Ancient Quarrying of Rare *in situ* Palaeogene Hertfordshire Puddingstone

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Abstract: Previously elusive *in situ* siliceous concretions of the conglomerate commonly known as Hertfordshire Puddingstone are identified at two locations as patches of puddingstone in the lowermost few metres of the marine and nonmarine Palaeogene sequence that overlies Chalk in the Colliers End outlier, Hertfordshire. The siliceous concretions of puddingstone consist of rounded flint pebbles and cobbles set in a matrix of fine sand and silica cement. It is suggested that silica diagenesis took place soon after deposition of the lowermost Palaeogene, beneath the surface of a Hertfordshire landscape that enjoyed an unusually warm climate around 55 Ma. A Neolithic quern-stone, made from puddingstone, is recorded from a site that was evidently used as a flint and puddingstone quarry in Neolithic times and as a puddingstone quarry and factory by the Romans.

Key words: Hertfordshire Puddingstone, siliceous concretions, Palaeogene, Neolithic implement, Roman quern-stone.

Hertfordshire Puddingstone is a conglomeratic siliceous concretion consisting of rounded flint pebbles and cobbles set in a matrix of fine sand and silica cement (Fig. 1) (Page, 1859; Holmes, 1928; Milner, 1940). Its origin has been discussed for well over a century, from Hopkinson (1884) to Hepworth (1998) and Catt & Hepworth (2000). The report of Hopkinson (1884) on the Geologists' Association excursion to Radlett, Hertfordshire, on 12th July 1884, is a matchless combination of fine prose, field observation and early interpretation of 'the Hertfordshire conglomerate' as a 'shore-deposit…the shingle-bed of flint-pebbles consolidated by the infiltration of silica'.

This silica infiltration of the 'shingle-bed' has formed a cement that is as hard as the flint pebbles themselves. The processes involved are part of a continuing debate on the formation of silcretes at or near the surface of present-day southern England (Hepworth, 1998; Ullyott *et al.*, 2004). Hepworth (1998) provided an introduction to puddingstone literature, drawing comparisons between English and Australian silcretes. Catt (2000) adopted a more cautious approach, suggesting that 'silcretes form in a wide range of surface and subsurface environments'. Climatic control of silicification is detailed by Thiry *et al*. (2006). All this lends considerable current scientific interest to the puddingstone, already renowned for centuries for its extreme hardness and its long role in Hertfordshire folklore.

Yet Hertfordshire Puddingstone is elusive in two respects, one geological and one archaeological. Geologically, it is 'an elusive material to find *in situ*, although it occurs widely as loose blocks across parts of the London Basin' (Robinson, 1994, 77). As for archaeology, '[Roman]…quern manufacture…must have left significant traces. Production sites are little known and outcrops of Hertfordshire Puddingstone would certainly repay study' (Glazebrook, 1997, 41); querns are ancient corn grinders that incorporated large blocks of strong stone in their construction.

Progress has recently been made on the fronts of both geology and archaeology, thanks to the stoical behaviour of the local farmers. They discover the largest specimens of puddingstone at the cost of broken ploughs, yet retain their enthusiasm for its study. In 2005-2006 they helped to recover specimens for public display in Hertford and Bishop's Stortford. Members of a farming family, whose land has recently been sliced by construction of the A10 High Cross and

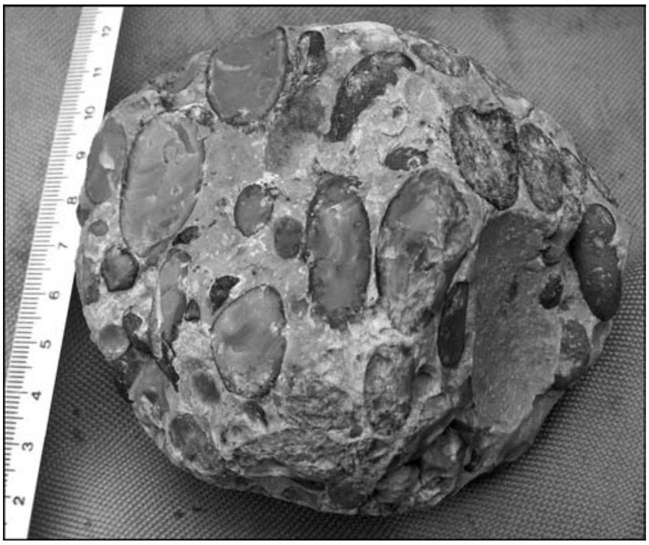

Figure 1. The upper face of the Neolithic quern-stone made from Hertfordshire Puddingstone, found in 2005 by Jane Tubb at the site of the ancient quarry south of Puckeridge. It measures 102 mm long by 95 mm wide and 72 mm high, and weighs 857 g. Specimen is now on loan to Hertford Museum.

Colliers End bypass (Fig. 2), have recovered most of the puddingstone encountered during construction of the road and have stored it on their land. This they have done on their own initiative.

This paper records evidence of Neolithic and probable Roman quarrying and shaping of puddingstone for quern-stones, at a location on private land south of Puckeridge. It also records the recent discovery of a dozen large (*c*.1 m maximum diameter) specimens of puddingstone that appear to have been found *in situ*. They were recovered from a former temporary exposure of the lowermost Palaeogene sediments some 200 m east of Colliers End [NGR 374207 to 374205] (Fig. 2). These specimens were revealed during recent construction of the A10 bypass from Thundridge to Puckeridge, which cuts through the Colliers End Palaeogene outlier (Hopson *et al.*, 1996). Another large (1.6 m maximum diameter) and, unusually, quite complete concretion was found in 2005 by Peter Glogner at Bushey Leys Field, Bromley [412215], close to the 110 m contour, 3 km SE of Puckeridge. The geological setting of the ancient quarry, south of Puckeridge, and of the Colliers End specimens, are described.

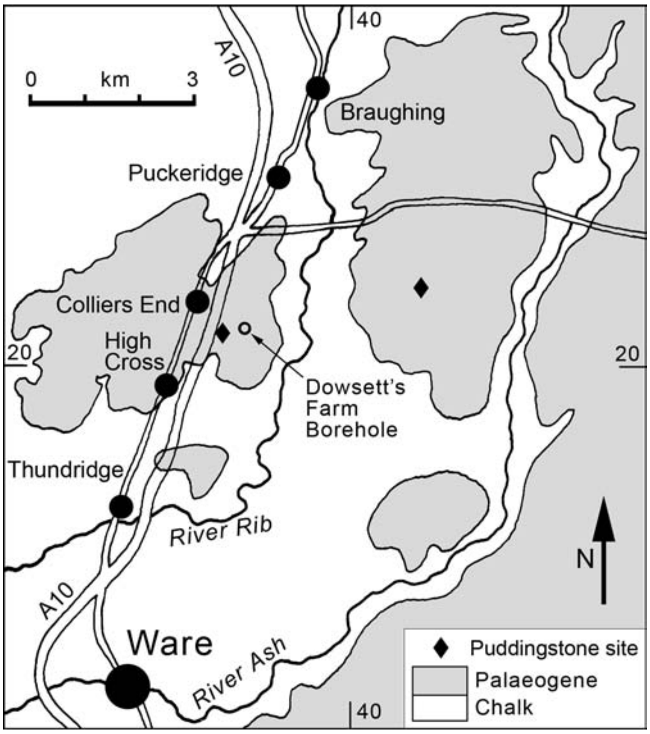

***Figure 2**. Outline map of the area around Puckeridge, Braughing and Colliers End, between Hertford and Bishop's Stortford. The new A10 bypass cuts through the Palaeogene outlier at Colliers End just to the east of the village. The limits of the Palaeogene outlier are after Figure 18 in Hopson et al. (1996). The location of the ancient quarry is not shown (see site access below).*

Archaeology

There is clear evidence for excavation and working of puddingstone at a quarry site south of Puckeridge. Most of the surface area at the location has been disturbed by excavation for solid rock. At the north end of the site, a steep and narrow "valley" is cut into the Upper Chalk; this "valley" has no topographic expression beyond the site itself, and is interpreted as a quarry worked in the abundant large flints found within that rock at this location. Pending full archaeological investigation, this quarry is tentatively assigned a Neolithic age.

A puddingstone implement (Fig. 1) was discovered some 50 m from the putative flint quarry. It has been identified by Julian Watters (Finds Liaison Officer at St Albans Museum) as a Neolithic quern-stone. In his description of this find (BH-416BD3, Portable Antiquities Scheme), he states that it has: 'been deliberately formed and used as a tool in prehistory. It is possible that the object is a hammerstone used in the production of flint tools, but, given the extent of the initial shaping and the subsequent even wear pattern on the underside, it is more likely to be a grain rubber for use with a saddle quern. The object is roughly ovoid, apart from a flat area on the upper surface which has been created in order to make the object easier to handle. On the convex underside is an area which has been flattened by regular use of the implement. It dates from *c*.3500 BC to *c*.100 BC.'

The greater part of the site of discovery of the Neolithic implement is marked by pits and mounds left from working of the lowermost *c*.5 m of Palaeogene sediments. Sharp-edged fragments of puddingstone are scattered amongst these pits and mounds. A specimen, consisting of three-quarters of an original egg-shaped concretion, 0.5 by 0.25 m, was discovered at the western edge of the area (Fig. 3). Its dimensions and shape suggest a failed attempt at beehive quern manufacture. This putative Roman specimen is on loan to Hertford Museum, with a quarter-fragment of a broken but fully shaped beehive quern. This fragment has dimensions of 0.24 by 0.1 m and fits neatly into the missing quarter of the egg-shaped 'failed quern' (Fig. 3). It was found some 50 years ago in the garden of a house in Puckeridge, near Ermine Street (the old A10) and just a few hundred metres south of Braughing [388243], which was an 'important pre-Roman *entrepot* and Roman small town' (Glazebrook, 1997, 40).

At the site of the ancient quarry, a shallow depression extends from the deepest pit towards the edge of the worked area, to join a slope that falls across the Upper Cretaceous Chalk towards a ditch adjacent to Ermine Street. The 'failed quern' specimen was found at the top of this slope. Other fragments of puddingstone, of various sizes up to and just over a metre in greatest diameter, are found across a broad, roughly 20 m, section of the field between the quarry and the ditch. The puddingstone fragments are largely confined to this section of the field, although some redistribution of larger fragments by the plough is apparent. The ditch itself contains several large fragments of puddingstone. The 20 m wide puddingstone-strewn section is interpreted as the route down which both rock and implements were exported from the quarry and factory.

Site geology

The ancient quarry

The unconformity of Palaeogene on Cretaceous has been mapped across fields at this location, south of Puckeridge, and lies close to the 90 m contour. Geological excavation in search of remaining puddingstone *in situ* at the quarry has been postponed, in favour of a future more detailed archaeological examination of the material in both the pits and mounds. What can be asserted with some confidence at this stage is that the puddingstone formed as siliceous concretions within the lowermost section of the Palaeogene sequence, which was penetrated by the Dowsett Farm Borehole [38062079]. This would place it in the Upnor Formation, of the lower Lambeth Group, following Hopson *et al.* (1996). That correlation is supported by additional subsurface data, resulting from the recent construction of the A10 Colliers End bypass, which have kindly been made available by the British Geological Survey.

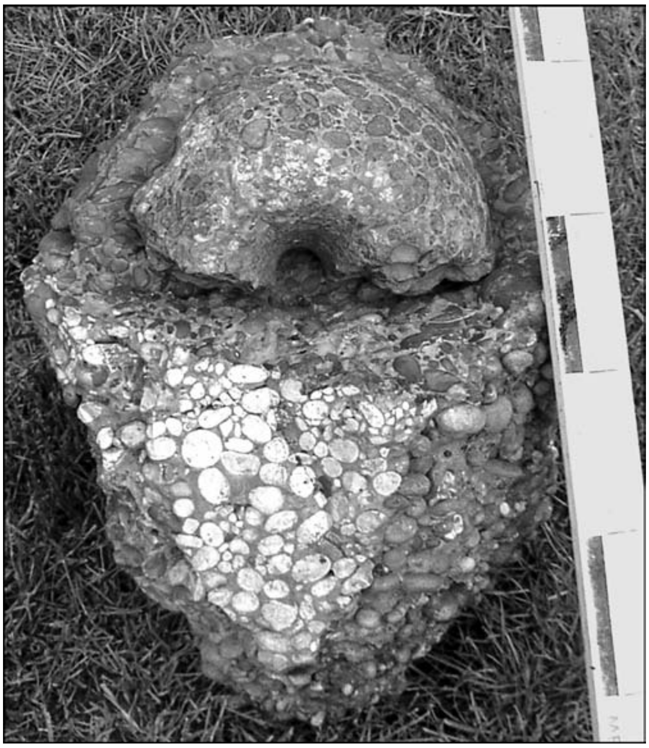

Figure 3*. Remaining three-quarters of an originally egg-shaped specimen of puddingstone, found by Jane Tubb at the site of the ancient quarry south of Puckeridge. This specimen is interpreted as a failed attempt in Roman times to fashion a beehive quern. A quarter fragment of a Roman beehive quern rests on it. Both specimens are now on loan to Hertford Museum. Scale bars are 100 mm long.*

Colliers End

A dozen large (*c.*1m maximum diameter), isolated, specimens of puddingstone were recovered by the Parkins family during construction of a *c.*200 m long section [374207 to 374205] of the A10 bypass east of Colliers End (Fig. 2). These rocks are retained on private land at High Cross. Their total volume is of the order of 10 cubic metres. It is suggested by Russell Parkins, who regularly inspected the route during construction, that they represent some three-quarters of the volume of puddingstone intersected by workings for the new road.

Were these Colliers End specimens unearthed *in situ*? Mr Parkins collected the largest specimens from around the 90 m contour over a roughly 200 m north-northeast to south-southwest stretch of the route of the new bypass, some 200 m east of the line of the old A10 through the village. The evidence from temporary survey-pits dug in December 1989 indicates that the route of the new A10 intersects base-Palaeogene a little below the 90 m contour about 200 m east of Colliers End, along the 200 m long stretch where the large pieces of puddingstone were found. Only smaller puddingstone fragments were collected from glacial till to the south of that stretch. So it appears that the main puddingstone specimens that Russell Parkins recovered were *in situ*.

The Colliers End specimens do not show clear internal evidence of the fractures described by Robinson (1994) from the famous but well-protected *in situ* puddingstone near Radlett, Hertfordshire (Hopkinson, 1884), but the specimens do show at their broken edges the quite smooth fractured surfaces running through both flint pebbles and siliceous matrix that are characteristic of Hertfordshire puddingstone. These fractures tend to be vertical or sub-vertical to apparent bedding in the Colliers End specimens. In this case the fractures may be the work of ice, or may have arisen during excavation by the heavy machinery used in work on the new road.

One of Russell Parkins' specimens retains uncemented fine white sand on its surface (Fig. 4). This may be compared to Hopkinson's 'beautifully white, fine sand seen reposing upon an unconsolidated portion of the [Radlett] pebble-bed' (Hopkinson, 1884, 455). The presence of the loose sand on the Colliers End specimen reinforces the claim that it was found in place and gives a useful insight into the truly bimodal size distribution of the original sediment. The question of environment of deposition remains open, although it may be hard to improve on Hopkinson's interpretation (1884, 453) that this is 'a shore deposit' of 'a true shingle-bed'.

The puddingstone specimens found in the Colliers End outlier indicate a minimum thickness of 0.3-1.0 m for the original bed of fine sand and pebbles in which these siliceous concretions formed. Hopson *et al.* (1996) give 0.2-0.9 m for the thickness of pebble beds at the base of the Palaeogene (Upnor Formation, lower Lambeth Group) in this area. These thicknesses are confirmed by records from A10 route-survey pits, and current exposures in A10 ditches and adjacent ploughed fields, notably an exposure on the east flank of the new A10 [379200].

Origin of puddingstone

The concretionary masses of puddingstone from the Puckeridge and Colliers End sites contain rounded pebbles and cobbles, characteristically of black-coated flint, set in an abundant matrix of fine sand and silica cement. The pebble beds near the base of the Palaeogene in other parts of the Colliers End outlier (Hopson *et al.*, 1996), recorded in boreholes, temporary pits and present-day exposures in ditches and ploughed fields, are commonly embedded in a muddy and sandy matrix rather than in clean sand. No puddingstone has yet been found in these muddier pebble beds in this area. This supports Hepworth's view (1998) that puddingstone is a minor component of the Lambeth Group, restricted by original depositional environment. Evidence from this new material suggests that an original patchy distribution of sandy Palaeogene pebble beds was a major control on the location of the pervasive silica cementation that formed puddingstone.

Current knowledge of the Colliers End outlier and adjacent areas does not constrain the date of formation of the siliceous concretions found there. The data are compatible with the early formation of puddingstone described elsewhere in the London Basin (Woods *et al.*, 2004) The evidence from current exposures, and from records of temporary pits on the line of the A10 bypass, indicates that the upper surface of the Chalk was weathered and also vegetated in places. Rootlets reported from Palaeogene muds immediately overlying Chalk, in temporary pit no. 53 [37405.20514], 200 m east of Colliers End, indicate contemporary exposure. Desiccation cracks are recorded in Palaeogene muds overlying the 3 m of glauconitic sand with pebble beds that lies immediately above Chalk in the Dowsetts Farm Borehole (Hopson *et al*., 1996).

A first-order control on silica dissolution is temperature (Pettijohn *et al*., 1987). The age of the Lambeth Group sediments that host the puddingstone at Colliers End is 56-55 Ma (Neal, 1996), close to the time of the Paleocene-Eocene thermal maximum (Norris & Rohl, 1999). That notable warming event may have been triggered by regional uplift associated with the early Iceland mantle plume (Maclennan & Jones, 2006). Other putative effects of the plume manifest in the Colliers End outlier may be recognized as the emergence of Britain from the Chalk Sea and its tilting to the southeast (Cope, 1994; Gibbard & Lewin, 2003; Knox, 1996), and episodic changes in Palaeogene regional sea level in response to thermal pulses within the plume itself (White & Lovell, 1997).

So the thoroughly provincial Hertfordshire Puddingstone reflects far broader events. On the local evidence, it is believed that a respectable working hypothesis for its origin includes silica diagenesis that affected the locally sandy patches of Palaeogene pebble beds. On broader evidence, it is suggested that these shore-line deposits were cemented beneath a 55 Ma land surface that enjoyed a climate closer to that of present-day Penang (in Malaysia) rather than that of Puckeridge.

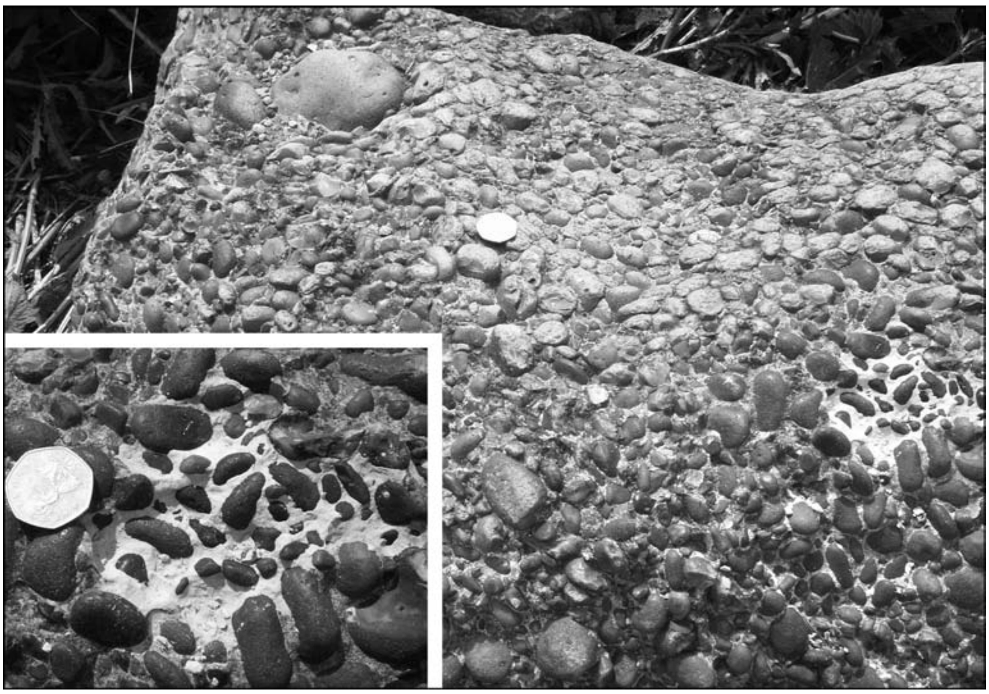

Figure 4. *Fine white sand in-place, adhering to a small part of the surface of a specimen recovered from puddingstone, evidently in situ, during recent construction work on the A10 bypass at Colliers End. The coin is 25 mm in diameter. The specimen is now on private land at High Cross.*

Inset shows the sand enlarged.

Puddingstone and site access

Key archaeological and geological material is available at Hertford Museum, including a large specimen of puddingstone from the location of the ancient quarry; this now sits in the Museum garden beneath an explanatory plaque prepared by East Herts Geology Club. An even larger specimen of puddingstone from that location was put on permanent display in a prominent position in the grounds of Hertford Castle in March 2006, with another explanatory plaque by the Geology Club. The large and unusually complete specimen recovered some 3 km SE of Puckeridge was moved to Bishop's Stortford in May 2006, to form a feature in a new commercial and residential development by Wilson Bowden at Jackson Square, in the centre of the town.

With these excellent specimens already on public display in Hertfordshire towns, there is no need to trample the farmers' crops to view the material. A search for metal at the key archaeological site in 2005, by John Bullen, was fruitless: nothing of material value exists there. In the interests of geological conservation, and especially given the archaeological discoveries, this report follows Robinson (1994) in not being specific about this puddingstone site: site disturbance or even damage by those in mistaken search of treasure would only diminish the scientific values. On behalf of the farmers and the local and scientific community that they support so willingly, visitors to the area are requested to keep to the clearly identified public rights of way.

Acknowledgements

The two large specimens of Hertfordshire puddingstone now on public display in the County Town, one in the garden of Hertford Museum, the other in the grounds of Hertford Castle, were kindly donated by Philip Smith, whose plough they broke. They were put in place through the combined efforts of John Bullen, East Herts Geology Club, Hertford Museum and Hertford Town Council. We much appreciate the work by Julian Watters on the Neolithic implement and thank him for permission to quote his description of this. We are most grateful for the help given by those farming and working on the area we have studied, namely John Bullen, Peter Glogner, Bessie Parkins, Chris Parkins, Russell Parkins and Philip Smith. We thank the British Geological Survey for kindly giving us access to subsurface data resulting from planning and construction of the A10 bypass of Colliers End. The key archaeological specimens are on loan to Hertford Museum: we thank Curator Helen Gurney and Assistant Curator Sara Taylor for their help with this. We thank Professors Richard Howarth and Eric Robinson for their valuable advice on the manuscript.

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