Geology of the Clatford Bottom catchment and its sarsen stones on the Marlborough Downs

Peter Worsley

Abstract: The now vanished Palaeogene geology of the Marlborough Downs area can be plausibly reconstructed by extrapolation from the surviving rock record lying immediately to the east. The Lambeth Group succession dominated by the Reading Formation, formerly extended westwards over the Downs. Anastomosing river channels draining from NW to SE created linear belts of sand extending across a clay-rich floodplain and coastal plain. During the Palaeogene/Eocene Thermal Maximum (PETM) global warming event (*c*.55.5 Ma), groundwater silicification within the sand bodies led to concretion formation (sarsens). Denudational processes led to the sarsens and their Reading Formation host being incorporated into a complex residual deposit, the Clay-with-flints, over Chalk Group bedrock. Following dissection, the Clay-with-flints now occupies the higher chalk interfluves and spurs. During progressive late Cenozoic erosion over at least the last 3 Ma, the present-day relief and its dry valley systems developed under a fluctuating temperate/cold climatic regime. The dominant processes were dissolution of the chalk (this continues today) and fluvial incision, mainly during phases of permafrost development. Following exhumation, the sarsens were lowered as the chalk landscape evolved and later redistributed by solifluction process during repeated cold climate stages.

In April 2019, the writer led a field excursion for the Reading and Farnham local groups of the Geologists' Association (GA) to the Marlborough Downs, focussing on the sarsens in the dry valley known as Clatford Bottom at Fyfield Down (Fig. 1). The GA had visited the same locality in June 1969 under the leadership of John Small (Small *et al,* 1970); by chance the writer was a participant. This latter GA event was to demonstrate the results of a University of Southampton Geography Department project to investigate the '*periglacial rock-stream*' in Clatford Bottom. For consistency the term '*rock-stream*' will be retained in the subsequent narrative although the term 'block-stream' is now in wider usage. The locality is popularly known as the 'valley of the stones', the stones being sarsens (Figs 2, 3). Earlier, the detailed results of the Southampton investigation were published as a departmental paper by Clark *et al* (1967) and later were amplified by Clark & N.C.C. (1976) as a geomorphological field teaching resource. In 1955 some 325 ha of Fyfield Down was designated a National Nature Reserve, but the site is no longer managed directly by Natural England. Nevertheless, the notices at the entrances declare it to be one of the most important *geological* sites in England. Since the Southampton study, no in-depth field work appears to have been published relating to Clatford Bottom, although as will be revealed, alternative ideas as to the rock-stream's geomorphological significance have been postulated. Just three km west of the reserve, the largest megalithic monument in the world at Avebury was built exclusively of locally derived sarsens.

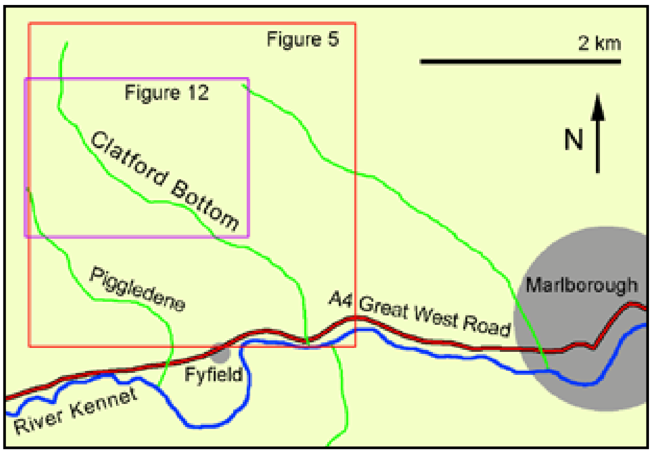

Figure 1. *Clatford Bottom on the Marlborough Downs.*

Traditionally sarsen stones are regarded as fragments of a former silcrete duricrust (Fr. *meulieres*) and the original model of their subsequent movement is well illustrated (Fig. 4) by Goudie & Gardner (1985). The word sarsen is believed to be Anglo-Saxon in origin: *sar stan* = troublesome stone or *sel stan* = great stone; an alternative is *saracen* = alien or strange. Locally a sarsen is known as a greywether and a Colonel Richard Symonds's diary in 1644 records: 'They call that place Grey-wethers because a far off they looke like a flock of sheepe' (a wether is a castrated ram).

Peter Fowler is the doyen archaeologist of the western Marlborough Downs and after almost 40 years investigating the district, he wrote an accessible account of his work in a delightful book titled 'The land of Lettice Sweetapple – an English countryside explained' (Fowler & Blackwell, 1998). This was a precursor to his detailed monograph (Fowler, 2000). The book features photographs with the caption: 'Valley of Stones, Fyfield Down, showing a relatively undisturbed field of sarsen stones, sandstone remnants of a former sea-bed which had drifted down the slope from the right, probably in wet and muddy conditions at the end of the last glaciation'. More recently, another archaeologist stated in the National Trust guide to Avebury: "Sarsens now lie in 'Trains' along the bottom of valleys in the downs. Alternative theories explain this: either by suggesting that the sarsens were broken up and slump down slopes during Ice Age cycles of

Figure 2*. The lower periglacial rock stream in Clatford Bottom, looking to the south. The chalky debris dug from Pit 6 by the GA lies left and in front of the Land Rover (June 1969).*

Figure 3*. The Toadstone, a globular, irregularly shaped sarsen, which is the largest sarsen now surviving anywhere on Fyfield Down.*

freezing and thaw, or that the sarsens formed in the valleys" (Cleal, 2011, p11). Geologists are not exempt from vagueness; Geddes (2003, p132) referring to Clatford Bottom wrote '… an ancient river valley on Fyfield Down (now dry due to a lowering of the water table) densely strewn with sarsens. The underlying sands at that time covering the Chalk became locally cemented by silica carried by in the ground water as it moved towards the valley bottom, which may then have contained a seasonal stream'. In the light of these somewhat muddled explanations of sarsen geology, discussion on the origin of these sarsens in the context of their local landscape geology, and consideration of the geoarchaeological aspects, are both worthwhile.

Geomorphological context

The Marlborough Downs form the northern part of the western closure of the London Basin syncline with the main chalk escarpment swinging from a north facing direction to a westerly one. The crest is a major watershed and is followed by The Ridgway, an ancient thoroughfare. For the most part it defines the upper limits of the River Kennet catchment. In the Clatford Bottom catchment a dry valley network descends generally southeastward, from close to the main watershed at *c*.260 m, down to the floodplain of the upper River Kennet at *c*.132 m (Fig. 5). Just to the west on Overton Down is Piggledene, a similar sized catchment which is also a left bank Kennet tributary. Throughout the catchment, the Chalk subgroup dips gently to the southeast at less than 1°. Three formations are present, New Pit Chalk with a crop fingering up the valley beneath the floor, Lewis Nodular Chalk forming the main slopes and Sleaford Chalk beneath the plateau-like headwaters. About one third above the base of the Lewis Nodular Chalk is the traditional Middle–Upper Chalk boundary. The superficial deposits consist of Clay-with-flints and periglacial slope and valley bottom sediments.

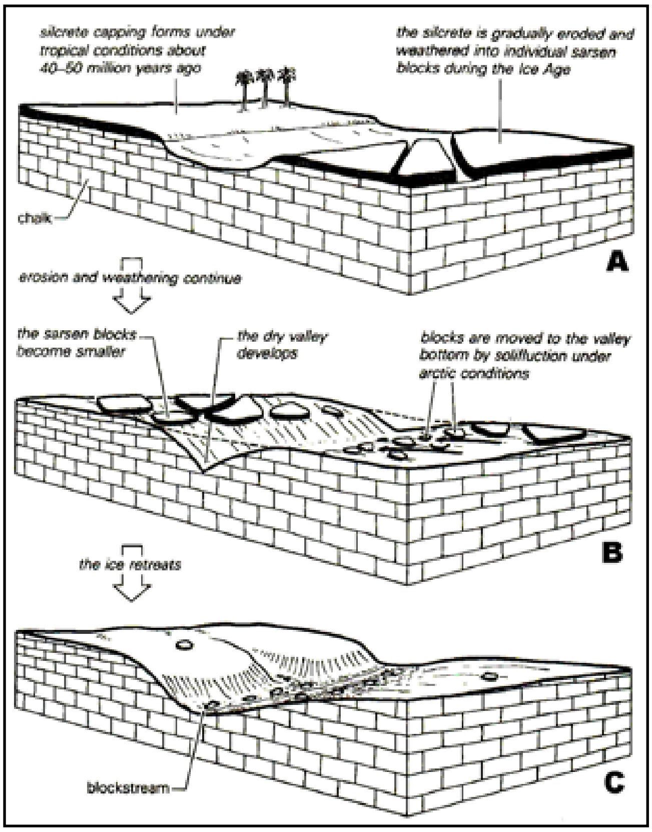

Figure 4*. A three-stage model of rock-stream formation (after Goudie & Gardner, 1985). A: initial break-up of a silcrete cap rock to form sarsens during the Ice Age. B: dry valley formation and downslope movement of the sarsens in conjunction with solifluction. C: sarsens move as a rock stream along the valley floor. This model does not recognise the Reading Formation nor the Clay-with-flints; the B–C transition states 'the ice retreats' when it would have been more appropriate to state 'end of cold stage'; this illustration was produced for a popular non-academic book.*

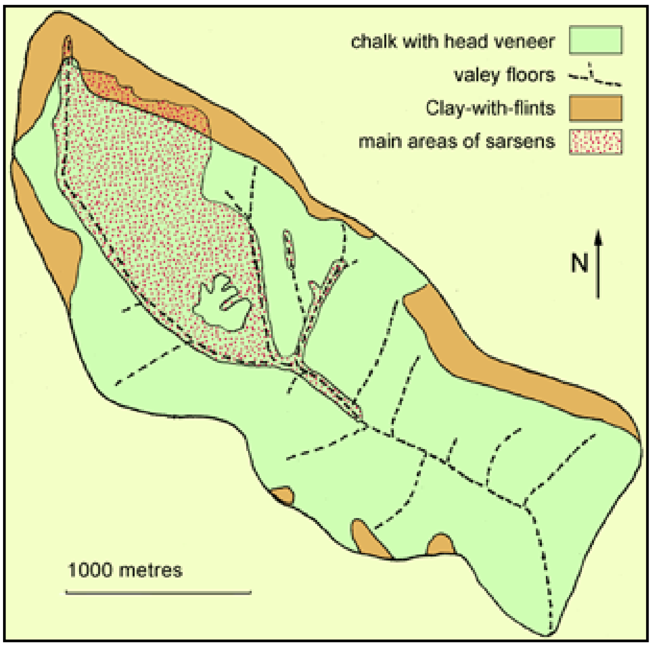

***Figure 5**. The Clatford Bottom catchment and its main concentrations of sarsens, with the fluvial network based on the distribution of 'valley bottom head' (coombe rock). The extent of the Clay-with-flints Formation is based on mapping by BGS, and does not include the areas of soliflucted Clay-with-flints downslope from the Formation's outcrop.*

British Geological Survey mapping

The Downs were first geologically surveyed by a team consisting of W.T. Aveline, W. Whitaker and H.W. Bristow in 1857–59 at the 'one-inch to the mile scale' old series sheets 12. A three-fold succession consisting of chalk, Lower Tertiary clays and sands, and Clay-with-flints was identified. William Whitaker also summarised the geology in a three-part paper (Whitaker, 1862). In the first part, to describe 'a stiff clay of a brown or red colour with angular flints' he introduced the term '*Clay-with-flints*'. He noted that the Clay-with-flints lay irregularly on the chalk and often occurred in solution pipes. The third part of his paper was devoted to a discussion of the 'Age of the Greywethers'.

Subsequently, 'six-inch to the mile' mapping of the Tertiary and Cretaceous rocks was undertaken in 1888–1895 by A.J. Jukes-Browne and F.J. Bennet, and was revised by Wilfrid Edwards during 1923–24. The New Series one-inch map Marlborough sheet 266 was published in 1925, along with an accompanying memoir (White, 1925). Unusually, White was not directly involved in the mapping of this sheet, but he had earlier mapped substantial parts of the adjacent Hungerford and Newbury sheet (267) and had written the accompanying memoir (White, 1905). The current Marlborough sheet (266) of 1974 is a 1:50,000 scale version of the 1925 six-inch scale map without any revision. This lack of modern mapping is in part compensated by the recent revision of the adjacent (to the east) Newbury sheet 276, (plus part of Abingdon sheet 253), by a large team of geologists and a descriptive memoir accompanies this (Aldis *et al,* 2012); this is significantly more detailed than the now normal brief explanation booklets. Since the western boundary of the Newbury sheet lies only 9 km east of Clatford Bottom, extrapolation of the currently recognised Newbury rock unit names and their character into the Marlborough Downs district is plausible. However, the current lack of exposures is problematic and the nearest Tertiary outcrop to Clatford Bottom lies 8 km to the southeast in the Savernake Forest.

A synopsis of BGS classification of the London Basin Lower Tertiary (Palaeogene) stratigraphy has been presented by Aldiss (2014). An important element for present purposes concerns the Lambeth Group which embraces the now redundant names of Reading Bottom Bed and Reading Beds of the old memoir (White, 1926). The Lambeth Group as represented in the Newbury district consists of a basal thin Upnor Formation (0–4 m thick) and an overlying Reading Formation (20–30 m thick). These are both of upper Palaeocene age. The earlier recognition of Bagshot Sands (White 1925) is no longer considered valid by the BGS.

The Upnor Formation, typically 1 m thick, consisting of shallow water marine glauconitic sands and clays with flint pebbles and nodules overlies a transgressive unconformity underlain by chalk. Above, a mainly non-marine Reading Formation is dominated by clays with minor silt and sand. However, beds of sand (fine to coarse grained) are also present throughout but most frequent in the lower part. The sands appear to represent the fills of river and allied distributary channels which aggraded within a predominately clay-rich floodplain. These arenaceous beds range up to 10 m in thickness. Locally siliceous concretions are present – these are the progenitors of the sarsen stones. Unfortunately, apart from numerous surface sarsens, none is currently exposed *in situ*.

Age of silicification

Although stratigraphically there are several phases of silicification in the London Basin Palaeogene, increasingly evidence is stacking up favouring a major event at the time of the Paleocene-Eocene thermal maximum (PETM) dated as 55.5 Ma. This boundary is associated with breaks in the fossil record, i.e. extinction events (Lovell, 2016). Chronologically, this falls within the Reading Formation.

Silcrete

A terrestrial, geochemical sediment that is formed by low-temperature, near-surface, physico-chemical processes operating within the zone of weathering, in which silica has accumulated in, and/or replaced, a pre-existing soil, sediment, rock or weathering material. Silcretes contain more than 85% silica by weight, with some pure examples consisting of more than 95% silica (Sommerfield, 1983). The term was first introduced by Lamplugh (1902) to describe (in an Irish context) "sporadic masses of 'grey wether' type, indurated by a siliceous cement". (Fr. *silcrete*)

Superficial geology

Clay-with-flints

The descriptive term of Clay-with-flints was first introduced by William Whitaker in 1861, and in his 1864 memoir he postulated that 'the Clay-with-flints is of many ages, and may be forming even at the present day, and that it is owing in great part to the slow decomposition of the Chalk under common atmospheric action'. Essentially, he saw the Clay-with-flints as a residue arising from dissolution of the chalk. In contrast, Thomas Codrington, although supporting the concept of chalk dissolution, went further to suggest that an associated overlying bed of clay or loam was also an essential element in its formation (Codrington, 1865). He wrote (p179) 'a drift of re-arranged Tertiary beds lies on the chalk, the upper surface of which is exceedingly irregular' and described infilled potholes 4.5 m deep in the chalk [solution pipes]. He also noted the inclusion of 'sarsen stones in large masses'. Codrington's observations were possible due to the construction of the Savernake–Marlborough branch of the broad gauge Great Western Railway (opened in 1864). Generally, the Geological Survey in Victorian times identified an upper extremely variable unit <15 m thick given the name 'brickearth' above a lower much thinner unit <1 m, the Clay-with-flints. In the 20th century these two elements were merged by the Geological Survey into a single unit for mapping purposes. In a now classic paper, Jukes-Browne (1906) showed that the residue following the dissolution of c.100 m of Middle and Upper Chalk would only yield *c*.1 m of Clay-with-flints. Based on his mapping experience in Wiltshire, he argued that the main constituent must be derived from Eocene sediments and thereby supported Codrington's original proposal (Fig. 6).

Clear morphological evidence of karstic process is an infilled doline within the Clay-with-flints outcrop [SU125729] on the plateau at the head of Clatford Bottom. A pond marks the site of a former pit which worked a red clay in the 18th and 19th centuries for brick making. A kilometre to the south, on the western valley flank [SJ128714] a doline remains as an open depression (Fig. 7) although the Ordnance Survey map erroneously shows this as a disused pit. Archaeologists appear not to have recognised this as a natural feature.

Figure 6*. Cultivated surface of the Clay-with-flints on the plateau north of New Totterdown with a characteristic mix of sarsen and flint clasts in a red-brown silty clay matrix.*

Clay-with-flints Formation

A residual deposit formed from the dissolution, decalicification and cryoturbation of bedrock strata of the Chalk Group and Palaeogene formations. It is unbedded and heterogeneous, dominated by orange-brown and red-brown sandy clay with abundant nodules and rounded pebbles of flint. Locally it includes bodies of fine to medium grained sand, clayey silt, sandy clay, with beds of well-rounded pebbles and sarsen stones (modified from the BGS online Lexicon). (Fr. *Argiles à silex*)

Since the mid-20th century, field research by soil surveyors has greatly expanded our understanding of the nature of the Clay-with-flints. A key paper is Loveday's (1962) study of part of the Chiltern dip-slope. He reverted to the earlier two-fold division and named Whitaker's residual deposit characterised by flint nodules in a clay matrix as Clay-with-flints *sensu stricto*. The overlying associated bed of heterogeneous flinty and clayey deposit containing appreciable sand and rounded flint pebbles he called Plateau Drift. Locally the Plateau Drift includes blocks of silcrete up to several meters across (Sherlock & Nobel, 1922). Thick Plateau Drift can frequently be inferred to pass laterally into or overlay outliers of the Upnor and Reading formations. Jarvis's (1973) soil mapping on the Berkshire Downs recognised the presence of Plateau Drift on the dip slope and interpreted it as 'heterogeneous resulting from the wastage and mixing by periglacial processes of a former Eocene cover with chalk and loessial debris in several cycles of weathering …. small patches of little altered Eocene clay and sand can occasionally be identified'; these are Lambeth Group sediments. He also noted that Clay-with-flints crops out along the convex edges of the Plateau Drift. Gallois (2009), has usefully suggested that the Plateau Drift would be better termed Clay-with-flints *sensu lato,* thereby avoiding any ambiguity in meaning. Maintaining his reputation for 'thinking outside the box', Kellaway (1977), accepting the association of the sarsens with the Clay-with-flints, suggested that the latter might simply be the decalcified remains of a

Figure *7. A doline formed over the chalk, on the western flank of upper Clatford Bottom.*

calcareous flinty till although he later retracted from this view (Kellaway, 1991). Under his glacigenic hypothesis the sarsens were regarded as erratics.

The BGS has maintained a unified 'Clay-with-flints Formation' mapping unit which incorporates both the *sensu stricto* and *sensu lato* ('Plateau Drift') variants of the soil surveyors. Nevertheless, the recent Newbury geological sheet recognises a 'Sand in clay-with-flints' of clean medium to fine grained sands lateral to and within the Clay-with-flints forming a low-lying blanket over the chalk. Tellingly, it has admitted that in the absence of exposure, the sand in clay-with-flints might even represent undisturbed elements of the Lambeth Group (Aldiss *et al,* 2010). The base of the Clay-with-flints reflects the approximate position of the early Palaeocene unconformity beneath the Lambeth Group; in the Clatford catchment it cuts across the Sleaford Chalk.

Head deposits

The conventional wisdom is that the Marlborough Downs lie south of any English Pleistocene glaciation and hence each of the *c*.50 Quaternary cold stages were associated with the establishment of periglacial environmental conditions. Setting aside the 'periglacial rock-streams' for the time being, these phases of periglacial conditions would have witnessed prolonged multiple freeze-thaw cycles impacting on the chalk and Clay-with-flints. As a result, throughout southern England significant parts of the chalkland landscape are mantled by diamicts. Evans (1968) concluded that almost the entire chalk outcrop was mantled by such material until the later prehistoric period when its destruction occurred. These diamicts constitute the ubiquitous head deposits which at the base of slopes pass laterally into coombe deposits on the valley floors. The presence of head does not necessarily imply evidence *per se* of permafrost, but major episodes are likely judging from the presence of ice-wedge casts in several of the upper Thames gravel terraces which lie just to the north-east of the Downs. The floodplain of parts of the upper River Kennet is littered by sarsens and downstream a gas pipeline trench across it revealed sarsens within the sub-floodplain gravels. Stratigraphic evidence in the lower Kennet demonstrates that these gravels were mobile in the Loch Lomond Stadial *c*.12 ka BP (Figs 8 & 9).

Figure 8*. Sarsens bordering the channel of the River Kennet near West Overton.*

Head

Head is a uniquely British term (some call it archaic as is Drift!), for describing non-sorted and poorly stratified debris mantling hillslopes and partially infilling valley floors. It is the result of solifluction, the slow downslope flow of saturated unfrozen sediments over either dissipating seasonal frost or where the substrate is permafrost, the flow occurs within a thickening active layer. A synonym is gelifluctate. (Fr. *depots de couverture*)

Coombe deposits

Compact gravel containing flints and clasts of chalk in a matrix of weathered finely divided chalk-rich and silty material. Frequently found beneath the floors of southern English chalkland dry valleys and where such valleys cut open onto low ground, they form low angle alluvial fans. They reflect a combination of solifluction and fluvial transport, the latter being meltwater deposits derived from either ground ice or snow. Can be crudely mixed or roughly stratified. (Fr. *glisements de coombe*)

A major part of the Southampton study (Clark *et al,* 1967), involved the excavation of pits in the floor of Clatford Bottom in order to establish the sub-sarsen stratigraphy. The sarsens were found to either lie on or be embedded in coombe deposits which attained a maximum thickness of 3.5 m. Typically, the upper part of the coombe deposits was decalcified to depths within the 0.6–1.2 m range but some non-calcareous pipes extended into the chalk below (Fig. 10). It is suggested here that the concentration of sarsens in the upper part of the coombe rock could be due to frost heave resulting from segregation ice lens formation as occurs beneath frost-jacked bedrock boulders (Worsley, 2007). Since fluvial activity has been minimal in the post-glacial due to seepage into the chalk, the decalcification process has extended over at least some 10 ka. Any sarsen mobility must be dependent upon the flux of head during times when a periglacial environment prevailed. In contrast,

Figure 9*. A rounded sarsen within Kennet sub-floodplain gravels near Hungerford; scale bars are each 500 mm.*

Figure 10. Section in the valley bottom deposits exposed during July 1964 in Pit 6 (Clark et al, 1967) with 0–0.15 m tabular sarsen fragments in a sandy matrix, being stone mason debris; 0.15– 0.8 m brown flinty loam (decalcified); 0.8–1.1 m chalky coombe rock with few scattered flints and small sarsen clasts.

excavations at the base of two sarsens on the interfluve between Clatford Bottom and Piggledene revealed that the sarsens rested directly upon the frost fractured chalk bedrock (Bowen & Smith, 1977). Adjacent to these excavations is the British Association Experimental Earthwork site and when this was dug in 1960 the top 0.5 m of the chalk displayed involutions or ‘festooning’ indicative of multiple freeze-thaw cycles relating to the Late Devensian cold period (Evans, 1969, Plate 11b).

The Marlborough Downs sarsens

Thanks to the industry of our Neolithic forefathers, the Avebury henge monument is effectively a geological museum displaying a splendid range of locally obtained sarsen clast morphologies (Fig. 11). Although some archaeologists have tried to classify them into masculine and feminine forms, complexity dominates. Unlike Stonehenge, none of the sarsen blocks has been modified artificially and they thereby represent the original shape of the stones when collected and/or quarried (Marshall, 2016). Judging by the surviving profusion of blocks on parts of the adjacent Downs there must been have little incentive to excavate, and selection was probably based on size, the bigger the better. These sarsens are characterised by highly irregular surfaces including hollows and shallow channels. Overall, the Avebury sarsens and those on the Marlborough Downs are generally tabular, with rounded edges and irregularities in shape. Their morphology is consistent with derivation from either a fragmented silcrete sheet or individual concretions. Evidence for subsequent fluvial transport is limited. Clark *et al* (1967) established that 77% of the sarsens on Fyfield Down were between 0.3 and 1.5 m in diameter and Small *et al* (1970) estimated the number of sarsens with long axes of <4–5 m in a 750x60-metre strip in Clatford Bottom to be between 8000 and 10,000; this figure relates only to the sample area and not to the total catchment (Fig. 12).

Figure 11. Three members of the Southern Inner Ring at Avebury (right to left stones #101–103); the two entrance stones of the primary outer ring (#98 ‘Devil’s Chair’ on the left, and #1).

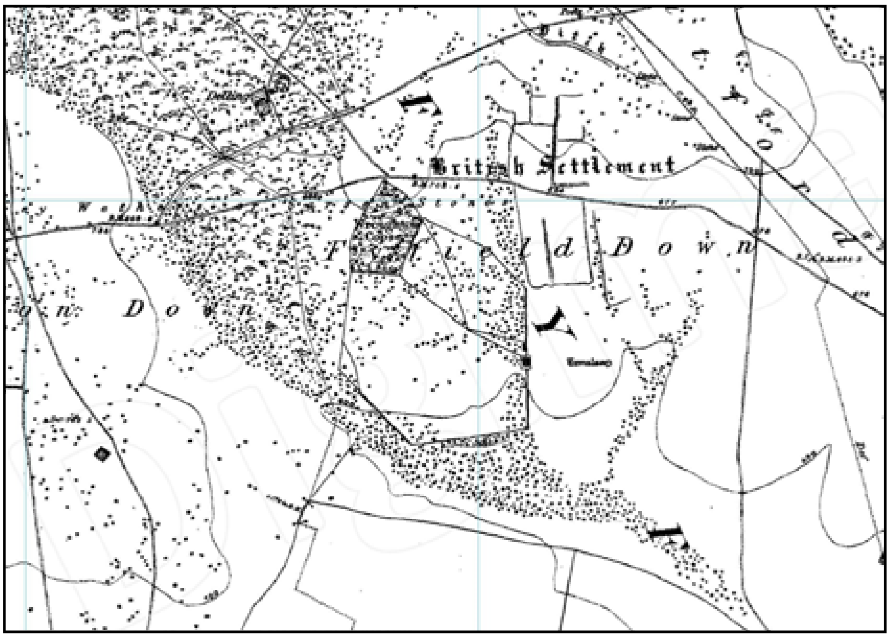

Figure 12. Distribution of sarsens in the lower part of Clatford Bottom, as shown on the Ordnance Survey ‘six-inch scale’ map from the 1880s. A tongue of sarsens extended along the valley floor, to a lower limit that corresponds with the upstream boundary of total sarsen removal.

Figure 13. *Rare example of a sarsen revealing a cross-bedded set that shows a palaeocurrent flow left to right.*

Petrographically, the sarsens are largely grain-supported sandstones with former void spaces infilled by optically continuous overgrowths. Fresh fractured surfaces show a saccharoidal texture. At Clatford Bottom, included flint clasts are rare, as are conglomerates, so there are no puddingstones. Weathering reveals the presence of some small-scale cross-stratification (Fig. 13). Aeolian features, such as faceted and polished surfaces, are absent. This possibly reflects the non-availability of surface sand and/or snow cover that could abrade the clast surface.

A relatively common feature is the occurrence of tubular fossil rootlet structures within the sarsens (Fig. 14). These were first described Carruthers (1886) from a specimen collected by Thomas Codrington. Tentatively, he suggested that the roots were related to a species of palm. Some larger tubular structures might be animal burrows. In the lower Kennet valley, Hawkins (1946) reported the discovery of a silicified tree trunk, 4.24 m long and 0.6 m in diameter, within an unlithified crossed-bedded sand more than 4.57 m thick of the Reading Formation. A species of tree akin to *Magnolia* was suggested.

Figure 14. *Vertical and horizontal root hollows in a sarsen block on Totterdown.*

An enigma is the unusual concentration of sarsens in the upper Clatford Bottom catchment despite the undoubted quarrying (Fig. 15). This distribution appears to be natural, and could reflect an enhanced amount of silicification within the Reading Formation during the PETM at this locality. Clearly, this would be dependent upon the extent of the original sand body. Since the area involved exceeds the dimensions of a single river channel, several factors might be involved, including the occurrence of a major crevasse splay (where a flood caused a levee breach on a main channel and thereby fed an alluvial fan on the floodplain), a river channel confluence or simply an environmental setting leading to enhanced silicification.

Impact of sarsen clearance and quarrying

Apart from defining the term greywethers, Col. Symonds also commented that it had once been possible to walk the 9 km from Avebury to Marlborough entirely by stepping from one sarsen to another, such was their profusion. Sadly, the modern sarsen landscape today is far from being anthropogenically undisturbed; even the Neolithic Avebury monument is testimony to this. Large areas of the downland have been subject to total sarsen clearance in order to facilitate arable agriculture, a process that commenced as early as the Bronze Age. In the Clatford Bottom catchment a spectacular illustration of this is the decision to show on the current Geological Survey Digimap an area of worked ground on Fyfield Down; normally the 'made ground' symbol used is applied where industrial activities have created massive disturbance. The Ordnance Survey denotes the area with the words 'British Settlement'. Another example is apparent by comparing successive editions of the large-scale Ordnance Survey map. Victorian clearance of an area east of New Totterdown is manifest by a huge linear pile of sarsens just inside an area of woodland. King (1968) has documented the impact of the sarsen masons and the lower limit of the Clatford rock-stream, which corresponds to the upper limit of

Figure 15. *A sarsen stone split by a mason, and then abandoned. There is a natural rounded channel (to the right) on the sarsen surface.*

Figure 16*. The famed 'polissoir' (polishing stone) in upper Clatford Bottom; this sarsen stone has a dish-shaped hollow and multiple grooves that were left from flint axes being polished and sharpened during the Neolithic. The natural surface beneath the scale bar has also been used for polishing.*

total sarsen clearance. The Rev. A.C. Smith (1884) mapped the distribution of sarsens *c*.1880, as did the Ordnance Survey, and these provide a good base line to assess the degree of clearance in the following half century. Experience has shown that Smith's mapping was not particularly accurate as he had to improvise his own large-scale base maps.

One sarsen in the catchment has special geoarchaeological status. This relates to its usage in the Neolithic as a *polissoir*, i.e. a polishing stone. The stone surface has five grooves and a dish-shaped hollow that truncates one of the grooves (Fig. 16). These are thought to result from centuries of laborious work sharpening and polishing of knapped flint axes. Excavation has shown that the western part of the parent sarsen has been removed, and this can be dated to the early 13th century, as a coin from that era was found in the debris left by the mason's work.

The Clatford Bottom sarsens

Periglacial environmental model

Woodward (1912) was probably the first to suggest that the Clatford landscape might be genetically related to cold-climate environmental processes. He drew a parallel between the 'stone rivers' of the east Falkland Islands and the Marlborough area sarsen streams. These 'stone rivers' had been visited and described as early as 1839 by Charles Darwin who wrote (p254): 'In many parts of the island, the bottoms of the valleys are covered in an extraordinary manner, by myriads of great angular fragments of the quartz rock. ….. The whole may be called "a stream of stones" …. blocks vary in size …. spread out into level sheets, or great streams'. A number of papers relating to the 'stone streams' followed Darwin's pioneering observations. Probably the most important of these was by the Swedish geologist Johan Gunnar Anderson (1906) who proclaimed (p102): 'the birth of the stone-rivers is a facies of the ice age of the southern lands'. Importantly in the context of 1906, he specifically ruled out glaciation *per se* for their genesis; in current terminology they were periglacial. The process of 'the slow flowing from higher to lower ground of masses of waste saturated with water [this may come from snow-melting or rain] I propose to name *solifluction* (derived from *solum*, "soil," and *fleure*, "to flow")' (p95-6). Specifically, he was referring to active solifluction on Bear Island in the extreme northern North Atlantic Ocean at 74.5°N. This was three years before Walery Łoziński introduced the 'periglacial' concept.

The periglacial origin of the sarsen rock-streams in the Marlborough area was endorsed by M.T. Te Punga (1957). A visiting academic New Zealander, he developed a hypothesis that southern English landscape bore the imprint of long term periglacial processes, but sadly, was unable to persuade the establishment of the day of the validity of his ideas and was forced to publish in The Netherlands rather than in a British journal (Worsley, 2005). Williams (1968) examined the fossil rock-streams in southern England and included Marlborough Downs examples in his study. He argued that the farthest travelled block at Clatford Bottom had covered 4 km with an average gradient of 1°30´. This estimate is very dependent upon a sarsen source located only on the watershed, a highly implausible scenario in the writer's opinion.

In their seminal synthesis of British periglaciation Ballantyne & Harris (1994) present only a brief account of Clatford Bottom. This is subsumed into a chapter section titled 'Coombe rock: head derived from periglacially weathered chalk'. Certainly, the commentary is not consistent with Natural England's view of the reserve's geological importance.

Drainage-line silcrete model

A radically different interpretation of the sarsens at Clatford Bottom was proposed by Hepworth (1998), Nash *et al* (1998) and Ullyott *et al* (1998), although paradoxically their conclusions have not been challenged. With field experience of silcretes in both southern Africa and Australia, these workers were able to give a totally different perspective. This development followed from earlier work (Summerfield & Goudie, 1980), where a fundamental distinction between pedogenic and non-pedogenic silcrete formation was emerging.

First, John Hepworth rejected the idea that the concentration of sarsens to form a rock-stream within Clatford Bottom was due to a periglacial 'sludging' processes. Rather, he envisaged that the sarsens were a relict weathered and fragmented linear silcrete bed almost in situ. He gave four reasons for his opinion: (a) he questioned the assumption that the hillslope gradients were sufficient for the sarsens to move down valley; (b) he was unconvinced that a realistic movement mechanism had been demonstrated; (c) he saw no evidence of any increase in concentration from some original density; (d) the absence of sarsens on the western valley slope demonstrated that an original lenticular silicified sand body had not extended further westwards. In the writer's view, all four of these reasons are contentious and unsustainable, primarily because most of the sarsens must have originally been formed up to 100 m above their current elevations.

Secondly, experience of Nash and his co-workers on silcretes in the Okavango Delta area of Botswana, suggested that the traditional fragmented surface silcrete model for Clatford Bottom might be replaced by a more appropriate analogue. They identified three non-pedogenic silcrete types each of which is independent of the position of a former land surface. These were: (a) groundwater forms due to silicification at zones of phreatic outflow at or close to water tables; (b) lacustrine/pan types at the margins of ephemeral lake basins; and (c) so-called drainage-line silcretes forming within the alluvial fills of channels. They suggested that the drainage-line variety provided the best analogue to account for the sarsens at Clatford Bottom. However, it is difficult to accept that the present-day sarsen landscape, particularly the locations of the dry valleys, is directly inherited from a drainage line silicification event(s) in the Palaeocene, so the answer to the question proposed by the Nash *et al* paper, 'an analogue for Cenozoic sarsen trains?', is No in this particular case.

A Stonehenge sarsen source?

In total, the Stonehenge monument incorporates 96 sarsens, each weighing between 15 and 32 tonnes (Fig. 17). Yet, the source, or sources, is unknown. As of 2019, archaeologists have not yet identified any precise sources for the sarsens of Stonehenge (Parker Preston *et al,* 2015; Whitaker, 2019). Nevertheless, despite this commendable caution, intense speculation has continued since the mid-17th century, when the Marlborough Downs were first proposed as a prime source suspect. This hypothesis has endured despite the problem of 32 km separating alleged source and destination. Indeed, Parker Pearson *et al* (2015) throw caution to the wind by mentioning the presence of

Figure 17*. Two dressed uprights and their lintel in part of the Main Sarsen Circle at Stonehenge, formed of sarsen stones that might have been dragged from the Marlborough Downs by Neolithic people. The two smaller stones in front are bluestones thought to have a source in northern Pembrokeshire (April, 1977).*

an earthwork some 15 m wide, 80 m long and 0.5 m deep on Clatford Down as possibly being related to an extraction pit!. Then Parker Pearson (2016) drew attention to a historic record that he interpreted to suggest that several dressed blocks were previously to be found on the Kennet floodplain close to the Clatford Bottom confluence. The implication was that they had been abandoned while en route to Stonehenge. No evidence of these remains and the assumption is that they were later broken up for construction materials.

Geological evidence in confirmation of this haulage hypothesis is conspicuous by its absence (John, 2018), although in 2019 the Natural England web site for Fyfield Down has no doubts! A pioneering heavy-mineral study (Howard, 1982) concluded that the Stonehenge sarsen materials differed from sarsen samples from the Marlborough Downs, namely Clatford Bottom and Piggledene. This conclusion has been supported by recent laser scanning data from Stonehenge, which indicate differing chemistries that in turn are likely to reflect source variability. Currently, a project by Nash and Ciborowski at the University of Brighton, using ICP-MS/AES (inductively coupled plasma: mass or atomic emission spectroscopy) analyses seeks to establishing geochemical fingerprints of sarsens both at Stonehenge and at potential sources in southern England (including the Marlborough Downs). The jury is still out.

Evolution at the Marlborough Downs

In the late Cretaceous, sedimentation of the chalk ceased, and, following uplift, a terrestrial environment was established in the early Palaeogene. In southern England <350 m of chalk were eroded to a low-relief polygenetic land surface. Wiltshire was at the western extremity of any early Tertiary marine transgression and it is just possible that the basal Lambeth Group is marine. However, the main sedimentation upon the erosional unconformity was fluvial and related to major fluvial drainage from the northwest to the southeast. Effectively this was a proto-Thames (Gibbard & Lewin, 2003). During the late Palaeocene, the Reading Formation formed by the aggradation of river transported sediments. The facies reflect either the style of a major meandering river or estuary, with linear sand bodies representing channel infills hosted by extensive floodplain deposits or inter-tidal flats. Both were dominated by fine-grained sediments. As the relief was low, at times the river might have drained onto a coastal plain, and thereby created a deltaic complex. The climate was likely to be semi-arid and hot leading to multi-palaeosol development on the slowly aggrading floodplains. The PETM induced the groundwater and drainage-line silicification of the sand bodies within the Reading Formation. Within the Downs district, no *in situ* Lower Tertiary, post-Reading Formation, sedimentary record survives, but less than 10 km to the south-east, deposits of a major transgression constitute the Thames Group (the London Clay) within the Kennet basin.

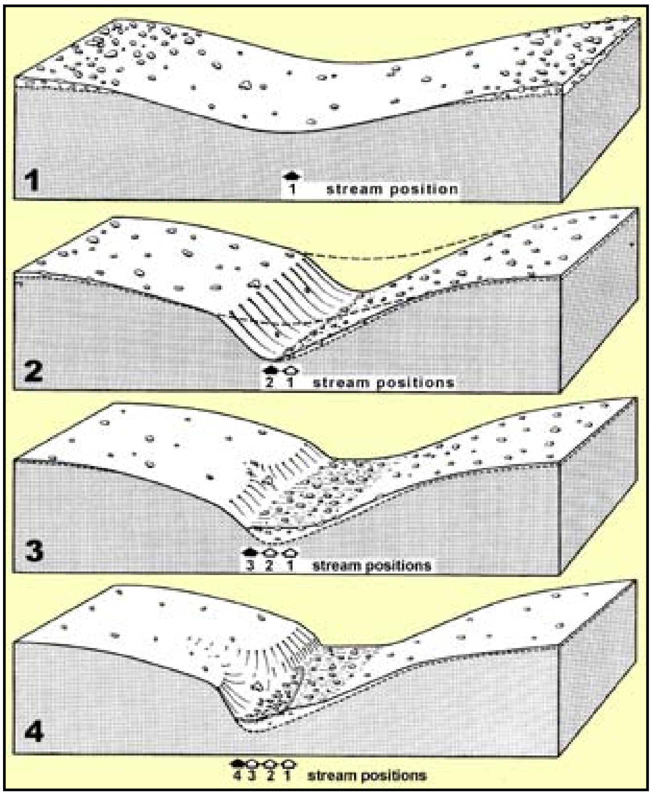

***Figure 18**. Stages of valley evolution in the asymmetric middle reach of Clatford Bottom (after Mike Clark, 1976). The Clay-with-flints is present in Stage 1 with its included sarsens, but has almost disappeared by Stage 2.*

Locally, and across much of Britain, the remainder of the Tertiary is unrepresented, apart from remainé formations such as the Clay-with-flints, which may have started to form in the Miocene. The indications are that a low-relief terrestrial environment prevailed until the onset of landscape instability once the late Cenozoic climatic cycles increased in amplitude (Jones, 1999). River incision led to greater relief, and denudational unloading therefore led to isostatic rebound. This triggered the development of the present-day relief of a chalk cuesta with its dip slope. Run-off down the dip slope produced the modern valley system, especially when the chalk was rendered impermeable by frozen ground. Crucially, dissection and erosion of the Clay-with-flints led to the exhumation of the entombed sarsens, which were redistributed as the land surface was progressively lowered by dissolution (Fig. 18). Irrespective of any lateral displacement, the net lowering of many of the sarsens approaches 100 m. Independently, Walsh (2001) argued for a value as much as 150 m. During Pleistocene cold stages, repeated phases of solifluction led to the sarsens moving downslope and along the valley axes towards the Kennet floodplain. The now fossilised rock-streams represent the cumulative effect of periglaciation events over 2–3 Ma, and not just during the last (Devensian) cold stage, as is often assumed. Their reactivation awaits the onset of the next cooling stage.

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Peter Worsley, p.worsley@reading.ac.uk

School of Archeaology, Geography and Environmental Science, Wager Building, University of Reading, RG6 6AB