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Puddingstones and related silcretes of the Anglo-Paris Basin – an overview

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ABSTRACT

Anglo-Paris Basin silcretes are rarely observed in situ, particularly in the UK, do not form continuous layers, are mostly under a metre thick and are readily displaced in the surrounding soft sediments, moved by periglacial and/or subsequent human agencies (e.g. Stonehenge). Hertfordshire Puddingstone (HPS) was widely used in quern manufacture, mainly during the Romano-British period. New stratigraphic interpretations, and isotopic data presented here, are consistent with the HPS having formed at the Palaeocene–Eocene Thermal Maximum. The existing evidence is in favour of the HPS being a groundwater deposit, though other Tertiary silcretes in the Anglo-Paris Basin may be pedogenic.

1. Introduction

On 16 May 2014 a Conference on *Puddingstones and related Silcretes of the Anglo-Paris Basin* was held at the Geological Society of London, organised by the Geologists' Association, the Geological Society of London, and the Society of Antiquaries to review research on the subject and bring the findings to a wider audience. This overview summarises the principal findings that were presented at the conference. An excellent outcome of the meeting was that the speakers took away the ideas that were new to them and have incorporated them into their final papers. Whilst the evidence in favour of a sub-surface origin is favoured by many, there is evidence, particularly from France, that a single origin cannot be applied to all Tertiary silcretes. Evidence from diverse sources does however point to *the conclusion that* acid leaching of soils/clays in an exceptionally warm climate generated the silica cement.

There has long been widespread public recognition of the Tertiary silcretes, in both the UK and in northern France. As a result of this interest these rocks have been given many vernacular names such as puddingstone, breeding stone, sarsens, and grey-wethers, but their origin was not widely debated in geological circles before the 1970s. The Geologists' Association has a long tradition of field trips to view these rocks, including that led by Robinson (1994) and the field trip associated with the 2014 conference. These recent trips followed many earlier excursions (Green, 1890; Hopkinson and Whitaker, 1892; Woodward and Herries, 1905; Evans, 1953; Potter, 2013). Recent collaboration between archaeologists and geologists, on both sides of the English Channel, has brought previously separate lines of inquiry within the two communities together. The first discovery by geologists Bryan Lovell and Jane Tubb of a Roman quarry for Hertfordshire Puddingstone (Lovell and Tubb, 2006) was followed by archaeological work led by Chris Green (Green, 2016) of the Society of Antiquaries. This combined research helped a fusion of interests between the disciplines, leading to the joint 2014 conference. Following the 2014 conference, a second Roman quarry was discovered at Great Gaddesden in Hertfordshire, England. We include here an account of this latest development in archaeological–geological collaboration (Green et al., 2016). The area of the quarry has now been surveyed by LIDAR and joint studies are underway.

2. Geology

The origin of the Hertfordshire Puddingstone (HPS) has been much discussed over the years, with Hopkinson (1884) being the earliest study. This paper is a report of a the Geologists' Association excursion to Radlett, Hertfordshire, on 12th July 1884 in which the 'Hertfordshire conglomerate' is described as a

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'shore-deposit. . .the shingle-bed of flint-pebbles consolidated by the infiltration of silica' (Hopkinson, 1884, p. 453)", a description that is still accepted (Lovell and Tubb, 2006; Lovell, 2015; Lovell, 2016).

Although these silcretes are both geologically and culturally important rocks, in England at least, research into their origins is at something of a disadvantage. They are very rarely observed in situ; they do not form continuous layers, are mostly under a metre thick and the discontinuous concretions/rafts/lenses/boulders are readily displaced in the surrounding soft sediments, or are moved by periglacial and/or subsequent human agencies. A consequence of this is that the HPS features in Geological Survey reports rather than on maps, yet may be obvious features where found at the ground surface. Typically they are included in a periglacial slope deposit (gelifluctate), shown as 'head' on the British Geological Survey maps. A similar situation pertains in the Paris Basin, where pedogenic silcrete has been reworked into Pleistocene fluvial deposits.

Pebbles in the HPS are predominantly flint with very rare quartz and quartzite. They are typically well rounded, brown, or light to dark grey, variably stained red to brown. Occasional examples of HPS have a high proportion of fractured pebbles (Huggett and Longstaffe, 2016). Questions remain as to which lithostratigraphic units were silicified to form the HPS, and when the silicification took place. Catt and Doyle (2010) suggest three potential episodes of silicification: (1) after deposition of the Upnor Formation but before deposition of the Reading Formation, (2) soon after deposition of the Reading Formation basal pebble bed and (3) during breaks in deposition of the Reading Formation. All of these propositions would place the period of silcrete formation in the Lambeth Group of the Palaeocene Epoch. We may note that these timings could apply both if the HPS is a groundwater silcrete, or if silcrete formation was a surface phenomenon.

The papers in this volume discuss the mainly detached boulders of HPS in a range of ways, both geological and archaeological, beginning with the stratigraphy. The importance of correctly interpreting the stratigraphic position of the HPS is essential for understanding its possible relationship to the Palaeocene–Eocene Thermal Maximum [PETM]. It is reasonable to propose that the PETM warming event may have provided the environmental conditions conducive to silcrete formation, either as a tropical soil at the surface, or diagenetically within the host rock. Lovell (2016) and Tubb (2016) seek to constrain the date of deposition of the pebble bed host rock, and the date of silicification, focussing on evidence from the Palaeogene outlier at Colliers End, near Hertford and Ware in the northern part of the London Basin. The Colliers End Pebble Bed (CEPB, Lovell, 2016) has recently been exposed in situ through road building, and drilling of the Dowsett's Farm borehole also in Hertfordshire. The regional extent of the CEPB remains to be determined, although it is known to be at least 10 km from East to West (Hopson personal communication, quoted in Lovell, 2016). Tubb (2016) describes the stratigraphy and sediments of the Colliers End outlier using data from the Dowsett's Farm borehole, the A10 bypass and associated survey pits, plus historic data from the A120 road widening. From her observations she concludes that the HPS is of early Eocene age. The sequence of events she proposes are:

(1) Early Palaeocene regression led to exposure of flints.
(2) Marine transgression resulted in rounding of angular flints to rounded pebbles.
(3) Continued transgression led to deposition of the Upnor Formation, with both pebbles and fresh flints incorporated into the basal bed.
(4) Reading Formation: regression revealed a beach-line of rounded flint pebbles. The pebbles were partially reddened (by formation of a thin coating of haematite) on exposure to air.

Tubb (2016) goes on to propose that the sandy matrix then became cemented as a result of evaporation of groundwater, drawn upwards during the PETM. An early Eocene timing for silicification is broadly consistent with the scenarios proposed previously by Catt and Doyle (2010), Lovell and Tubb (2006) and here by Lovell (2016). Taking a sequence stratigraphic approach to understanding the timing of the CEPB, Lovell (2016) interprets the CEPB as a part of the Lambeth-2 depositional sequence of Knox (1996) that includes deposits assigned to both the Upnor Formation and the lower part of the Reading Formation. Lovell (2016) suggests that silicification occurred beneath the Mid-Lambeth Group land surface (the Mid-Lambeth hiatus), at the time of the PETM.

Ullyott and Nash (2016) looked at silcretes not just in the Anglo-Paris Basin but also across the world and show how their structure, both at a macro scale and in thin section, may indicate formation both through pedogenesis at the land surface or by groundwater in the sub-surface. They discuss in detail the four main forms of silcrete: (1) pedogenic, (2) groundwater, (3) drainage-line, and (4) pan/lacustrine. Unfortunately identification of silcrete type is complicated because seemingly diagnostic features result from more than one mode of origin. Indeed, the mode of origin of features is not everywhere clear, for example hollow tubes may be pedogenic root casts or sub-surface dissolution features. Pedogenic silcretes are typically laterally continuous (Thiry and Milnes, 1991), unlike the HPS that has a discontinuous distribution, although continuity is an imperfect guide to origin. Further complication results when composite profiles are formed as a result of more than one period of silicification: most commonly groundwater silcretes form at the base of older pedogenic silcrete.

Ullyott and Nash (2016) emphasise that all features, both macroscopic and microscopic should be taken into account when attempting to determine the origin of a silcrete. Non-pedogenic silcrete generally, but not in all cases, lacks the complex macroscopic structure of pedogenic silcrete, while the micromorphological features, principally caps above pebbles, geopetal structures below pebbles, and colloform structures, that were once thought to occur only in pedogenic silcrete are now known to form in sub-surface silcretes (e.g. Thiry and Milnes, 1991; Milnes et al., 1991; Callender, 1978; Ullyott et al., 2015). To aid correct identification of silcrete, Ullyott and Nash (2016) provide a checklist of criteria (their Table 1). Effective use of the checklist requires, ideally, an understanding of the wider context, especially the palaeolandscape, as well as observation of the silcrete features. As emphasised by Ullyott et al. (2015), it is not simply the presence or absence of features that should be taken into account when attempting to determine the forces of silcrete formation, but the combination, abundance and degree of development of features that make-up the rock.

At the conference in 2014, Christian Dupuis presented the findings of a study of a rare in situ example of silcrete that will be published at a later date. He discussed the so-called "Grès landéniens", from the terrestrial-lagoonal "Sparnacian" beds between the Late Paleocene (Thanetian sand units) and the earliest Eocene, that occur from the northern part of the Paris Basin to the southern part of Belgium. Both near-surface and sub-surface features are observed in the Grès landéniens, implying that silicification either has either occurred over a wide depth range, or surface silcrete features (e.g. roots), have developed on an older silcrete formed at depth and subsequently become exposed through erosion.

Huggett and Longstaffe (2016), and Baele et al. (2016), report novel petrographic studies that shed light on the environment of silcretisation. Both papers use cathodoluminescence (CL) to study cement structure. Huggett and Longstaffe (2016) combined CL petrography with oxygen stable isotope analysis, while Baele et al.