

A NEW TERTIARY BASIN IN NORTH DEVON — A PROGRESS REPORT

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Investigations around Orleigh Court, south of Bideford, have established that the Eocene flint gravels are overlain by a series of clays and silts of probable Late Palaeogene age. The sole outcrop known hitherto is diminutive, but present topography suggests that it is an erosional remnant of a much larger basin formed along part of the Sticklepath-Lustleigh Fault Zone. Mapping of the area around Orleigh Court suggests that the area of outcrop of the flint gravels has been significantly over-estimated in the past.

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INTRODUCTION

Orleigh Court in North Devon, to the south of Bideford, has long been known for the occurrence of flint gravels (Figure 1). The first detailed report on these was by Rogers and Simpson (1937) and various workers have subsequently examined these gravels (e.g. Edmonds *et al.*, 1979; Freshney *et al.*, 1979). Hancock (1969) examined the collection of fossils from the flints of Orleigh Court in the Barnstaple Museum and concluded that the latest fossils there were of Late Campanian age. He suggested that the gravels accumulated as the Chalk cover was stripped off Cornubia in the Palaeogene and suggested the gravels were comparable with those atop the Haldon Hills to the west of Exeter.

Cope (2004) suggested that the Orleigh Court gravels might instead have been derived from the north-west. These would have been produced by erosion of a domed area of Chalk in Barnstaple Bay that resulted from Eocene uplift of the Lundy area occasioned by the injection of a thick dolerite sheet in the upper crust (Brooks and Thompson, 1973) before intrusion of the Lundy granite.

The new idea on the derivation of the Orleigh Court gravels prompted the late Roland Goldring to contact me. He recalled that he had spent some time at Orleigh Court in 1950 when he and his brother were working on a university vacation project on the beach at Westward Ho! and during this time visited Barnstaple Museum where they met Inkerman Rogers, a retired local watchmaker and jeweller, who had collected fossils from the Orleigh Court Gravels and co-authored the paper with Simpson (Rogers and Simpson, 1937). He suggested to the Goldring brothers that they get hold of an auger and investigate the Orleigh Court area further. An auger was duly obtained and the brothers visited the abandoned and overgrown ruin that was Orleigh Court. Here the story becomes rather vague, as Roland was unable to recall where the auger holes were made, but did say that one was within sight of the front door of the house. He said he recalled finding some sand and a lilac-coloured clay, but unfortunately neither their field notes nor the samples had survived.

I immediately suggested that we should re-investigate the area, to which he keenly assented and said he would involve members of the Reading Geological Society. He set to work to contact the owner of the main house at Orleigh Court and together with David Ward of the Reading Geological Society

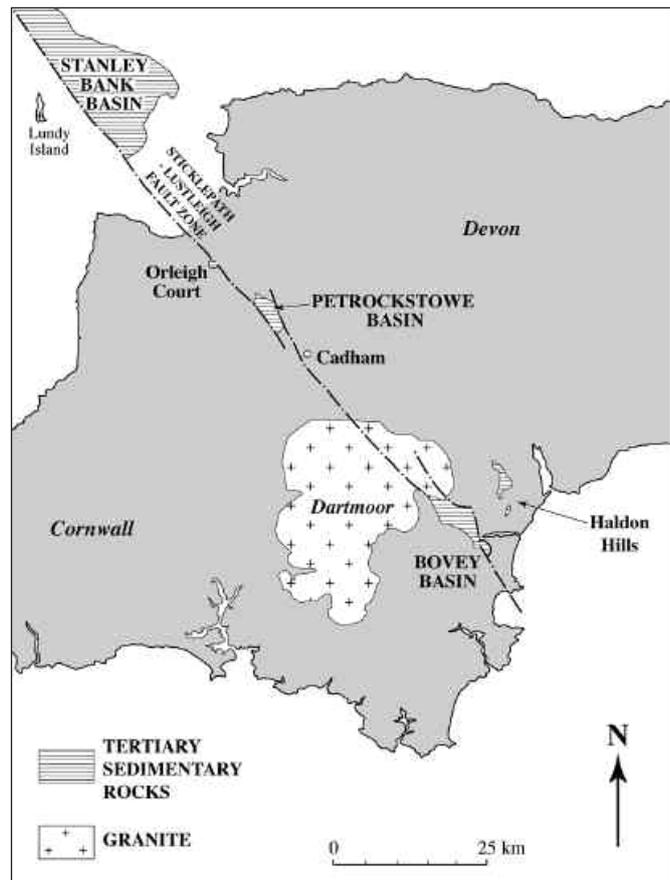


Figure 1. The distribution of Tertiary rocks in Devon (modified after Tappin *et al.*, 1994).

agreed some sites where we could auger in September 2005. Unfortunately Roland's untimely death in August 2005 put the project in jeopardy, but on contacting the Reading Geological Society I found they were keen to continue with the work.

FIELDWORK, SEPTEMBER 2005 AND ITS RESULTS

The Reading Geological Society had allocated a day's investigation into the area in September 2005. An initial walk over the ground in the vicinity of Orleigh Court established that the flint gravel outcrop forms a plateau on which Orleigh Court sits. The house itself is clearly on the outcrop and it was difficult to understand why Roland had selected the sites he had agreed for auger holes, as it appeared to me, from the topography, that they were all sited on the gravels and it would be difficult, if not impossible to put down auger holes there. So it proved, with flints in the immediate subsurface at each of the agreed sites.

Our preliminary survey of the area suggested that the higher ground, to the immediate south-west of Orleigh Court could be worth exploring. A ploughed field showed clays turned up from the deepest part of the furrows and, with the agreement of the landowner, an auger hole was put down close to the field margin. This proved a thickness of white and yellowish clays, but at 1.8 m depth the auger met an impenetrable obstruction and the hole was abandoned. However, some good clay samples were collected for analysis. Lack of time precluded further augering on that visit.

With the kind agreement of Mr Gordon Witte and Messrs WBB Minerals Group Central Laboratory in Sandbach, Cheshire, the clays were examined for comparison with the Petrockstowe Palaeogene basin. They reported that the clays had similar Al_2O_3 values to those of the ball clays in the Petrockstowe Basin, but that the Petrockstowe ball clays generally had higher TiO_2 (1.3 - 1.7%), lower CaO (0.05 - 0.07%), slightly lower K_2O (1.5 - 2.5%), and lower Fe_2O_3 (0.7 - 1.5%), with the other major oxides having similar values. XRD analysis of the Orleigh Court samples showed that all samples contained quite well ordered kaolinite with better ordering than typical Petrockstowe ball clays. Quartz content of the clays varied from 34.7% to 40.3% and all three samples contained major illitic mica. All samples also contained minor amounts of albitic feldspar, with accessory amounts of rutile and goethite. Particle size analysis showed that the Orleigh Court Clays were of somewhat larger particle size (31-39% < 2 μm) than the ball clays (45-60% < 2 μm). The carbon content of the Petrockstowe ball clays is usually about 0.1 to 0.15%, but no carbon was detected in the Orleigh Court clays.

Mr Witte's summarised the results of the analyses of the Orleigh Court clays by concluding that they were not closely comparable to the Petrockstowe Basin ball clays which were almost certainly derived from weathered Carboniferous slates. The somewhat different Orleigh Court clays were probably derived from another source rock (he suggested that perhaps the albitic feldspar could be a pointer), but they could still be a product of deep Tertiary or Cretaceous weathering. They appeared to have been deposited in a freshwater environment, but with higher energy levels than is typical for the lacustrine ball clays in the Petrockstowe and Bovey basins.

Further samples of the clays were submitted to Dr David Jolley (University of Aberdeen) for palynological analysis, in the hope that a microflora would indicate a likely age for the clays. Unfortunately, the clays samples proved to be too weathered for preservation of spore or pollen although there was inertinite present, indicating the former presence of plant material.

It was clear that to establish the age of these clays, fresher material would be required and a second visit to the site was planned together with the Reading Geological Society for September 2006.

FIELDWORK, SEPTEMBER 2006 AND ITS RESULTS

Prior to the planned day's fieldwork in September 2006, David Ward of the Reading Geological Society visited the area and made contact with Mr G. Beer, the landowner at Orleigh Mills Farm, to gain permission for a more extensive programme of excavation, including the use of an excavator, the funds for

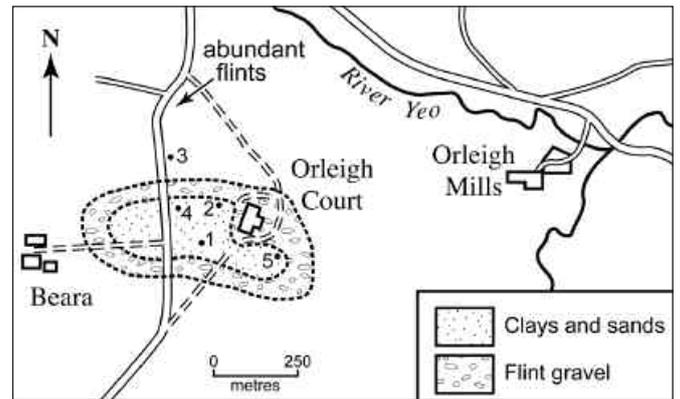


Figure 2. Map showing the outcrop of the flint gravels and overlying clays and silts, together with the locations of the excavations.

which were kindly made available by the Reading Geological Society. Mr Beer gave us permission to excavate wherever we wanted on his land and a list of possible sites was drawn up.

The first site chosen was where we had augered the previous year (Figure 2). At this site the excavator dug down to some 3.6 m, passing through the pale clays of the previous samples and reaching laminated dark and light grey clays at 3.2 m below the surface. This material was clearly fresh and promised some palynological results.

A second site was chosen in the field to the west of the previous one, where the ploughed field showed a clear line between soil with abundant flints and soil without (Figure 2). The site chosen was expected to show the clays seen at the first site overlying flint gravels. Unexpectedly, yellow sands were found lying above the flints, with no trace of the clays. Further work is needed to establish the relationship between the sands and the clays of the first site.

Walking around the large ploughed field in which the second excavation was made established that there was a clear outcrop of the flint gravels forming a major feature (Figure 2). Below this, flints were relatively rare and there was a red clay soil indicating probable Permian weathering of the local Carboniferous slates. At the northern end of the field, on the lowest ground, flints were again abundant. Unlike previous mappers, however, we concluded that these flints had been moved down slope from the outcrop around Orleigh Court and were not part of the outcrop of the gravels.

A third excavation was made near the western boundary of this field, at the foot of the feature made by the flint gravels, where the plough had turned up pale clays. The pale colour disappeared within one metre's depth and seems likely to be the result of local intense chemical weathering on the Carboniferous bedrock. The fourth excavation in the south-western corner of the field proved *c.* 1 m of pale clays overlying flint gravels.

A final excavation was made to the south-east of Orleigh Court and proved flint gravels with sporadic large flints (up to 30 cm across) these being much larger than any found in the fields to the west.

WBB Minerals Group kindly agreed for their Central Laboratory to examine the dark clay sample from the first excavation. Mr Witte reported that the analyses were conducted on the <125 μm fraction, but as the >125 μm residue content of the trench sample was nil they could also be regarded as whole rock analyses. His report also made interesting comparisons with our earlier auger samples, as well as with the Petrockstowe Basin. He reported that the trench sample had a significantly higher alumina content, lower Fe_2O_3 and much higher alkalis ($K_2O + Na_2O$) when compared with the auger samples. In comparison with the Petrockstowe ball clays, the high alkali content of the trench sample is the major difference. The TiO_2 content of the Petrockstowe ball clays generally ranges from 1.3 to 1.7%, whereas the trench sample is 0.97%.

XRD analysis of the trench clays showed a composition of kaolinite 28%; illitic mica 35%; orthoclase feldspar 12%; albite feldspar 5% and quartz 18%. The kaolinite in the trench sample was disordered and similar in type to that found in the Petrockstowe Basin ball clays.

The quartz content (18%) was lower than the 35 to 40% in the auger samples. The kaolinite to illitic mica ratio was similar to some Petrockstowe Basin ball clays, but no ball clays from the Petrockstowe Basin had been found to contain feldspar. The interbedded sands at Petrockstowe were also devoid of feldspar, suggesting that the material had been derived from the adjacent Carboniferous rocks and not the Dartmoor granite. However, braided river sediments at the base of the Petrockstowe sequence had been probably derived from the Dartmoor massif.

Particle size analysis showed that the trench sample had a Sedigraph particle size analysis of 64% <2 µm, which was slightly finer than the Petrockstowe Basin ball clays (45 - 60% <2 µm) and much finer than the auger samples collected previously (31 to 39% <2 µm). The trench sample had no material >125 µm, whereas the auger samples had a quartz residue content of 0.3 to 0.39% >125 µm. The trench sample was comparable to some clay seams in the Petrockstowe Basin. Unlike the auger sample clays, which contained no carbon, the trench sample had a carbon content of 0.5% which is a little higher than for the Petrockstowe Basin ball clays (typically 0.1 to 0.2%). Specific Surface Area (SSA) value of 17.7 m²/g was lower than for a typical South Devon ball clay (~25 m²/g) but higher than for the auger samples which ranged from 7.9 to 10.2 m²/g.

Mr Witte's report concludes that the analyses of the Orleigh Court trench sample revealed it to be different from the auger samples. The trench sample has a lower Fe₂O₃ content, higher alkali content, higher carbon content, a finer particle size and

less quartz residue when compared to the auger samples. The trench sample had some similarities with the Petrockstowe Basin ball clays, but the major difference is the 17% feldspar content in the trench sample. The Petrockstowe Basin ball clays do not contain feldspar.

The trench clay sample sent to Dr David Jolley also yielded results. He reported that there were some unusual fossils in it. The sample was principally composed of black wood, some of which may have been derived from older strata. There were some thermally mature reworked palynomorphs (?Dev-Carb indeterminate spore; a Jurassic spore - possibly *Klukisporites*) and a fragmentary indeterminate dinocyst. The *in situ* flora was very sparse and contained: *Baculatisporites primarius* (an *Osmunda* type fern), ?*Tricolpites* cf. *bians* (plane or *Cercidiphyllum* type - angiosperm often mid-successional plant) and ?*Inaperturopollenites dubius* (probably Cyperaceae pollen).

As far as the age of the assemblage was concerned, Dr Jolley concluded that its age was most probably Palaeogene, as if it had been younger than early Miocene he would have expected to see at least some Poaceae or Asteraceae pollen instead of the fern that he did find. He believed that the assemblage was probably derived from an area of early-mid successional vegetation and noted that the amount of black wood in the sample was sometimes associated with soil profiles, but in this case he believed that it may be at least in part have been derived from other strata.

The source of the feldspar in the Orleigh Court clay is unknown and it would seem that there are two possible sources, Dartmoor and Lundy. Palaeogene uplift of the Lundy area would have meant that the area would have been undergoing erosion as soon as the granite was emplaced in the Eocene (Cope, 2004) and it must be regarded as a potential source. Contrary to this hypothesis are the preliminary results from investigation of the heavy mineral content of the yellow

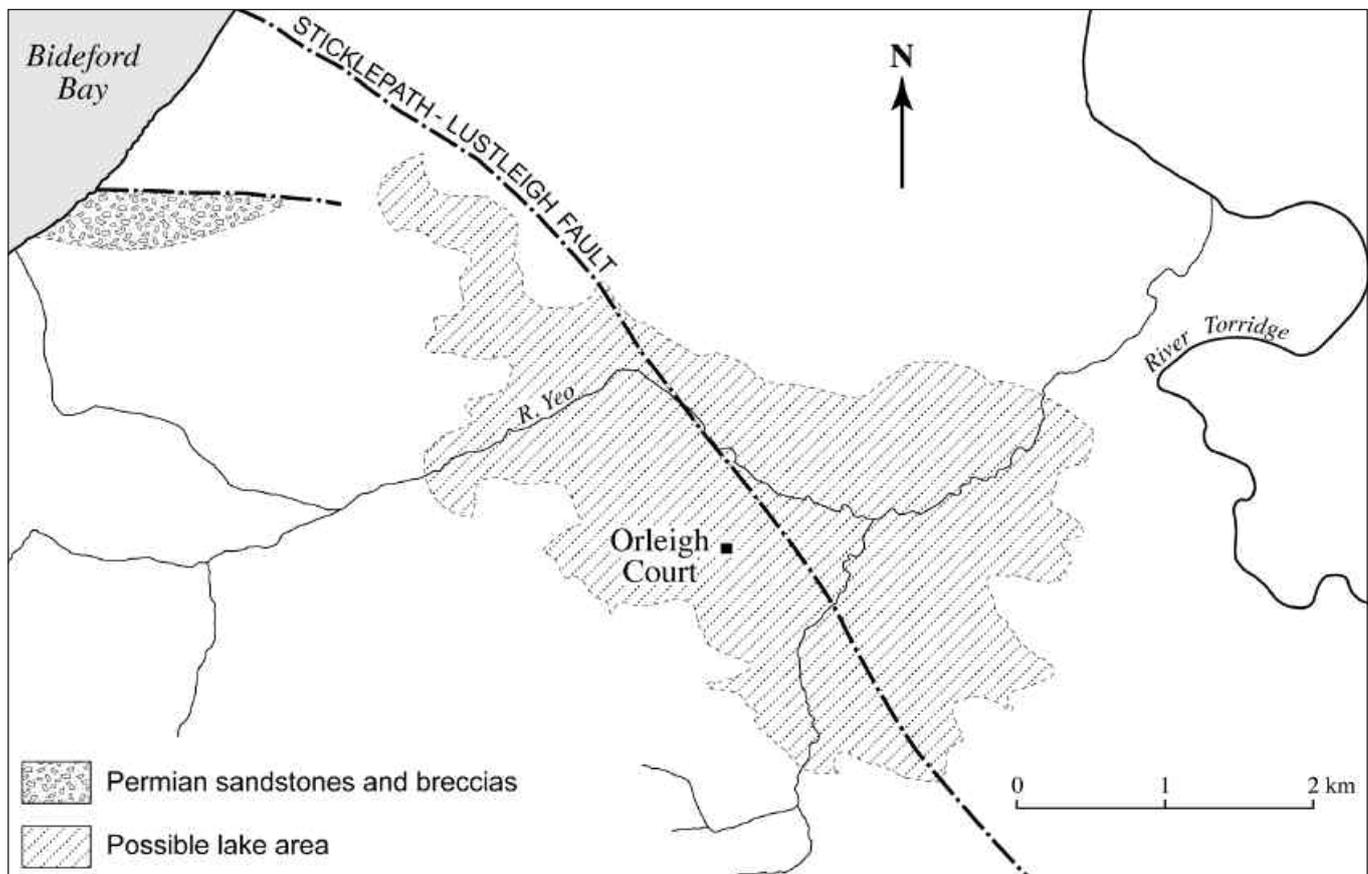


Figure 3. Possible extent of the lake in which the clays and silts accumulated. This shape is determined from the position of the present 90 m contour line (which has not been followed up the minor valleys). Note the possible earlier drainage from the lake north-westwards along part of the River Yeo and then along the Sticklepath-Lustleigh Fault.

sand in the second excavation. These have shown that the principal heavy mineral is schorl type tourmaline, indicating Dartmoor to be a more likely source than Lundy. However, as stated above, the relationship between the sands and the clays is not yet clear and they may have different origins.

Ball clays are also known to exist in the Palaeogene Stanley Bank Basin along the continuation of the Sticklepath-Lustleigh Fault Zone beneath the Bristol Channel. The small Orleigh Court outcrops are mid-way between the Petrockstowe and Stanley Bank basins. The Bristol Channel Offshore regional report (Tappin *et al.*, 1994 figure 57) shows that the Stanley Bank Basin was drilled and that the clays contain carbonaceous debris and lignite. It would thus be interesting to compare the analysis of these clays with the Orleigh Court trench sample; unfortunately no-one on the present staff of the British Geological Survey can provide information on this and no details appear to have been published.

EXTENT OF THE ORLEIGH COURT DEPOSITS

The flint gravels of Orleigh Court appear to have a more restricted outcrop than that shown on previous maps (e.g. those of Rogers and Simpson (1937) and the Geological Survey). Whereas the map in Rogers and Simpson (1937) shows an estimated outcrop area of some 1 200 000 m², Freshney *et al.* (1979) suggested an area of some 640 000 m² (800 by 800 m). However, Edmonds *et al.* (1979) suggest 120 000 m² (300 by 400 m). This last figure agrees with the area now mapped as being underlain by the flint gravels, but over about half of this area the gravel outcrop is overlain by clays and sand. It seems that earlier workers may have mistaken reworked gravels for the Eocene gravels that appear to be restricted to the plateau around Orleigh Court.

Edmonds *et al.* (1979) suggested that Rogers' and Simpson's upper gravel was the original deposit whilst their lower gravel was reworked. However, the latest mapping suggests that the exposures of both the upper and lower divisions of the gravels described by Rogers and Simpson (1937) were in fact reworked.

The clays and sands around Orleigh Court appear to be at present of very limited extent. The highest ground at Orleigh Court where the clays crop out is at just over 80 m above OD. Assuming that the original basin was at least up to the present 90 m contour, this suggests that the basin may have been up to 3.5 km long, elongated along the line of the Sticklepath-Lustleigh Fault and have averaged about 1.5 km wide (Figure 3). The question then arises why is it only this small area where these sediments are preserved? There are two possible answers here: one is that there are other outcrops that have, similarly to the Orleigh Court clays, been overlooked hitherto; the other requires that all other outcrops have been eroded. A possible answer to the latter scenario may be provided by possible river capture by the seaward end of the River Torridge of a former main drainage direction along part of the present River Yeo, in a reverse direction to that now used, and thence to the sea along the line of the Sticklepath-Lustleigh Fault. Such river capture may well have induced a major scouring episode that eroded the majority of the lacustrine sediments.

In conclusion, it appears that the Orleigh Court sands and clays are part of a formerly more extensive basin, developed along the line of the Sticklepath-Lustleigh Fault and lying mid-way between the Petrockstowe and Stanley Bank basins. It is planned to continue with investigations in the area; one of the first objectives is to establish whether any other outcrops of these rocks exist in the vicinity.

ACKNOWLEDGEMENTS

This work would not have been possible without the enthusiasm and commitment of the Reading Geological Society and especially David Ward who has done so much of the preliminary work that made possible the excavations. Even

with such support, it is essential to have co-operation of landowners and we have received this in full measure from Messrs Roger Lucas at Orleigh Court and Geoffrey Beer at Orleigh Mills Farm. Subsequent testing has relied upon the willing assistance of Mr G. Witte and the Central Laboratory of the WBB Minerals Group and of Dr D. Jolley; this assistance is gratefully acknowledged. Mrs L. C. Norton drafted the figures.

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