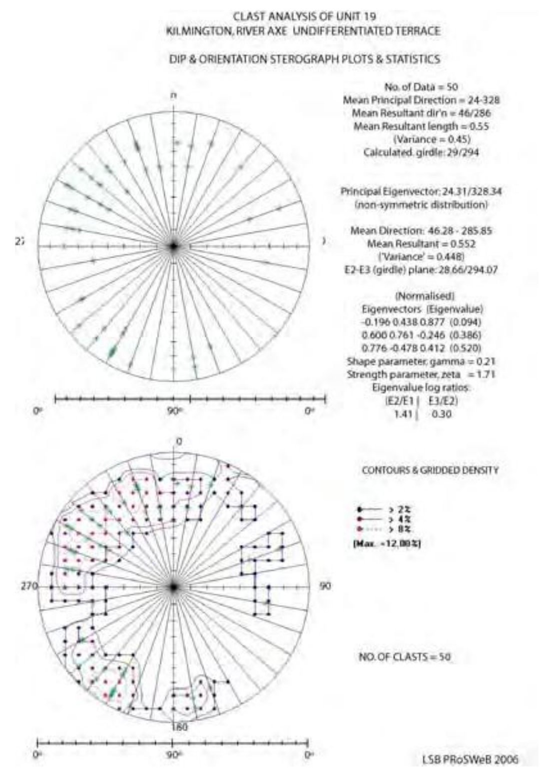


CONTOURS & GRIDDED DENSITY

> 2%
> 4%
> 8%
> 16%
(Max. = 18.00%)

NO. OF CLASTS = 50

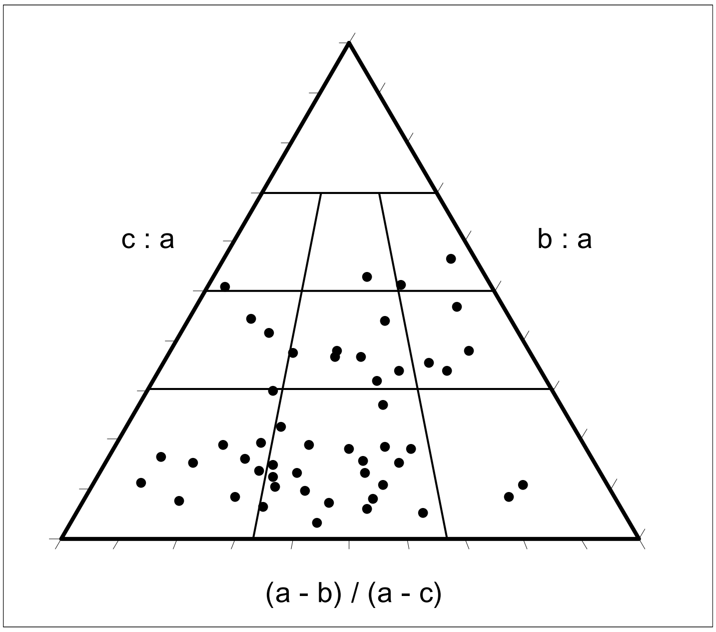
LSB PRoSWeB 2006



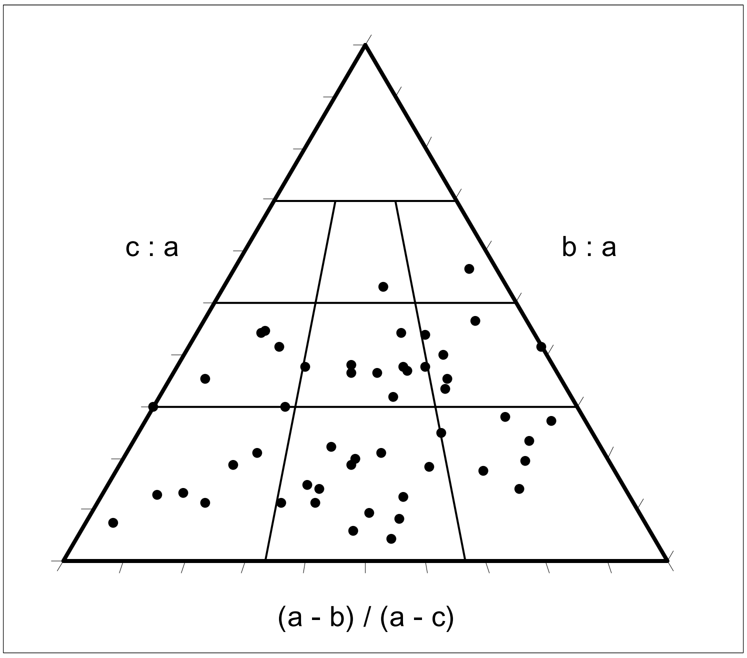
CLAST ANALYSIS OF UNIT 19
KILMINGTON, RIVER AXE UNDIFFERENTIATED TERRACE
DIP & ORIENTATION STEROGRAPH PLOTS & STATISTICS
No. of Data = 50
Mean Principal Direction = 24-328
Mean Resultant dir'n = 46/286
Mean Resultant length = 0.55
(Variance = 0.45)
Calculated. girdle: 29/294
Principal Eigenvector: 24.31/328.34
(non-symmetric distribution)
Mean Direction: 46.28 - 285.85
Mean Resultant = 0.552
('Variance' = 0.448)
E2-E3 (girdle) plane: 28.66/294.07
(Normalised)
Eigenvectors (Eigenvalue)
-0.196 0.438 0.877 (0.094)
0.600 0.761 -0.246 (0.386)
0.776 -0.478 0.412 (0.520)
Shape parameter, gamma = 0.21
Strength parameter, zeta = 1.71
Eigenvalue log ratios:
(E2/E1 | E3/E2)
1.41 | 0.30
0°
90°
0°
CONTOURS & GRIDDED DENSITY
> 2%
> 4%
> 8%
(Max. =12.00%)
0
270
90
180
NO. OF CLASTS = 50
0°
90°
0°
LSB PRoSWeB 2006

APPENDIX 2 Ternary Diagrams

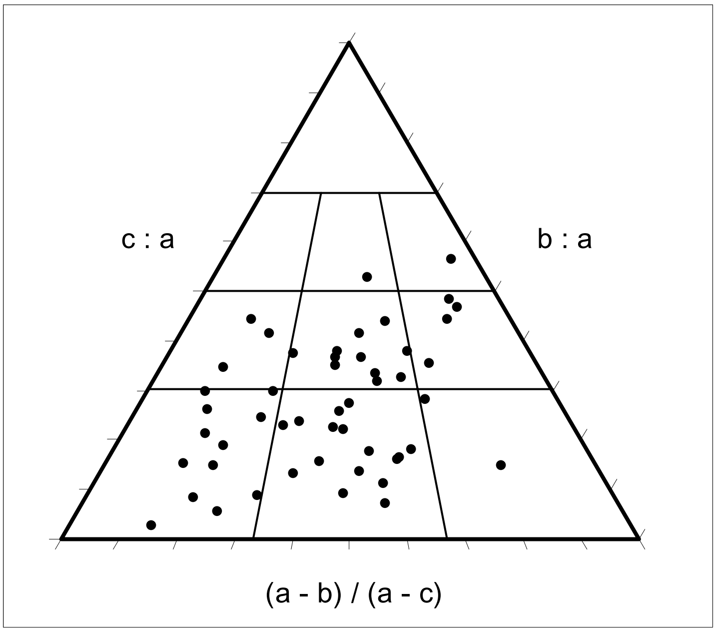
A2.1 Fortescue



Disrupted Unit

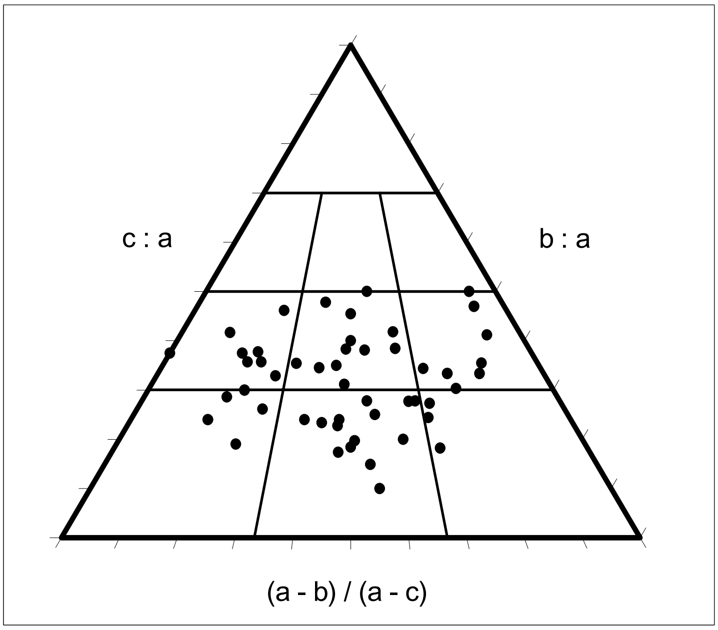


Bimodal Unit

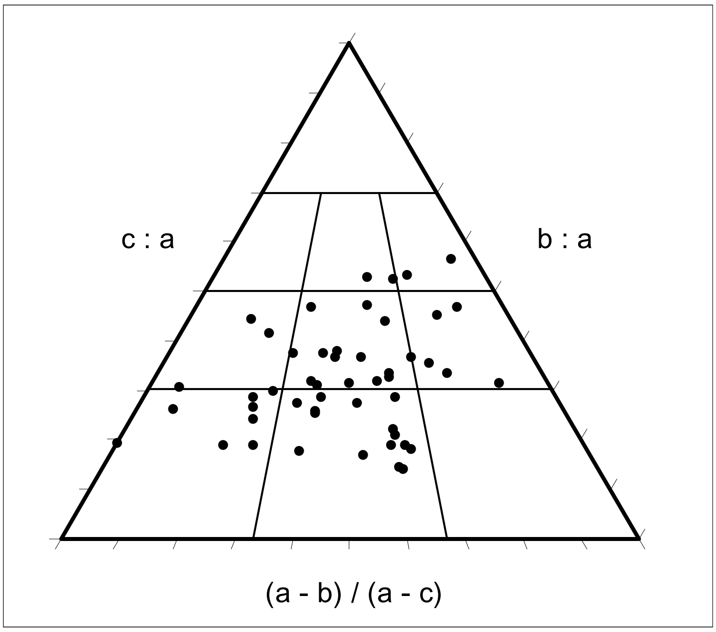


Unit 2

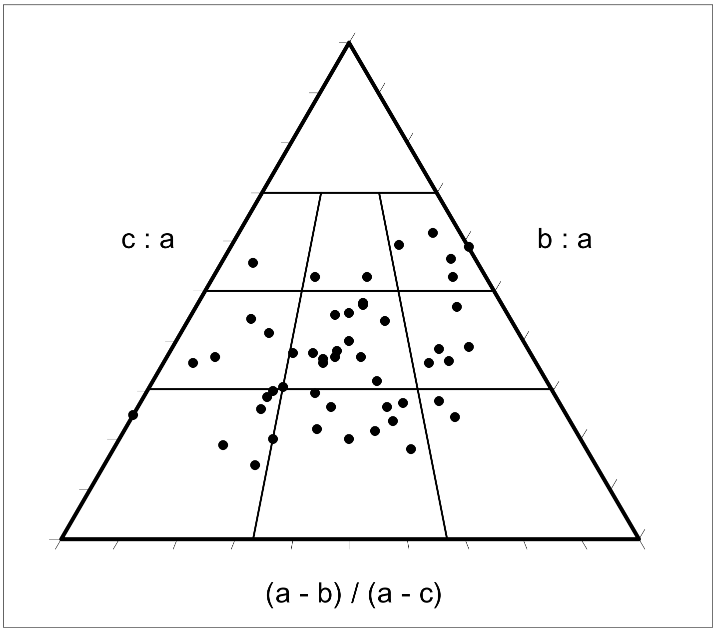
A2.2 Kilmington



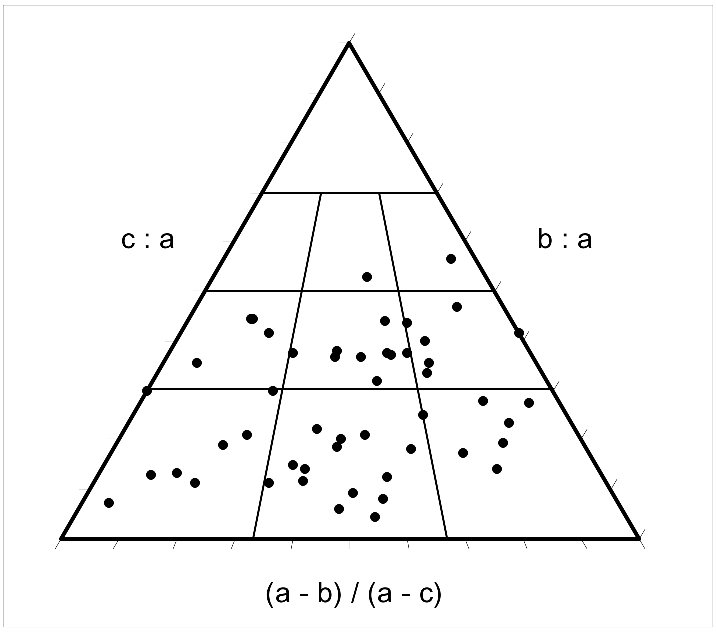
Kilmington Clast Supported Unit 19 Sneed and Folk Diagram



Kilmington Sloping Unit 5 Sneed and Folk Diagram



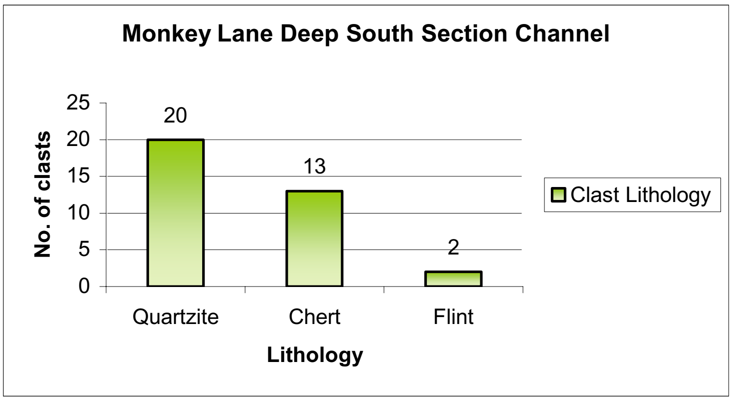
Kilmington Disrupted Unit 6 Sneed and Folk Diagram



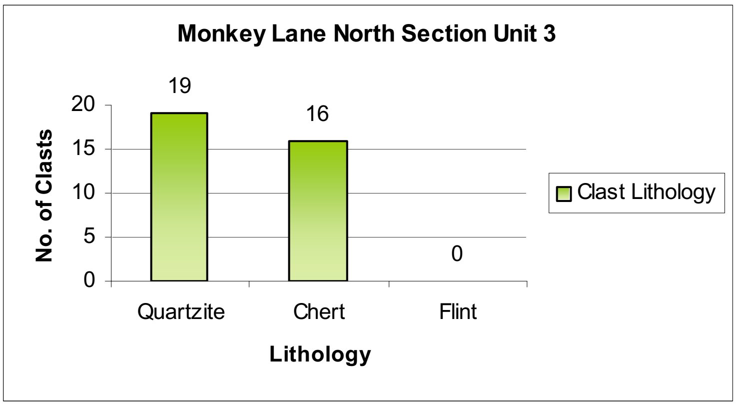
Clast Supported Unit

APPENDIX 3 Clast Lithology Bar Charts

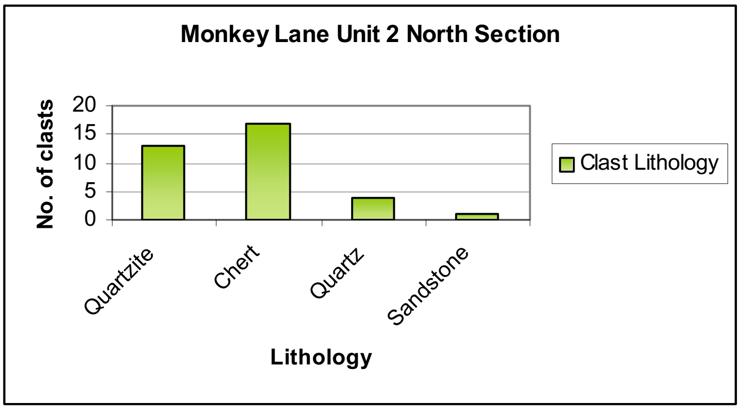
Monkey Lane



Monkey Lane Deep South Section Channel
No. of clasts
25
20
15
10
5
0
20
13
2
Quartzite
Chert
Flint
Lithology
Clast Lithology

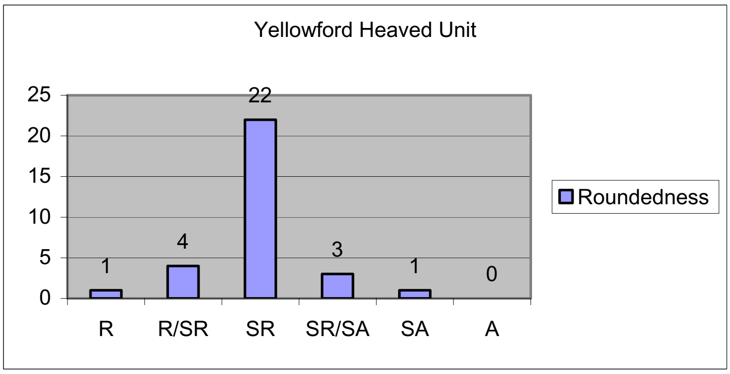


Monkey Lane North Section Unit 3
No. of Clasts
20
15
10
5
0
19
16
0
Quartzite
Chert
Flint
Lithology
Clast Lithology

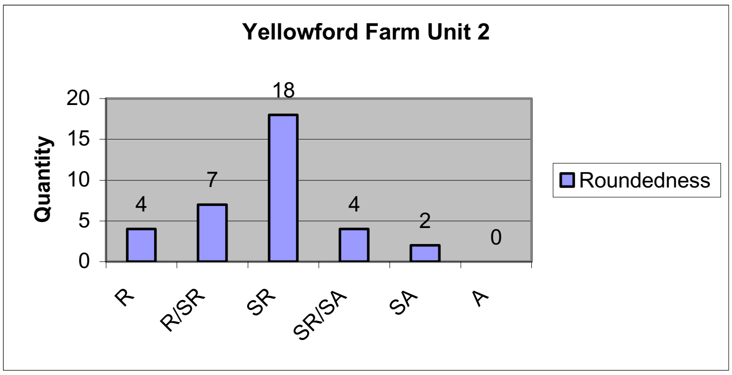


Monkey Lane Unit 2 North Section
No. of clasts
20
15
10
5
0
Quartzite
Chert
Quartz
Sandstone
Lithology
Clast Lithology

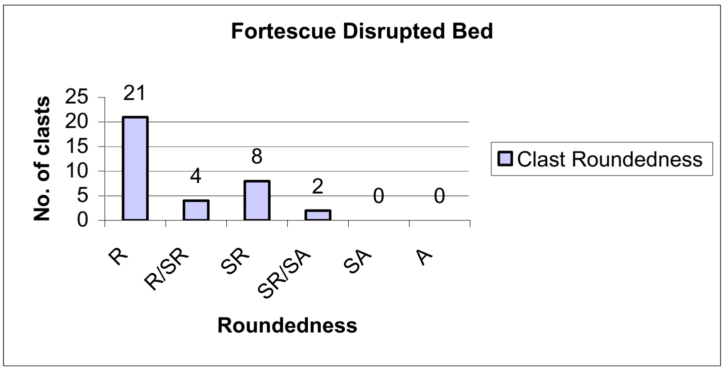
APPENDIX 4 Clast Roundedness Charts

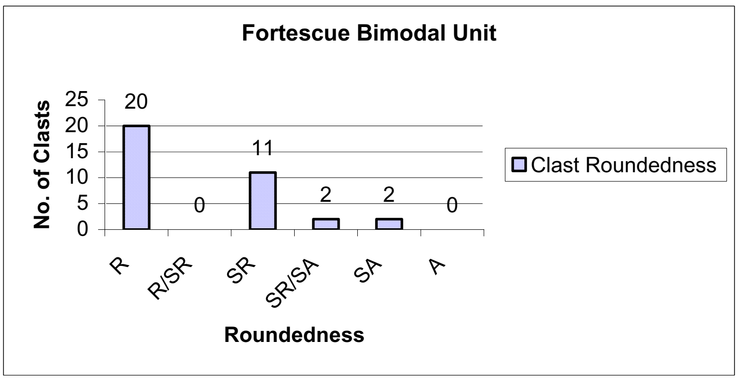


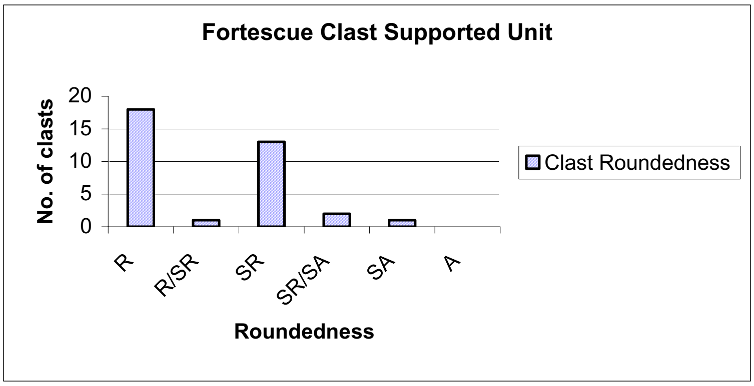
A4.1 Yellowford

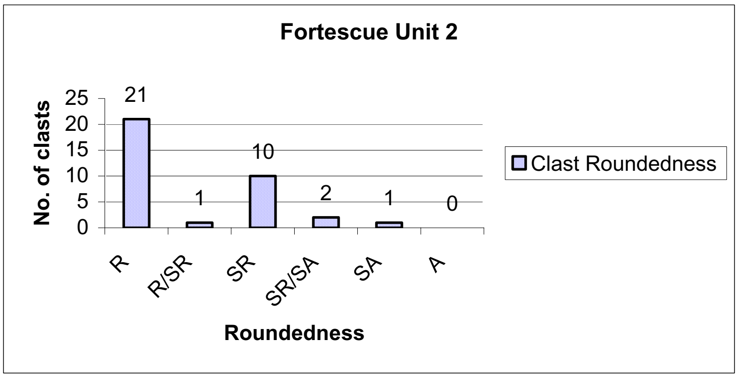


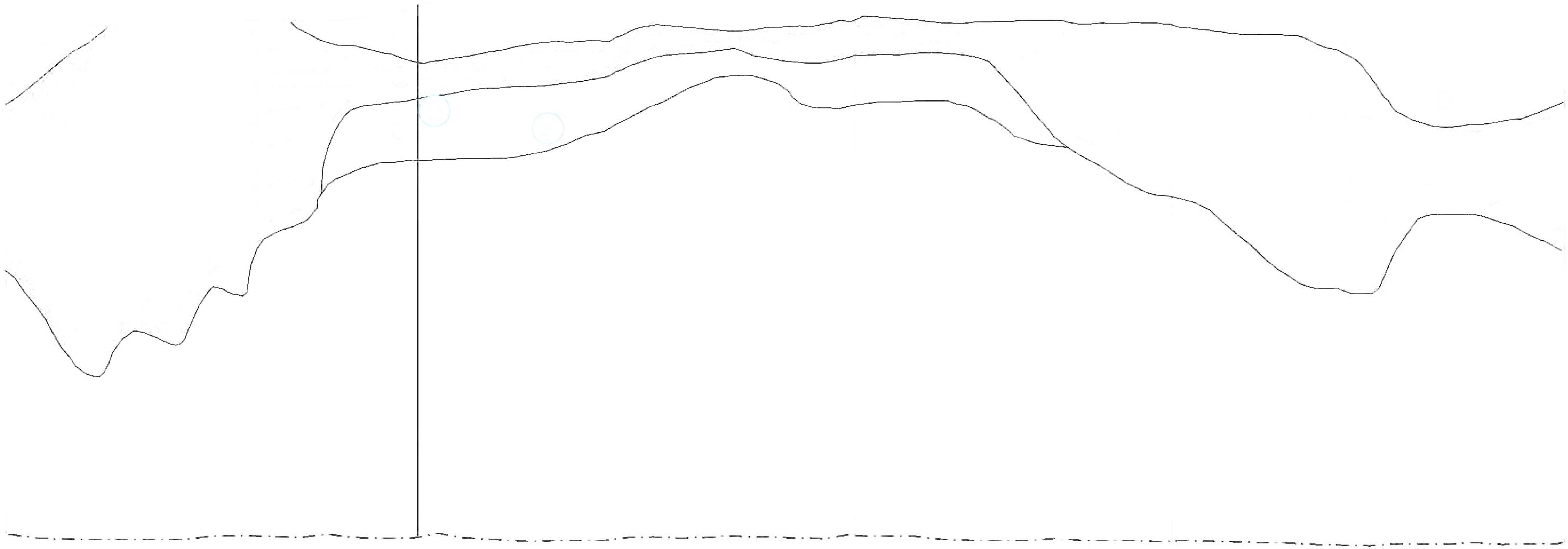
A4.2 Fortescue

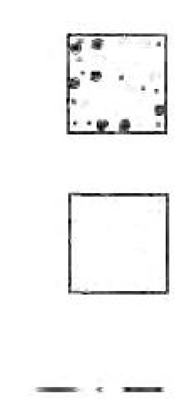




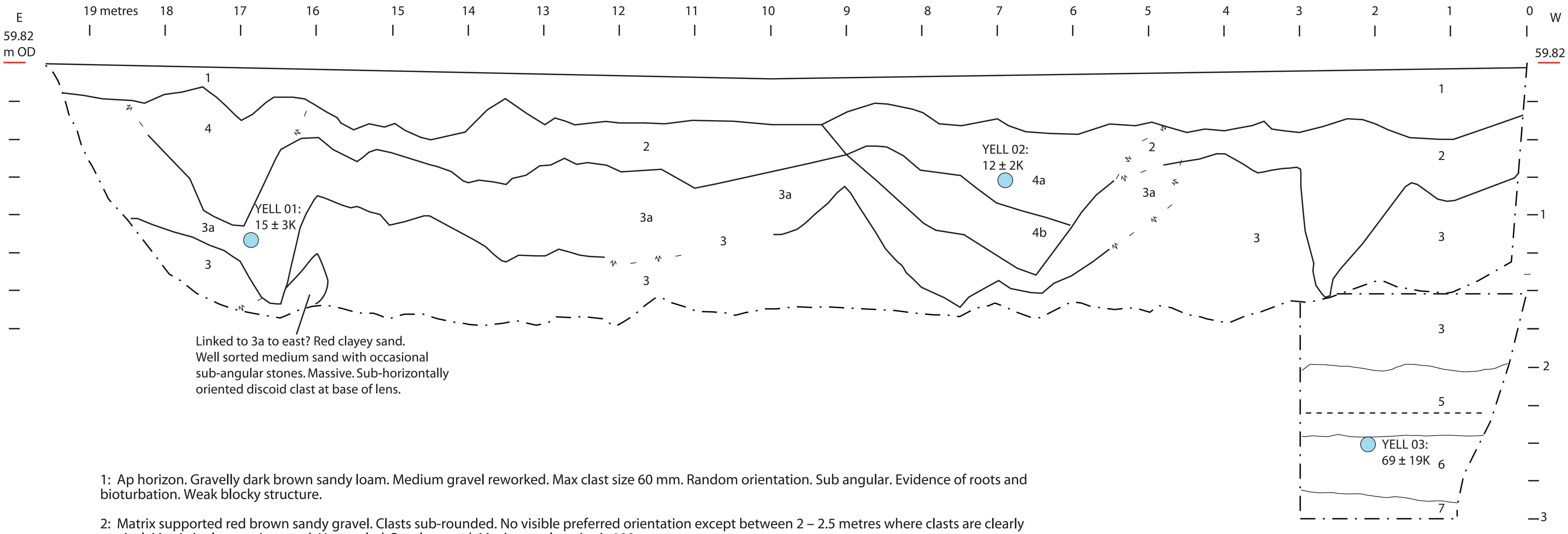

Fortescue Clast Supported Unit
No. of clasts
20
15
10
5
0
R
R/SR
SR
SR/SA
SA
A
Roundedness
Clast Roundedness


Fortescue Unit 2
No. of clasts
25
20
15
10
5
0
21
1
10
2
1
0
R
R/SR
SR
SR/SA
SA
A
Roundedness
Clast Roundedness





YELLOWFORD FARM SECTION TERRACE 6 OF RIVER EXE.
RECORDED BY LSB & AGB. DRAWN UP BY LSB 2006.



1: Ap horizon. Gravelly dark brown sandy loam. Medium gravel reworked. Max clast size 60 mm. Random orientation. Sub angular. Evidence of roots and bioturbation. Weak blocky structure.

2: Matrix supported red brown sandy gravel. Clasts sub-rounded. No visible preferred orientation except between 2 – 2.5 metres where clasts are clearly vertical. Matrix is clayey gritty sand. Unmottled. Poorly sorted. Maximum clast size is 100 mm.

3: Indurated massive clast supported very poorly sorted rounded to sub-angular clasts with iron and manganese cementation particularly on clast faces. Generally no visible preferred orientation, except between1.5 – 2.5 metres where clasts are clearly vertical. Maximum clast size 120 mm. Matrix is clayey gritty sand with iron and manganese mottling. Frequent clast shattering both by the mechanical excavator but also clasts with manganese stained shattered faces.

3a: Sub unit if 3 of fine to medium gravel. Matrix supported containing increased red clayey sand. But still indurated.

4: Sub mottled brown to red clayey sandy loam. Sand is fine to medium with occasional sub-angular stones up to 30 mm. Structure massive with narrow worm/root channels up to 5 mm in width. Occasional manganese concretions reworked from sub-unit 3a. Lateral diffuse changes in colour from yellow brown to red brown sandy loam.

4a: Silty clayey sand. Well sorted medium sand. Clay <10%. Massive. Red brown very weak mottling to red. Reworked manganese and iron reworked nodules. Vertical and sub-vertical root and worm holes. Very occasional sub-rounded clasts. Maximum 30 mm.

4b: Yellow brown massive sandy clay. Slight induration. Manganese and iron. Weak prismatic structure. Very occasional clasts ~30 mm. Angular and weathered. Reworked from 3a below.

5: Very poorly sorted medium calst supported sub-angular gravel. Most clasts of 5 – 30 mm. Occasional clasts up to 80 mm. Very weak lenticular horizontal bedding. Matrix red brown coarse sand and grit. Occasional coarser stone clusters. Possible cryoturbation to dotted line on section.

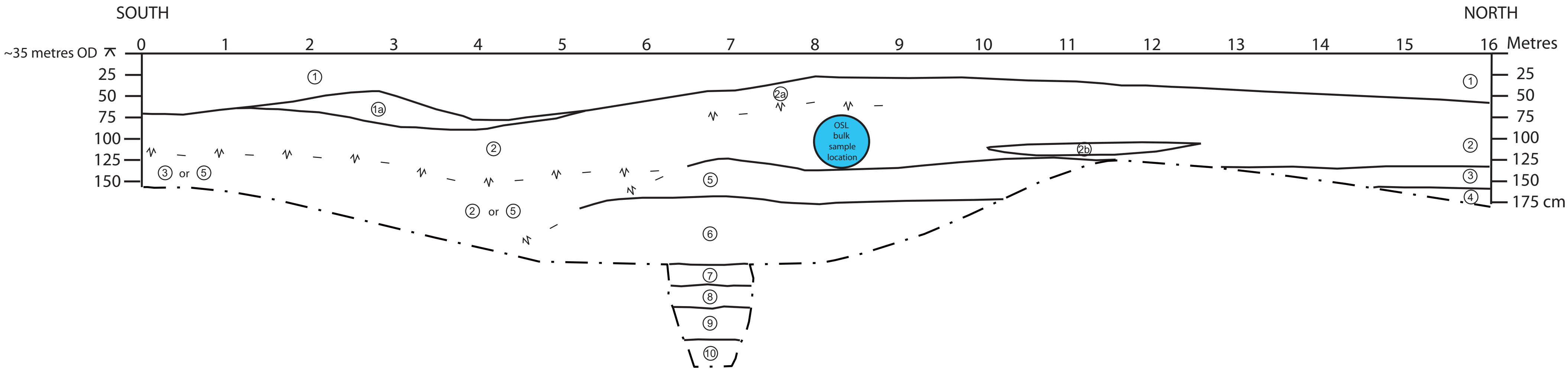
6: Sub-horizontally bedded very fine sandy gravel to fine gravel. Predominant stone size is grit to pea gravel. Occasional stones to 80 mm. Weak horizontal clast orientation. Clear open framework lenses dipping gently west. Total unit is moderate to well sorted. Boundary to 7 undulating erosional with a layer 1 clast thick of subrounded and often discoidal clasts up to 80 mm maximum. Boundary dipping to west, probably into bedrock hollow. Basal lag gravel thicker to the west in the hollow.

7: Bedrock: shute sandstone.

KEY

- Limit of Cryoturbation (see unit description)
- Limit of Excavation
- Main Unit Boundaries
- Unclear Boundary
- OSL Sample Locations

FORTESCUE FARM TERRACE 4 OF THE RIVER EXE:
SCHEMATISED REPRESENTATION OF EAST FACING EXPOSURE. LSB 2006.



KEY

1 Ap Horizon: sandy loam with common roots and foliage.

1a Ap Horizon with increased number of clasts.

2 Matrix supported poorly sorted gravel. Matrix is very coarse sand/grit and small stones (shillet-like). Maximum clast size of 80 - 90 mm. Some crude sub-horizontal bedding and occasional imbrication.

2a As for 2, but matrix is slightly sandier and the colour is more like 1. Crude bedding still apparent as in 2, but roots penetrate in this area to ~60 cm.

2b Discontinuous lens of clast supported gravel within 2.

3 Clast supported, poorly sorted gravel. Matrix is red-brown coarse sand/grit. Possible sub-horizontal bedding, but extremely crude. Maximum clast size is 90 mm.

4 Matrix supported poorly sorted gravel. Matrix is very coarse sand/grit and small stones. Maximum clast size of 130 mm.

5 Clast supported poorly sorted gravel with crude sub-horizontal bedding. Matrix where present is coarse sand/grit and very small stones. Maximum clast size is 200 mm. Distinguished from 2 on basis that this unit is more clast supported than matrix supported.

6 Chaotically oriented, poorly sorted matrix supported gravels. Clast size is generally 30 to 110 mm with occasional clasts of 200 mm. No bedding. Matrix is yellow, orange-brown coarse sand and grit.

7 Open framework gravel.

8 Matrix supported, poorly sorted gravel. Matrix is coarse sand, grit and small stones and red-brown in colour. Maximum pebble size is 50 - 60 mm.

9 Clast supported bimodal and extremely poorly sorted gravel. The small amount of matrix is grey-brown grit and small stones. The unit is very loose. In the basal 15 cm there is an increase in the proportion of large clasts to the small stones and grit. Some very crude sub-horizontal bedding.

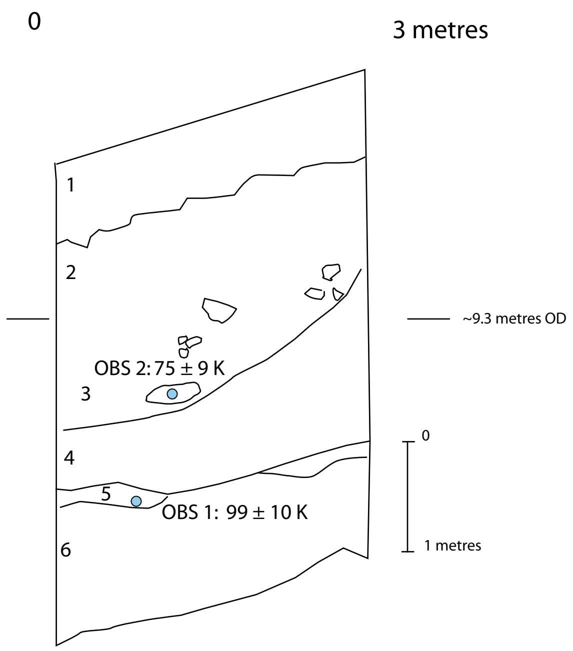
10 Matrix supported gravel. The most matrix supported of all the units. Matrix is red-brown grit, coarse sand and some silt/clay. Exposure is too small to see whether there is any structure or bedding. Maximum clast size is 150 mm. Average clast size is 80 - 90 mm. There are no smaller clasts in this as there are in 2.

— · — Base of section exposure, not base of gravels.

—— Gradational boundary between major units.

ᐱ – ᐱ – Uncertain boundary between units.

SECTION AT BUDLEIGH SALTERTON THROUGH TERRACE 2 EXPOSURE OF RIVER OTTER
RECORDED BY LSB AND AGB



1: Dark brown humic horizon with roots and evidence of bioturbation. Occasional clasts up to 150 mm.

2: Clast supported gravel of sub rounded to well rounded quartzite. Clusters of large clasts common. (main locations shown). Imbrication in places. Max clast size 400 mm. Average clast size 110 to 50 mm. Matrix is red brown medium sand.

3: Discontinuous sand lens, part of 2 sampled for OSL dating. Medium to coarse orange red sand with wavy bedding.

4: As for 2 but with smaller average clast size (50 - 60 mm) and less matrix.

5: Red brown reworked Otter Sandstone with occasional of clasts at base of unit of ~30 mm. Sampled for OSL.

6: Bedrock: Otter Sandstone.

KEY

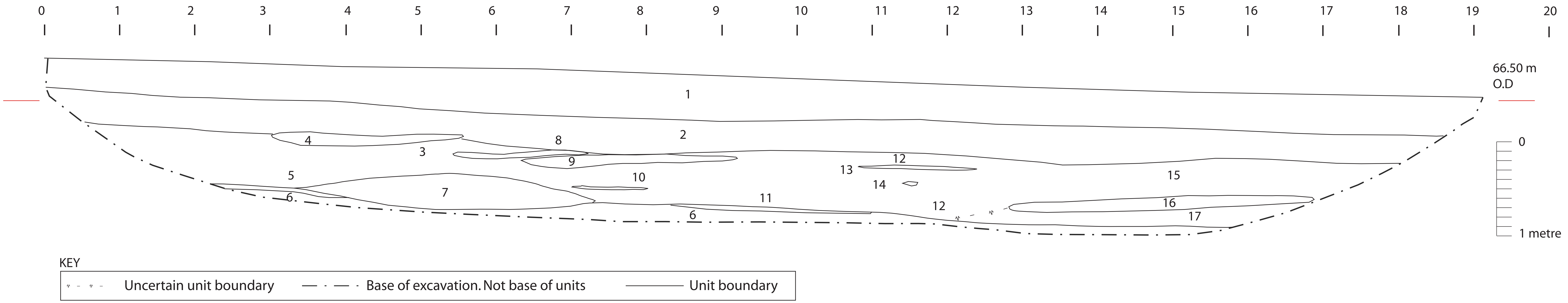
— (line)	Main unit boundaries and arbitrary limits of recorded exposure. Basal line is exposure limt, not base of unit 6.
(clast outlines)	Key clast clusters.
● (dot)	OSL sample locations

PHOTOGRAPH OF BUDLEIGH SALTERTON CRICKET GROUND EXPOSURE
LSB 2006

IMBRICATION IN UNIT 2.
LSB 2006

SAND LENS UNIT 3
LSB 2006.

MONKEY LANE SECTION FROM TRENCH INTO TERRACE 7 OF RIVER OTTER.
NORTH SECTION.
RECORDED & DRAWN UP BY LSB 2006.



1: Dark brown sandy loam with fine rootlets throughout. Occasional clasts, sub angular to angular and sub-rounded quartzite. Maximum clast size is 80 mm. Quantity of clasts increase below 20 cm. Evidence of ploughing.

2: Matrix supported gravel. Clasts are sub-angular to sub-rounded of chert, mudstone and quartz. Poorly sorted. Maximum clast size is 120 mm. Matrix is orange-yellow sand medium to coarse grained. Some dip to the north-west. Massive. Fine rootlets throughout. Gradational boundary with 1.

3: Clast supported gravel. Very poorly sorted. Clasts are well rounded, sub-rounded and occasionally sub-angular. Some sub-horizontal bedding. Maximum clast size is 170 mm. Stacks in places and imbrication as well. Matrix is very coarse orange brown sand and grit. Gradational upper contact with 2.

4: Poorly sorted framework gravel forming a discontinuous lens. Clasts are largely sub-angular and occasionally sub-rounded. Mean clast size is grit. Upper and lower contacts are sharp.

5: Fine gravel and grit. Some coarse sand matrix. Clear upper and lower contacts.

6: Compact slightly silty medium sand. Red. Occasionally patches of friable clay ~30 mm in size. Mottled in other places with purple-brown. Possible organics? Also mottled with dark brown and yellow green occasionally. At 14 metres there is a lcm silty clay band at the top of the unit.

7: Matrix supported gravel. Graded bed with grit at base (same as 5). Matrix fines upwards through coarse sand to fine silty sand which is yellow orange. Maximum clast size is 200 mm. Clasts are sub-angular to sub-rounded. Occasionally well rounded. Crude sub-horizontal bedding. No clear imbrication. Sharp erosional lower contact with 6.

8: Dark red indurated band within 3 dipping westward.

9: Discontinuous sand lens of yellow-orange medium sand. This contains a small dark brown root mark half way through the lens and a hard cemented red band extends along the top of the sand lens which probably corresponds to 8.

10: Discontinuous lens of framework gravel, coarse sand and grit. Sharp lower contact.

11: Pink-brown fine to medium slightly silty sand.

12: Clast supported gravel. Maximum clast size is 120 mm. Sub-angular to sub-rounded. Matrix is coarse sand at base, which fines upwards to medium sand. Matrix is mottled red orange and yellow orange. Crude sub-horizontal bedding. Some imbrication to east (15 degree dip).

13: Discontinuous lens of indurated clast supported gravel of fine gravel and coarse sand within 12.

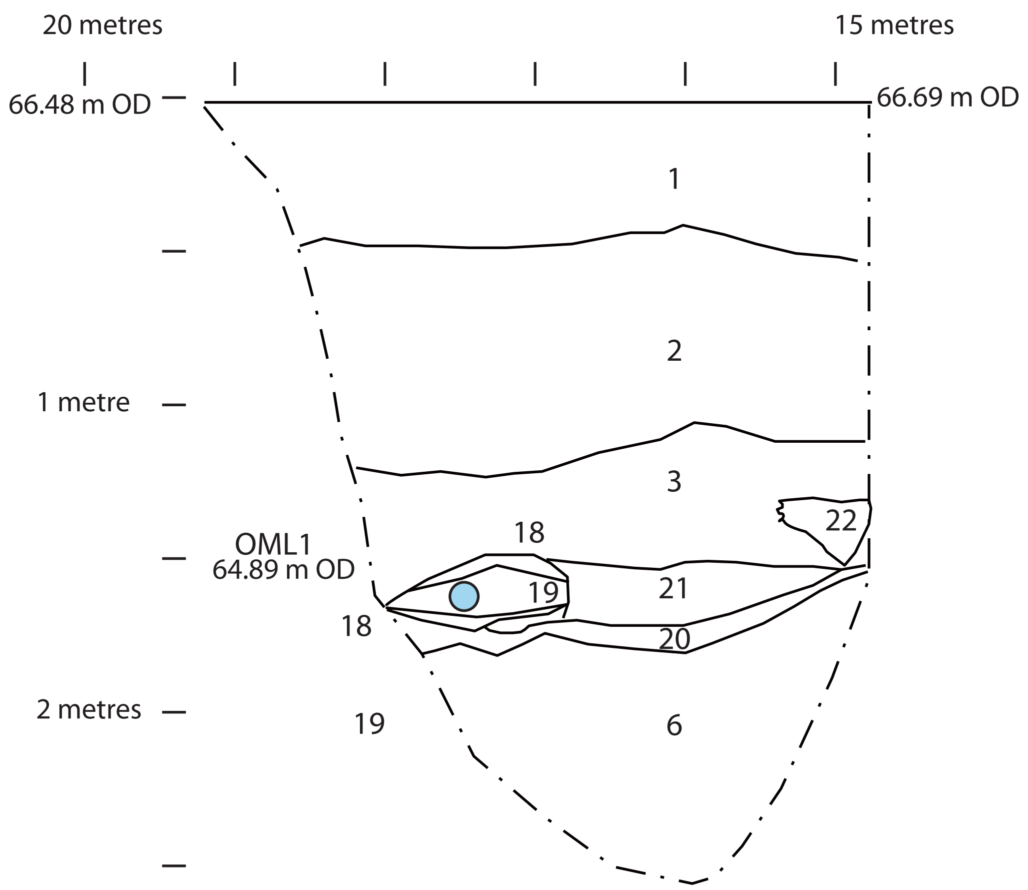
14: Framework gravel lens within 12. Maximum clast size is 60 mm but rare. Generally 10 mm very fine gravel and grit.

15: Clast supported gravel similar to 12. Matrix is coarse sand and coarsens upwards to fine gravel, grit. Dark root feature apparent at about 14 metres along the section.

16: Coarse discontinuous sand lens. Orange. Becomes redder towards base.

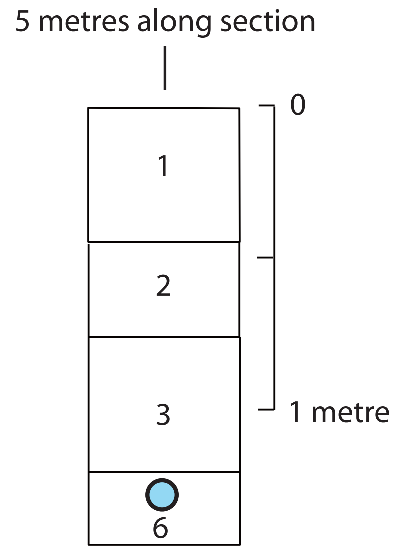
17: Clast supported cemented gravel. Very poorly sorted. Maximum clast size is 80 mm. No clear bedding. No imbrication. Chaotic clast orientation including some near vertical. Clasts are generally sub-angular. Occasionally well-rounded. Pocket of wet, pale grey coarse sand at 14 metres along section. Quartzite cobble which is also covered in pale grey- white “clay” coating.

MONKEY LANE DEEP PIT SOUTH SECTION, RIVER OTTER TERRACE 7 AND POSITION OF OTHER OSL SAMPLES. RECORDED AND DRAWN UP BY LSB 2006.



PHOTOGRAPH OF DEEP PIT: LSB 2006

PHOTOGRAPH OF OML 3 AT BASE OF SOUTH SECTION 5 METRES ALONG THE SECTION. (O METRES IS AT THE WESTERN END) HEIGHT OD IS 65.42 (HOLE BASE) DATE 116 ± 17K. PHOTOGRAPH PT 2006.



SCALED LOG THROUGH OML 3 LOCATION. SEE DEEP PIT FOR UNIT DESCRIPTIONS

1: Dark brown sandy loam with fine rootlets throughout. Occasional clasts, sub angular to angular and sub-rounded quartzite. Maximum clast size is 80 mm. Quantity of clasts increase below 20 cm. Evidence of ploughing.

2: Matrix supported gravel. Clasts are sub-angular to sub-rounded of chert, mudstone and quartz. Poorly sorted. Maximum clast size is 120 mm. Matrix is orange-yellow sand medium to coarse grained. Some dip to the north-west. Massive. Fine rootlets throughout. Gradational boundary with 1.

3: Clast supported gravel. Very poorly sorted. Clasts are well rounded, sub-rounded and occasionally sub-angular. Some sub-horizontal bedding. Maximum clast size is 170 mm. Stacks in places and imbrication as well. Matrix is very coarse orange brown sand and grit. Gradational upper contact with 2.

6: Compact slightly silty medium sand. Red. Mottled with dark brown and yellow green occasionally. Narrow bedding. Quite soft. Weathered Otter Sandstone. (Bedrock).

18: Yellow grey silty clay.

19: Orange red silty sand.

20: Clast supported gravel. Sub-rounded and rounded with no bedding. Matrix is clayey sand.

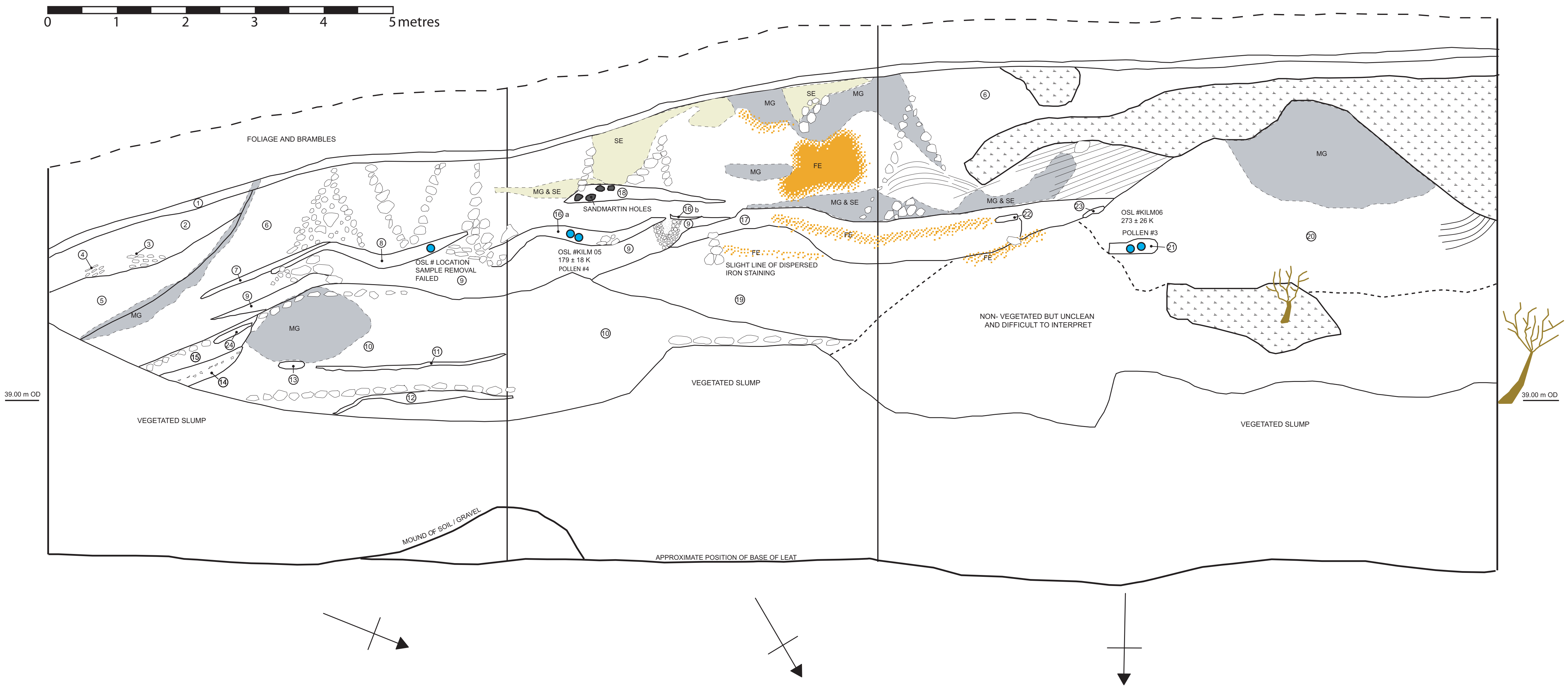
21: Clast supported gravel. Very poorly sorted. Ranges from very coarse sand to fine gravel to 150 mm. Average clast size is 80 or 90 mm.

22: Patch of poorly sorted framework gravel within 3.

PHOTOGRAPHS OF OML 2 LOCATION IN WEST SECTION OF DEEP PIT. ALSO SHOWS RAFT OF MERCIA MUDSTONE. PHOTOGRAPHS LSB 2006.

KILMINGTON: DETAILED SECTION OF PART OF SOUTH QUARRY FACE

Recorded by LSB and JB. Drawn and digitised by LSB.

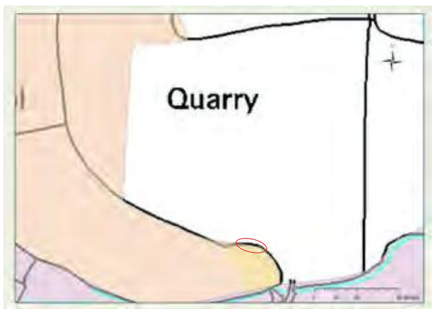


Munsell Colours	
7.5 YR 5/6	2.5 Y 6/4
10 YR 7/6	10 YR 7/2
10 YR 7/8	10 YR 7/4
10 YR 8/2	5 GY 7/1
10 YR 3/4	10 YR 5/8
10 YR 2/2	5 Y 5/6
2.5 Y 5/4	5 Y 7/2
	10 YR 6/6

KEY

- Grass/vegetation cover
- Indication of bedding direction in some areas to supplement unit descriptions.
- MG — Indication of main areas of manganese staining
- FE — Indication of main areas of iron staining
- Sandmartin holes
- Prominent saplings
- SE — Indication of areas of salt efferescence
- Indication of prominent clast structures/ features within gravels. E.g. cryoturbation, bedding, clast clustering.
- OSL sample locations

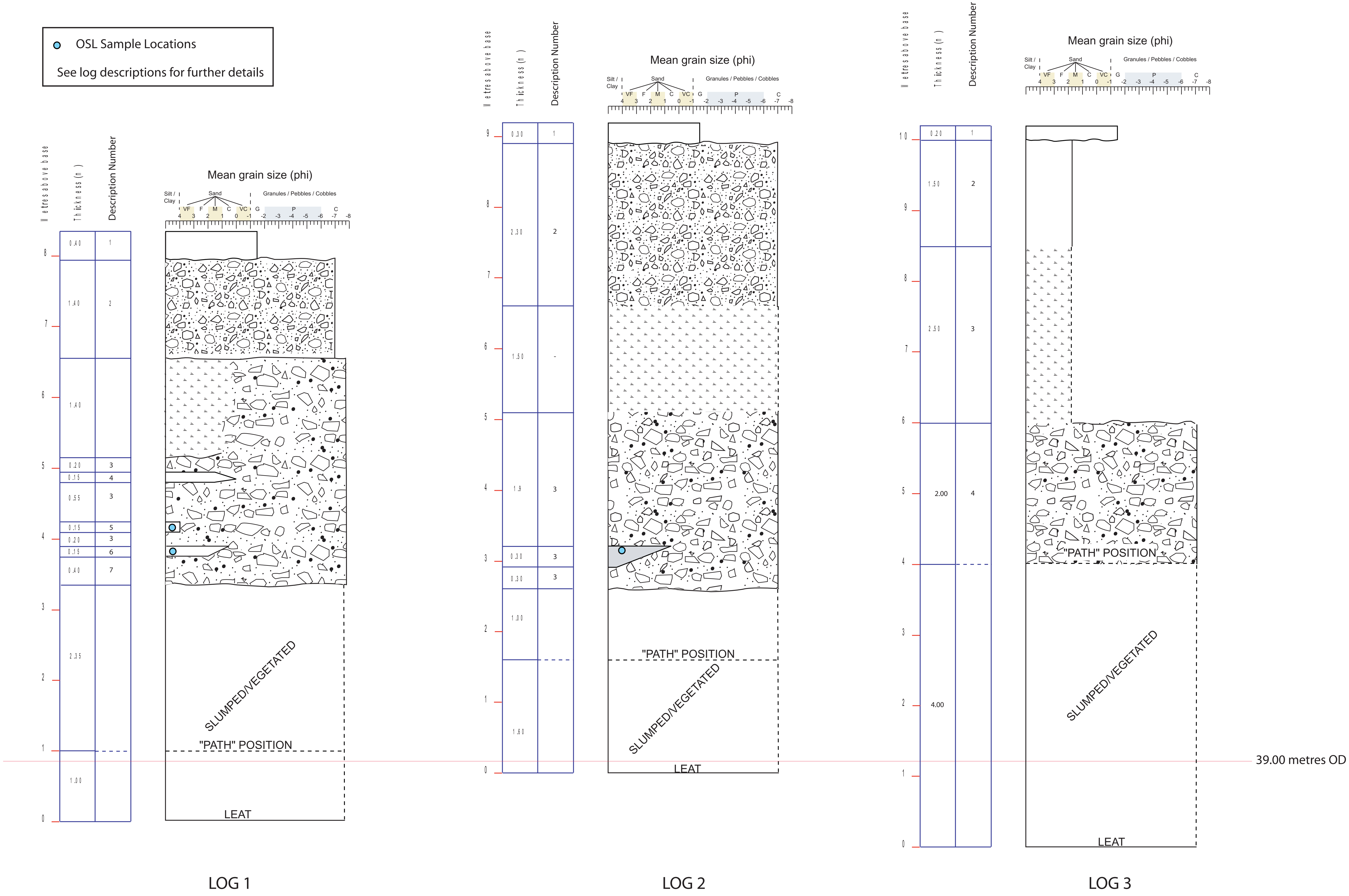
Red circle shows approximate location of the detailed section shown above. Background map is from Digimap (under licence to Exeter University). The orange and purple shading represent BGS mapping of river terrace and head deposits respectively. These geological data are © and issued under licence number 2005/089 to Laura Basell. The map was created in ArcGIS by L.S. Basell.



This part of the section at Kilmington curves considerably. It was therefore drawn in three parts, marked by the vertical lines. The orientation of each face is shown by the directional arrows underneath each section. If the clast analyes conducted as part of this study are aligned with the directional arrow appropriate to the unit, the dominant flow directions of some units can be indicated.

No.	Description	Average Clast Size	Max Clast Size	Roundedness	Lithology	Matrix	Sorting	Structure	Munsell	Major Units
1	Topsoil	-	-	-	-	-	-	-	Not possible due to inaccessibility	A
2	Matrix supported gravel	2.5 - 5 mm	Occasional 40 mm	Angular to sub-angular, occasionally rounded	Chert, Quartz and Sandstone	Sandy Silt	Poor	No clear structures except for 3 & 4.	7.5YR 5/6	
3	Matrix supported gravel	20 - 40 mm	40 mm	Angular to sub-angular, occasionally rounded	Chert, Quartz and Sandstone	Sandy Silt	Poor	Horizontal bedding.	7.5YR 5/6	
4	Matrix supported gravel	2.5 - 5 mm	Occasional 40 mm	Angular to sub-angular, occasionally rounded	Chert, Quartz and Sandstone	Sandy Silt	Poor	Clasts bedded following orientation of base of unit.	7.5YR 5/6	B
5	Clast supported gravel	Chert: 30 - 250 mm, Sandstone: 20 - 50 mm	Occasional 250 mm	Chert: angular to sub-angular. Sandstone: sub-rounded. Quartz: angular	Chert dominant, sandstone, very occasional quartz	Fine Silt to Coarse Sand of ~2 mm.	Poor	Crude bedding follows orientation of base of unit.	10YR 7/6	C
6	Matrix supported gravel	<200 mm	200 mm	Chert: angular to sub-angular. Sandstone: sub-rounded. Quartz: angular	Chert dominant, sandstone, very occasional quartz	More matrix supported than 10.	Poor	Clear cryoturbation features (as shown on section drawing). Heaves, stacks and clusters of clasts. No clear bedding at all. Areas of manganese, iron and salt efferescence (as shown).	Not possible due to inaccessibility	
7	Very fine sandy gravel lens grading horizontally (NNW) into sand and silt.	2 mm	2 mm	-	-	Very fine sandy gravel lens grading horizontally (NNW) into sand and silt.	Moderate	No clear bedding or structure within the lens, although the complete lens has been affected and disrupted by cryoturbation (see section drawing).	10YR 7/8	
8	Very fine gravel and sand lens: *failed OSL sampling location*	Fine gravel is <5 mm		-	-	Very fine gravel fining upwards into sand.	Moderate	Bedding visible. Clearly a continuation of 7.	10YR 8/2	
9	Matrix supported gravel	<50 mm	Occasional 100 mm	-	-		Poor	No clear bedding or structures.	10YR 3/4	D
10	Matrix supported gravel	<300 mm	Occasional 300 mm	Sub-angular to sub-rounded	Chert dominant, sandstone, very occasional quartz	35% sand matrix.	Very poor	Horizontal bedding. Unit is also manganese stained, very compact and rather "cemented"	10YR 2/2 in Manganese area. Other areas broadly 10YR 7/4	
11	Clast supported fine to medium gravel lens	1 mm - <10 mm	20 mm	Sub-angular	Chert	-	Moderate	Framework gravel.	N/A because clast supported.	E
12	Matrix supported gravel	50 mm - 100 mm	Occasional 200 mm	Angular to sub-angular	Chert dominant, sandstone, very occasional quartz	Coarse silty sand.	Poor	Bedding is horizontal, following line of large clasts immediately above the unit, except in south-western "tail" where row of small clasts dips to base as shown.	10YR 7/4	
13	Silty clay lens	-	-	-	-	Silty clay.	Good	Stratified - see photograph. Horizontal bedding with some manganese staining at the base, and with some brown (iron?) flecks.	2.5Y 5/4	
14	Silt, gravel, sand lens	-	-	-	-	From the bottom, this grades from silty sand to fine gravel with a coarse sand matrix, to coarse sand, then fine sand and then 15.	Moderate	Graded bedding parallel to the base of the lens.	2.5Y 6/4	
15	Fine gravel lens (could be considered as a continuation of 14)	-	-	-	-	Fine gravel	Moderate	Bedding is parallel to the base of the lens.	N/A because clast supported.	
16	Silt lens: *sampled for OSL & pollen*	-	-	-	-	Silt with patches of clay/sand within it.	Good	No structure. Probably originally contiguous with 16b but cryoturbation feature has caused disruption.	10YR 7/2 & 7/4	F
17	Matrix supported "cemented" gravel	100 mm - 200 mm & 2 - 40 mm	200 mm	Angular to sub-angular	Chert dominant, sandstone, very occasional quartz	Matrix changes from coarse sand below iron staining to silt above.	Very poor	Some crude sub-horizontal bedding. Areas of iron staining following lines of bedding.	5GY 7/1 - silt above iron line. 5Y 5/6 - sand below iron line.	G
18	Cross bedded sand and silt lens	-	-	-	-	Interbedded layers of coarse sand and silt. See sketch for details.	Moderate	Cross bedding. Holes are from sandmartins, not OSL samples.	10YR 7/4	Lens within 6, so D
19	Clast supported gravel	2 mm - 120 mm	120 mm	Generally sub-rounded to sub-angular with angular broken fragments. Occasional sub-rounded 20 - 70 mm quartz. Chert appears very battered.	Chert dominant, and occasional quartz.	Very small amount of medium to coarse sand.	Poor	Crude sub-horizontal bedding. Gravel is packed quite tightly.	N/A because clast supported.	H
20	Clast supported gravel	2 mm - 250 mm	250 mm	Sub-angular to sub-rounded. A few angular broken fragments.	Chert	Small amount of medium to coarse sand, but more than 19.	Poor	No clear bedding, over majority of this area, except at the far west of the section where shown on the drawing. Relationship to other basal units not particularly clear partly due to unclean/vegetated area to east of 20.	N/A because clast supported.	
21	Sand lens: *sampled for OSL & pollen*	-	-	-	-	Coarse to fine sand.	Good	Cross bedded. See sketch and photograph for detail. Small row of clasts at very base of this	2.5Y 6/4 with bands of 10YR 5/8	I
22	Silt lens	-	-	-	-	Silt.	Good	No structure or bedding.	5Y 7/2	Part of 17, so G
23	Coarse sand lens	-	-	-	-	Coarse sand.	Good	No structure or bedding.	10YR 7/2 & 7/4	Part of 17, so G
24	Silty sand lens	-	-	-	-	Silty sand, some iron and manganese staining.	Moderate	No structure or bedding.	10YR 6/6	Part of 15, so F

KILMINGTON LOGS 1 - 3

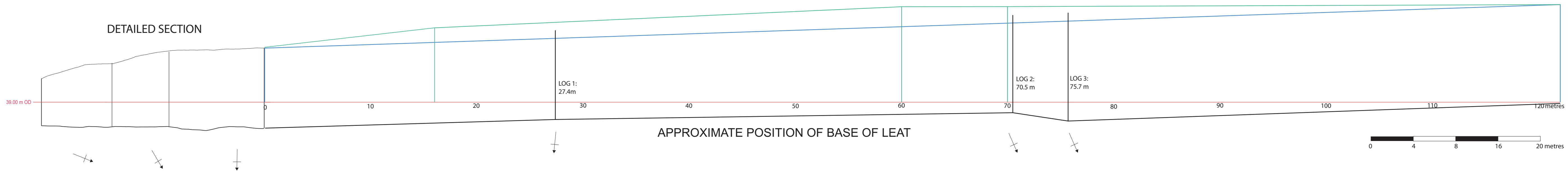


UNIT NUMBER	DESCRIPTION	SEDIMENTARY STRUCTURES	CORRESPONDING UNIT IN DETAILED SECTION	MAX CLAST SIZE (mm)	AVERAGE CLAST SIZE	SORTING	ROUNDEDNESS	CLAST/MATRIX SUPPORTED	OTHER INFORMATION	LOG 1
1	Topsoil with occasional clasts	N/A	A	0	0	N/A	N/A	N/A	Gradational boundary with 2. Roots/rootlets.	
2	Cryoturbated Gravel	Some evidence of frost heave.	D (6?)	200	60	Poor	A/SA. Occasionally SR	N/A	Roots/rootlets. Gradational boundary with 3. Matrix varies from silt to coarse sand.	
3	Grass/ Matrix Supported Bedded Gravel	Some crude sub-horizontal bedding.	E (10?)	300	60	Poor	A/SA. Occasionally SR	Matrix	Some broken clasts. Clasts are predominatntly chert. Matrix varies from silt to coarse sand.	
4	Discontinuous Sand Lens	Bedding parralel to lense.		-	-	Good	-	Matrix	Grades from medium to coarse and then medium sand. Forms unit within 3.	
3	Matrix Supported Bedded Gravel	Some crude sub-horizontal bedding.		100	60	Poor	A/SA. Occasionally SR	Matrix	Matrix is silt to coarse sand.	
5	Discontinuous Silt Clay Lens	Bedding parralel to lense with some iron staining.		-	-	Good	-	Matrix	Forms unit within 3. Sampled for OSL, but sample not processed. Sampled for pollen (Pollen#3).	
3	Matrix Supported Bedded Gravel	Some crude sub-horizontal bedding.		100	60	Poor	A/SA. Occasionally SR	Matrix	Matrix is silt to coarse sand.	
6	Discontinuous Sand Lens	Bedding parralel to lense with some iron staining.		-	-	Medium	-	Matrix	Medium to coarse sand with some clay. OSL Sample Location **KILM03** dated to **309+/-26 K**. Also sampled for Pollen #3.	
3	Matrix Supported Bedded Gravel	Some crude sub-horizontal bedding.		150	60	Poor	A/SA. Occasionally SR	Matrix	Matrix is silt to coarse sand.	
/	*Slumped and vegetatated to base of section*	-	-	-	-	-	-	-	-	

UNIT NUMBER	DESCRIPTION	SEDIMENTARY STRUCTURES	CORRESPONDING UNIT IN DETAILED SECTION	MAX CLAST SIZE (mm)	AVERAGE CLAST SIZE	SORTING	ROUNDEDNESS	CLAST/MATRIX SUPPORTED	OTHER INFORMATION	LOG 2
1	Topsoil with occasional clasts	N/A	A	0	0	N/A	N/A	N/A	Gradational boundary with 4. Roots/rootlets.	
2	Cryoturbated Gravel	Some evidence of frost heave; moreso than in log 1	D (6?)	200	60	Poor	A/SA. Occasionally SR	N/A	Some manganese and iron staining. Matrix varies from silt to coarse sand.	
-	Grass	-	-	-	-	-	-	-	-	
3	Matrix Supported Bedded Gravel	Some possible crude sub-horizontal bedding, but not very convincing and difficult to tell due to vegetation etc.	SLUMPED D?	150	60	Good	A/SA. Occasionally SR	Matrix	Grades from medium to coarse and then medium sand	
4	Discontinuous Sand Lens	-		40	40	Poor	SR	Matrix	Grey silty clay coarsening upwards into sand. Discontinuous lense about 30 cm in length. Sand is stained bright orange and contains occasional sub rounded clasts of ~40mm. OSL Sample Location **KILM01** dated to 154+/-19K.	
3	Matrix Supported Gravel	Some possible crude sub-horizontal bedding, but not very convincing and difficult to tell due to vegetation etc.		150	60	Poor	A/SA. Occasionally SR	Matrix	Matrix is silt to coarse sand.	
/	*Slumped and vegetatated to base of section*	-	-	-	-	-	-	-	-	

UNIT NUMBER	DESCRIPTION	SEDIMENTARY STRUCTURES	CORRESPONDING UNIT IN DETAILED SECTION	MAX CLAST SIZE (mm)	AVERAGE CLAST SIZE	SORTING	ROUNDEDNESS	CLAST/MATRIX SUPPORTED	OTHER INFORMATION	LOG 3
1	Topsoil with occasional clasts	N/A	A	0	0	N/A	N/A	N/A	Gradational boundary with 4. Roots/rootlets.	
2	Silty sand with occasional clasts	Inaccessible - none visible.	D? Not clear.	? Clasts visible, but impossible to tell size.		Moderate	SA	N/A	Inaccessible.	
-	Grass	-	-	-	-	-	-	-	-	
3	Matrix Supported Gravel	Some possible crude sub-horizontal bedding, but not very convincing and difficult to tell due to vegetation etc.	SLUMPED D?	200	50	Poor	A/SA. Occasionally SR	Matrix	Matrix is silt to coarse sand.	
/	*Slumped and vegetatated to base of section*	-	-	-	-	-	-	-	-	

KILMINGTON QUARRY: PROFILE OF SOUTHERN QUARRY FACE SHOWING RELATIONSHIP BETWEEN LOGS 1-3 AND SECTION DRAWN IN DETAIL. LSB.



Ascertaining the levels of KILM03 and KILM01 in Logs 1 and 2 respectively was extremely difficult, as access to the top of the quarry face and along the face was impeded by tree and bush cover, which meant it was not possible to see the staff, or to use the GPS without clearing the area which we did not have permission to do. The heights OD were calculated using two profiles of the top of the quarry edge. One profile of the top of the quarry was generated from GPS measurements as close to the quarry edge as was possible (green lines). The other was created from two points at either end of the section and at the section edge, known to be accurate (blue line). These two profiles differed to a maximum of 4 metres in the easternmost half of the section. The sections were logged at OSL sample locations KILM 03 and KILM 01. These logs were measured from the top of the section, down, with the height of the top of the section being calculated from the profile. The levels of detailed section drawing (which covered KILM06 and KILM05) are accurate and therefore have no error margins.Logs 1 to 3 have a maximum error of plus or minus 2 metres.

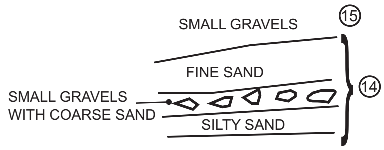
PHOTOGRAPH OF SOUTHERN SECTION AT KILMINGTON QUARRY- NOTE VEGETATION IN FRONT OF AND ONTOP OF FACE. PHOTO BY LSB

PHOTOGRAPHS OF SECTION OF KILMINGTON SOUTHERN QUARRY FACE DRAWN IN DETAIL

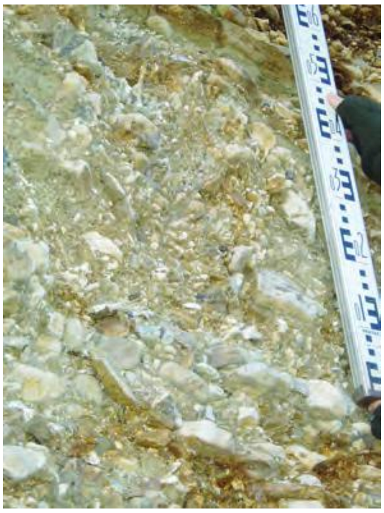
PHOTOGRAPHS BY LSB

SUPPLEMENTARY INFORMATION FOR UNITS IN KILMINGTON DETAILED SECTION

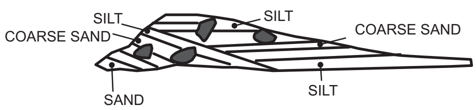
DETAIL OF UNITS (14) & (15) (NOT TO SCALE)



BEDDING IN SILTY SAND,
SMALL GRAVELS AND
COARSE SAND

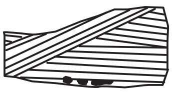


CRYOTURBATION FEATURE IN (9)



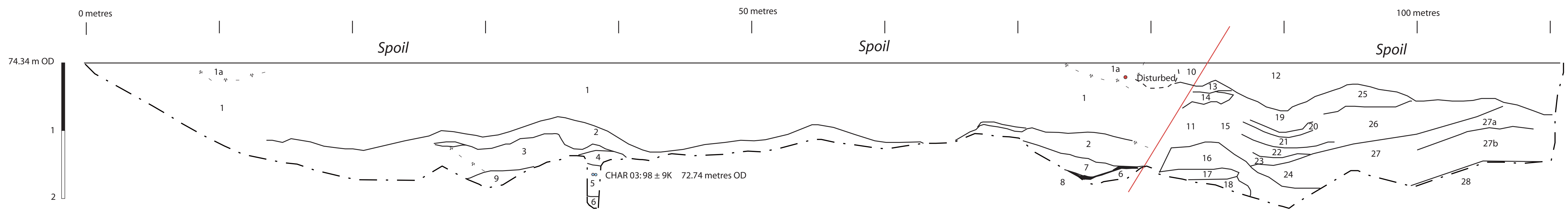
DETAIL OF (18) (NOT TO SCALE)

DETAIL OF (21)
(NOT TO SCALE)
SAMPLED FOR OSL (#KILM06)
AND POLLEN (POLLEN#3)



ALL PHOTOGRAPHS & SKETCHES BY LSB

CHARD JUNCTION QUARRY HODGE DITCH AREA. SECTION THROUGH FIRST TAKE. NORTH FACING EXPOSURE.
GRAVEL ASSOCIATED WITH THE RIVER AXE. RECORDED BY LSB & AGB. DRAWN UP BY LSB 2006.

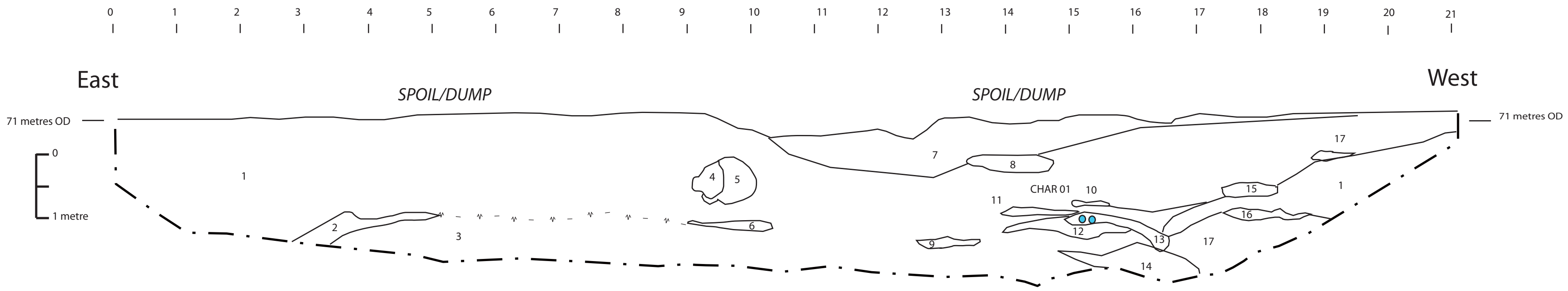


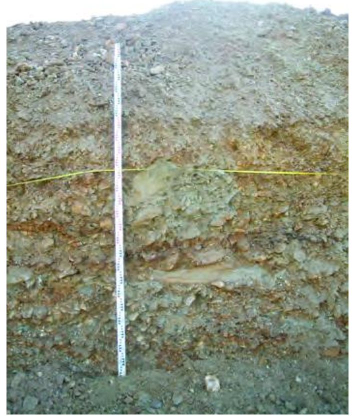
KEY

Field Drain	Uncertain unit boundary	Base of excavation. Not base of units	OSL sample location	Clear boundary within the section

1: Poorly sorted sandy silt and gravel. Matrix supported. Generally no structure, but slight bedding in basal deposits in some patches along the section. No imbrication. Clasts sub-angular to angular. Red brown. Many clasts are vertically orientated. Stones and cobbles. Maximum clast size 150 x 100 mm.
1a: As for 1 but matrix is darker grey. Possible young soil in pit due to quarry activity.
2: As for 1 but slightly better sorted and redder in colour. Dominant small cobbles and small stones. Rounded to sub-angular. Occasion clasts in lower unit are manganese coated.
3: Discontinuous sand lens grading along the section into silty sand channel with festoon incorporation of stones into the sand lens. Iron and manganese discontinuous horizons and flecks.
4: Pink red very poorly sorted angular matrix supported gravel. Matrix is pink sandy silty with ~10% clay. Clasts up to 60 mm. Clear sharp boundary to 5.
5: Sub-horizontally laminated silty fine sand. Shallow wavy laminations. 6 mm to 1 mm. Slight mottling and iron and manganese flecks. Upper 70 mm coarser with bands of fine grit. Sampled for OSL.
6: Gritty clast supported poorly sorted sub angular gravel with small stones to small cobbles. Common manganese coating.
7: Probably corresponds to laminar sands of 5. Extremely poorly sorted matrix supported cobbles in a medium sand with silt and clay. Discontinuous disrupted laminations. Mottled. No further structure.
8: Very strongly indurated iron and manganese pan dipping west.
9: Poorly sorted grit and angular clast supported gravel. Inter-clast matrix is coarse sand and angular grit. No bedding. No imbrication. Occasional manganese stained clasts. Clast size 40 – 80 mm. Angular to sub-angular.
10: As for 1 but matrix more yellow and more sand and grit. Clasts are all angular.
11: Poorly sorted clast supported gravel with occasional cobbles sub-angular to sub-rounded. Matrix, silt clay and abundant coarse sand and grit with small stones. Unit grades into a bedded framework trough structure to the west within 40 cm of the log.
12: Poorly sorted angular gravel. Cobbles. Matrix supported. Red-brown silty fine sand and clay matrix. Possibly ploughed to max depth of 11 cm.
13: Poorly sorted sub-rounded gravely sand with grit. Yellow.
14: Sharp boundary from 13 to mottled well sorted medium to coarse discontinuous grey sand lens with purple sandy clay drape in middle. Occasional small stones
15: Moderately sorted matrix supported fine to medium gravel. Rounded to sub angular. Particularly rich in flint. Lag cobbles at top. Matrix is coarse to medium sand and silt. Clay grey at top and pink at base.
16: Wavy abrupt upper boundary with 15. Well sorted medium sand with sub-horizontal wavy bedding. Occasional rounded dropstones. Sand grey – orange bands.
17: Mixed gravel and grey sand. Very poorly sorted. Sub-angular 20 – 40 mm.
18: Well sorted coarse red sand. Base not reached.
19: Well sorted medium to coarse sand with faint wavy bedding.
20: Red sandy clay. Matrix supported fine gravel dipping to east.
21: Olive green well sorted medium sand with no bedding.
22: Thick mottled grey clay with irregular lower boundary.
23: Well sorted olive medium sand, relatively clean.
24: Bright orange and black clay. Plunging orange staining and fine to medium sand.
25: Well sorted fine gravel 5 – 10 mm. Clast supported sandy grit matrix with weak horizontal bedding and sub-rounded clasts.
26: Very poorly sorted gravels. Sub-angular. No bedding. Gritty sandy matrix.
27 a & b: Sandy clay. Upper orange horizon with iron and manganese mottling and sub-horizontal weak laminations.
28: Gravel. Unobserved.

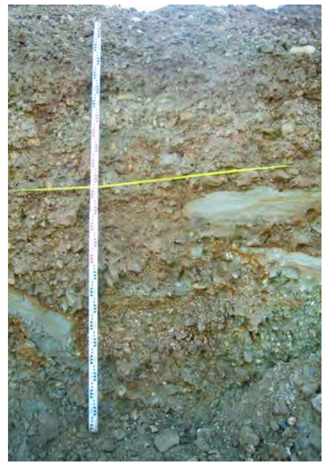
CHARD JUNCTION QUARRY: HODGE DITCH AREA. SECTION THROUGH SECOND TAKE. NORTH FACING EXPOSURE.
POSITIONED NORTH OF THE FIRST TAKE NORTH FACING SECTION DRAWN (ALSO SAMPLED FOR OSL).
RECORDED AND DRAWN BY LSB 2006.





DETAIL OF UNITS 4, 5 & 6.
PHOTOGRAPH LSB 2006.

DETAIL OF SECTION AT OSL
CHAR 01 SAMPLE LOCATION.
PHOTOGRAPH LSB 2006.



DETAIL OF UNITS 15 & 16.
PHOTOGRAPH LSB 2006.

KEY

- - - Uncertain unit boundary	— · — · Base of excavation. Not base of units
——— Unit boundary	• OSL sample location.

1: Matrix supported poorly sorted gravel. Angular to sub-angular. Clast size from grit to 150 mm. Some rounded cobbles. Very crude sub-horizontal bedding. Matrix is grey green and orange red mottled and banded.

2: Discontinuous band of framework gravel. No bedding 200 mm to 2 mm clast size. Poorly sorted.

3: Matrix supported gravel. Massive. Clasts sub-angular and rounded (occasional). Matrix grey clayey silt. No clusters or cryoturbation features noticed or evidence for channels in this unit.

4: Coarse sand and grit bedded with bands of clay lenses ~5 mm thick. Clear upper and lower boundaries, but lateral boundary to 5 is diffuse.

5: Unit 4 grades laterally into 5 which is a matrix supported gravel with a higher degree of matrix than 1. Matrix is medium sand with claly and silt which is olive grey in colour. Chaotic arrangement of clasts. Maximum size is 160 mm, more commonly 50 mm. Manganese flecks in matrix and on clasts.

6: Discontinuous lens of medium to coarse sand. Occasional small manganese flecks and mottled iron staining. Wavy sub-horizontal bedding. Well sorted.

7: Matrix supported gravel with no structure or bedding. Maximum clast size is 100 mm. Matrix is coarse sand or occasionally clayey silt. Matrix is olive grey. Upper 30 cm is more red brown, probably due to spoil on top/quarry activity.

8: As for 7 but with evidence of some sub-horizontal bedding.

9: Probably related to 12. Matrix supported gravel with more iron staining than the overlying unit. Maximum clast size is 120mm to grit. Average size is about 20 mm. Matrix where unstained is olive grey coarse sand.

10: Framework gravel. No clear structure. Poorly sorted. Maximum clast size is 100 mm. Sub-rounded to rounded.

11: Medium sand with some silt. Mottled. Laterally discontinuous lens. Wavy sub-horizontal bedding. Well sorted. Occasional manganese flecks. Iron staining. Clearly related to underlying sand lens but separated from it by lateral wedge of matrix supported gravel.

12: As for 9. Numbered separately due to discontinuity of 9.

13: OSL sample location of CHAR 01 dated to 174 +/- 18 K. Horizontally bedded discontinuous sand lens. Grades from medium sand at the top into coarse sand and then medium sand again at the base. Very occasional manganese flecks. Where it plunges, the bedding follows the plunge.

14: Poorly sorted matrix supported gravel with large clasts of up to 250 mm. Small amounts of grit and occasional quartzite. Angular to sub angular chert. Directly overlain at OSL location by narrow discontinuous band of framework gravel

15: Laterally discontinuous sand lens. Medium sand with some silt. Horizontal bedding. Sub-horizontal iron staining and occasional manganese flecks. Grey to olive green in colour. Probably related to sand lens 13.

16: Graded lens of medium sand clay and silt. Sub-horizontal wavy bedding dipping westward. Clay bands of about 60 mm wide. Varies from white grey to orange to olive grey. Occasional clasts particularly towards the base of about 2 mm to 50 mm. General trend is of medium sand at the base of the unit grading to clay at the top.

17: Clast supported gravel. Maximum size is 200 mm. Angular to sub-angular. Olive green matrix with iron staining.

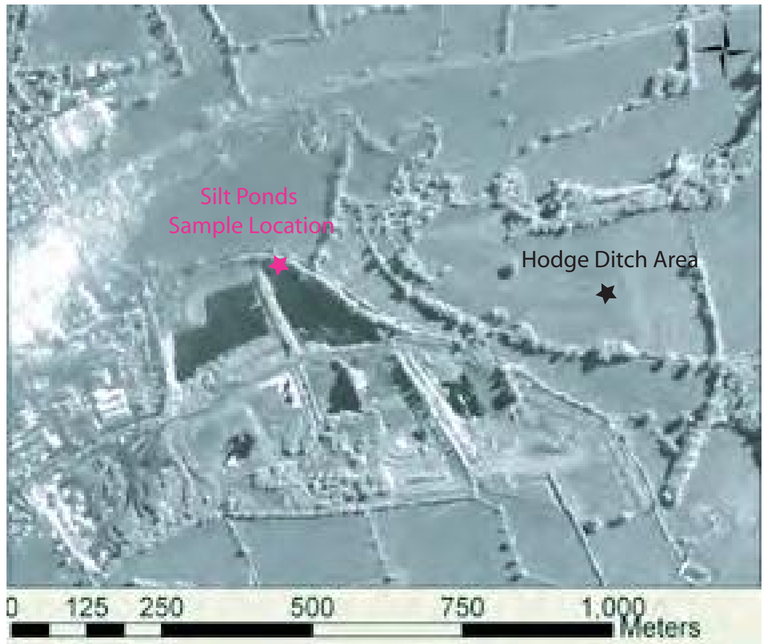
DETAIL OF OSL SAMPLE LOCATIONS AT CHARD JUNCTION

PHOTOGRAPH (LSB 2006) OF SAND FILLED LARGE CHANNEL FEATURE WITH WAVY BEDDING AND ICE CRACK FEATURE. POSITION OF OSL SAMPLE CHAR02 DATED TO 94 ± 9 K ALSO SHOWN. BASE OF OSL SAMPLE LOCATION IS 72.74 METRES OD. SMALL AMOUNT OF OVERLYING UNIT CORRESPONDING TO UNIT 1 OF FIRST TAKE SECTION (POSITION OF OSL SAMPLE CHAR 03) IS VISIBLE OVERLYING THE SAND AND UNDERLYING THE DUMP ON THE TOP OF THIS SECTION.

DETAIL OF OSL SAMPLE CHAR 03 FROM FIRST TAKE NORTH FACING SECTION. DATED TO 98 ± 9 K. LSB 2006.

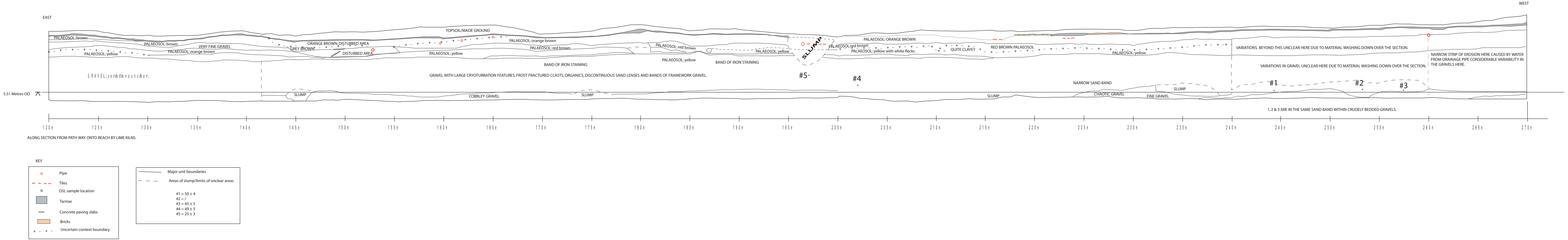
DETAIL OF OSL SAMPLE CHAR 04 DATED TO 274 ± 25 K. SAMPLE TAKEN IN SILT PONDS. LOGGING FORBIDDEN BY QUARRY STAFF DUE TO SAFETY CONCERNS AND VEGETATION COVER. DEPTH ~65.4 METRES OD.
THE SILT PONDS ARE IN A FORMER AREA OF EXTRACTION - NOT THE HODGE DITCH AREA. SEE MAP FOR CLARIFICATION.
PHOTOGRAPHS LSB 2006.

PHOTOGRAPH TO SHOW RELATIVE POSITIONS OF OSL SAMPLE LOCATIONS CHAR 01 - CHAR 03. LSB 2006.

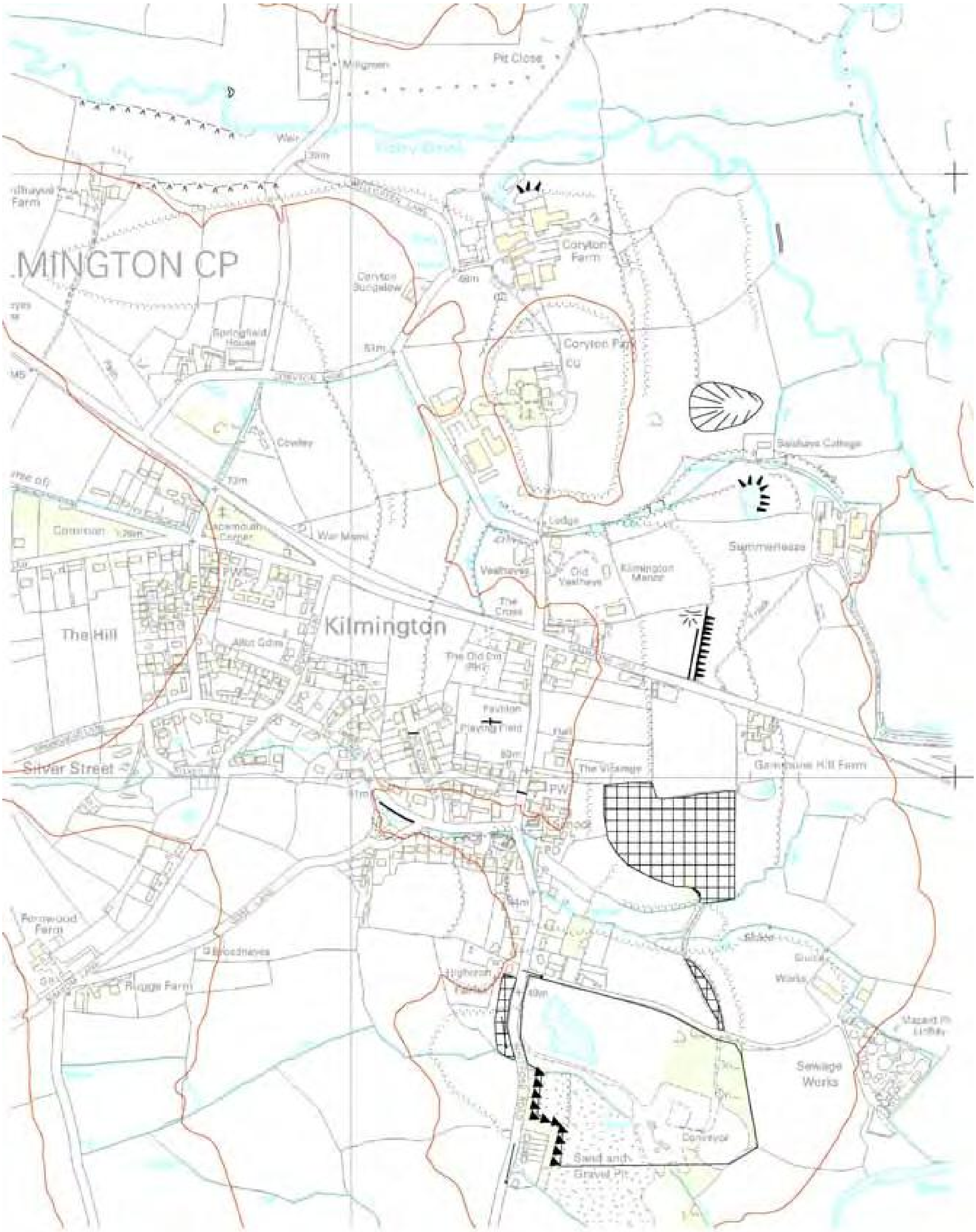


ORTHORECTIFIED AERIAL IMAGE OF CHARD JUNCTION QUARRY SHOWING THE POSITION OF THE HODGE DITCH OSL SAMPLE LOCATIONS RELATIVE TO THE SILT POND SAMPLE LOCATION. GENERATED USING ARC GIS AND DATA PURCHASED FROM BLUESKY.

DONIFORD GRAVELS. SECTION DRAWN BY LSB AND RECORDED BY LSB WITH BM AND JB.



APPENDIX 6: Kilmington Geomorphological Mapping



University of Gloucestershire

Geochronology Laboratories

Optical dating report for the
Palaeolithic Rivers of Southwest Britain ALSF project

to

Prof. A.G. Brown, University of Exeter

Prepared by Dr P.S. Toms, 20th January 2007

English Heritage Centre for Archaeology Optical dating report for the Palaeolithic Rivers of Southwest Britain ALSF project

Dr P.S. Toms[1], Prof. A.G. Brown[2], Dr L.S. Basell[2] and Dr R.T. Hosfield[3]

Summary

This study contributes to the Palaeolithic Rivers of southwest Britain project, which aims to synthesise the archaeological evidence for the Lower and Middle Palaeolithic occupation of southwest Britain. Such evidence is dominated by stone tool assemblages found in secondary context within river terrace deposits. Dating these sediments offers an opportunity to delimit periods of hominin occupation. The purpose of this study is to provide an outline of the temporal range of artefact bearing terraces of the Rivers Axe, Exe, Otter and Washford by means of Optical dating. In total, 26 sediment samples were dated. The reliability of age estimates was assessed on the basis of analytical acceptability and, where possible, the degree of age convergence from samples of divergent dosimetry obtained from equivalent stratigraphic units. It is surmised that the Axe was depositing at intervals between at least 86 and 401 ka (MIS 5 to 10), the Exe before 10 ka and perhaps further back than 86 ka (MIS >1 to>5), the Otter before 66 ka and by at least 209 ka (MIS >3 to 7) and the Washford at intervals between at least 22 and 71 ka (MIS 2 to 4).

Keywords

Optical dating, Fluvial Terrace, Palaeolithic

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1.0 Introduction

This study contributes to the Palaeolithic Rivers of southwest Britain (PRoSWeB) project, funded through the Aggregates Levy sustainability Fund administered by English Heritage (EH project number: 3847MAIN). The aim of ProSWeB is to synthesise the archaeological evidence for the Lower and Middle Palaeolithic occupation of southwest Britain (c. 500,000–40,000 BP). The majority of evidence for hominin presence within this period consists of assemblages of stone tools, entrained by ancient rivers and archived within terrace deposits. Through dating these secondary contexts, the timing of occupation can be delimited. The aim of this study is to provide the first estimates of the chronological spread in residual deposits of the proto Axe, Exe, Otter and Washford rivers, within which artefacts are dispersed. Optical dating is used as the chronometer. This investigation builds on the earlier luminescence study of Toms *et al*. (2005) at Broom on deposits of the River Axe that were optically dated to Marine Isotope Stage (MIS) 7 to >MIS 9 (195 ka to >297ka).

2.0 Optical dating: Mechanisms and principles

Upon exposure to ionising radiation, electrons within the crystal lattice of insulating minerals are displaced from their atomic orbits. Whilst this dislocation is momentary for most electrons, a portion of charge is redistributed to meta-stable sites (traps) within the crystal lattice. In the absence of significant optical and thermal stimuli, this charge can be stored for extensive periods. The quantity of charge relocation and storage relates to the magnitude and period of irradiation. When the lattice is optically or thermally stimulated, charge is evicted from traps and may return to a vacant orbit position (hole). Upon recombination with a hole, an electron's energy can be dissipated in the form of light generating crystal luminescence providing a measure of dose absorption.

Herein, quartz is segregated for dating. The utility of this minerogenic dosimeter lies in the stability of its datable signal over the mid to late Quaternary period, predicted through isothermal decay studies (e.g. Smith *et al*., 1990; retention lifetime 630 Ma at 20℃) and evidenced by optical age estimates concordant with independent chronological controls (e.g. Murray and Olley, 2002) This stability is in contrast to the anomalous fading of comparable signals commonly observed for other ubiquitous sedimentary minerals such as feldspar and zircon (Wintle, 1973; Templer, 1985; Spooner, 1993)

Optical age estimates of sedimentation (Huntley *et al*., 1985) are premised upon reduction of the minerogenic time dependent signal (Optically Stimulated Luminescence, OSL) to zero through exposure to sunlight and, once buried, signal reformulation by absorption of litho- and cosmogenic radiation. The signal accumulated post burial acts as a dosimeter recording total dose absorption, converting to a chronometer by estimating the rate of dose absorption quantified through the assay of radioactivity in the surrounding lithology and streaming from the cosmos.

$$\text{Age} = \frac{\text{Mean Equivalent Dose } (D_e, \text{Gy})}{\text{Mean Dose Rate } (D_r, \text{Gy.ka}^{-1})}$$

Aitken (1998) and Bøtter-Jensen et al. (2003) offer a detailed review of optical dating.

3.0 Sample Collection and Preparation

Twenty five conventional sediment samples – those located within matrix-supported units composed predominantly of sand and silt were collected in daylight from sections by means of opaque plastic tubing (150x45 mm) forced into each face or carved as lithified blocks (75x75x50 mm). In addition one non-conventional sample (GL06035), located within a clast-supported unit, was collected as an aggregated mass (500x500x250 mm). In order to attain an intrinsic metric of reliability and where possible, multiple samples were obtained from stratigraphically equivalent units targeting positions likely divergent in dosimetry on the basis of textural and colour differences (see section 8.0). Each sample was wrapped in cellophane and parcel tape in order to preserve moisture content and integrity until ready for laboratory preparation. For each sample, an additional *c* 100 g of sediment was collected for laboratory-based assessment of radioactive disequilibrium. The locations of the optical dating samples are shown within Table 1 and Fig. i.

To preclude optical erosion of the datable signal prior to measurement, all samples were prepared under controlled laboratory illumination provided by Encapsulite RB-10 (red) filters. To isolate that material potentially exposed to daylight during sampling, sediment located within 20 mm of each tube-end or the outermost 10 mm of each block face was removed.

The remaining sample was dried and then sieved. Depending upon each samples modal grain size, quartz within the fine sand (63-90 μm, 90-125 μm, 125-180 μm) fraction was then segregated (Table 1). Samples were subjected to acid and alkaline digestion (10% HCl, 15% H_2O_2) to attain removal of carbonate and organic components respectively.

A further acid digestion in HF (40%, 60 mins for 125-180 μm; 40%, 40 mins for 90-125 μm; 20% 15 mins for 63-90 μm) was used to etch the outer 10-15 μm layer affected by α radiation and degrade each samples' feldspar content. During HF treatment, continuous magnetic stirring is used to effect isotropic etching of grains. 10% HCl was then added to remove acid soluble fluorides. Each sample was dried, resieved and quartz isolated from the remaining heavy mineral fraction using a sodium polytungstate density separation at 2.68g.cm^{-3}. 12 multi-grain aliquots (*c*. 3-6 mg) of quartz from each sample were then mounted on aluminium discs for determination of D_e values.

All drying was conducted at 40°C to prevent thermal erosion of the signal. All acids and alkalis were Analar grade. All dilutions (removing toxic-corrosive and non-minerogenic luminescence-bearing substances) were conducted with distilled water to prevent signal contamination by extraneous particles.

4.0 Acquisition and accuracy of D_e value

All minerals naturally exhibit marked inter-sample variability in luminescence per unit dose (sensitivity). Therefore, the estimation of D_e acquired since burial requires calibration of the natural signal using known amounts of laboratory dose. D_e values were quantified using a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2000; 2003) facilitated by a Risø TL-DA-15 irradiation-stimulation-detection system (Markey *et al* 1997; Bøtter-Jensen *et al* 1999). Within this apparatus, optical signal stimulation of each sample was provided by one of two light sources; an assembly of blue diodes (5 packs of 6 Nichia NSPB500S), filtered to 470±80 nm conveying 15 mW.cm^{-2} using a 3 mm Schott GG420 positioned in front of each diode pack or a 150 W tungsten halogen lamp, filtered to a broad blue-green light, 420-560 nm conveying 16 mWcm^{-2}, using three 2 mm Schott GG420 and a broadband interference filter. Infrared (IR) stimulation, provided by 6 IR diodes (Telefunken TSHA 6203) stimulating at 875±80nm delivering ~5 mW.cm^{-2}, was used to indicate the presence of contaminant feldspars (Hütt *et al*., 1988). Stimulated photon emissions from quartz aliquots are in the ultraviolet (UV) range and were filtered from stimulating photons by 7.5 mm HOYA U-340 glass and detected by an EMI 9235QA photomultiplier fitted with a blue-green sensitive bialkali photocathode. Aliquot irradiation was conducted using a 1.48 GBq $^{90}Sr/^{90}Y$ β source calibrated for multi-grain aliquots of each isolated quartz fraction against the 'Hotspot 800' ^{60}Co γ source located at the National Physical Laboratory (NPL), UK.

SAR by definition evaluates D_e through measuring the natural signal (Fig. 1) of a single aliquot and then regenerating that aliquot's signal by using known laboratory doses to enable calibration. For each aliquot, at least 4 different regenerative-doses were administered so as to image dose response. D_e values for each aliquot were then interpolated, and associated counting and fitting errors calculated, by way of exponential or exponential plus linear regression (Fig. 1).

Weighted (geometric) mean D_e values were calculated, given sufficient mass, from 12 aliquots using the central age model outlined by Galbraith *et al.* (1999) and are quoted at 1σ confidence. The accuracy with which D_e equates to total absorbed dose and that dose absorbed since burial is assessed. The former can be considered a function of laboratory factors, the latter, one of environmental issues. Diagnostics were deployed to estimate the influence of these factors and criteria instituted to optimise the accuracy of D_e values.

4.1 Laboratory Factors

4.1.1 Feldspar contamination

The propensity of feldspar signals to fade and underestimate age, coupled with their higher sensitivity relative to quartz makes it imperative to qualify feldspar contamination. At room temperature, feldspars generate a signal (IRSL) upon exposure to IR whereas quartz does not (Fig. 1). The feldspar index (Table 1) was used to evaluate the presence of this contaminant. A regenerative-dose equivalent in magnitude to the mean D_e value of a sample was administered to aliquots and IR response measured. The feldspar index is a ratio of (initial 0.2 s) measured IRSL to 3σ background IRSL; the presence of feldspar is confirmed where this index exceeds unity. The source of feldspar contamination is rarely routed in sample preparation; it predominantly results from the occurrence of feldspars as inclusions within quartz. Where significant feldspar content was detected, samples were immersed in 35% H_2SiF_6 for two weeks in an attempt to etch inclusions that may be partially exposed at grain surfaces. Samples were then resieved. The influence upon D_e of any remaining contamination was estimated by two methods. The D_e value was measured from 12 aliquots; if feldspar contamination had been reduced and the original content affected the D_e value then a statistically greater D_e might evolve from that sub-sample that had undergone additional acid digestion. The repeat dose ratio of OSL to post-IR OSL was also quantified (Duller, 2003). The signal from feldspars contributing to OSL can be depleted by prior exposure to IR. If the addition to OSL by feldspars is significant, then the repeat dose ratio of OSL to post-IR OSL should be greater than unity. Samples from the River Otter (GL06045 to GL06049) exhibited minor to substantial feldspar contamination and were the subject of these further tests. Each sample exhibited an insignificant adjustment in mean D_e value and OSL to post-IR OSL repeat dose ratios were statistically consistent. There was limited depletion of IR signal in response to a standard regenerative dose, rendering the comparison of mean D_e values of little utility. Given the lack of a significant difference between OSL and post-IR OSL signals and that there appears little relationship between the magnitude of IRSL and age suggests for these samples the presence of feldspars has limited influence upon D_e values. These terrace samples come from two sites separated by several terraces. The similarity of their optical age estimates suggests either the age estimates are anomalous at one/both sites or that the terrace forming events on the River Otter operated over finite periods, indistinguishable by Optical dating.

4.1.2 Preheating

Preheating aliquots between irradiation and optical stimulation is necessary to ensure comparability between natural and laboratory-induced signals. However, the multiple irradiation and preheating steps that are required to define single-aliquot regenerative-dose response leads to signal sensitisation, rendering calibration of the natural signal inaccurate. The SAR protocol (Murray and Wintle, 2000; 2003) enables this sensitisation to be monitored and corrected using a test dose, here set at *c* 20 Gy preheated to 220°C for 10s, to track signal sensitivity between irradiation-preheat steps. However, the accuracy of sensitisation correction for both natural and laboratory signals can be preheat dependent. Three diagnostics were used to assess the optimal preheat temperature for accurate correction and calibration.

Irradiation-preheat cycling (Fig. 2) quantifies the preheat dependence of sensitisation correction for laboratory-induced signals. If sensitisation is accurately corrected, then the same regenerative-dose should yield an equivalent sensitivity corrected value irrespective of the number of times it is applied and its associated signal measured. The ratio of subsequent to initial corrected regenerative-dose signals should be statistically concordant with unity. Alternatively, this ratio may differ from unity yet attain consistency after one or more cycles evidencing accurate sensitivity correction exists if the sample is primed by irradiation-preheat cycles. For this diagnostic, 18 aliquots were divided into sets of 3 and assigned a 10 s preheat between 180°C and 280°C.

D_e preheat dependence (Fig. 3) quantifies the combined effects of thermal transfer and sensitisation on the natural signal. Insignificant adjustment in D_e values in response to differing preheats may reflect limited influence of these effects. Samples generating D_e values <10Gy and exhibiting a systematic, statistically significant adjustment in D_e value with increasing preheat temperature may indicate the presence of significant thermal transfer; in such instances low temperature (<220°C) preheats may provide the apposite measure of D_e. For this diagnostic, the D_e value of each of the same 18 aliquots and their assigned preheat was assessed.

Dose Recovery (Fig. 4) attempts to replicate the above diagnostic, yet provide improved resolution of thermal effects through removal of variability induced by heterogeneous dose absorption in the environment, using a precise lab dose to simulate natural dose. The ratio between the applied dose and recovered D_e value should be statistically concordant with unity. For this diagnostic, a further 6 aliquots were each assigned a 10 s preheat between 180°C and 280°C.

That preheat treatment fulfilling the criterion of accuracy for all three diagnostics was selected to refine the final D_e value from a further 9 aliquots. Further thermal treatments, prescribed by Murray and Wintle (2000; 2003), were applied to optimise accuracy and precision. Optical stimulation occured at 125ºC in order to minimise effects associated with photo-transferred thermoluminescence and maximise signal to noise ratios. Inter-cycle optical stimulation was conducted at 280°C to minimise recuperation.

4.1.3 Irradiation

For all samples having D_e values in excess of 100 Gy, matters of signal saturation and laboratory irradiation effects are of concern. With regards the former, the rate of signal accumulation generally adheres to a saturating exponential form and it is this that limits the precision and accuracy of D_e values for samples having absorbed large doses. For such samples, the functional range of D_e interpolation is defined from log-linear plots of dose response (Fig. 1). Within these plots, the maximum D_e value is delimited by the cessation of statistically significant increases in signal response.

Laboratory irradiation effects may evolve from the contrasting rates of natural dose exposure and the calibrating laboratory dose, the latter delivered to each aliquot at 9 orders of magnitude faster than the former. Bailey (2004) has suggested that for doses in excess of ~40 Gy an overestimation of age may arise due to competing mechanisms of signal accumulation within the crystal lattice of quartz. Bailey (2004) suggests this effect can be countered by using pulsed irradiation-preheats (10 Gy, 240°C cycles) rather than single large doses. Dose response to this revised irradiation procedure was quantified for a portion of the sample suite having D_e >40 Gy (Fig. 1). Where pulsed irradiation D_e values are significantly less than those generated from continuous irradiation, Bailey (2004) advises the mean D_e generated from the former be used to define age. However, of those samples examined only two samples (GL06001 & GL06047) exhibited a significant contrast in dose response. Of these, GL06047 did not perform as predicted, producing a higher D_e value from pulsed rather than continuous irradiation. Given the embryonic stages of pulsed irradiation research and the lack of distinction between continuous and pulsed dose responses in this study, the D_e value of the remainder of the sample suite was derived from continuous irradiation.

4.1.4 Internal consistency

Quasi-radial plots (Fig. 5; *cf* Galbraith, 1990) are used to illustrate inter-aliquot D_e variability for natural and regenerated signals. D_e values are standardised relative to the central D_e value for natural signals and applied dose for regenerated signals. D_e values are described as overdispersed when >5% lie beyond $\pm 2\sigma$ of the standardising value; resulting from a heterogeneous absorption of burial dose and/or response to the SAR protocol. For multi-grain aliquots, overdispersion for natural signals does not necessarily imply inaccuracy. However where overdispersion is observed for regenerated signals, the age estimate from that sample should be accepted tentatively.

4.2 Environmental factors

4.2.1 Incomplete zeroing

Post-burial OSL signals residual of pre-burial dose absorption can result where pre-burial sunlight exposure is limited in spectrum, intensity and/or period, leading to age overestimation. This effect is particularly acute for material eroded and redeposited sub-aqueously (Olley *et al.*, 1998, 1999; Wallinga, 2002) and exposed to a burial dose of <20 Gy (e.g. Olley *et al.*, 2004) and can have some influence in sub-aerial contexts but is rarely of consequence where aerial transport has occurred.

Within single-aliquot regenerative-dose optical dating there are two diagnostics of partial resetting (or bleaching); signal analysis (Agersnap-Larsen *et al.*, 2000; Bailey *et al.*, 2003) and inter-aliquot D_e distribution studies (Murray *et al.*, 1995).

Within this study, signal analysis is used to quantify the change in D_e value with respect to optical stimulation time for multi-grain aliquots. This exploits the existence of traps within minerogenic dosimeters that bleach with different efficiency for a given wavelength of light to verify partial bleaching. D_e (t) plots (Fig. 6; Bailey *et al.*, 2003) are constructed from separate integrals of signal decay as laboratory optical stimulation progresses. A statistically significant increase in natural D_e (t) is indicative of partial bleaching assuming three conditions are fulfilled. Firstly, that a statistically significant increase in D_e (t) is observed when partial bleaching is simulated within the laboratory. Secondly, that there is no significant rise in D_e (t) when full bleaching is simulated. Finally, there should be no significant augmentation in D_e (t) when zero dose is simulated. Where partial bleaching is detected, the age derived from the sample should be considered a maximum estimate only. However, the utility of signal analysis is strongly dependent upon a samples pre-burial experience of sunlight's spectrum and its residual to post-burial signal ratio. Given in the majority of cases, the spectral exposure history of a deposit is uncertain, the absence of an increase in natural D_e (t) does not necessarily testify to the absence of partial bleaching.

Although not investigated in this study, the insensitivities of multi-grain single-aliquot signal analysis may be circumvented by inter-aliquot D_e distribution studies. This analysis uses aliquots of single sand grains to quantify inter-grain D_e distribution. At present, it is contended that asymmetric inter-grain D_e distributions are symptomatic of partial bleaching and/or pedoturbation (Murray *et al.*, 1995; Olley *et al.*, 1999; Olley *et al.*, 2004; Bateman *et al.*, 2003). For partial bleaching at least, it is further contended that the D_e acquired during burial is located in the minimum region of such ranges. The mean and breadth of this minimum region is the subject of current debate, as it is additionally influenced by heterogeneity in microdosimetry, variable inter-grain response to SAR and residual to post-burial signal ratios. Presently, the apposite measure of age is that defined by the D_e interval delimited by the minimum and central age models of Galbraith *et al*. (1999).

4.2.2 Turbation

The accuracy of sedimentation ages can further be controlled by post-burial trans-strata grain movements forced by pedo- or cryoturbation. Berger (2003) contends pedogenesis prompts a reduction in the apparent sedimentation age of parent material through bioturbation and illuviation of younger material from above and/or by biological recycling and resetting of the datable signal of surface material. Berger (2003) proposes that the chronological products of this remobilisation are A-horizon age estimates reflecting the cessation of pedogenic activity, Bc/C-horizon ages delimiting the maximum age for the initiation of pedogenesis with estimates obtained from Bt-horizons providing an intermediate age 'close to the age of cessation of soil development'. Singhvi *et al.* (2001), in contrast, suggest that B and C-horizons closely approximate the age of the parent material, the A-horizon, that of the 'soil forming episode'. At present there is no post-sampling mechanism for the direct detection of and correction for post-burial sediment remobilisation. However, intervals of palaeosol evolution can be delimited by a maximum age derived from parent material and a minimum age obtained from a unit overlying the palaeosol. Pedogenic effects are not considered significant within this study owing to the lack of visible soil development and dominance of clast-supported units. Inaccuracy forced by cryoturbation may be bidirectional, heaving older material upwards or drawing younger material downwards into the level to be dated. All but one of the samples in this study was obtained from matrix-supported material; these sediments exhibited little evidence of cryogenic deformation.

5.0 Acquisition and accuracy of D_r value

Lithogenic D_r values were defined through measurement of U, Th and K radionuclide concentration and conversion of these quantities into β and γ D_r values (Table 1). β contributions were estimated from sub-samples by Neutron Activation Analysis (NAA) delivered by Becquerel Canada. γ dose rates were estimated from *in situ* NaI gamma spectrometry or, where direct measurements were not possible, laboratory-based Ge gamma spectrometry of sub-samples. *In situ* measurements were conducted using an EG&G μNomad portable NaI gamma spectrometer (calibrated using the block standards at RLAHA, University of Oxford); these reduce uncertainty relating to potential heterogeneity in the γ dose field surrounding each sample. Estimates of radionuclide concentration were converted into D_r values (Adamiec and Aitken, 1998), accounting for D_r modulation forced by grain size (Mejdahl, 1979) and present moisture content (Zimmerman, 1971). Cosmogenic D_r values are calculated on the basis of sample depth, geographical position and matrix density (Prescott and Hutton, 1994).

The spatiotemporal validity of D_r values can be considered as five variables. Firstly, age estimates devoid of *in situ* γ spectrometry data should be accepted tentatively if the sampled unit is heterogeneous in texture or if the sample is located within 300 mm of strata consisting of differing texture and/or mineralogy. However, where samples are obtained throughout a vertical profile, consistent values of γ D_r based solely on, for example, NAA may evidence the homogeneity of the γ field and hence accuracy of γ D_r values. Secondly, disequilibrium can force temporal instability in U and Th emissions. The impact of this infrequent phenomenon (Olley *et al.*, 1996) upon age estimates is usually insignificant given their associated margins of error, however this effect is pronounced for at least one sample (GL06034) in this study (Fig. 7). For this sample, ongoing or recent migration of U from the underlying Shute sandstone has generated disequilibrium and a D_r significantly higher than that that may have dominated since deposition of GL06034 producing an age underestimate for this sample. Thirdly, pedogenically-induced variations in matrix composition of B and C-horizons, such as radionuclide and/or mineral remobilisation, may alter the rate of energy emission and/or absorption. If D_r is invariant through a dated profile and samples encompass primary parent material, then element mobility is likely limited in effect. In this study, there is limited evidence of pedogenesis for any unit sampled. Fourthly, spatiotemporal detractions from present moisture content are difficult to assess directly, requiring knowledge of the magnitude and timing of differing contents. However, the maximum influence of moisture content variations can be delimited by recalculating D_r for minimum (zero) and maximum (saturation) content. Finally, temporal alteration in the thickness of overburden alters cosmic D_r values. Cosmic D_r often forms a negligible portion of total D_r. It is possible to quantify the maximum influence of overburden flux by recalculating D_r for minimum (zero) and maximum (surface sample) cosmic D_r.

6.0 Estimation of Age

Age estimates reported in Table 1 provide an estimate of sediment burial period based on mean D_e and D_r values and their associated analytical uncertainties. Uncertainty in age estimates is reported as a product of systematic and experimental errors, with the magnitude of experimental errors alone shown in parenthesis (Table 1). Probability distributions indicate the inter-aliquot variability in age (Fig. 8). The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness is illustrated in Fig. 8. Where uncertainty in these parameters exists this age range may prove instructive, however the combined extremes represented should not be construed as preferred age estimates.

7.0 Analytical uncertainty

All errors are based upon analytical uncertainty and quoted at 1σ confidence. Error calculations account for the propagation of systematic and/or experimental (random) errors associated with D_e and D_r values.

For D_e values, systematic errors are confined to laboratory β source calibration. Uncertainty in this respect is that combined from the delivery of the calibrating γ dose (1.2%; NPL, pers. comm.), the conversion of this dose for SiO_2 using the respective mass energy-absorption coefficient (2%; Hubbell, 1982) and experimental error, totalling 3.5%. Mass attenuation and bremsstrahlung losses during γ dose delivery are considered negligible. Experimental errors relate to D_e interpolation using sensitisation corrected dose responses. Natural and regenerated sensitisation corrected dose points (S_i) are quantified by,

$$S_i = (D_i - x.L_i) / (d_i - x.L_i) \qquad \textbf{Eq.1}$$

where D_i = Natural or regenerated OSL, initial 0.2 s
L_i = Background natural or regenerated OSL, final 5 s
d_i = Test dose OSL, initial 0.2 s
x = Scaling factor, 0.08

The error on each signal parameter is based on counting statistics, reflected by the square-root of measured values. The propagation of these errors within Eq. 1 generating σS_i follows the general formula given in Eq. 2. σS_i are then used to define fitting and interpolation errors within linear or exponential regressions (Green and Margerison, 1978; Ixaru et al., 2004).

For D_r values, systematic errors accommodate uncertainty in radionuclide conversion factors (5%), β attenuation coefficients (5%), matrix density (0.20 $g.cm^{-3}$), vertical thickness of sampled section (specific to sample collection device), saturation moisture content (3%), moisture content attenuation (2%), burial moisture content (25% relative, unless direct evidence exists of the magnitude and period of differing content), NaI gamma spectrometer calibration (3%) and/or NAA (2%). Experimental errors are associated with radionuclide quantification for each sample by gamma spectrometry and/or NAA.

The propagation of these errors through to age calculation is quantified using the expression,

$$\sigma y (\delta y/\delta x) = (\Sigma ((\delta y/\delta x_n).\sigma x_n)^2)^{1/2} \qquad \textbf{Eq. 2}$$

where y is a value equivalent to that function comprising terms x_n and where σy and σx_n are associated uncertainties.

Errors on age estimates are presented as combined systematic and experimental errors and experimental errors alone. The former (combined) error should be considered when comparing luminescence ages herein with independent chronometric controls. The latter assumes systematic errors are common to luminescence age estimates generated by means equal to those detailed herein and enable direct comparison with those estimates.

8.0 Intrinsic Assessment of Reliability

Here, intrinsic assessment of reliability is divided into two categories, analytical acceptability and inference. Table 2 details the analytical acceptability of age estimates evolved in this study, drawn principally from diagnostics illustrated in Figs. 1 to 7 and detailed in sections 4.0 to 5.0. The inference of reliability comes from the level of intra-site stratigraphic consistency and the convergence of age estimates from stratigraphically equivalent units of divergent dosimetry.

All but one sample (GL06001; Kilmington, River Axe) generated age estimates consistent with their relative stratigraphic position at each site. GL06001 may have been obtained from a slipped deposit that is in effect stratigraphically younger than samples from the lower units. Fig. 9 shows D_e:D_r plots (Toms *et al.*, 2005); the gradient of lines from the origin to a data point or through data points of samples from stratigraphically equivalent units represents the age of the sample. The utility of D_e:D_r plots is two-fold. Firstly, they readily illustrate the spread of luminescence ages. Secondly, they demonstrate the reliability of age estimates from stratigraphically equivalent units where there is significant bivariation in D_e and D_r yet statistical concordance of data points with the mean isochron (i.e. a line regressed through the data points to the origin). Hierarchically, as intrinsic measures of reliability, comparable ages derived from stratigraphically equivalent units of differing D_r supersede analytical acceptability even where the latter is questionable. The D_e:D_r plot for Chard (River Axe) demonstrates the reliability of the ages from the upper unit where a significant variation in D_r was recorded. It is possible that the D_e:D_r plot of data from the lower unit at Kilmington substantiates the accuracy of ages from this level, however the stratigraphic equivalence of these samples is unclear.

9.0 Summary

This study provides the first estimates of the chronological spread in residual deposits of the proto Axe, Exe, Otter and Washford rivers (incorporating data from Broom, River Axe; Toms *et al.*, 2005). The age envelopes in Fig. 10 indicate the Axe was depositing at intervals between at least 86 and 401 ka (MIS 5 to 10), the Exe before 10 ka and perhaps further back than 86 ka (MIS >1 to>5), the Otter before 66 ka and by at least 209 ka (MIS >3 to 7) and the Washford at intervals between at least 22 and 71 ka (MIS 2 to 4).

Field Code	Lab Code	Location	Overburden (m)	Grain size (µm)	Moisture content	NaI γ-spectrometry (in situ)			γ D_r (Gy.ka^{-1})	Neutron Activation Analysis ([†]or Ge γ-spectrometry)			α D_r (Gy.ka^{-1})	β D_r (Gy.ka^{-1})	Cosmic D_r (Gy.ka^{-1})	Total D_r (Gy.ka^{-1})	Feldspar index	Preheat (°C for 10s)	D_e (Gy)	Age (ka)
						K (%)	Th (ppm)	U (ppm)		K (%)	Th (ppm)	U (ppm)								
DON01	GL05058	51°N, 3°W, 7m	6.3	125-180	0.15 ± 0.04	1.45 ± 0.03	6.40 ± 0.22	3.32 ± 0.15	1.03 ± 0.04	1.75 ± 0.07	9.84 ± 0.42	3.34 ± 0.15	-	1.58 ± 0.14	0.08 ± 0.01	2.70 ± 0.14	12.0	260	136.7 ± 8.2	50 ± 4 (3)
DON02	GL05059	51°N, 3°W, 7m	6.3	63-90	0.17 ± 0.04	1.24 ± 0.03	6.52 ± 0.23	2.94 ± 0.15	0.94 ± 0.03	1.77 ± 0.08	8.01 ± 0.35	2.30 ± 0.12	-	1.47 ± 0.14	0.08 ± 0.01	2.49 ± 0.15	0.4	240	162.5 ± 9.1	65 ± 5 (4)
DON03	GL05060	51°N, 3°W, 7m	6.6	125-180	0.18 ± 0.04	1.41 ± 0.03	6.70 ± 0.21	2.87 ± 0.14	0.99 ± 0.03	2.96 ± 0.12	11.28 ± 0.48	3.07 ± 0.14	-	2.23 ± 0.22	0.08 ± 0.01	3.29 ± 0.22	5.7	240	148.4 ± 12.9	45 ± 5 (4)
DON04	GL05061	51°N, 3°W, 7m	5.0	125-180	0.18 ± 0.04	1.42 ± 0.03	7.28 ± 0.22	2.62 ± 0.13	0.99 ± 0.03	2.51 ± 0.11	9.80 ± 0.42	2.48 ± 0.12	-	1.88 ± 0.19	0.09 ± 0.01	2.97 ± 0.19	1.8	260	145.7 ± 12.6	49 ± 5 (5)
DON05	GL05062	51°N, 3°W, 7m	4.0	125-180	0.16 ± 0.04	1.53 ± 0.03	8.13 ± 0.22	2.84 ± 0.14	1.08 ± 0.04	3.17 ± 0.13	13.37 ± 0.56	2.97 ± 0.14	-	2.46 ± 0.23	0.11 ± 0.01	3.65 ± 0.23	2.4	260	89.8 ± 9.0	25 ± 3 (3)
PHAY01	GL05063	51°N, 4°W, 40m	0.5	125-180	0.17 ± 0.04	1.29 ± 0.03	6.12 ± 0.21	3.11 ± 0.14	0.96 ± 0.03	2.07 ± 0.09	7.57 ± 0.33	2.25 ± 0.11	-	1.59 ± 0.15	0.20 ± 0.02	2.74 ± 0.16	0.7	280	116.6 ± 11.9	43 ± 5 (5)
PHAY02	GL05064	51°N, 4°W, 40m	0.3	125-180	0.16 ± 0.04	1.16 ± 0.03	5.61 ± 0.21	3.13 ± 0.15	0.90 ± 0.03	2.16 ± 0.09	7.57 ± 0.33	2.47 ± 0.12	-	1.68 ± 0.16	0.20 ± 0.03	2.78 ± 0.16	0.8	260	121.8 ± 8.0	44 ± 4 (3)
KILM01	GL06001	51°N, 3°W, 40m	5.0	125-180	0.18 ± 0.05	0.49 ± 0.02	3.73 ± 0.13	1.69 ± 0.09	0.49 ± 0.02	2.10 ± 0.09	10.26 ± 0.44	2.85 ± 0.14	-	1.68 ± 0.17	0.10 ± 0.01	2.27 ± 0.17	19.0	260	350.2 ± 35.8	154 ± 19 (18)
KILM03	GL06002	51°N, 3°W, 40m	5.0	125-180	0.16 ± 0.04	0.51 ± 0.01	2.83 ± 0.12	1.10 ± 0.07	0.38 ± 0.02	1.33 ± 0.06	6.14 ± 0.27	1.56 ± 0.09	-	1.08 ± 0.10	0.10 ± 0.01	1.55 ± 0.10	6.2	260	480.5 ± 26.6	309 ± 26 (21)
KILM05	GL06003	51°N, 3°W, 40m	2.0	125-180	0.14 ± 0.03	0.57 ± 0.02	3.49 ± 0.16	1.20 ± 0.10	0.44 ± 0.02	1.52 ± 0.07	8.62 ± 0.37	2.42 ± 0.12	-	1.36 ± 0.11	0.15 ± 0.01	1.95 ± 0.12	16.0	260	348.7 ± 28.3	179 ± 18 (16)
KILM06	GL06004	51°N, 3°W, 40m	4.0	125-180	0.06 ± 0.01	0.38 ± 0.02	1.85 ± 0.13	0.87 ± 0.09	0.28 ± 0.01	0.62 ± 0.03	2.07 ± 0.11	0.52 ± 0.04	-	0.53 ± 0.04	0.11 ± 0.01	0.92 ± 0.04	8.8	240	250.6 ± 20.5	273 ± 26 (22)
CHAR01	GL06010	51°N, 3°W, 80m	4.3	125-180	0.16 ± 0.04	0.36 ± 0.01	2.28 ± 0.12	1.29 ± 0.08	0.34 ± 0.02	1.27 ± 0.06	6.86 ± 0.29	2.08 ± 0.10	-	1.09 ± 0.10	0.11 ± 0.01	1.54 ± 0.10	12.6	240	268.5 ± 22.0	174 ± 18 (16)
CHAR02	GL06011	51°N, 3°W, 80m	2.5	125-180	0.13 ± 0.03	0.30 ± 0.01	2.12 ± 0.10	1.01 ± 0.07	0.29 ± 0.01	0.60 ± 0.03	3.10 ± 0.15	0.95 ± 0.06	-	0.53 ± 0.04	0.14 ± 0.01	0.96 ± 0.05	9.7	260	90.2 ± 6.8	94 ± 9 (7)
CHAR03	GL06012	51°N, 3°W, 80m	1.7	125-180	0.14 ± 0.03	0.68 ± 0.02	3.85 ± 0.17	1.62 ± 0.11	0.53 ± 0.02	1.53 ± 0.07	7.23 ± 0.31	1.90 ± 0.09	-	1.28 ± 0.11	0.16 ± 0.02	1.97 ± 0.11	58.9	260	193.7 ± 11.0	98 ± 9 (6)
CHAR04	GL06013	51°N, 3°W, 75m	4.5	125-180	0.15 ± 0.04	0.36 ± 0.02	1.82 ± 0.13	0.79 ± 0.08	0.26 ± 0.01	0.99 ± 0.05	2.71 ± 0.13	0.65 ± 0.05	-	0.72 ± 0.07	0.10 ± 0.01	1.09 ± 0.07	11.9	240	298.6 ± 19.2	274 ± 25 (20)
YELL01	GL06032	51°N, 4°W, 60m	1.2	125-180	0.16 ± 0.04	0.82 ± 0.03	5.98 ± 0.20	4.59 ± 0.15	1.00 ± 0.04	1.89 ± 0.08	7.60 ± 0.32	2.31 ± 0.11	-	1.50 ± 0.14	0.17 ± 0.02	2.68 ± 0.15	1.0	280	39.0 ± 7.0	15 ± 3 (3)
YELL02	GL06033	51°N, 4°W, 60m	0.8	125-180	0.13 ± 0.04	1.41 ± 0.02	6.31 ± 0.19	3.31 ± 0.13	1.02 ± 0.03	2.10 ± 0.09	9.56 ± 0.40	2.67 ± 0.13	-	1.77 ± 0.15	0.19 ± 0.02	2.98 ± 0.16	19.2	220	35.8 ± 4.2	12 ± 2 (1)
YELL03	GL06034	51°N, 4°W, 60m	2.5	125-180	0.17 ± 0.04	0.28 ± 0.07	3.46 ± 0.22	25.20 ± 0.35	3.08 ± 0.15	2.15 ± 0.09	9.80 ± 0.41	14.45 ± 0.59	-	2.93 ± 0.26	0.14 ± 0.02	6.15 ± 0.30	0.9	260	407.5±117.4	66 ± 19 (19)
YELL04[†]	GL06035	51°N, 4°W, 50m	0.8	180-250	0.01 ± 0.00	-	-	-	1.22 ± 0.09	1.42 ± 0.07	11.39 ± 0.64	3.08 ± 0.15	-	1.62 ± 0.11	0.19 ± 0.02	3.02 ± 0.12	0.4	260	178.6 ± 44.1	59 ± 15 (15)
OML01	GL06045	51°N, 3°W, 60m	1.6	180-250	0.10 ± 0.03	0.97 ± 0.02	5.22 ± 0.17	2.41 ± 0.11	0.76 ± 0.03	1.96 ± 0.08	7.95 ± 0.32	2.12 ± 0.09	-	1.62 ± 0.13	0.16 ± 0.02	2.54 ± 0.13	5.3	260	462.5 ± 62.9	182 ± 26 (25)
OML02	GL06046	51°N, 3°W, 60m	1.7	180-250	0.13 ± 0.03	2.39 ± 0.03	7.72 ± 0.22	3.13 ± 0.14	1.30 ± 0.04	2.91 ± 0.12	9.02 ± 0.37	2.38 ± 0.10	-	2.19 ± 0.19	0.16 ± 0.02	3.65 ± 0.20	13.4	280	351.9 ± 26.2	96 ± 9 (7)
OML03	GL06047	51°N, 3°W, 60m	1.4	180-250	0.08 ± 0.02	0.70 ± 0.02	3.14 ± 0.13	1.68 ± 0.09	0.51 ± 0.02	1.76 ± 0.07	4.73 ± 0.19	1.13 ± 0.05	-	1.37 ± 0.11	0.17 ± 0.02	2.05 ± 0.11	72.6	240	237.2 ± 31.8	116 ± 17 (16)
OBS01	GL06048	51°N, 3°W, 10m	2.5	180-250	0.02 ± 0.00	0.74 ± 0.02	3.14 ± 0.13	1.68 ± 0.09	0.47 ± 0.02	1.31 ± 0.06	3.56 ± 0.15	0.83 ± 0.03	-	1.11 ± 0.08	0.14 ± 0.01	1.72 ± 0.08	66.2	280	169.5 ± 16.0	99 ± 10 (9)
OBS02	GL06049	51°N, 3°W, 10m	1.2	180-250	0.03 ± 0.01	0.80 ± 0.02	2.67 ± 0.14	0.94 ± 0.09	0.43 ± 0.02	2.57 ± 0.11	3.11 ± 0.13	0.61 ± 0.03	-	1.93 ± 0.15	0.17 ± 0.02	2.53 ± 0.15	57.8	220	189.1 ± 19.9	75 ± 9 (8)
CHAR05	GL06057	51°N, 3°W, 80m	6.7	125-180	0.16 ± 0.04	0.18 ± 0.01	1.32 ± 0.08	0.82 ± 0.06	0.20 ± 0.01	0.87 ± 0.04	5.30 ± 0.21	1.30 ± 0.05	-	0.75 ± 0.07	0.08 ± 0.01	1.02 ± 0.07	2.3	240	375.3 ± 24.6	367 ± 35 (29)
CHAR06	GL06058	51°N, 3°W, 80m	7.0	125-180	0.15 ± 0.04	0.23 ± 0.01	1.55 ± 0.10	0.67 ± 0.07	0.21 ± 0.01	1.09 ± 0.05	3.90 ± 0.16	1.00 ± 0.04	-	0.84 ± 0.08	0.07 ± 0.01	1.12 ± 0.08	5.7	280	318.3 ± 33.3	284 ± 36 (32)

Table 1 D_r, D_e and Age data of submitted samples. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect combined systematic and experimental variability and (in parenthesis) experimental variability alone (see 6.0). Blue indicates samples with accepted age estimates, red, age estimates with caveats (see Table 2).

Generic considerations	Field Code	Lab Code	Sample specific considerations
None	DON01	GL05058	Minor feldspar contamination (see 4.1.1); Dose Recovery underestimated (see 4.1.2); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	DON02	GL05059	Accept
	DON03	GL05060	Minor feldspar contamination (see 4.1.1); Dose Recovery underestimated (see 4.1.2); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	DON04	GL05061	Minor feldspar contamination (see 4.1.1); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	DON05	GL05062	Minor feldspar contamination (see 4.1.1). Accept
	PHAY01	GL05063	Overdispersion of regenerative-dose data, accept tentatively (see 4.1.4)
	PHAY02	GL05064	Dose Recovery underestimated (see 3.1.2); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	KILM01	GL06001	Minor feldspar contamination (see 4.1.1). Accept
	KILM03	GL06002	Minor feldspar contamination (see 4.1.1). Accept
	KILM05	GL06003	Minor feldspar contamination (see 4.1.1); Dose Recovery overestimated (see 4.1.2); overdispersion of regenerative-dose data (see 4.1.4); probably, yet relatively minor partial bleaching (see 4.2.1). Accept tentatively
	KILM06	GL06004	Minor feldspar contamination (see 4.1.1); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	CHAR01	GL06010	Minor feldspar contamination (see 4.1.1). Accept
	CHAR02	GL06011	Minor feldspar contamination (see 4.1.1). Accept
	CHAR03	GL06012	Substantial feldspar contamination (see 4.1.1); Dose Recovery underestimated (see 4.1.2); probable, yet relatively minor partial bleaching (see 4.2.1). Accept tentatively as minimum age estimate
	CHAR04	GL06013	Minor feldspar contamination (see 4.1.1). Accept
	YELL01	GL06032	Overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	YELL02	GL06033	Minor feldspar contamination (see 4.1.1); Limited sample mass. Accept tentatively
	YELL03	GL06034	Limited sample mass; U disequilibrium (see 5.0). Accept as minimum age estimate
	YELL04	GL06035	Limited sample mass; overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	OML01	GL06045	Minor feldspar contamination (see 4.1.1); Dose Recovery overestimated (see 4.1.2). Accept tentatively
	OML02	GL06046	Minor feldspar contamination (see 4.1.1); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	OML03	GL06047	Substantial feldspar contamination (see 4.1.1); Dose Recovery underestimated (see 4.1.2). Accept tentatively
	OBS01	GL06048	Substantial feldspar contamination (see 4.1.1); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively
	OBS02	GL06049	Substantial feldspar contamination (see 4.1.1); Dose Recovery overestimated (see 4.1.2). Accept tentatively
	CHAR05	GL06057	Minor feldspar contamination (see 4.1.1). Accept
	CHAR06	GL06058	Minor feldspar contamination (see 4.1.1); overdispersion of regenerative-dose data (see 4.1.4). Accept tentatively

Table 2 Analytical acceptability of sample suite age estimates and caveats for consideration

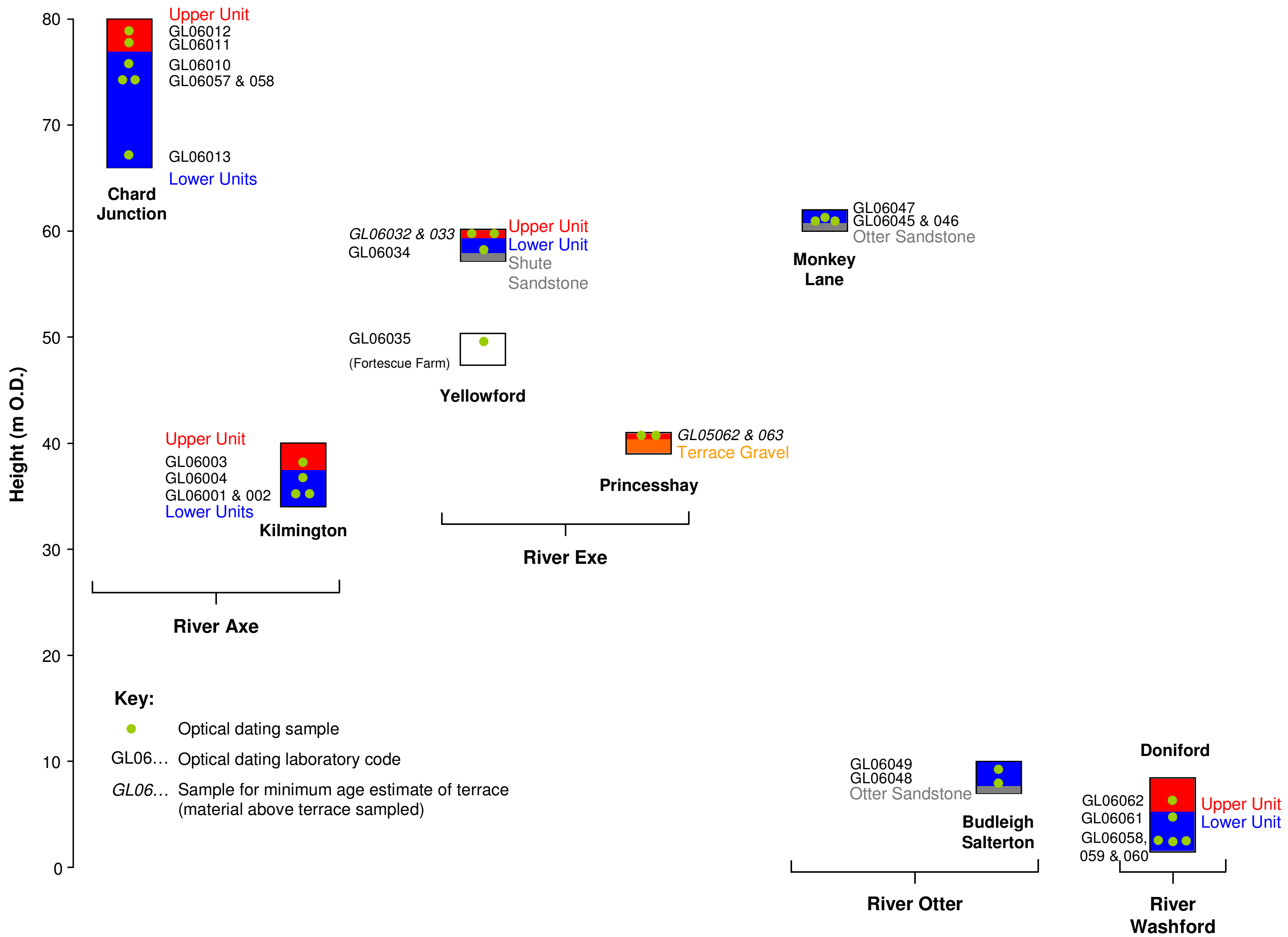
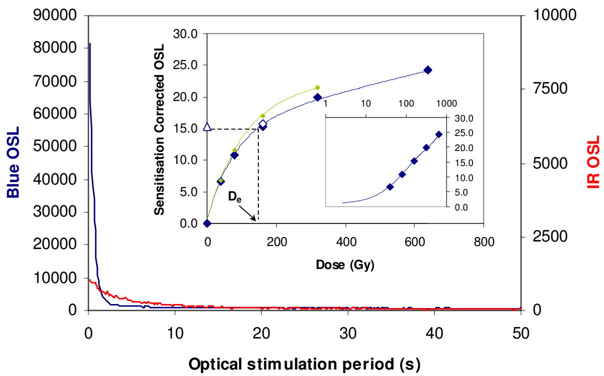


Fig.i Relative position of sections and optical dating samples.

Fig. 1 Signal Calibration



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

Irradiation-Preheat Cycling The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. Repeated irradiation and thermal treatment results in aliquot sensitisation, rendering calibration of the natural signal inaccurate. This sensitisation can be monitored and corrected for. The accuracy of correction can be preheat dependent; irradiation-preheat cycling quantifies this dependence for laboratory-induced signals, examining the reproducibility of corrected OSL resultant of repeat laboratory doses.

D_e Preheat Dependence Quantifies the combined effects of thermal transfer and sensitisation on the natural signal. Insignificant adjustment in D_e may reflect limited influence of these effects

Dose Recovery Attempts to replicate the above diagnostic, yet provide improved resolution of thermal effects through removal of variability induced by heterogeneous dose absorption in the environment and using a precise lab dose to simulate natural dose. Based on this and preceding data an appropriate thermal treatment is selected to refine the final D_e value.

Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from natural and laboratory irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching along with insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates.

Th & U Decay Activities Statistical concordance (equilibrium) in the activities of daughter radioisotopes in the Th and U decay series may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates

Age Range The mean age range provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Fig. 2 Irradiation-Preheat Cycling

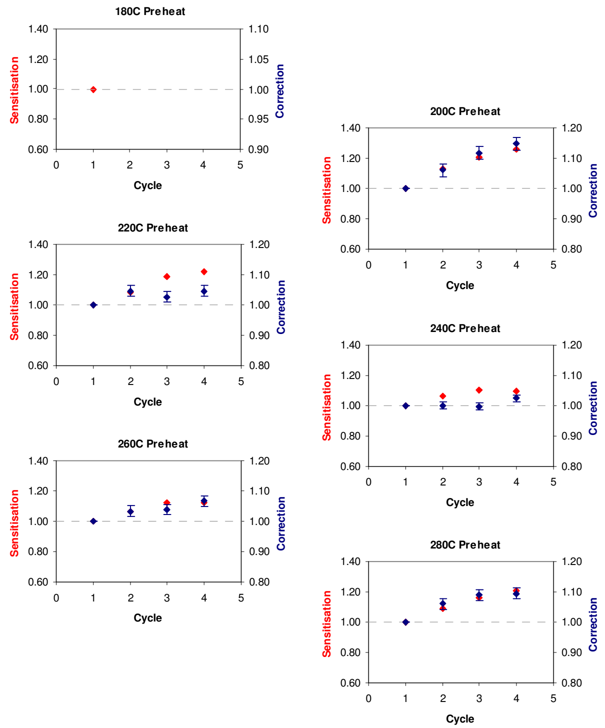


Fig. 3 D_e Preheat Dependence

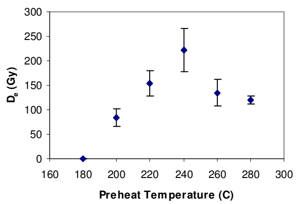


Fig. 4 Dose Recovery

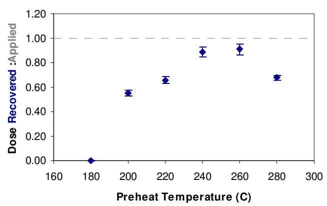


Fig. 5 Inter-aliquot D_e distribution

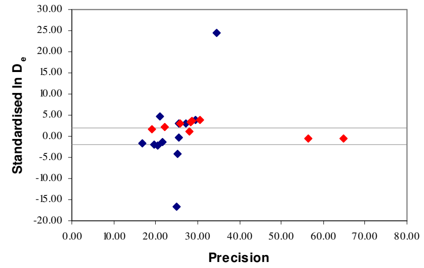


Fig. 6 Signal Analysis

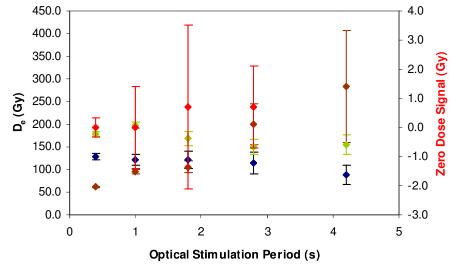
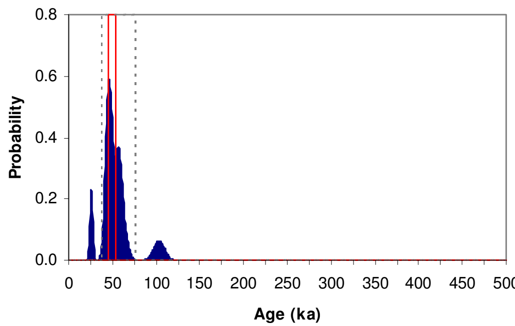


Fig. 7 Th & U Decay Activities

Activity (Bq.kg^{-1})

Insufficient Sample Mass

Fig. 8 Age Range



Sample: GL06058

Fig. 1 Signal Calibration

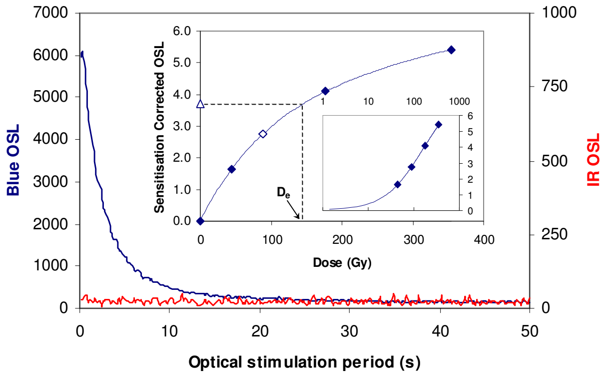


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Fig. 2 Irradiation-Preheat Cycling

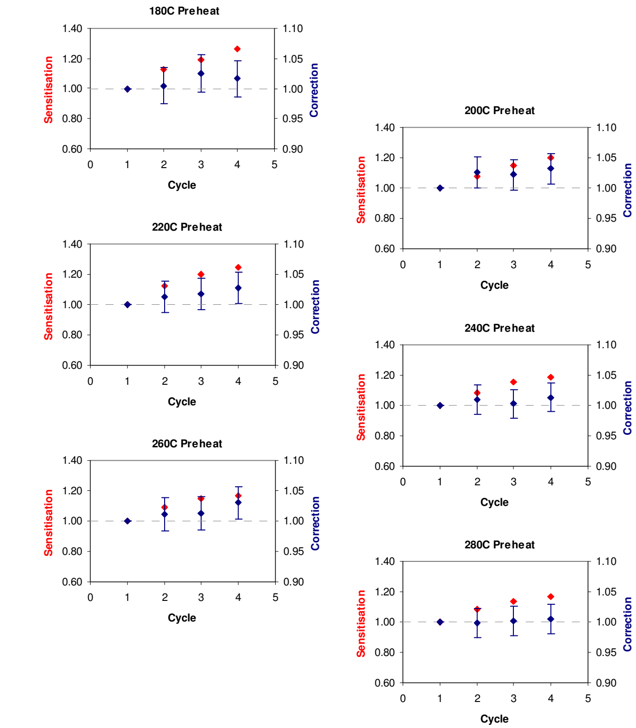


Fig. 3 D_e Preheat Dependence

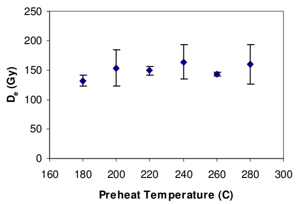
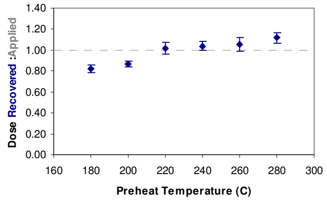


Fig. 4 Dose Recovery



Sample: GL05059

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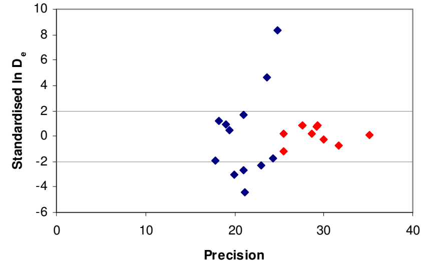
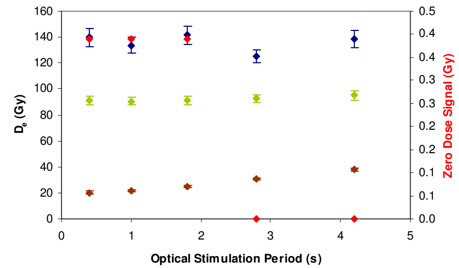


Fig. 6 Signal Analysis



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Activity (Bq.kg^{-1})

Insufficient Sample Mass

Fig. 8 Age Range

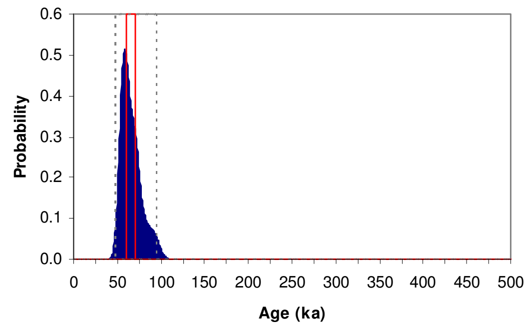

Fig. 1 Signal Calibration

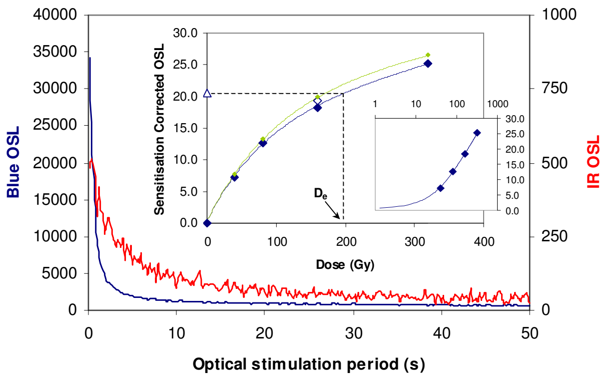

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Fig. 2 Irradiation-Preheat Cycling

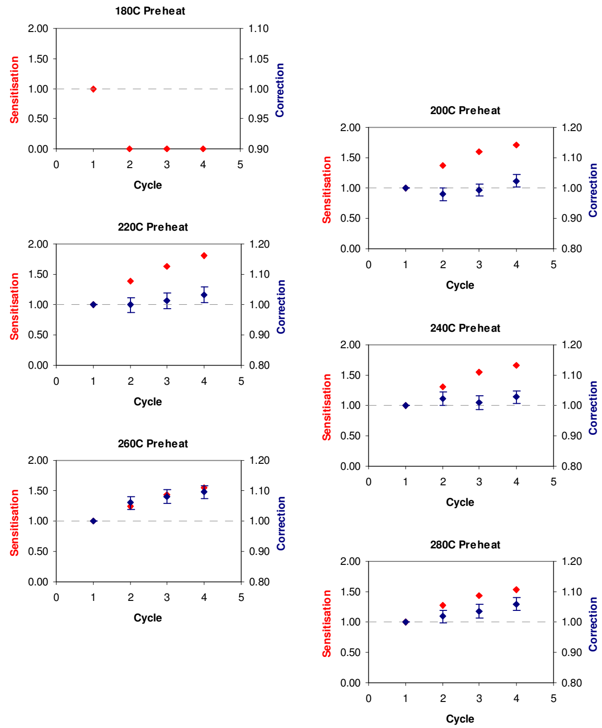


Fig. 3 D_e Preheat Dependence

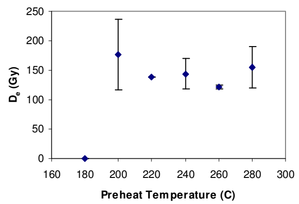
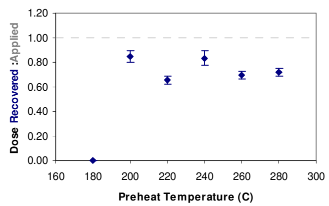


Fig. 4 Dose Recovery



Sample: GL05060

Fig. 5 Inter-aliquot D_e distribution

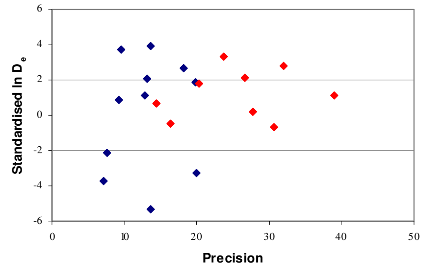


Fig. 6 Signal Analysis

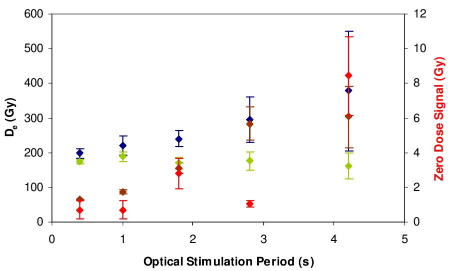


Fig. 7 Th & U Decay Activities

Activity (Bq.kg^{-1})

Insufficient Sample Mass

Fig. 8 Age Range

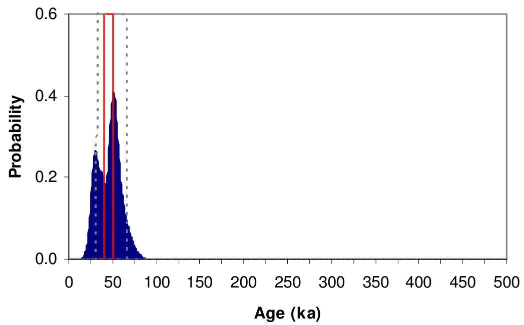
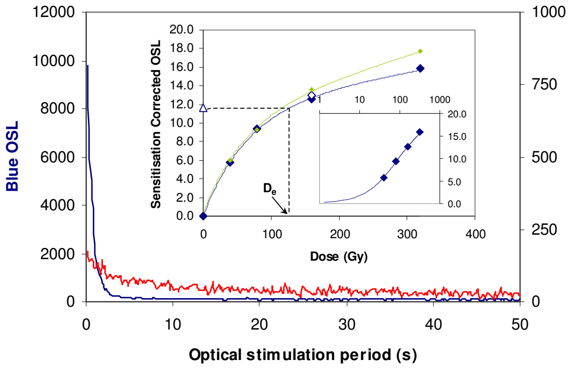


Fig. 1 Signal Calibration



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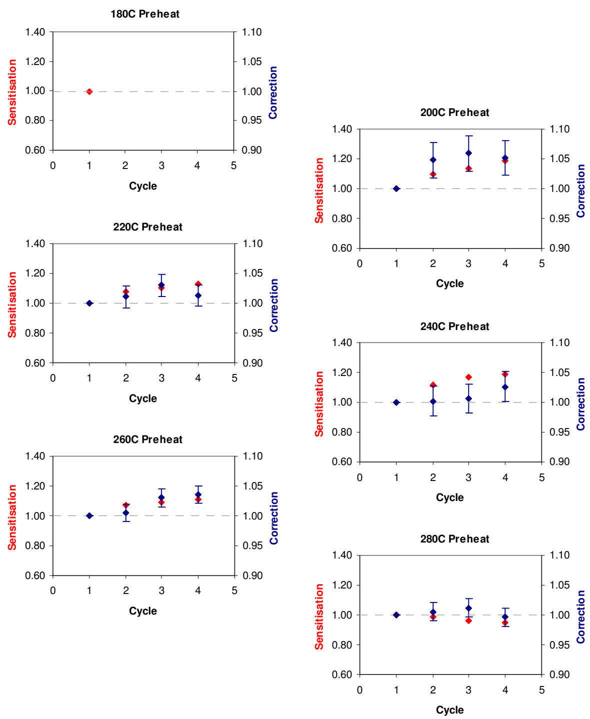


Fig. 3 D_e Preheat Dependence

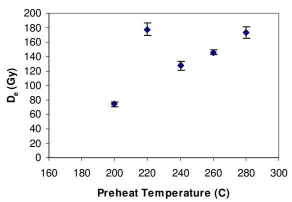


Fig. 4 Dose Recovery

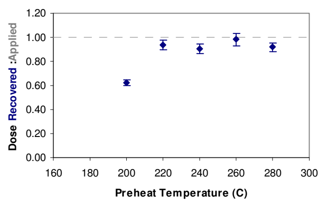


Fig. 5 Inter-aliquot D_e distribution

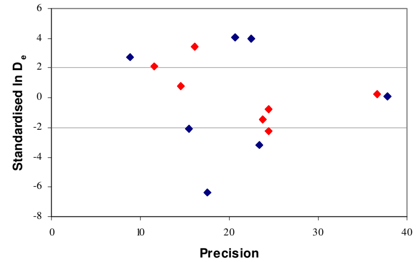


Fig. 6 Signal Analysis

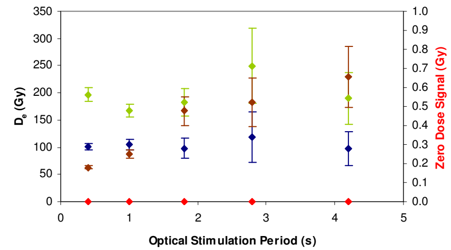
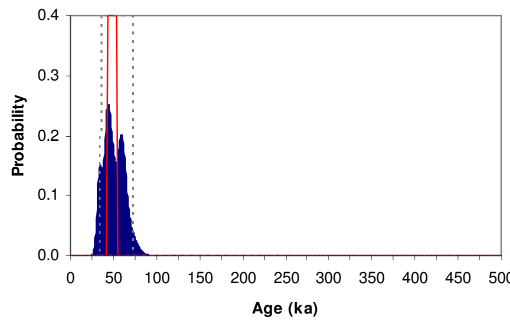


Fig. 7 Th & U Decay Activities

Activity ($Bq.kg^{-1}$)

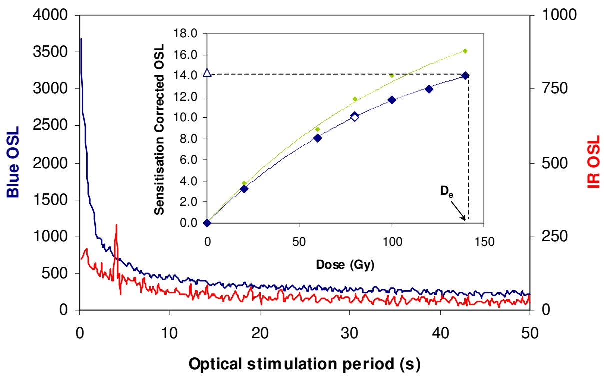
Insufficient Sample Mass

Fig. 8 Age Range



Sample: GL05061

Fig. 1 Signal Calibration



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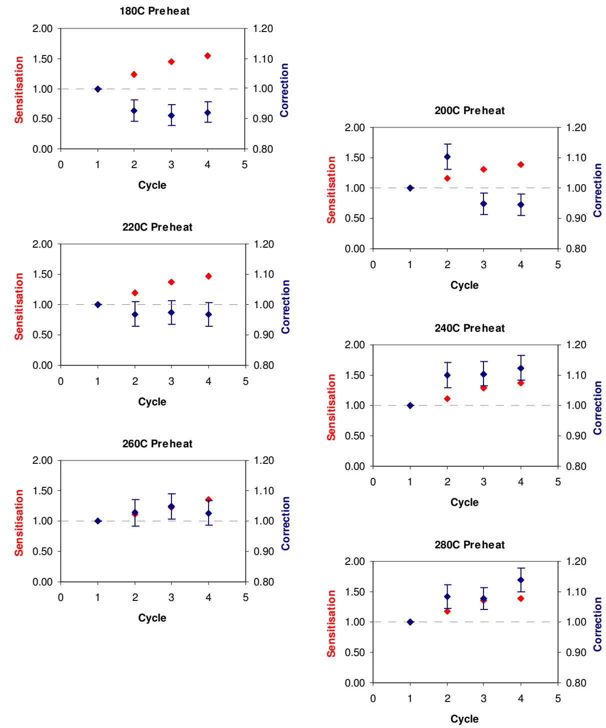


Fig. 3 D_e Preheat Dependence

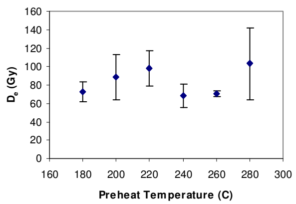


Fig. 4 Dose Recovery

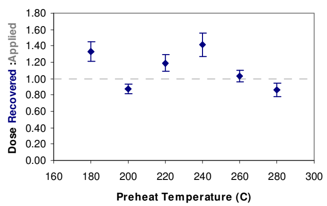


Fig. 5 Inter-aliquot D_e distribution

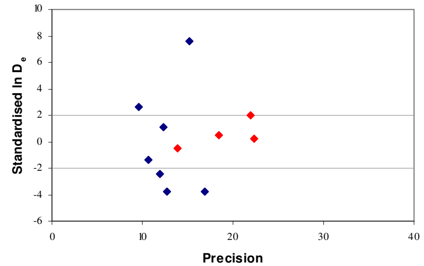


Fig. 6 Signal Analysis

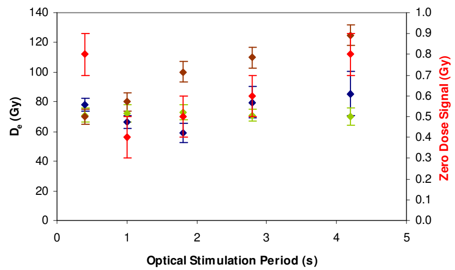
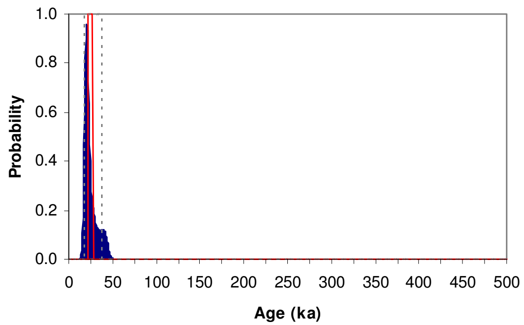


Fig. 7 Th & U Decay Activities

Activity (Bq.kg^{-1})

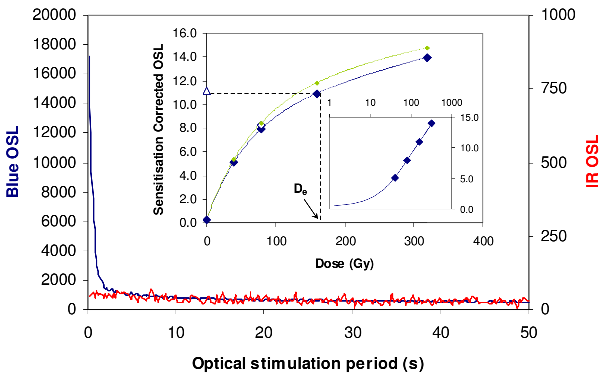
Insufficient Sample Mass

Fig. 8 Age Range



Sample: GL05062

Fig. 1 Signal Calibration



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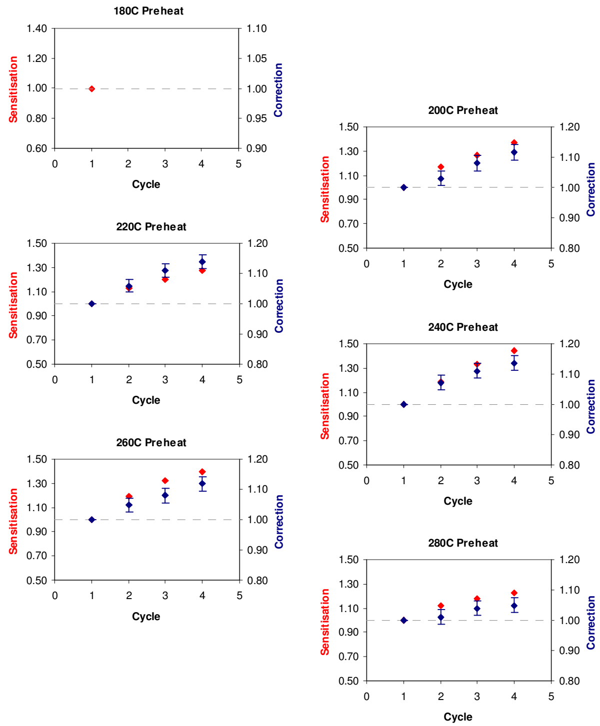


Fig. 3 D_e Preheat Dependence

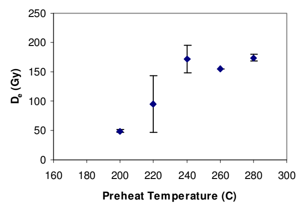


Fig. 4 Dose Recovery

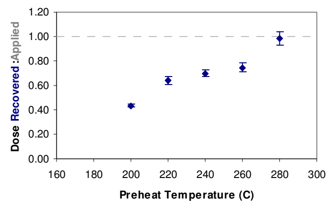


Fig. 5 Inter-aliquot D_e distribution

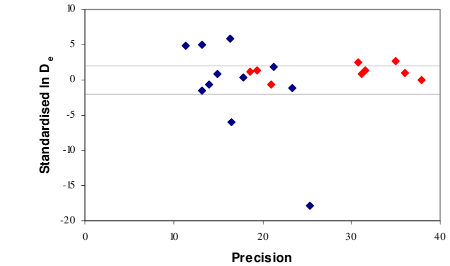


Fig. 6 Signal Analysis

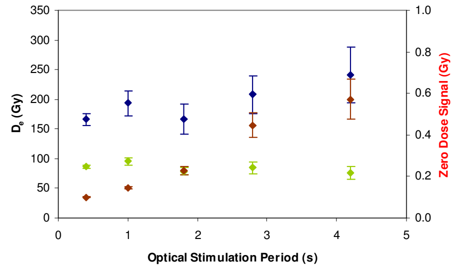


Fig. 7 Th & U Decay Activities

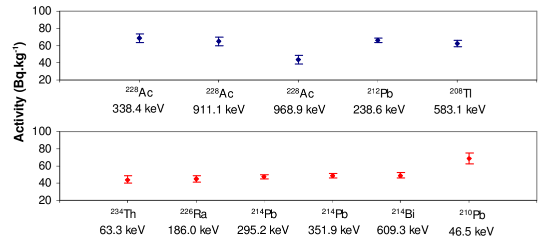
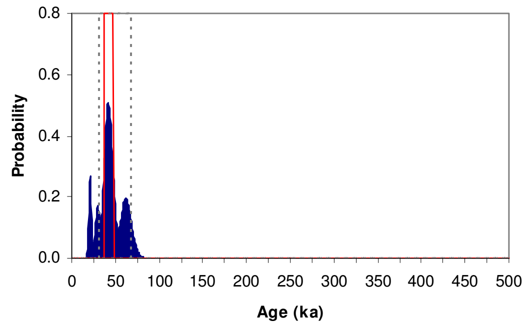
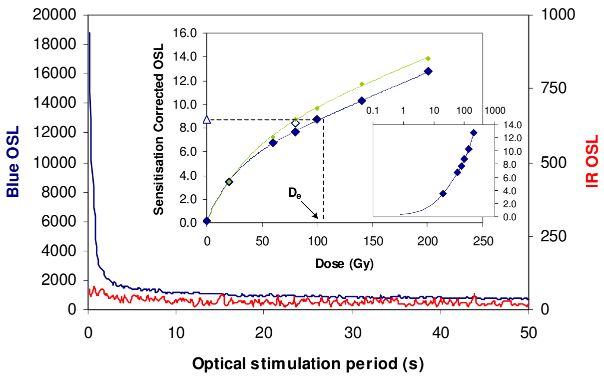


Fig. 8 Age Range



Sample: GL05063

Fig. 1 Signal Calibration



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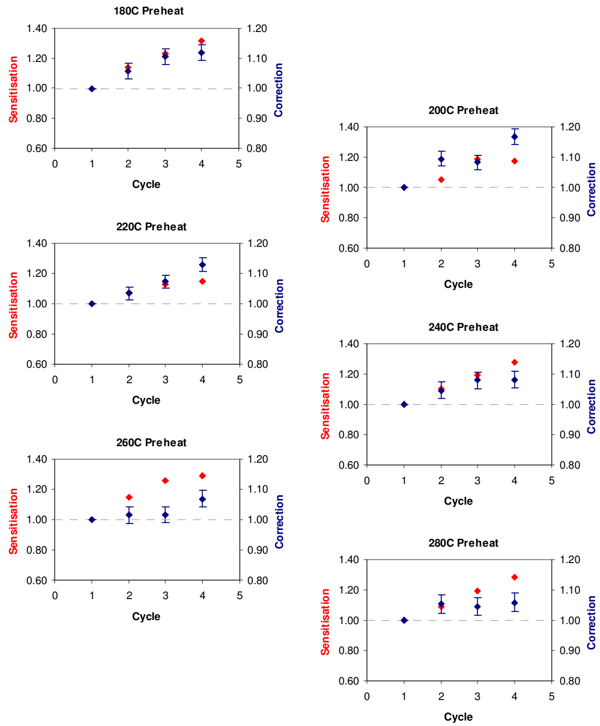


Fig. 3 D_e Preheat Dependence

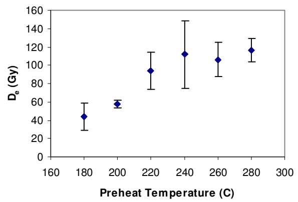
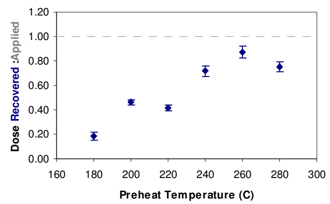


Fig. 4 Dose Recovery



Sample: GL05064

Fig. 5 Inter-aliquot D_e distribution

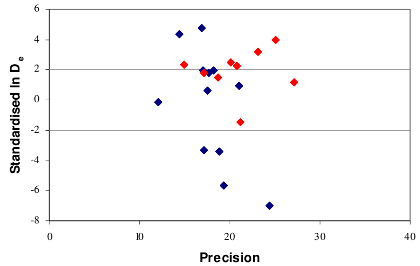


Fig. 6 Signal Analysis

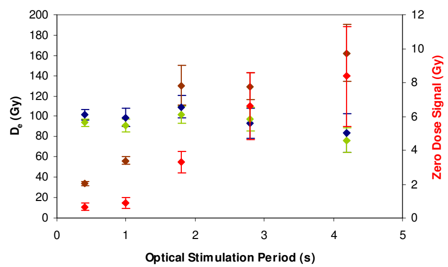


Fig. 7 Th & U Decay Activities

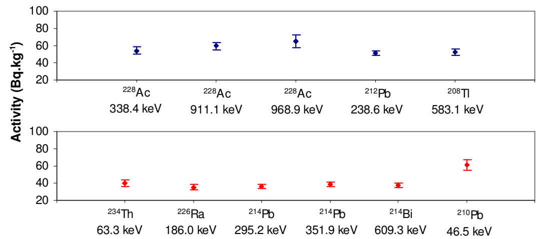
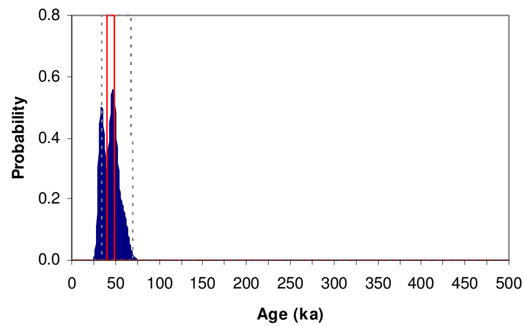


Fig. 8 Age Range



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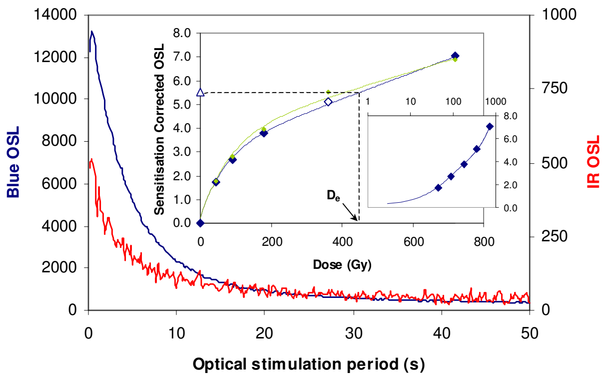

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Fig. 2 Irradiation-Preheat Cycling

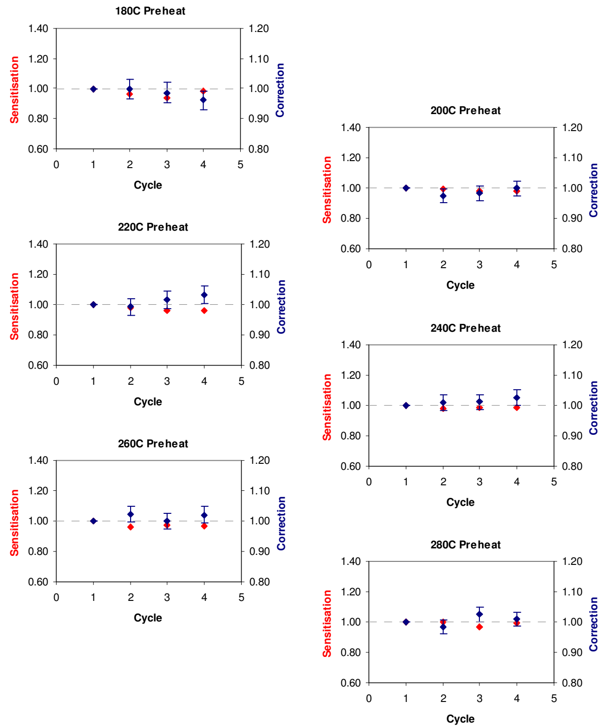


Fig. 3 D_e Preheat Dependence

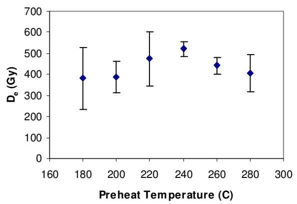
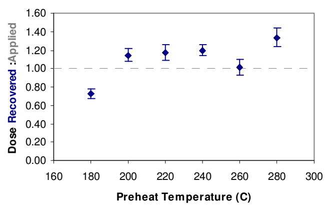


Fig. 4 Dose Recovery



Sample: GL06002

Fig. 5 Inter-aliquot D_e distribution

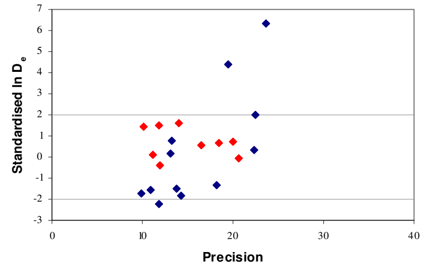


Fig. 6 Signal Analysis

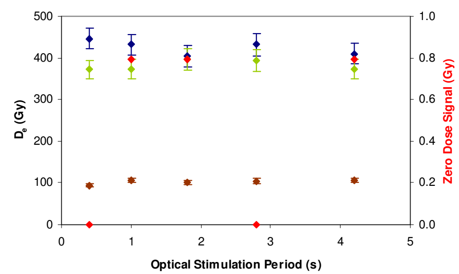


Fig. 7 Th & U Decay Activities

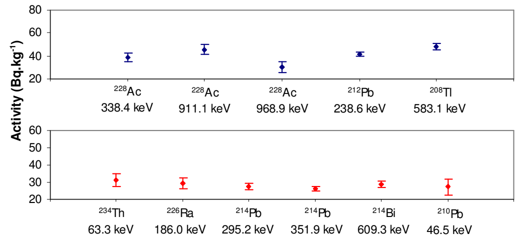


Fig. 8 Age Range

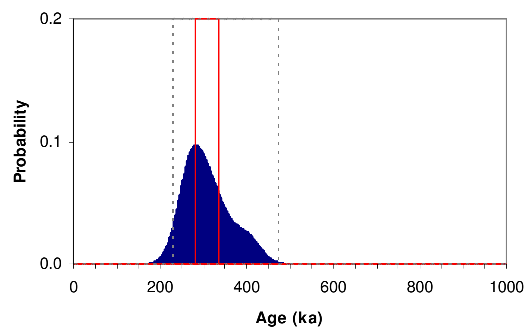


Fig. 1 Signal Calibration

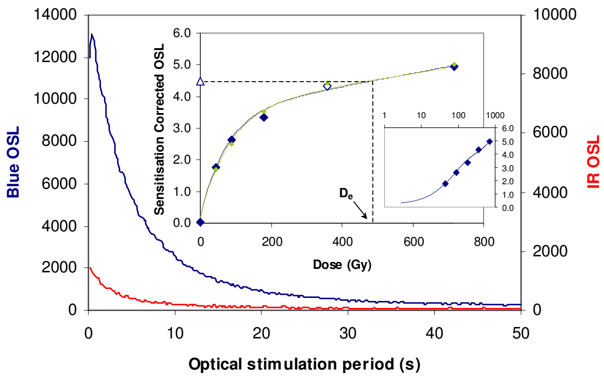


Fig. 2 Irradiation-Preheat Cycling

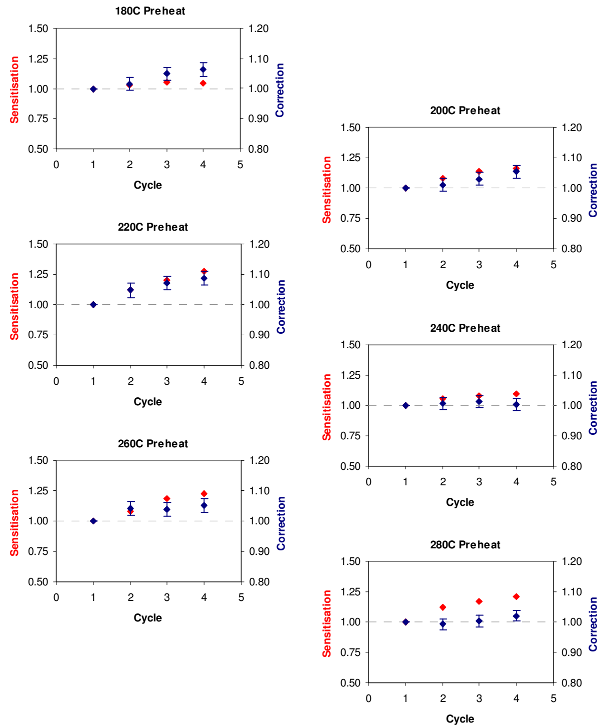


Fig. 3 D_e Preheat Dependence

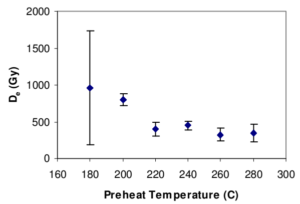


Fig. 4 Dose Recovery

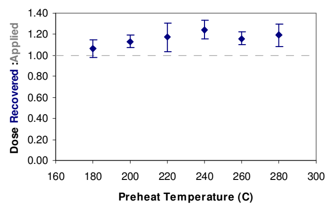


Fig. 5 Inter-aliquot D_e distribution

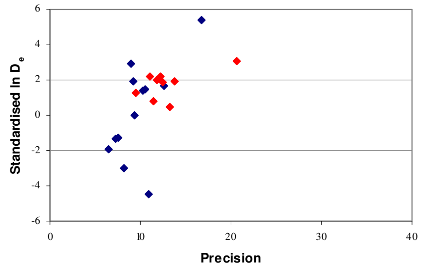


Fig. 6 Signal Analysis

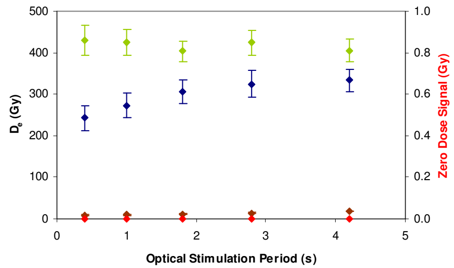


Fig. 7 Th & U Decay Activities

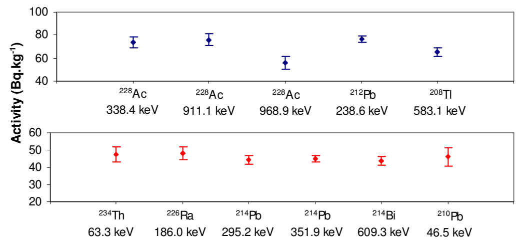
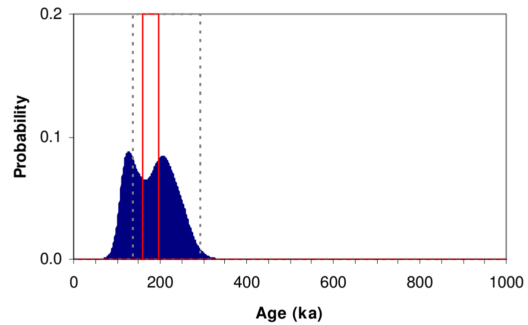


Fig. 8 Age Range



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

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Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching along with insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates.

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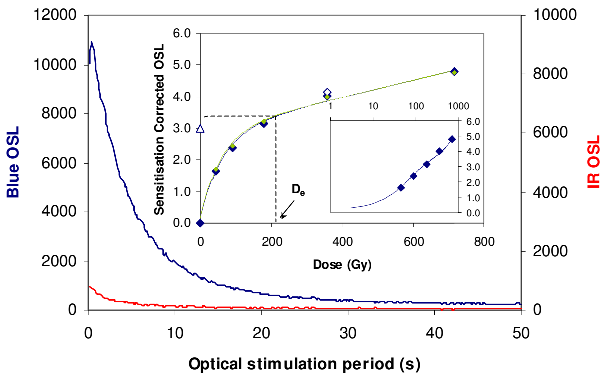
Sample: GL06003

Fig. 1 Signal Calibration



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

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Signal Analysis Statistically significant increase in **natural** D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from **simulated partial bleaching** along with insignificant adjustment in D_e for simulated **zero** and **full bleach** conditions. Ages from such samples are considered maximum estimates.

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Fig. 2 Irradiation-Preheat Cycling

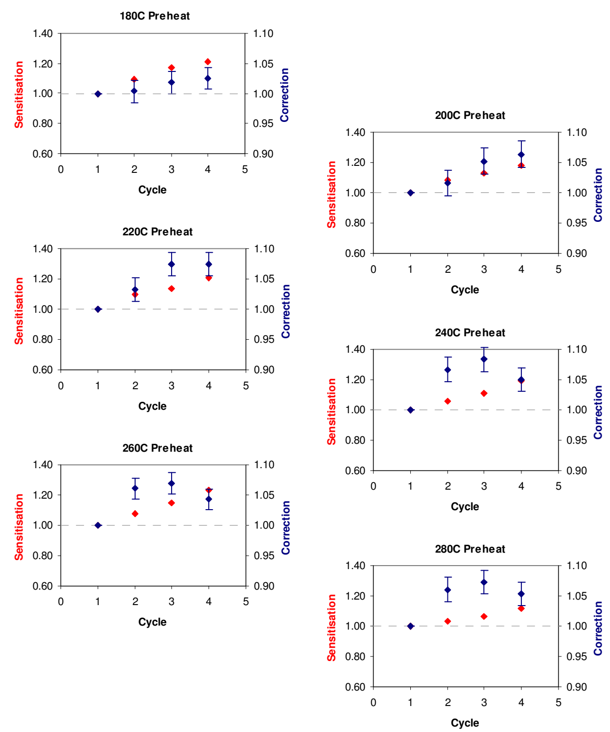


Fig. 3 D_e Preheat Dependence

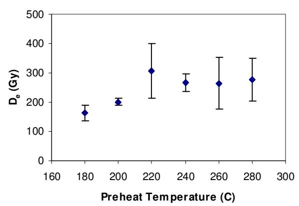
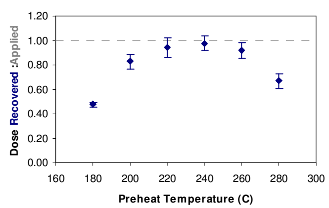


Fig. 4 Dose Recovery



Sample: GL06004

Fig. 5 Inter-aliquot D_e distribution

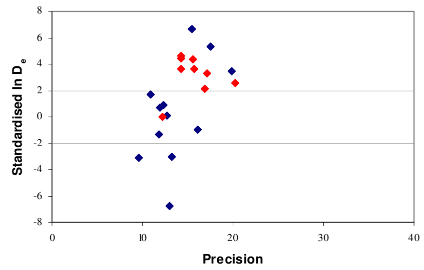


Fig. 6 Signal Analysis

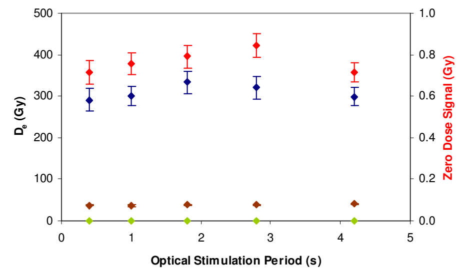


Fig. 7 Th & U Decay Activities

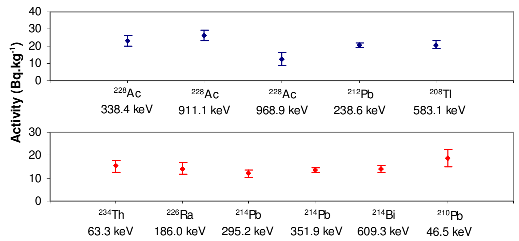


Fig. 8 Age Range

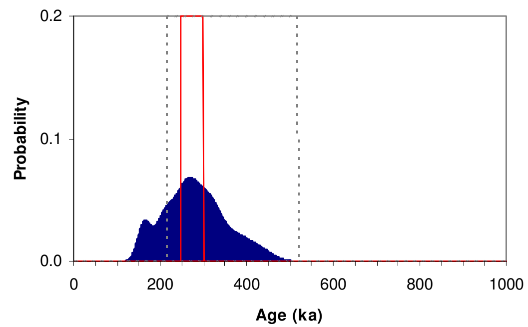


Fig. 1 Signal Calibration

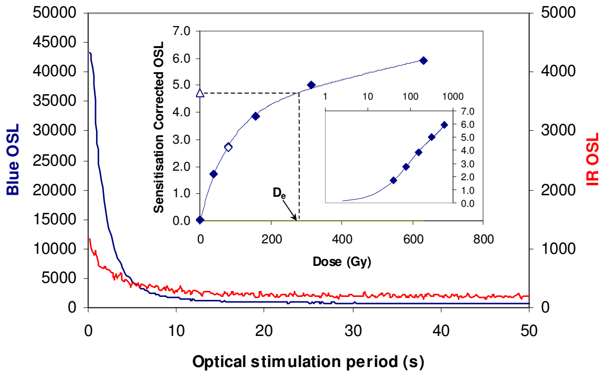


Fig. 2 Irradiation-Preheat Cycling

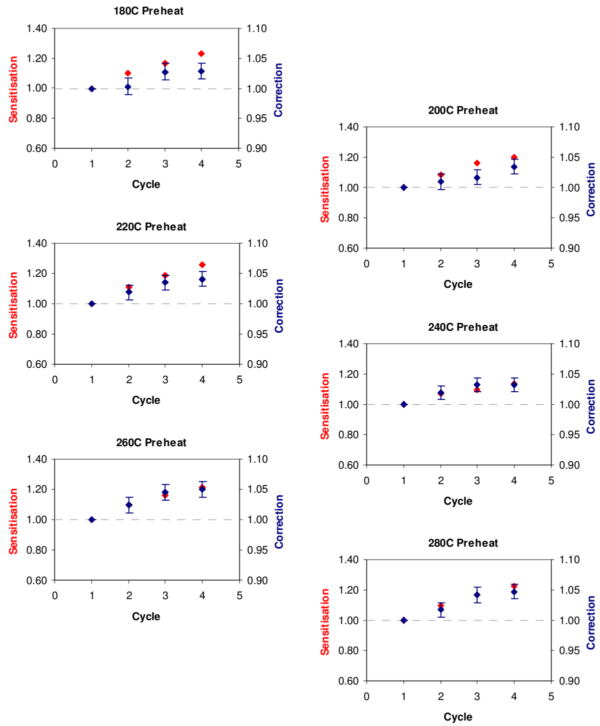


Fig. 5 Inter-aliquot D_e distribution

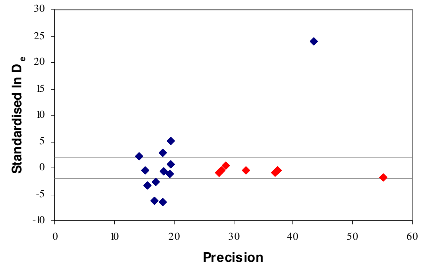
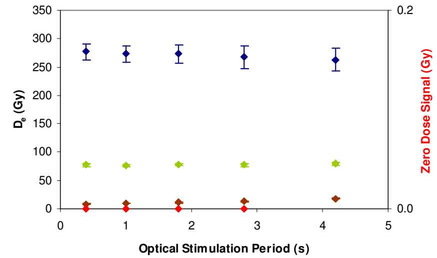


Fig. 6 Signal Analysis



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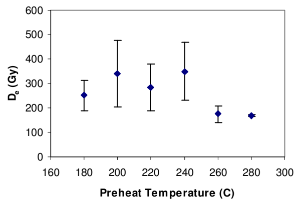


Fig. 4 Dose Recovery

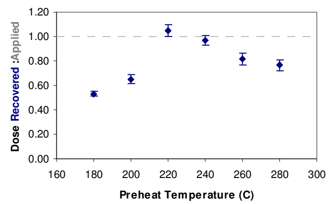


Fig. 7 Th & U Decay Activities

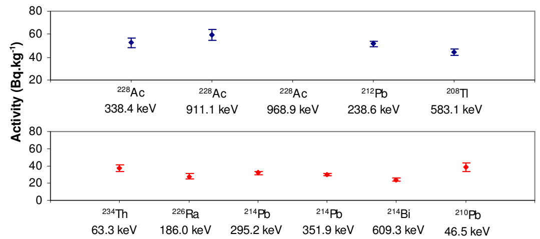
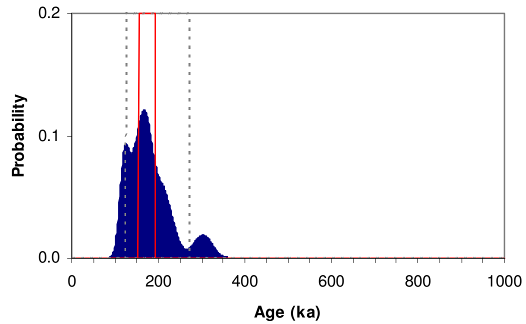


Fig. 8 Age Range



Sample: GL06010

Fig. 1 Signal Calibration

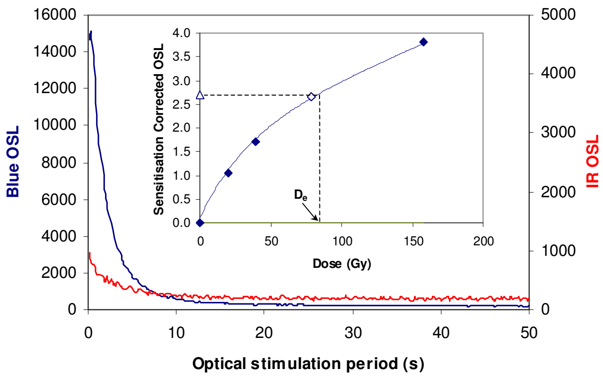


Fig. 2 Irradiation-Preheat Cycling

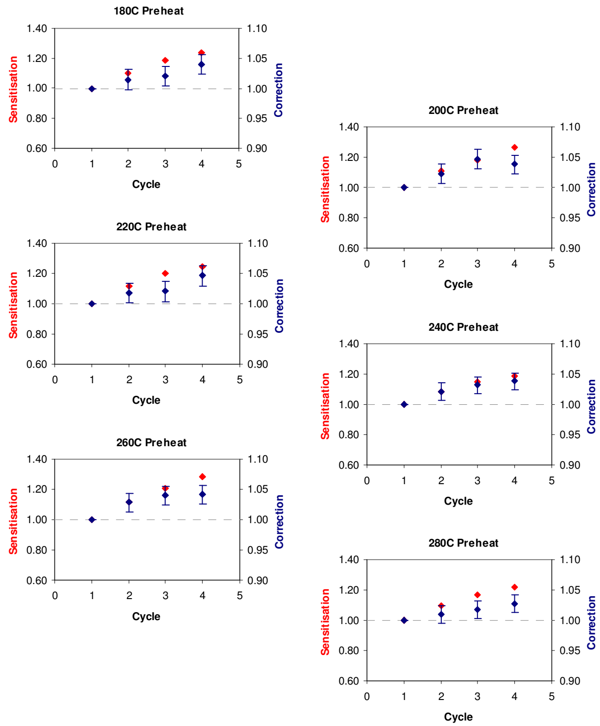


Fig. 5 Inter-aliquot D_e distribution

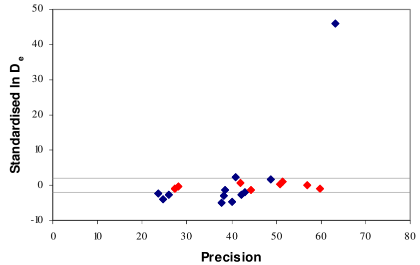


Fig. 6 Signal Analysis

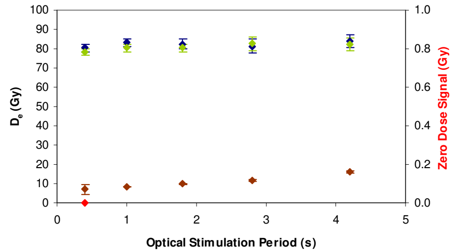


Fig. 7 Th & U Decay Activities

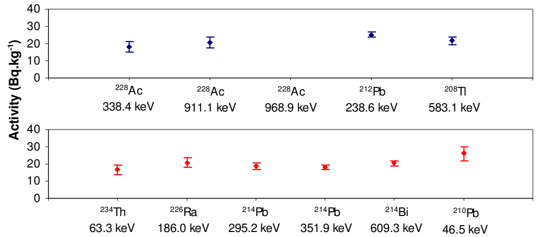


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Fig. 3 D_e Preheat Dependence

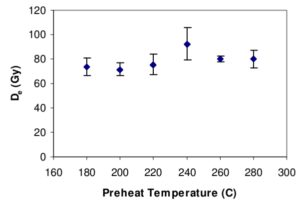


Fig. 4 Dose Recovery

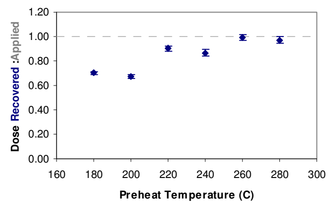
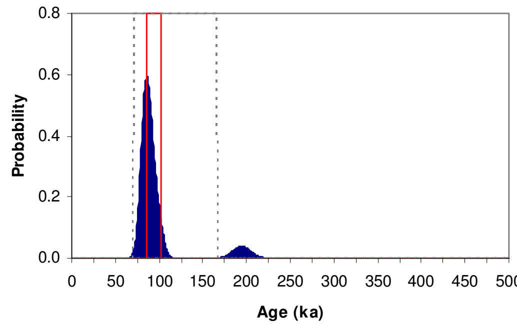


Fig. 8 Age Range



Sample: GL06011

Fig. 1 Signal Calibration

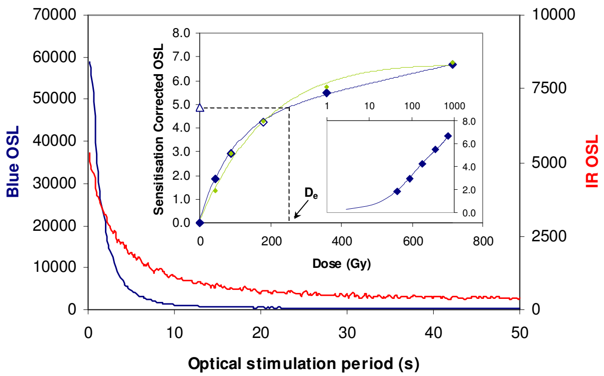


Fig. 2 Irradiation-Preheat Cycling

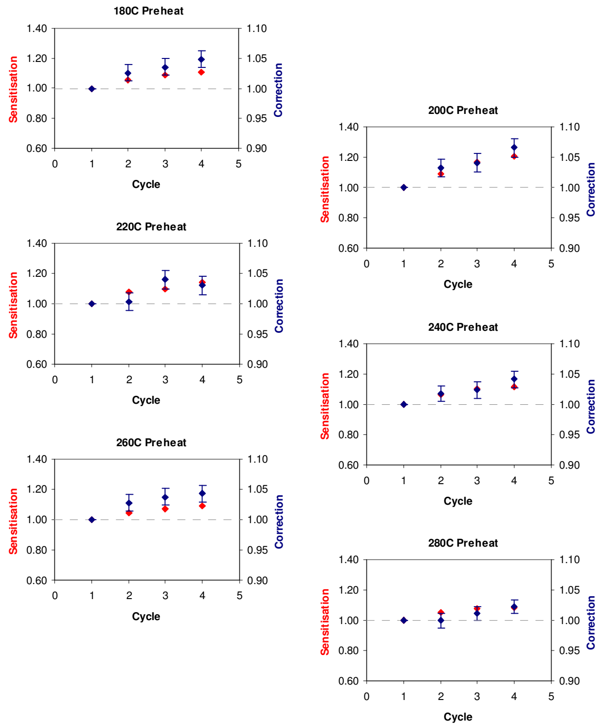


Fig. 5 Inter-aliquot D_e distribution

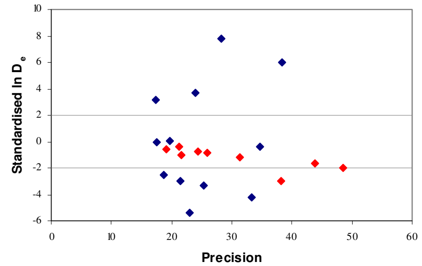
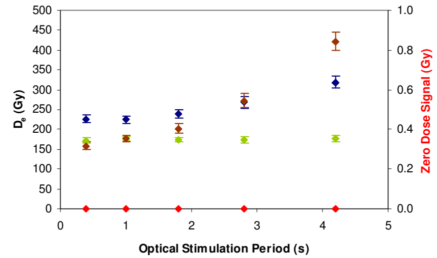


Fig. 6 Signal Analysis



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Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from **natural** and **laboratory** irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

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Fig. 3 D_e Preheat Dependence

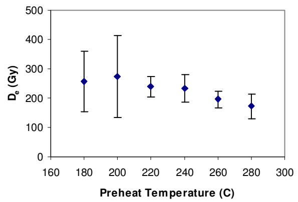


Fig. 4 Dose Recovery

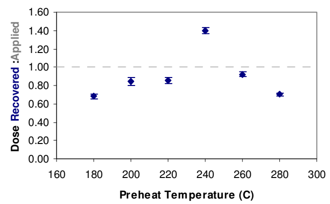


Fig. 7 Th & U Decay Activities

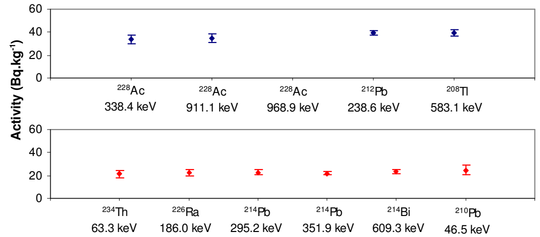
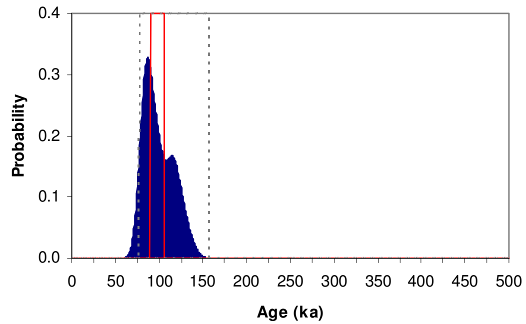


Fig. 8 Age Range



Sample: GL06012

Fig. 1 Signal Calibration

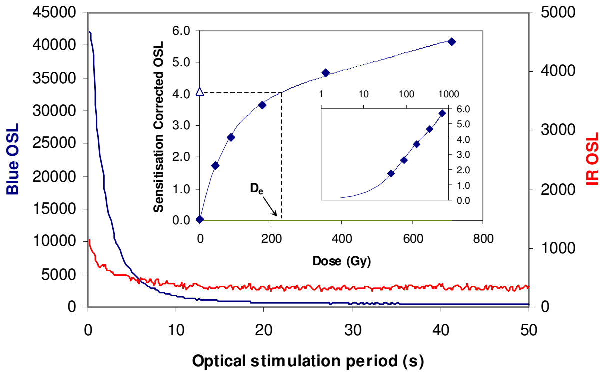


Fig. 2 Irradiation-Preheat Cycling

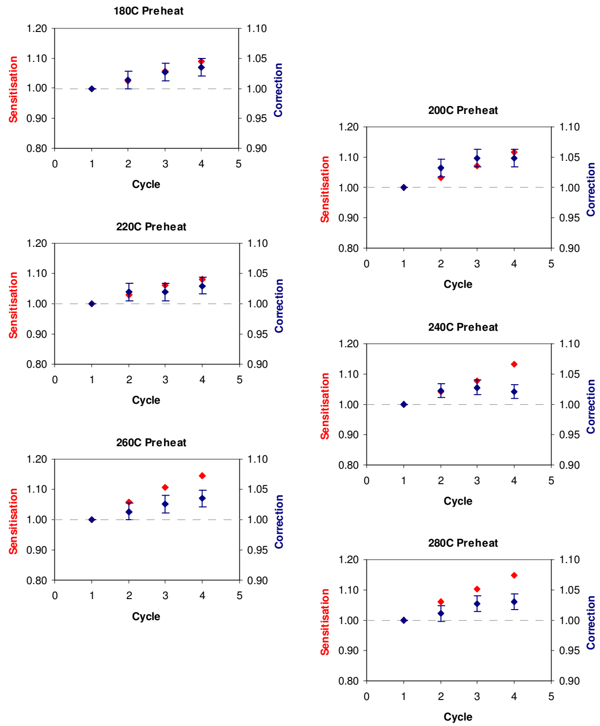


Fig. 3 D_e Preheat Dependence

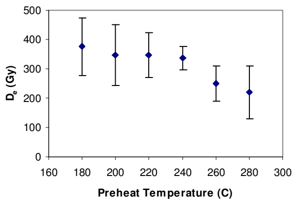


Fig. 4 Dose Recovery

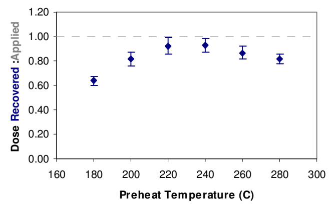


Fig. 5 Inter-aliquot D_e distribution

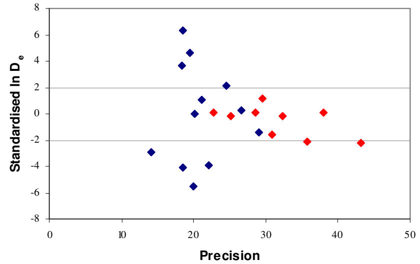


Fig. 6 Signal Analysis

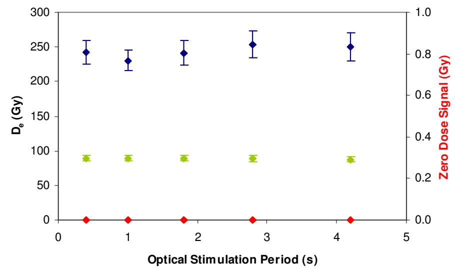


Fig. 7 Th & U Decay Activities

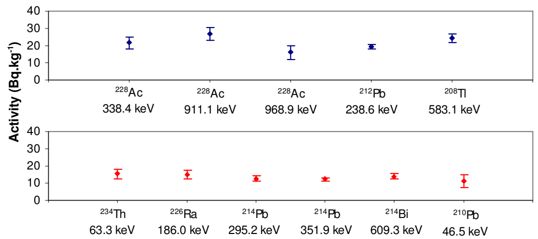
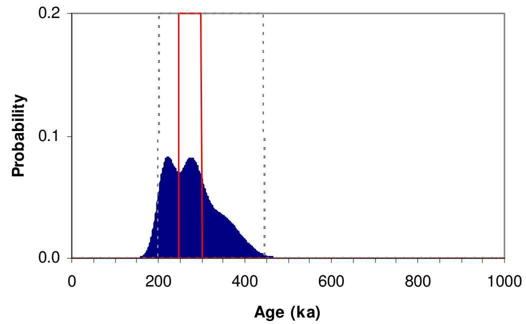


Fig. 8 Age Range



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

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Age Range The **mean age range** provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The **maximum influence** of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Sample: GL06013

Fig. 1 Signal Calibration

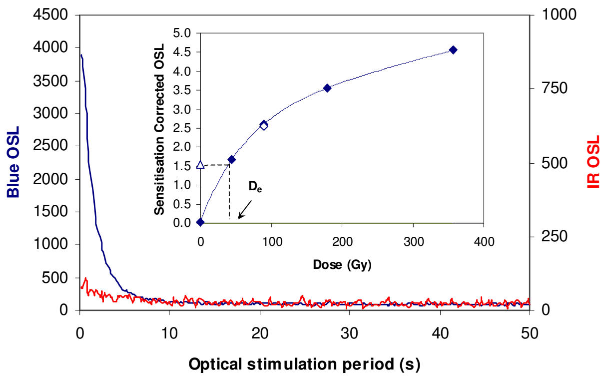


Fig. 2 Irradiation-Preheat Cycling

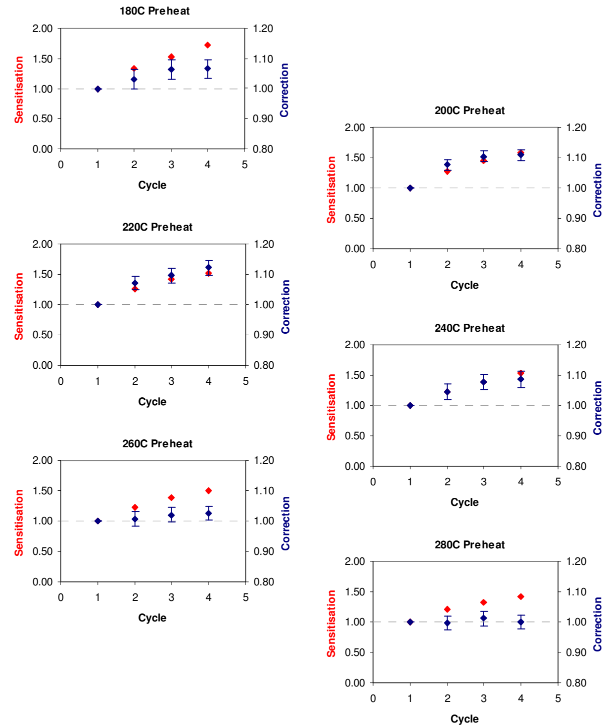


Fig. 3 D_e Preheat Dependence

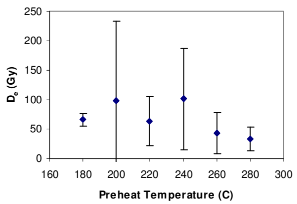


Fig. 4 Dose Recovery

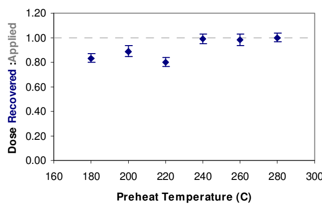


Fig. 5 Inter-aliquot D_e distribution

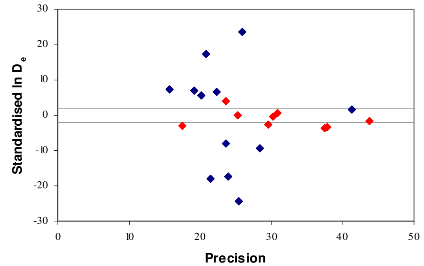


Fig. 6 Signal Analysis

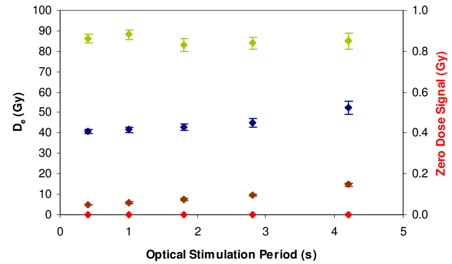


Fig. 7 Th & U Decay Activities

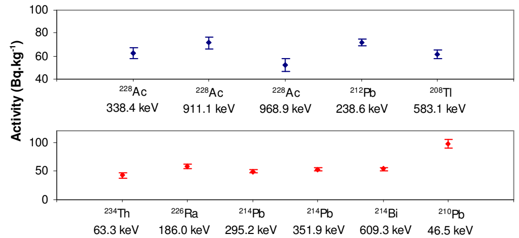
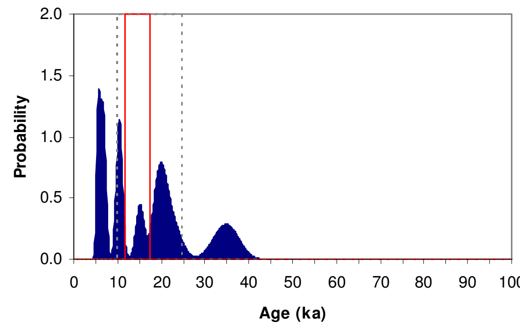


Fig. 8 Age Range



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

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Age Range The **mean age range** provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The **maximum influence** of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Sample: GL06032

Fig. 1 Signal Calibration

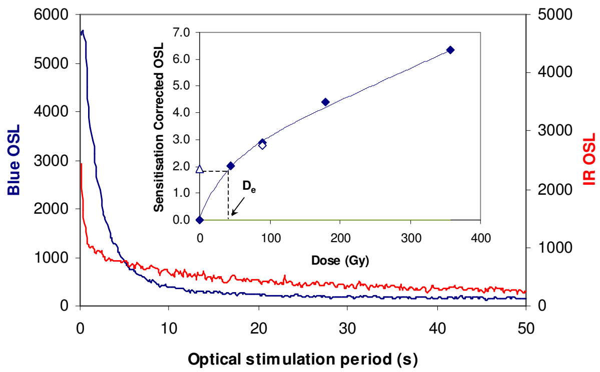

Fig. 2 Irradiation-Preheat Cycling

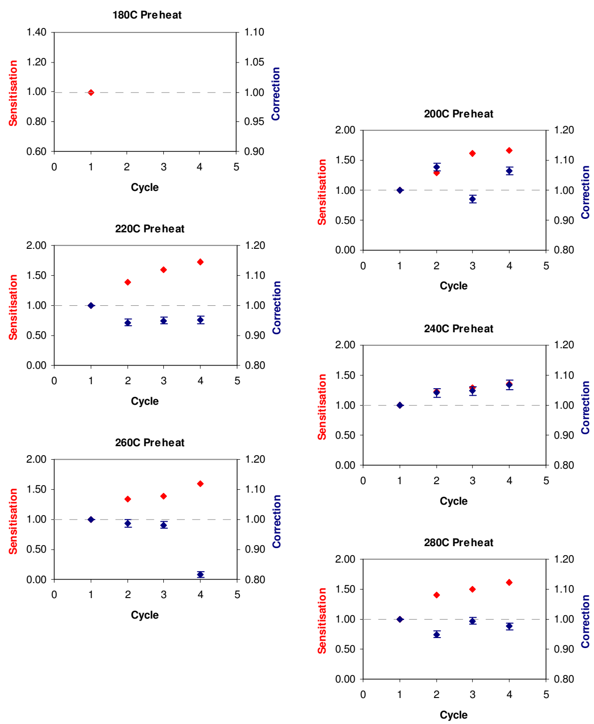

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Fig. 3 D_e Preheat Dependence

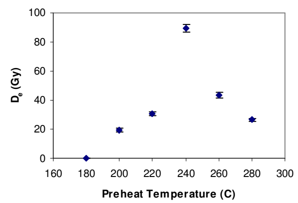
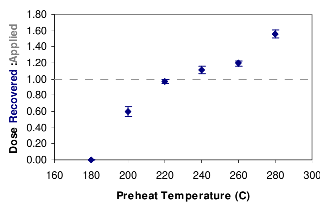


Fig. 4 Dose Recovery



Sample: GL06033

Fig. 5 Inter-aliquot D_e distribution

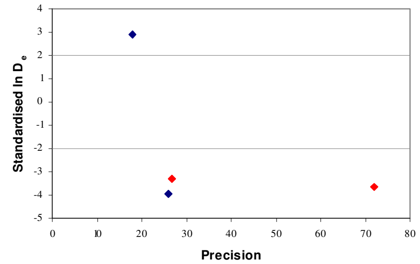


Fig. 6 Signal Analysis

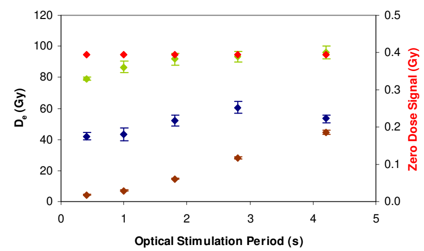


Fig. 7 Th & U Decay Activities

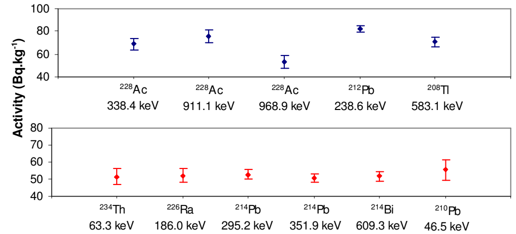


Fig. 8 Age Range

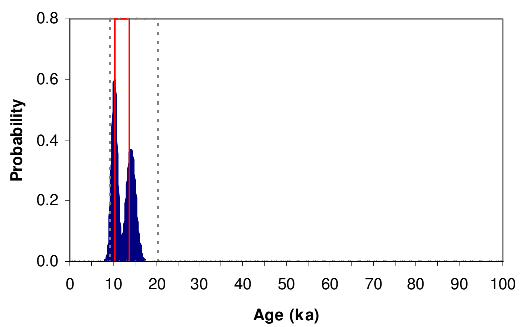


Fig. 1 Signal Calibration

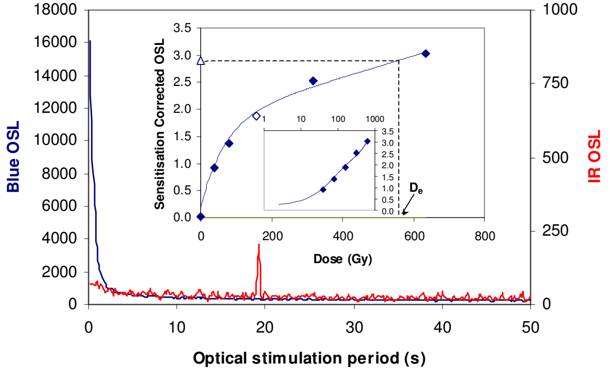


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Fig. 2 Irradiation-Preheat Cycling

Insufficient Sample Mass

Fig. 3 D_e Preheat Dependence

Insufficient Sample Mass

Fig. 4 Dose Recovery

Insufficient Sample Mass

Fig. 5 Inter-aliquot D_e distribution

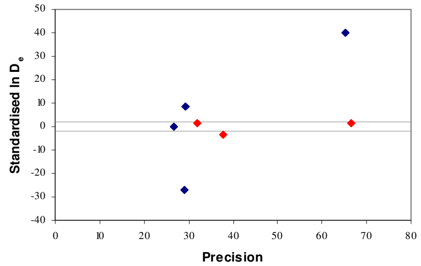


Fig. 6 Signal Analysis

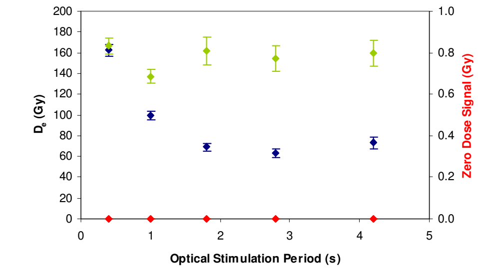


Fig. 7 Th & U Decay Activities

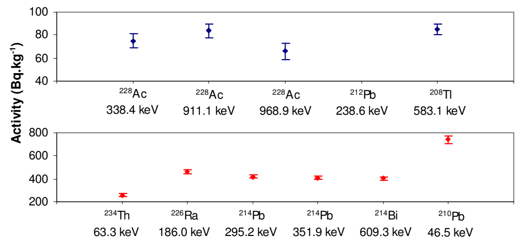
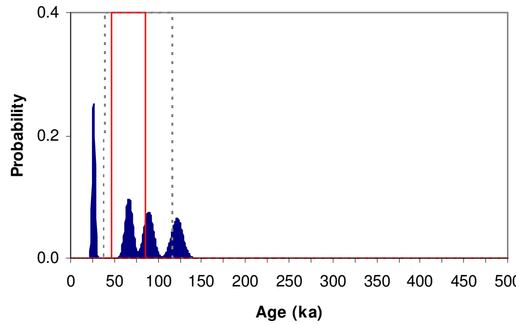
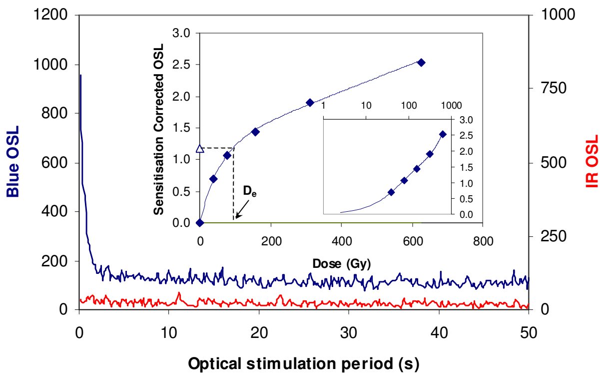


Fig. 8 Age Range



Sample: GL06034

Fig. 1 Signal Calibration



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a **pulsed irradiation** response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

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Fig. 2 Irradiation-Preheat Cycling

Insufficient Sample Mass

Fig. 3 D_e Preheat Dependence

Insufficient Sample Mass

Fig. 4 Dose Recovery

Insufficient Sample Mass

Sample: GL06035

Fig. 5 Inter-aliquot D_e distribution

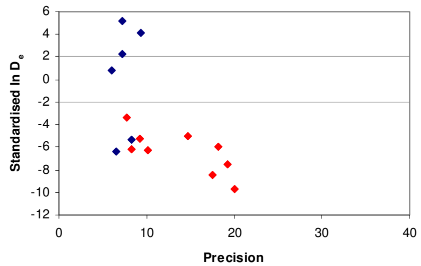


Fig. 6 Signal Analysis

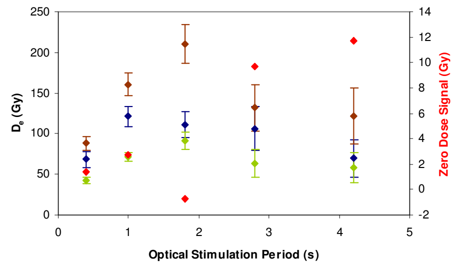


Fig. 7 Th & U Decay Activities

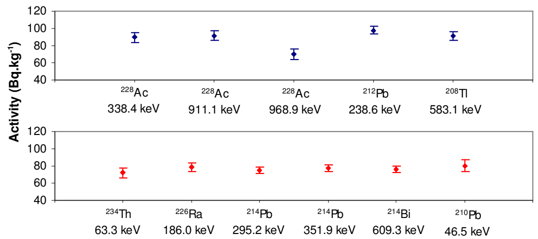


Fig. 8 Age Range

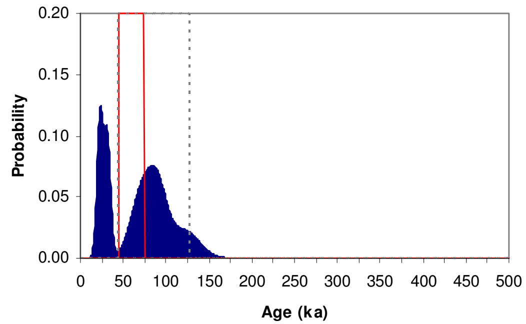


Fig. 1 Signal Calibration

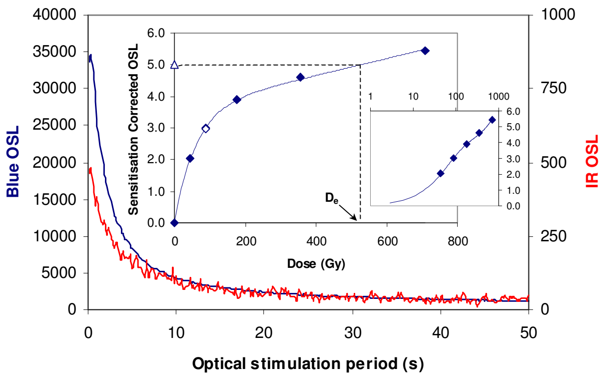


Fig. 2 Irradiation-Preheat Cycling

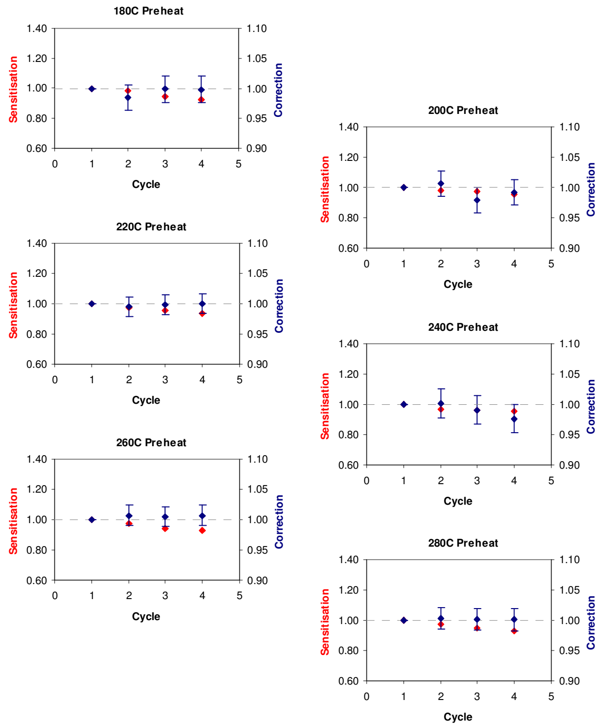


Fig. 3 D_e Preheat Dependence

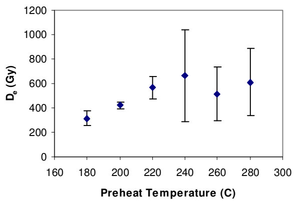


Fig. 4 Dose Recovery

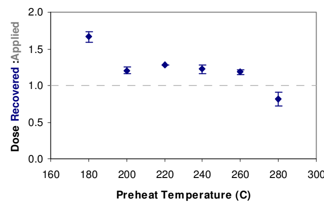


Fig. 5 Inter-aliquot D_e distribution

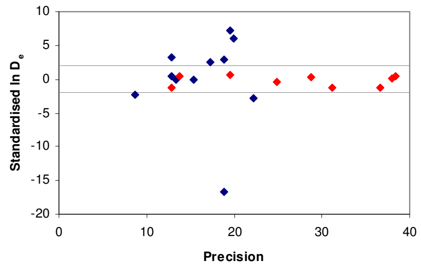


Fig. 6 Signal Analysis

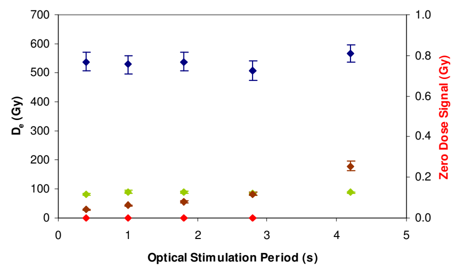


Fig. 7 Th & U Decay Activities

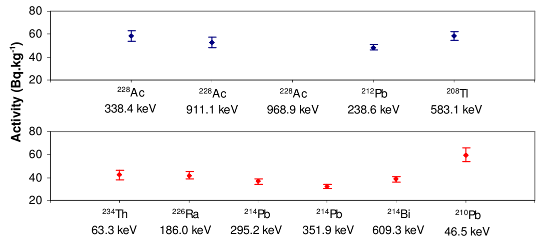
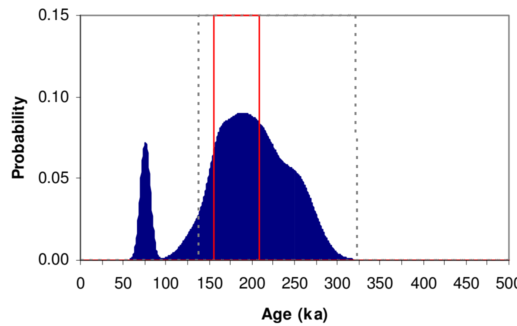


Fig. 8 Age Range



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

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D_e Preheat Dependence Quantifies the combined effects of thermal transfer and sensitisation on the natural signal. Insignificant adjustment in D_e may reflect limited influence of these effects

Dose Recovery Attempts to replicate the above diagnostic, yet provide improved resolution of thermal effects through removal of variability induced by heterogeneous dose absorption in the environment and using a precise lab dose to simulate natural dose. Based on this and preceding data an appropriate thermal treatment is selected to refine the final D_e value.

Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from natural and laboratory irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching along with insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates.

Th & U Decay Activities Statistical concordance (equilibrium) in the activities of daughter radioisotopes in the Th and U decay series may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates

Age Range The mean age range provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Sample: GL06045

Fig. 1 Signal Calibration

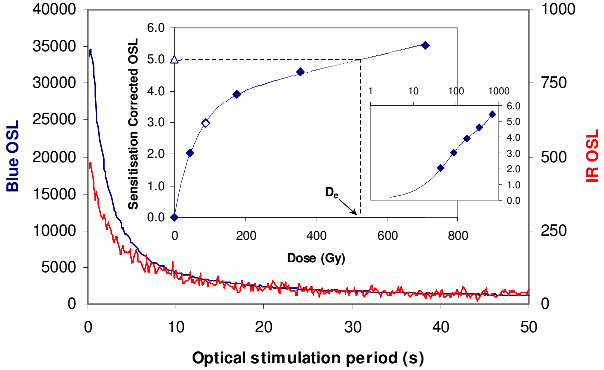

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Fig. 2 Irradiation-Preheat Cycling

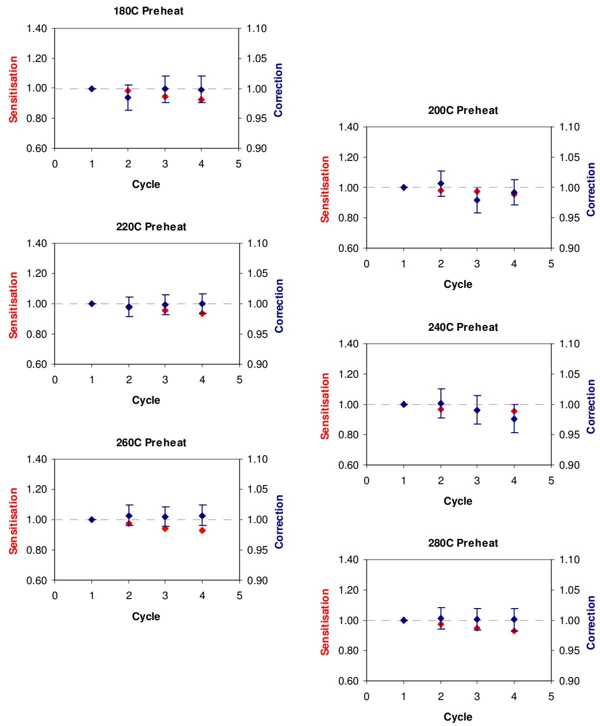


Fig. 3 D_e Preheat Dependence

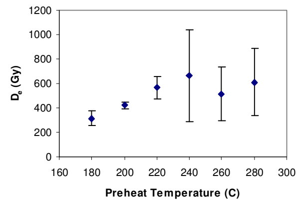
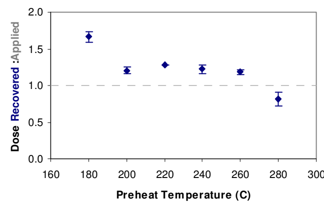


Fig. 4 Dose Recovery



Sample: GL06045

Fig. 5 Inter-aliquot D_e distribution

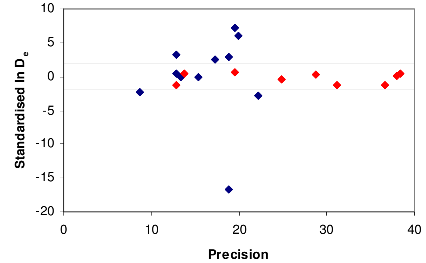


Fig. 6 Signal Analysis

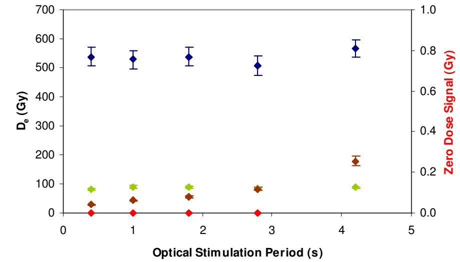


Fig. 7 Th & U Decay Activities

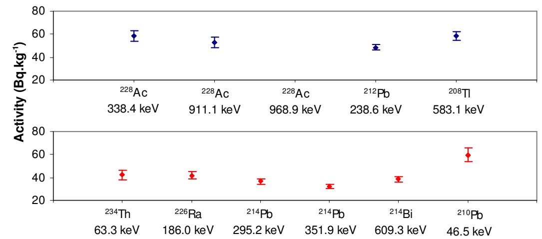


Fig. 8 Age Range

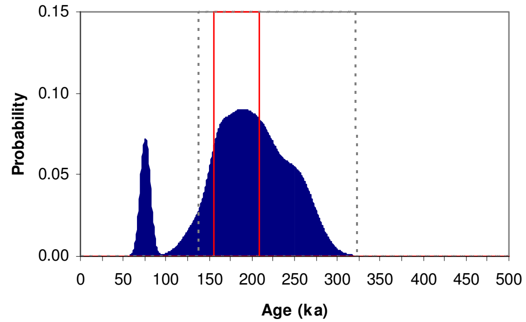


Fig. 1 Signal Calibration

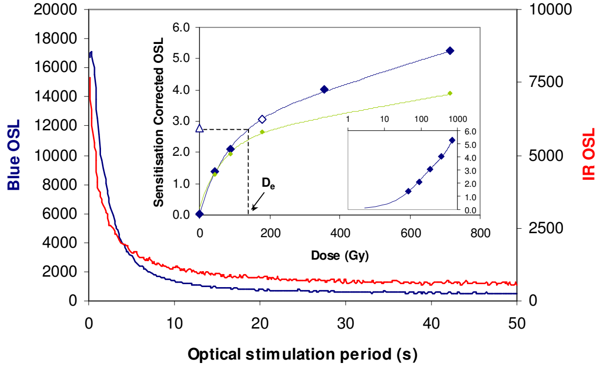


Fig. 2 Irradiation-Preheat Cycling

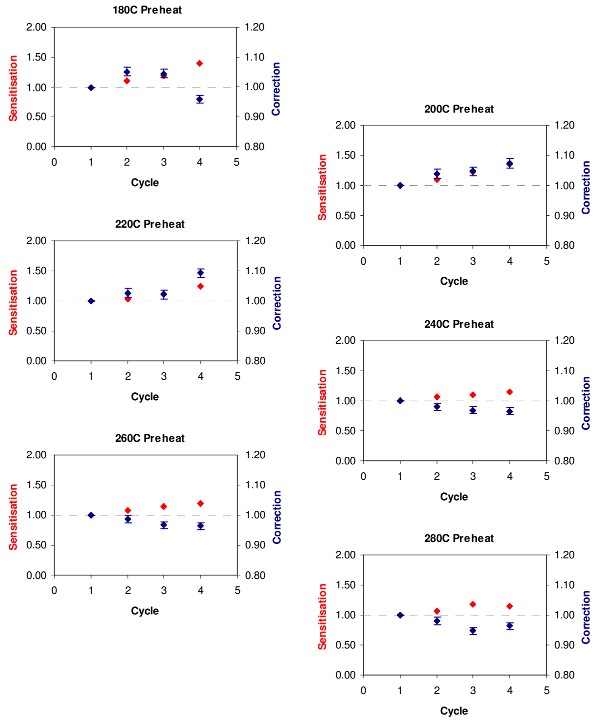


Fig. 3 D_e Preheat Dependence

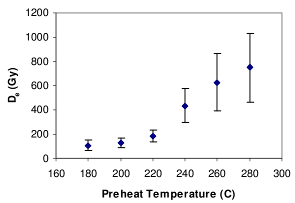
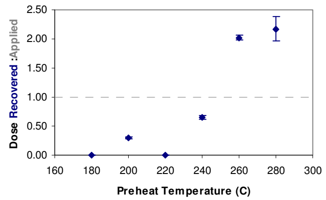


Fig. 4 Dose Recovery



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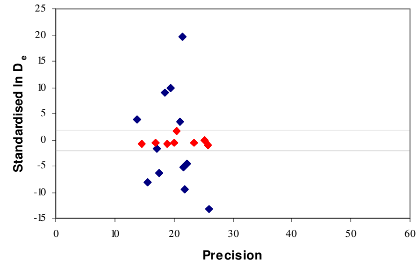
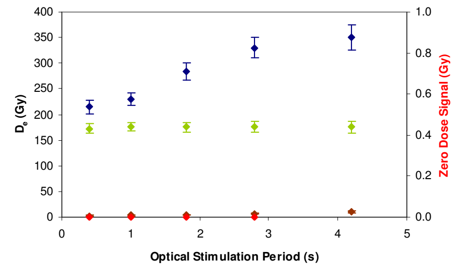


Fig. 6 Signal Analysis



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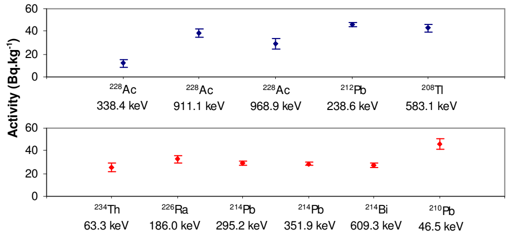
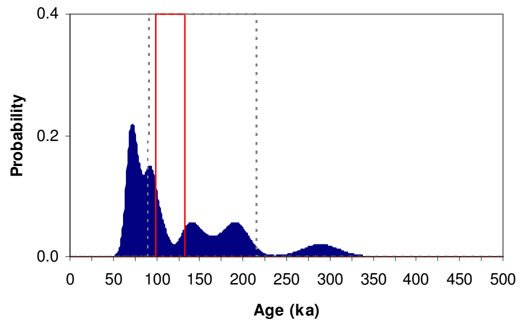


Fig. 8 Age Range



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Sample: GL06047

Fig. 1 Signal Calibration

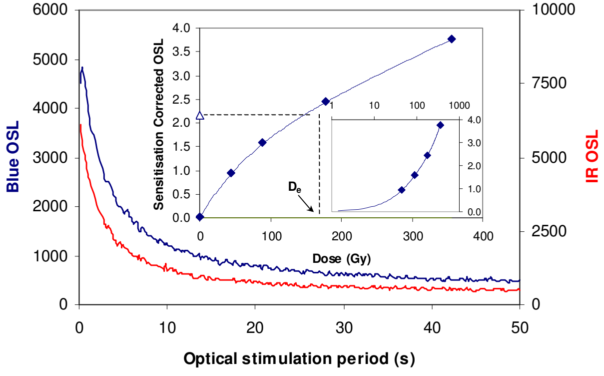


Fig. 2 Irradiation-Preheat Cycling

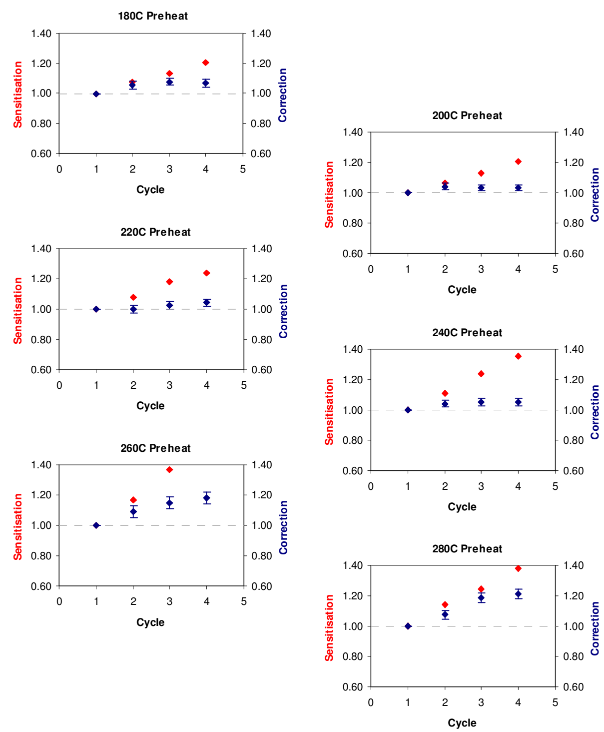


Fig. 3 D_e Preheat Dependence

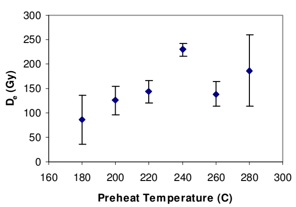


Fig. 4 Dose Recovery

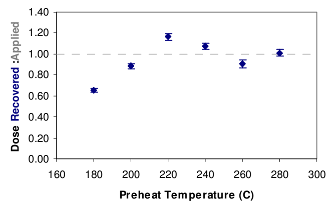


Fig. 5 Inter-aliquot D_e distribution

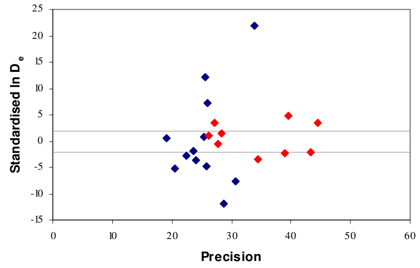


Fig. 6 Signal Analysis

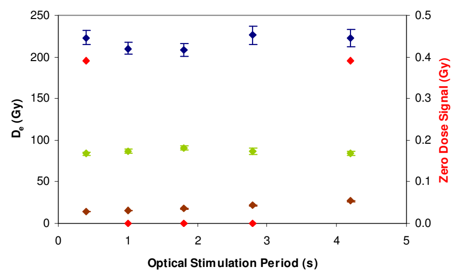


Fig. 7 Th & U Decay Activities

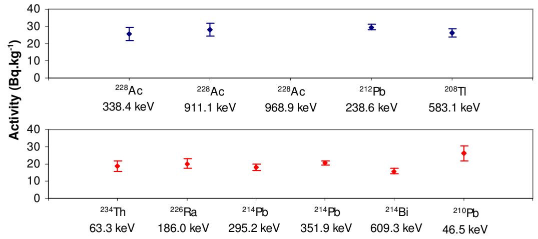
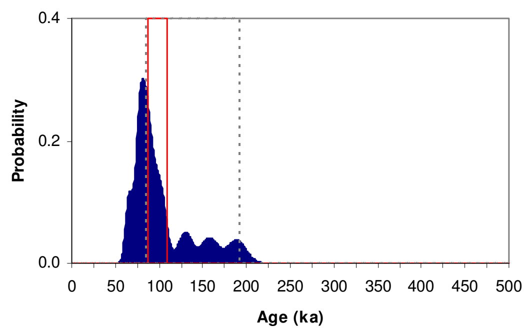


Fig. 8 Age Range



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Age Range The **mean age range** provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The **maximum influence** of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Sample: GL06048

Fig. 1 Signal Calibration

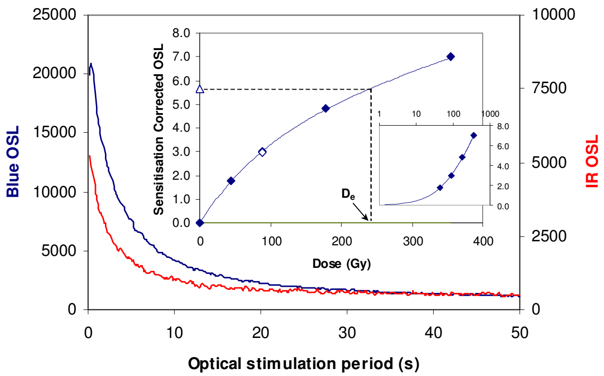

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Fig. 2 Irradiation-Preheat Cycling

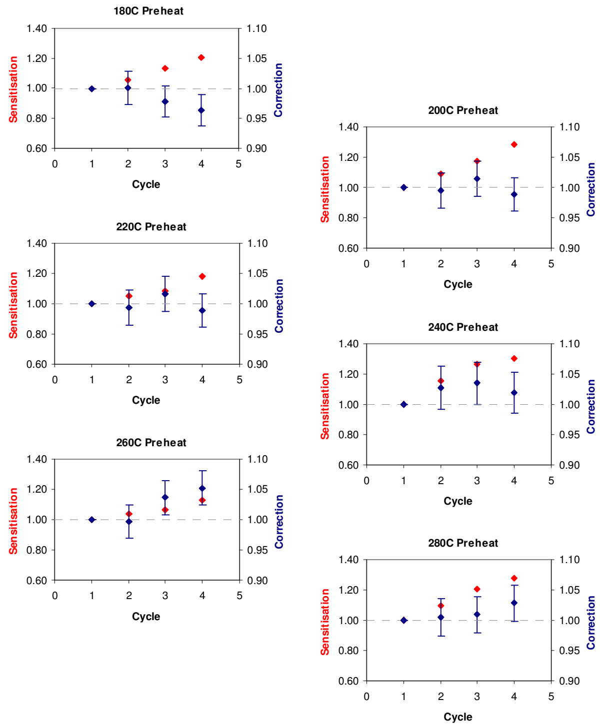


Fig. 3 D_e Preheat Dependence

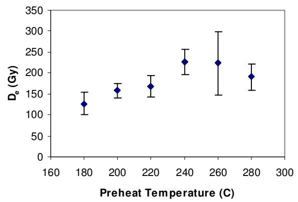
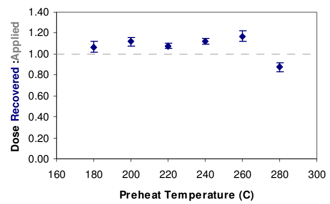


Fig. 4 Dose Recovery



Sample: GL06049

Fig. 5 Inter-aliquot D_e distribution

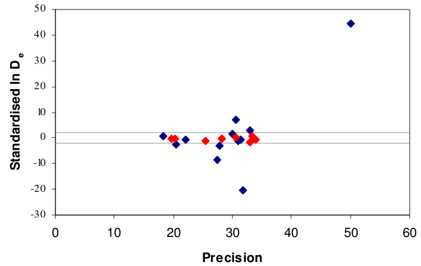


Fig. 6 Signal Analysis

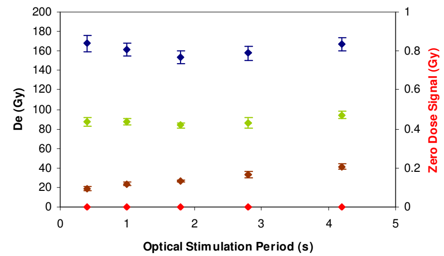


Fig. 7 Th & U Decay Activities

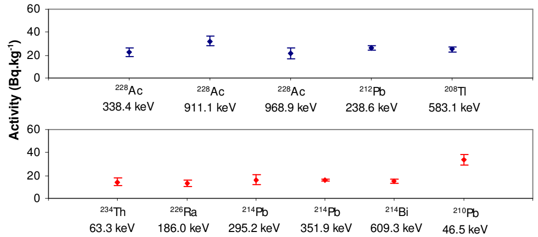


Fig. 8 Age Range

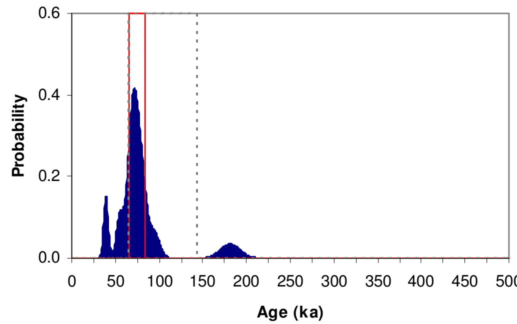


Fig. 1 Signal Calibration

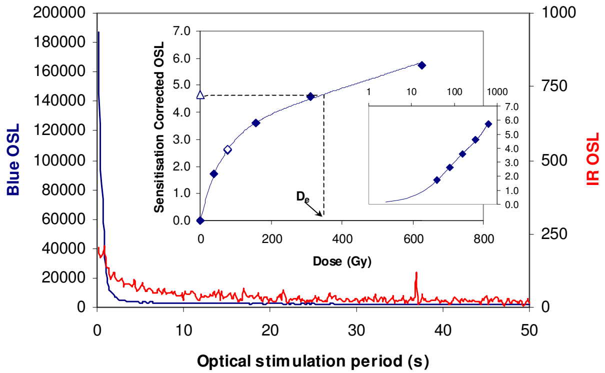


Fig. 2 Irradiation-Preheat Cycling

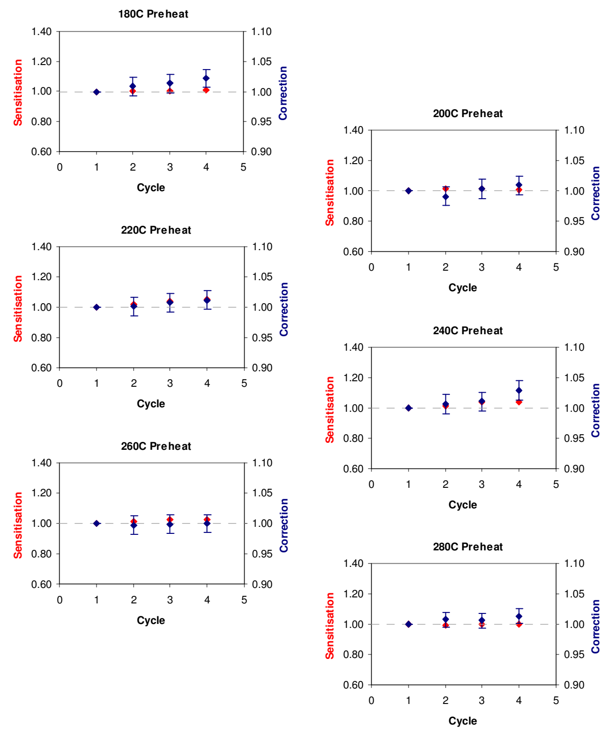


Fig. 3 D_e Preheat Dependence

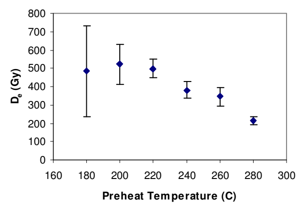


Fig. 4 Dose Recovery

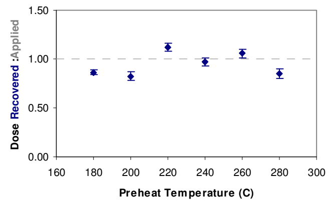


Fig. 5 Inter-aliquot D_e distribution

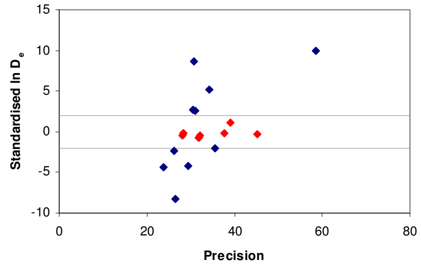


Fig. 6 Signal Analysis

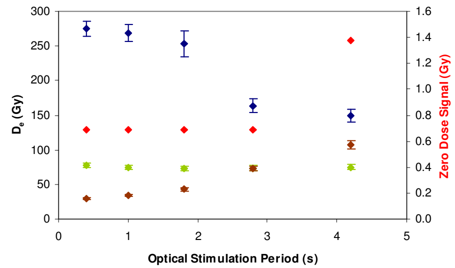


Fig. 7 Th & U Decay Activities

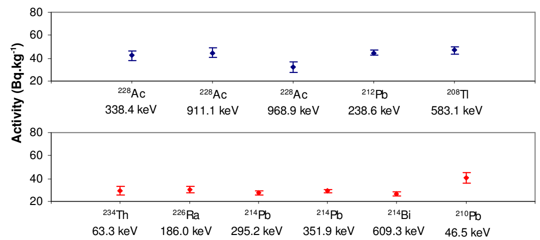
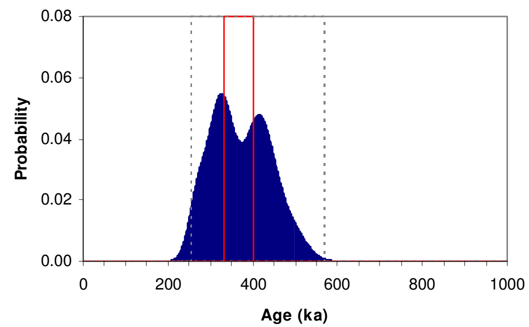


Fig. 8 Age Range



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

Irradiation-Preheat Cycling The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. Repeated irradiation and thermal treatment results in aliquot sensitisation, rendering calibration of the natural signal inaccurate. This sensitisation can be monitored and corrected for. The accuracy of correction can be preheat dependent; irradiation-preheat cycling quantifies this dependence for laboratory-induced signals, examining the reproducibility of corrected OSL resultant of repeat laboratory doses.

D_e Preheat Dependence Quantifies the combined effects of thermal transfer and sensitisation on the natural signal. Insignificant adjustment in D_e may reflect limited influence of these effects

Dose Recovery Attempts to replicate the above diagnostic, yet provide improved resolution of thermal effects through removal of variability induced by heterogeneous dose absorption in the environment and using a precise lab dose to simulate natural dose. Based on this and preceding data an appropriate thermal treatment is selected to refine the final D_e value.

Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from **natural** and **laboratory** irradiation. Discordant data (those points lying beyond **±2 standardised ln D_e**) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

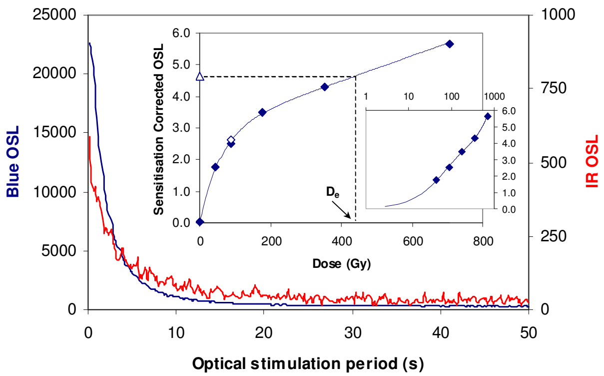
Signal Analysis Statistically significant increase in **natural** D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from **simulated partial bleaching** along with insignificant adjustment in D_e for simulated **zero** and **full bleach** conditions. Ages from such samples are considered maximum estimates.

Th & U Decay Activities Statistical concordance (equilibrium) in the activities of daughter radioisotopes in the Th and U decay series may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates

Age Range The **mean age range** provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The **maximum influence** of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Sample: GL06057

Fig. 1 Signal Calibration



Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Where D_e values are >40 Gy, a pulsed irradiation response is shown; pulsed irradiation D_e values are used in age calculations if significantly different from continuous irradiation-based D_e. Where D_e values are >100Gy, a log-linear plot of dose response is shown; D_e can be confidently interpolated if signal response increases with dose.

Irradiation-Preheat Cycling The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. Repeated irradiation and thermal treatment results in aliquot sensitisation, rendering calibration of the natural signal inaccurate. This sensitisation can be monitored and corrected for. The accuracy of correction can be preheat dependent; irradiation-preheat cycling quantifies this dependence for laboratory-induced signals, examining the reproducibility of corrected OSL resultant of repeat laboratory doses.

D_e Preheat Dependence Quantifies the combined effects of thermal transfer and sensitisation on the natural signal. Insignificant adjustment in D_e may reflect limited influence of these effects

Dose Recovery Attempts to replicate the above diagnostic, yet provide improved resolution of thermal effects through removal of variability induced by heterogeneous dose absorption in the environment and using a precise lab dose to simulate natural dose. Based on this and preceding data an appropriate thermal treatment is selected to refine the final D_e value.

Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from natural and laboratory irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching along with insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates.

Th & U Decay Activities Statistical concordance (equilibrium) in the activities of daughter radioisotopes in the Th and U decay series may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates

Age Range The mean age range provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Fig. 2 Irradiation-Preheat Cycling

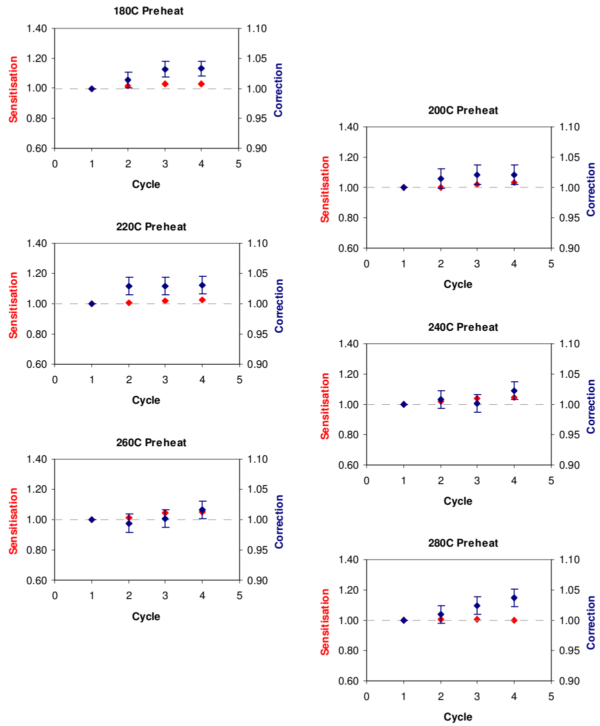


Fig. 3 D_e Preheat Dependence

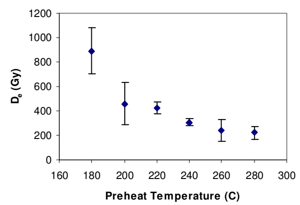
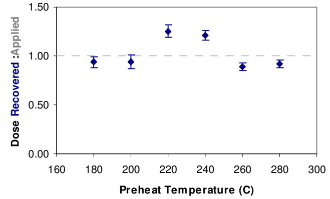


Fig. 4 Dose Recovery



Sample: GL06058

Fig. 5 Inter-aliquot D_e distribution

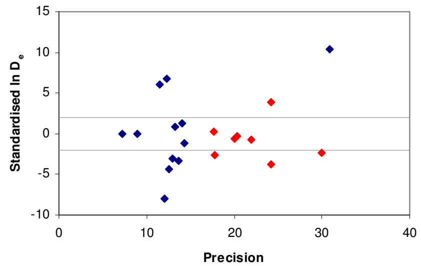


Fig. 6 Signal Analysis

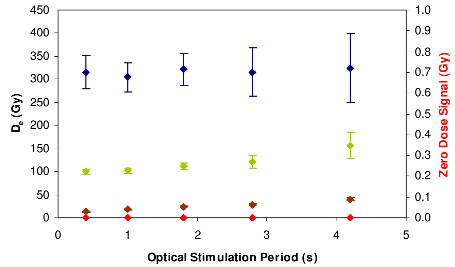


Fig. 7 Th & U Decay Activities

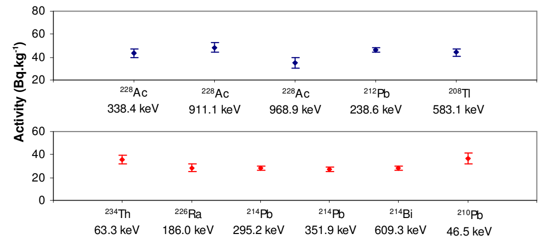
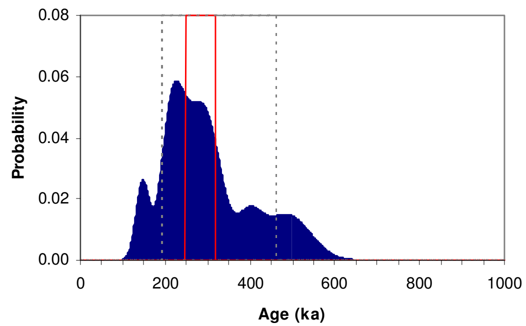


Fig. 8 Age Range



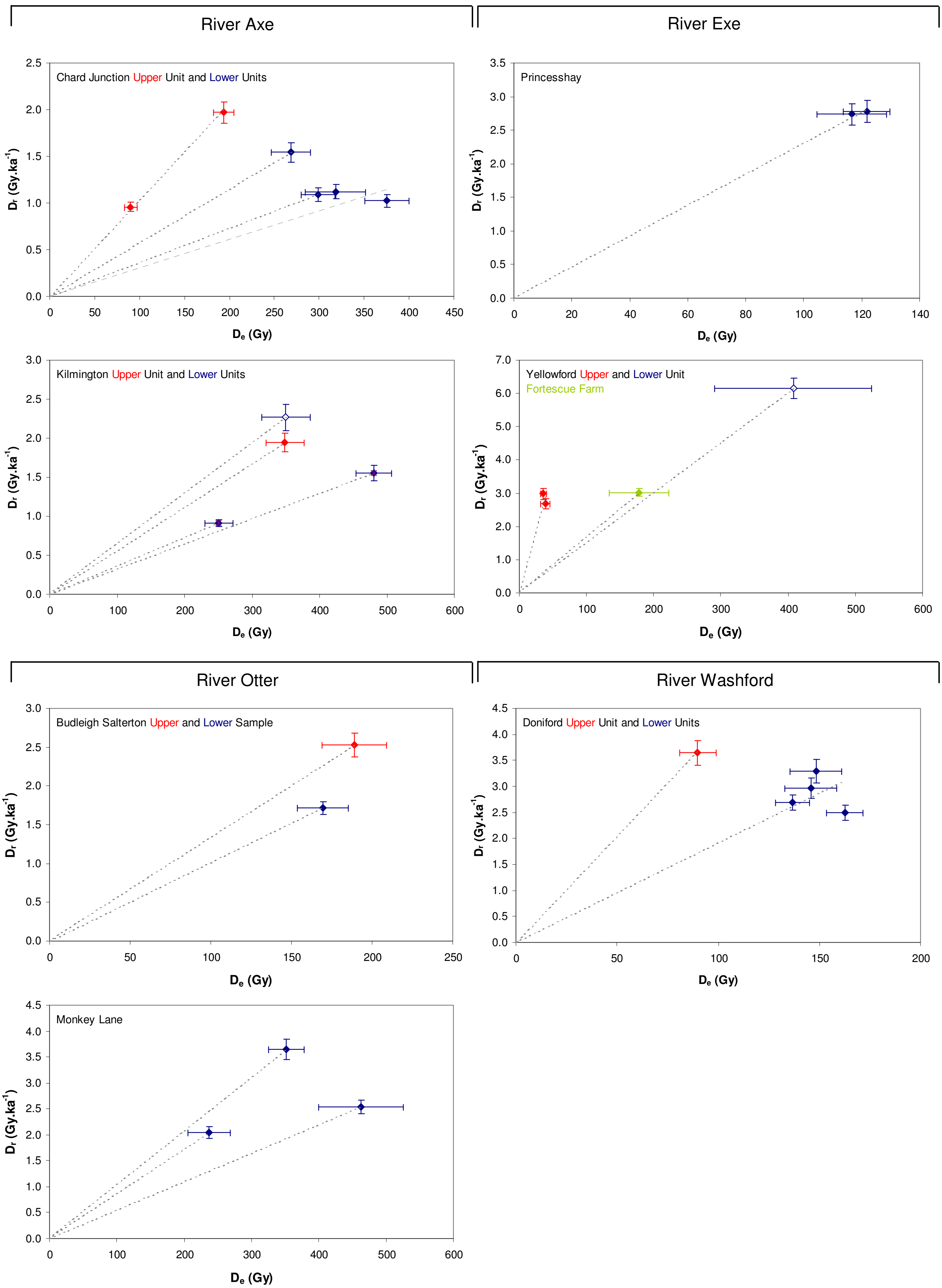


Fig. 9 D_e:D_r plots for this study's suite of samples. The gradient of a line drawn from the origin to the data point of any sample represents sample age; the shallower the gradient, the older the age estimate. Samples from a stratigraphically equivalent unit are fitted with a single line representing the isochron for that unit. Unfilled symbols reflect data where qualifications are made within the text.

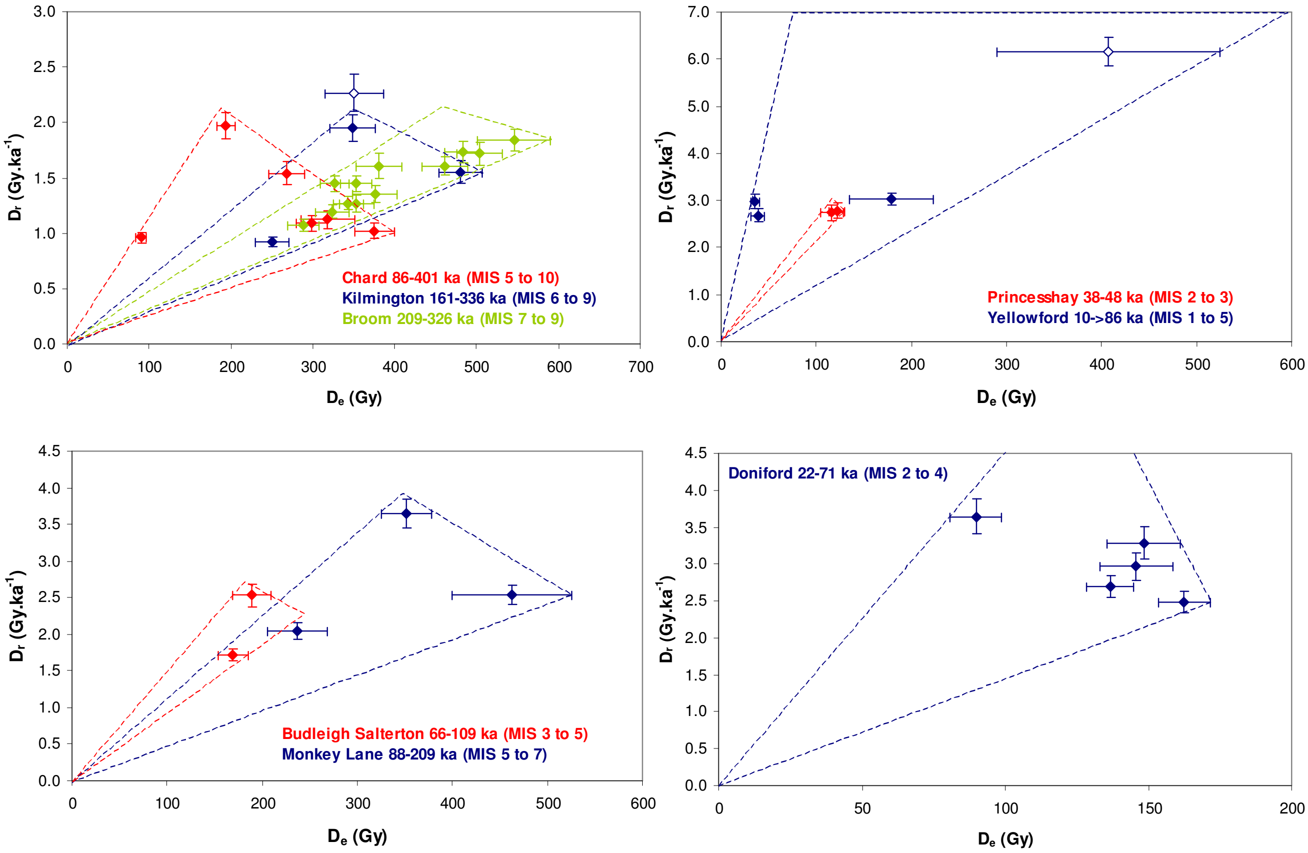


Fig. 10 Age envelopes for site deposits of the former i) Axe, ii) Exe, iii) Otter and iv) Washford Rivers.

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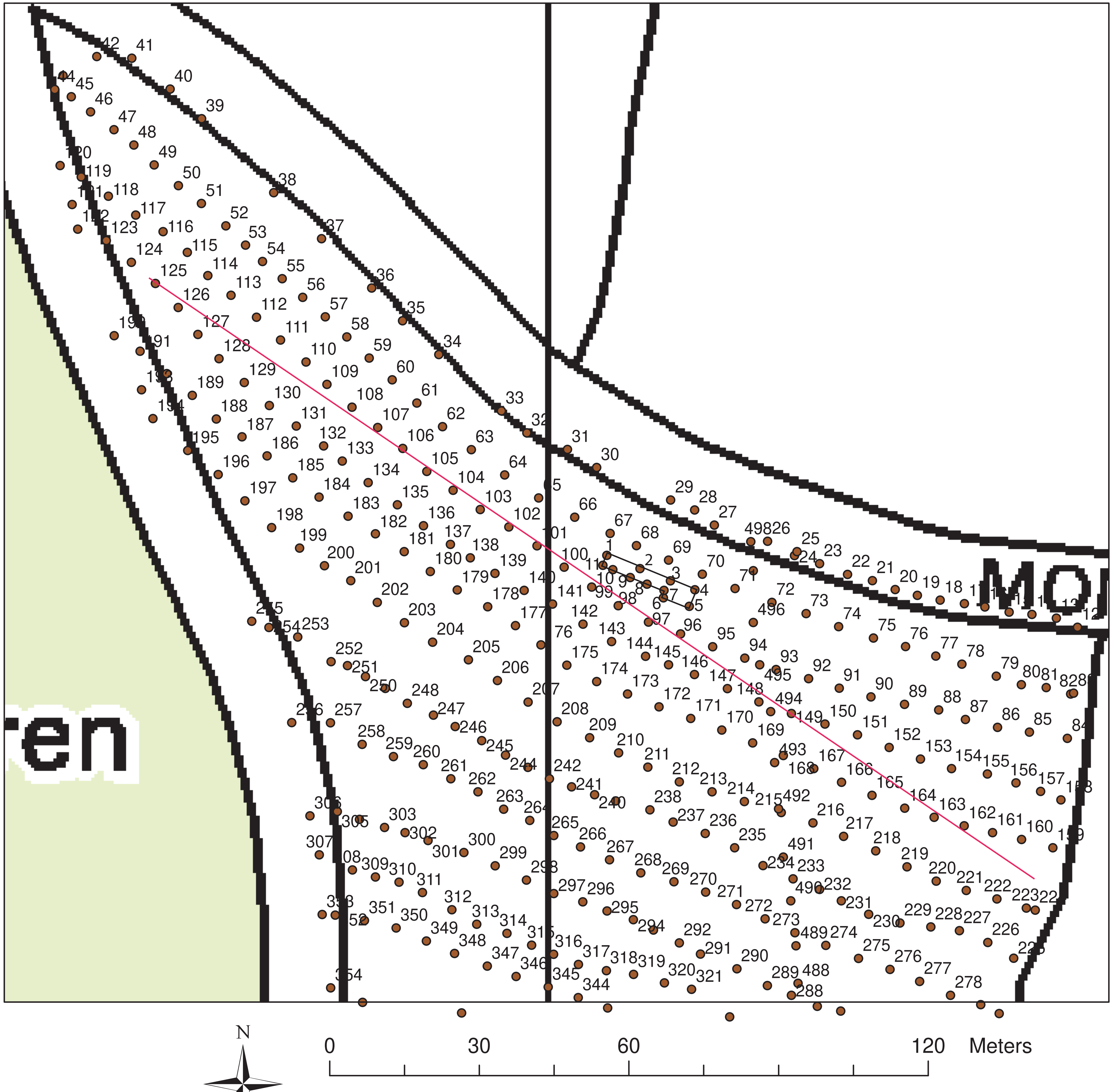
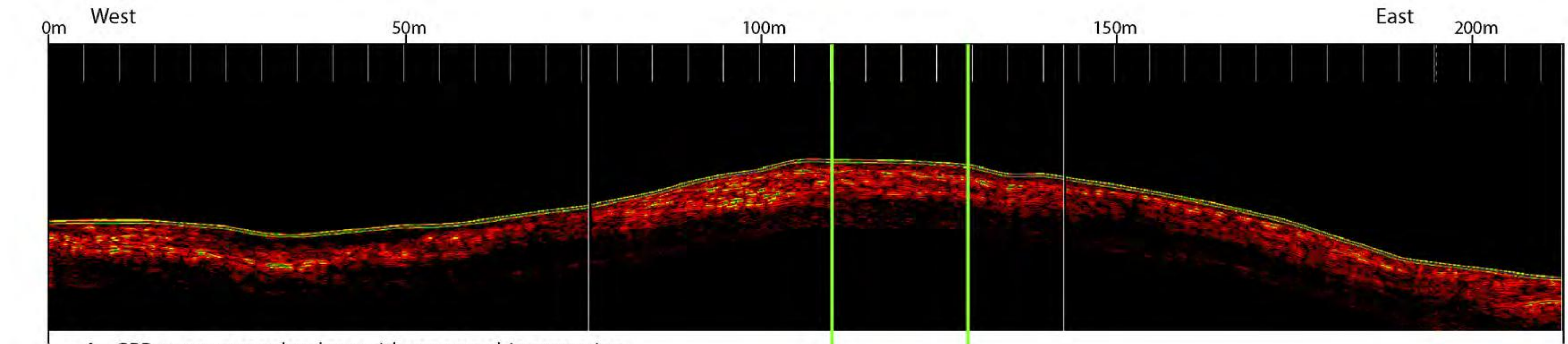
APPENDIX 8

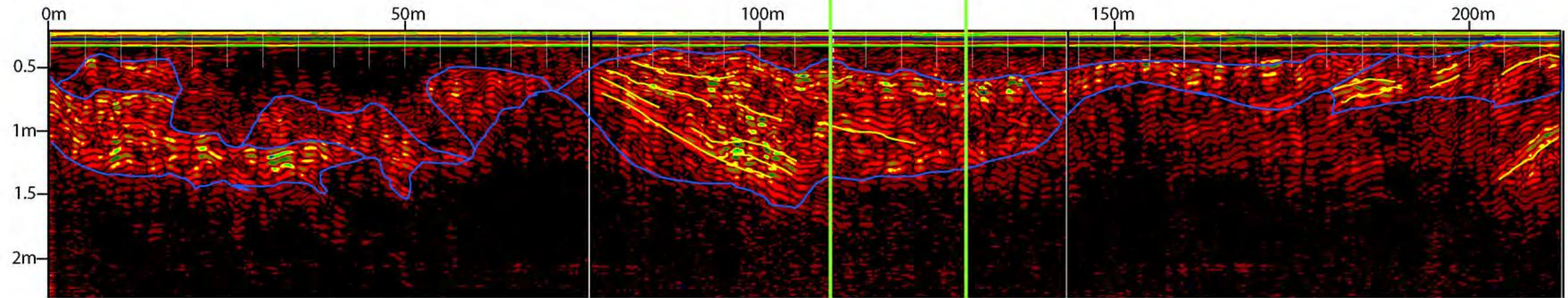
GPR PLOTS AND RELATED INFORMATION



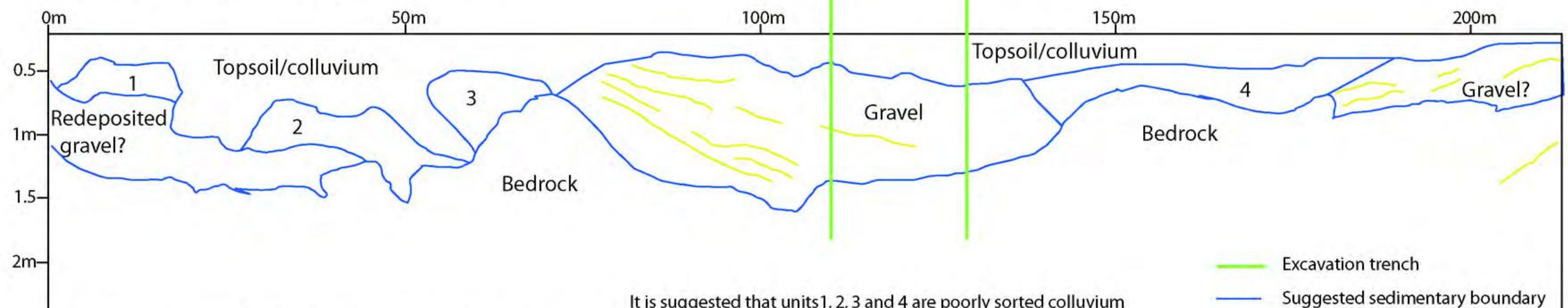
Monkey Lane GPS against OS at North End of Field
Red Line is GPR Transect Location



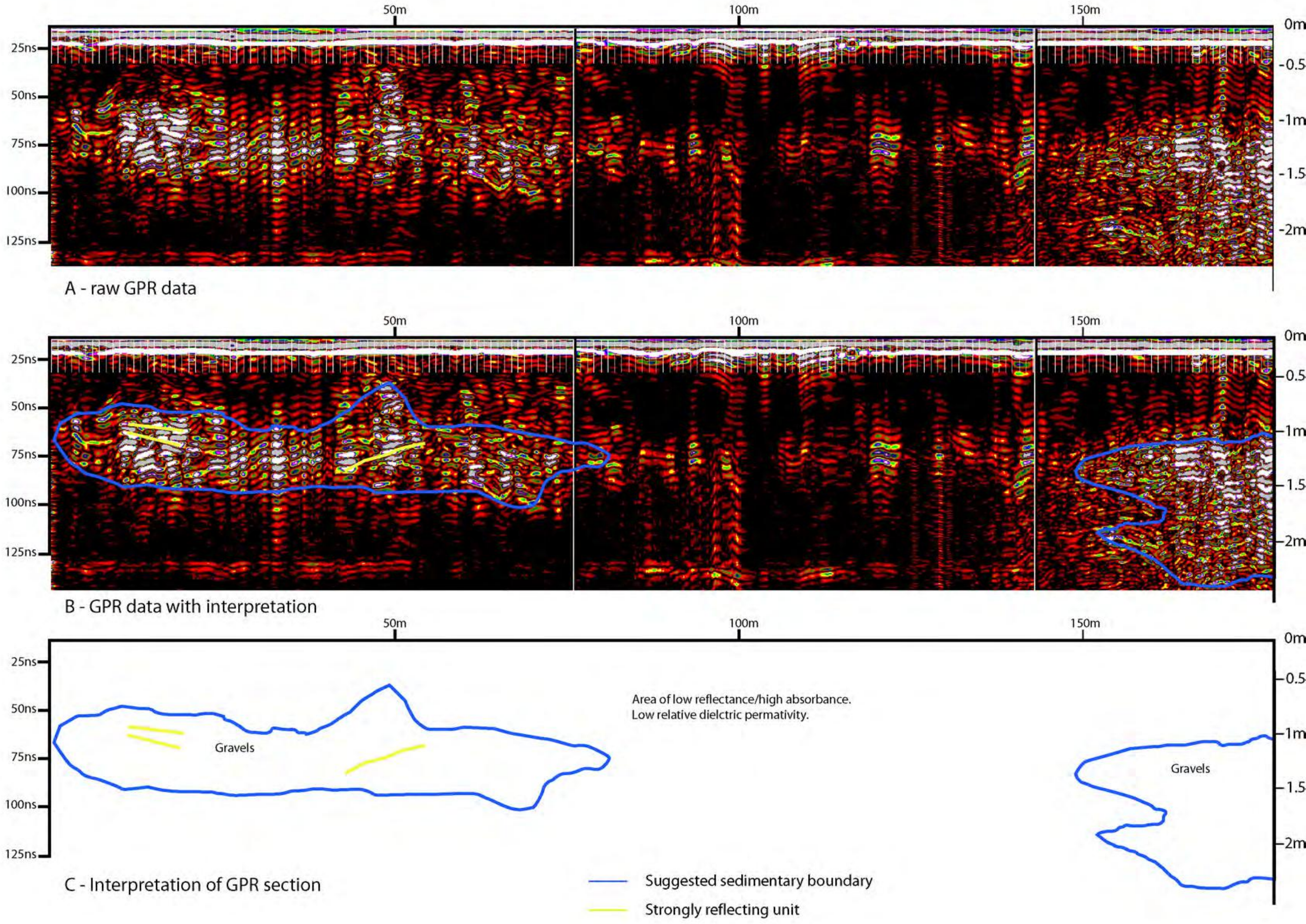
A - GPR transect monkey lane with topographic correction



B - GPR transect monkey lane, with interpretation



C - GPR transect Monkey Lane, interpretation only



50m
100m
150m
0m
-0.5
-1m
-1.5
-2m
25ns
50ns
75ns
100ns
125ns
A - raw GPR data
B - GPR data with interpretation
Area of low reflectance/high absorbance.
Low relative dielctric permativity.
Gravels
Gravels
C - Interpretation of GPR section
Suggested sedimentary boundary
Strongly reflecting unit

APPENDIX 8: RELATED INFORMATION

Palaeolithic Rivers of South West Britain Ground Penetrating Radar Surveys

Introduction

The preliminary results of two ground penetrating radar (GPR) surveys are shown, undertaken as part of the Palaeolithic Rivers of South West Britain project. The first survey investigated an area of terrace deposit on the River Axe, whilst the second survey was of an area of aggregates extraction commonly known as Broom pit, a terrace deposit of the Axe.

Materials and methods

At both Monkey Lane and Broom pit a single GPR transect was undertaken, providing a 2D cross sectional data set of the site. The GPR system employed was a GSSI SIR3000 unit, with a 200MHz frequency antenna, using a survey wheel for distance calibration. The SIR 3000 has only one fixed antenna so CMP (common mid point analysis) was not applicable for depth calibration. Instead calibration was made through the use of an excavated section dug earlier in the year by A. G. Brown and L. S. Basell, at the Monkey Lane site. The depth calibration at Broom pit was made through analogy to the Monkey Lane site. Data was collected at 512 samples/scan, with 16 bits per sample at 64 scans per second. The depth of the viewing field was set at 150ns. Field filters were set at three times the antenna frequency for the IIR vertical high pass (600MHz) and one quarter of the antenna frequency for the IIR low pass (50MHz). The processing of the data followed a prescribed route, developed through experimentation with GPR data collected on alluvial deposits. Data processing is subjective. The aim of the processing steps undertaken in this project was to set the correct time zero, correct for hyperbola reflections via migration, remove background noise and increase/decrease gains to provide good contrast in the data. This is a simple processing sequence that can bring out good quality results in alluvial data sets. For each set of survey data time zero was set through the first positive peak seen within GPR section. Migrations were undertaken through a variable velocity migration. A series of hyperboles were selected in the GPR diagram, coming from a variety of depths and sediment units. A graph was made of the relative velocity curve, taking into account the size of the parabolas combined with the depth of the parabolas, allowing changes in the velocity of the radar pulse through the profile to be calibrated. Normally several different graphs were experimented with in each survey until a satisfactory result was obtained. Background removal filters were used to ‘clean’ the data, along with some application of vertical high pass and vertical low pass filters. Deconvolution filters were generally not used. Deconvalution filters have the ability to remove ‘ringing’, multiple reflectors caused through wave diffraction in low absorption/high reflectance environments. However, deconvolution also has the ability to remove real data, which is interpreted as the effect of multiple reflections, such as some of the reflections seen within the gravel units.

Interpretation Monkey Lane

The Monkey Lane survey provided good quality results. This is a product of a relatively low water table, combined with a shallow sandy soil, with low clay content. The results from the GPR correlate well with the general site stratigraphy, as revealed by the excavation trench. In the western part of the section the GPR revealed an anomaly which is suggestive of a second gravel unit. This is supported by the GPS modelling which suggests a major high at the north of the field, a further distinctive high in the middle of the field and minor anomalies in the western and eastern areas.

Interpretation Broom Pit

The GPR survey at Broom pit provided extremely poor quality results. Penetration into the strata was extremely limited, with ringing visible in the data. The reason for the very low penetration/rapid signal attenuation is a product of a high water table in the area surveyed, combined with a white clay lense, sitting at the surface of the soil profile. A water-saturated clay has a low relative dielectric permativity, causing rapid attenuation of the radar pulse, due to it being highly conductive material. There is little useful information that can be gleaned from the GPR section and no inferences can be made on the gravel stratigraphy based on it.

APPENDIX 9: ASSESSMENT REPORT

A.9.1 Environmental Analyses

As per the project design, when encountered during fieldwork organic rich and very fine-grained sediments were sampled for environmental analyses. The aim of this was to assess the potential of terrace units in South-West England for environmental studies which could be used to reconstruct the environment of Lower and Middle Palaeolithic hominins. The methods used were standard based on an in-field evaluation, sampling where potential was thought to exist, and standard processing techniques where appropriate. For a full description of all the sediments encountered please refer to the fieldwork report.

A.9.2 Faunal Remains

None have been encountered during the fieldwork. None of the quarry or pit faces or exposures contained deposits finer than silty sands, which would normally be assessed by sieving. A careful search at each site was made for vertebrate remains but none were found. This is not unexpected in relation to vertebrates as all the terraces gravels in the Exe, Otter and Axe Valleys are largely decalcified. No sediments suitable for coleoptera analysis were identified.

A.9.3 Plant Macrofossil Analysis

Organic remains in these terraces are very rare, although they do exist. However, all the organic-rich sediments discovered within the gravels were highly humified and did not contain macroscopic plant remains.

A.9.4 Pollen and Spore Analysis (Palynomorphs)

A list of the samples taken with a description is given in Table 8. Initially large standard sample size (1 ml) was used for pollen analysis but as this proved to have too low a concentration in all cases, non-standard large samples were used of 4 ml for a second processing.

Site	Lab. No	Depth/Location	Description
Doniford	DGb07	Base of cliff	Sandy peaty “pebble”
	DGb172	6cm above base	Sandy peaty “pebble”
	DGb185	Basal bed	Sandy peaty “pebble”
	DGb197		Sandy peaty “pebble”
Yellowford	YF1		
	YF2		
	YF3		
Monkey Lane	OML1		Organic clay with reworked sand
	OML5		Mn and Fe mottled sandy clay clast
	OML6		Mn and Fe mottled sandy clay lens

	OML7		Red mottled silty clay with sand and pebbles (possible tree throw pit)
	OML8		Organic gritty sandy silty clay above basal gravel lag
Kilmington	KLM1		Grey/yellow medium sandy clay
	KLM2		Grey/yellow medium sandy clay
	KLM3	OSL 2 location	Grey/yellow medium sandy clay
	KLM4		Grey/yellow medium sandy clay

Table 8: Samples processed for pollen and spore assessment

Processing involved standard chemical preparation but with a prolonged hydrofluoric acid stage and triple sieving. In each case one slide (1 cm^2) was counted fully irrespective of the initial pollen and spore concentration. All counts were undertaken using a Nikon Optiphot microscope at a magnification of x400, and x1000 when needed. A target of 300 grains of pollen per level was set, excluding exotic grains, spores and aquatics to give a total land pollen (TLP) sum. Identification of pollen grains and spores was aided with the use of keys in pollen textbooks, including primarily Faegri & Iversen (1989) and Moore *et al*. (1991) and by comparison with modern pollen reference material (type slides) of the Department of Geography, University of Exeter.

A.9.4.1 Results

The results are tabulated in Table 9. As can be seen the majority of the samples contained virtually no pollen and spores. This is not surprising due to both the inorganic nature of most of the sediments (mostly sandy clays) and the considerable antiquity of the sediments. However, there are interesting inter-site variations.

The samples from sandy peaty pebbles contained in the basal member at Doniford were expected to yield pollen and spores. The disappointing results probably reflect the sandy nature of the organic pebbles which may have been derived from an oxidized humic peaty floodplain soil. Despite the disappointing results from Doniford it is felt that the site probably does contain environmental potential but that larger peat clasts are probably required which could afford some protection for pollen and spore content. One reason for continued interest in the site is that the dating (see the Fieldwork Report and Appendix 7) suggests that it spans the environmental changes that are believed to have occurred during OIS 3.

The Yellowford Farm samples contained virtually no pollen except for a very occasional *Betula* and *Pinus*. This is due to both their antiquity, free drainage and the inorganic nature of the sediments. This terrace (5) has very low environmental potential.

Only one sample from the Otter Valley terrace (Monkey Lane: OML) contained any pollen at all and at the low levels encountered it is not meaningful. Again this is due to their antiquity, free drainage, and the inorganic nature of the sediments. This terrace has very low environmental potential.

Most of the Kilmington (Axe Valley) samples produced no pollen or spores, however, two samples contained an interesting assemblage although at very low concentrations. KLM3 is dominated by *Acer* (maple) with *Salix* (willow) and *Quercus* (oak). One grain of *Robinia* (false acacia) was also identified. This is an unusual assemblage and clearly indicates interglacial conditions. *Acer* is particularly common in the British Ipswichian (OIS 5e), however it is common in interglacials from the Middle Pleistocene onwards. KLM on the other hand contained no tree pollen but a group of herbaceous types typical of damp to wet ground. These results, although only at the assessment level are important because:

- They indicate that potentially valuable pollen and spore data can be gained from the fine clastic sediments contained within gravel terrace sequences (this is also the case at Broom).
- The terrace gravels at Kilmington have accumulated both during cold phases and warm phases of the Middle-Late Pleistocene and so the archaeological potential of theses deposits is particularly high.
- Environmental monitoring should be conducted at any site which exposes these beds and members such as at Chard Junction pit.

Overall the environmental assessment suggests, as expected that the fine clastic sediments from strath terrace sequences of Mid-Late Pleistocene age have low environmental potential. However, similar sediments from cut and fill (or stacked) terrace sequences as is the case in the Axe Valley and to a lesser extent at Doniford, have a moderate to high potential for pollen and spore studies.

A.9.5 Artefacts

No artifacts have been discovered during the fieldwork. This is not unexpected due to the relatively short exposures except at Chard Junction. At Chard Junction the faces are still gravels which probably correspond to the "Upper Gravels" at Broom, which contained relatively few artefacts. Also Pleistocene gravels often tend to show clusters of lithic finds (e.g. as at Broom).

A.9.6 GPR Assessment

The results of the assessment are given in the fieldwork report. However, in summary, the results indicated that on an upstanding strath terrace, such as at Monkey Lane in the Otter Valley, GPR could indicate the base of the gravels, gaps between gravel bodies and show some structure within the gravels. Indeed GPR confirmed a suspicion from the surface topography that two gravels bodies underlay the transect. At Broom the results were far less rewarding, with a combination of a high water-table and disturbed and made ground producing results of little interpretive value. It is suggested that this is, however, nonetheless a useful finding and that GPR has in general higher potential on upstanding strath terrace fragments than in thick cut and fill/stacked terrace gravels.

A.9.7 Statement of Potential to Contribute to Research Issues of Wider Significance

The research assessment described here and in the fieldwork report has the potential to inform far wider questions of Palaeolithic research. In particular, as part of this research a 2D model of terrace formation has been formulated. This model has archaeological advantages (due to resource distribution) over the classic essentially 1D model proposed by Bridgland (1996, 2000). The assessment also highlights those areas with high potential to generate new Palaeolithic data in South-West England. The research will, after analysis, also allow a far better comparison of the South-West Palaeolithic record with that of the rest of Southern England and the Midlands. Lastly the use of GPR has proven of value in the identification of multi-level gravel bodies such as terrace fragments.

A.9.8 Dating Recommendations

All the material assessed was well beyond the limits of radiocarbon dating and so this is inappropriate. Luminescence dating has formed a key component of this study: the details which can be found in the fieldwork report and in the separate OSL dating report (Appendix 7). It has been found to have limitations (related to high dose rates and lack of suitable matrix) but has been applied to all the valleys studied and is clearly a technique of high applicability to the assessment of the archaeological potentials of terrace gravels.

A.9.9 Recommendations for Future Work

This study has identified three techniques of considerable potential in future studies, including archaeological assessments, of river terrace gravels in South-West England. Firstly OSL is clearly appropriate, despite its limitations, and will form the backbone of future terrace chronologies in South-West England, largely due to decalcification rendering AAR inappropriate. This should be recommended for future interventions into terrace gravels. Secondly GPR has been shown to be valuable in demarcating the edge of terrace fragments and terrace outliers and can be used as part of geophysical evaluation. Lastly pollen analysis has proved to have potential despite a paucity of polleniferous deposits and it is recommended that this be followed up by further assessment and evaluation of sites such as Kilmington and full pollen counts be made.

Pollen/Spore type	DGb07	DGb172	DGb185	DGb197	YF1	YF2	YF3	OML1	OML2	OML5	OML6	OML7	OML8	KLM1	KLM2	KLM3	KLM4
Acer																16	
Betula							1	3									
Pinus		4	2	2		1		2								1	
Quercus																3	
Robinia																1	
Salix																14	
Poaceae		1	4														
Anthemis	1																
Campanulaceae																	1
Cicuta virosa																	1
Cyperaceae				1													
Galium	2		1														
Helleborus																	2
Umbeliierae																	1
Crytogramma	3																
Filicales und.																	1
Charcoal	T	F	F	T	F	T	T	T	T	T	T	F	T		T	T	T
Unidentified			2			1								1		2	1
Exotics	281	63	27	174	13	10	40	39	44	90	202	30	15	548	330	231	244

Table 9: Raw pollen and spore counts by site. Charcoal: T=trace (1-20 fragments); F=frequent (20-200 fragments); A=abundant (>200 fragments).