

## SILCRETE DURICRUSTS WEST OF THE BOVEY BASIN

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Bristow, C. M. 1993. Silcrete duricrusts west of the Bovey Basin.

*Proceedings of the Ussher Society*, **8**, 177-180.



Siliceous duricrusts ('silcretes') produced by the precipitation of silica in a weathering environment have been described from south-east Devon by Isaac. Precipitation of silica is also evidenced by the Woolley Grit north of Bovey Tracey, presumed to be of early Tertiary age, which is a sequence of sands and gravels which have been cemented by chalcedonic silica. Further east, in south Somerset and on the chalk uplands surrounding the Hampshire Basin, there is extensive evidence of silcrete (sarsen) formation, which is also thought to be of Palaeogene age.

Recent exposures on the south side of the Bovey Basin at Ringslade ball clay pit have shown a number of large boulders of what appears to be silcrete/ferricrete duricrust up to 3 m in diameter, occurring in the Ringslade fault zone where upper Devonian slate is thrust over the Bovey Formation. These boulders have presumably originated close to the Tertiary/Palaeozoic unconformity and were carried up the fault zone by the thrust movement. Further north, close to the western boundary fault of the Bovey Basin at Higher Brimley, Carboniferous cherts are seen which have been extensively silicified, ferruginised and brecciated. Scattered over a wide area between Ilsington, Liverton and Bickington there are numerous blocks of siliceous and ferruginous material, totally unlike any of the cherts or volcanics in the Devonian and Carboniferous successions in that area.

Silcrete is known to be associated with radiolarian cherts and volcanic rocks, rock types which crop out extensively in the area between Ilsington, Liverton and Bickington. Comparison of the textures seen in the siliceous and ferruginous rocks from Devon, with documented examples of silcrete and ferricrete duricrust, suggest that the Devon rocks could be remnants of a duricrust. The most likely age for the formation of duricrust would appear to be Palaeocene/Eocene, based on a comparison with the Woolley Grit and the silcretes of east Devon and further east. If the age of this duricrust is confirmed, it suggests that the land surface west of the Bovey Basin has not been greatly lowered since the early Tertiary, or possibly the late Mesozoic.

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### INTRODUCTION

In 1961-2 the writer mapped the area between Ilsington, Liverton and Bickington in south Devon. Siliceous rocks occupy a considerable proportion of this area, mainly in the form of radiolarian cherts of Lower Carboniferous age (Bristow, 1962; 1963), however, other unusual siliceous rocks quite unlike the Palaeozoic cherts also occur in the area.

An interpretation of the geology of the area in question, based on the author's mapping in 1961-2 and 1992 is shown in Figure 1. The southern side of the Bovey Basin is formed by a thrust fault (Bristow and Hughes, 1971) similar in character to the thrust faults on either side of the Petrockstow basin (Bristow *et al.*, 1992). The western side of the basin is formed by a major fault (Fasham, 1971 and Selwood *et al.*, 1984), which has been interpreted on the basis of gravity geophysics as a steeply-dipping normal fault, although, in view of the new evidence from the Petrockstow Basin, the same gravity profile may be interpretable as a thrust or reverse fault. The northern and eastern boundaries of the basin are formed by normal sedimentary contacts, with a gentle dip of the contact towards the centre of the basin.

Immediately to the west of the Bovey Basin the geology is dominated by Lower Carboniferous cherts and volcanics (Bristow, 1962; 1963 and Selwood *et al.*, 1984). These cherts and volcanics are abruptly terminated on their west side by the north-south Ilsington fault, west of which there is a monotonous sequence of rusty weathering bluish-black pyritic slates of unknown age, named the Sigford beds by the writer, which are overlain by a group of unusual siliceous rocks, unlike any of the Carboniferous cherts (Bristow, 1962; 1963).

East of the Ilsington fault other unusual siliceous rocks were

found to be associated with the Carboniferous cherts and volcanics. At the time of the mapping in the early sixties no satisfactory explanation for the origin of these siliceous rocks was forthcoming.

Interest in these siliceous rocks was re-kindled in 1992 when Professor Cliff Ollier, who has published extensively in this field (Ollier, 1978; 1984; 1991a and 1991b and Ollier and Galloway, 1990) paid a visit to the south-west, primarily to look at the Palaeogene weathering mantles. In the course of visiting the south side of Ringslade ball clay pit in the Bovey Basin, some large boulders of very hard material with a curious brecciated appearance were examined, which Professor Ollier suggested was some form of duricrust. As a result of this identification, a re-examination of the peculiar siliceous rocks west of the Bovey Basin has been carried out, which has resulted in this note.

### SILCRETES AND DURICRUSTS

In a chemical weathering environment, such as in most humid tropical or subtropical climates; iron oxides and silica are liberated as part of the chemical weathering of many aluminium silicates such as feldspars and mica. The silica and iron oxides then enter into solution and, providing there is enough movement of groundwater, are flushed out of the system. In some cases the iron oxides accumulate near the top of the weathering profile to form a ferricrete. However the concentration of silica in the soil water can also rise to the point where silica is precipitated, often, although not invariably, as a result of arid conditions combined with alkaline groundwater, forming a hard material known as silcrete. Where there are limestones in the vicinity a calcrete can form.

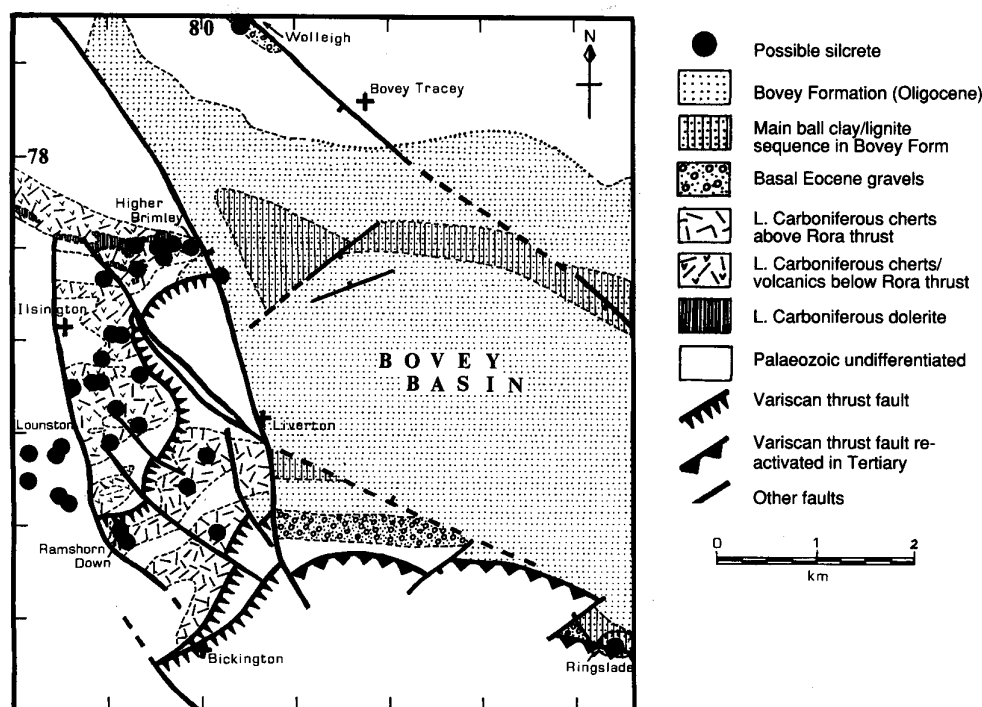


Figure 1: A geological map of the western side of the Bovey Basin, based on the writer's geological mapping in 1961/2 and more recently acquired information; indicating possible silcrete occurrences and their relationship with the Lower Carboniferous cherts and volcanics.

Ferricretes, silcreted and calcreted are collectively known as duricrusts (Wilson, 1983). Silcreted can form at any level in the weathering profile, or in underlying sediments; with a wide variety of textures.

Most of the classic occurrences of silcrete are in Australia and the southern part of Africa. Silcrete is known to be frequently associated with silica-rich rocks such as radiolarian cherts, as described from Western Australia by Van de Graaff (1983). Ollier (1991a) described silcrete invading Palaeozoic radiolarian chert in New South Wales, which resulted in the chert being broken up into a breccia composed of angular fragments of country rock, usually silicified, set in a siliceous matrix. Ollier also suggests that silcreted can be associated with outcrops of volcanic rocks. The silica forming the silcreted is usually either in the form of chalcedony or microcrystalline quartz, and colloform textures are characteristic of some silcreted. Sometimes the silica will overgrow existing grains of quartz sand in optical continuity and produce large euhedral crystals of quartz.

Isaac described silcreted from south-east Devon in 1979 and tentatively concluded they were of Palaeocene age. He then went on to publish several further papers which described many of the typical textures of silcreted from the area north of Sidmouth (Isaac 1981; 1983a; 1983b).

Mobility of silica is also evidenced by the Woolley Grit near Lustleigh, also presumed to be of early Tertiary age, which is a sequence of sands and gravels which have been cemented by chalcedonic silica to form a quartzite-like rock (Blyth & Shearman, 1962 and Selwood *et al.*, 1984). Silcreted of presumed Tertiary age have been reported from the Taunton area (Cameron, 1908 and Prudden, 1987) and from a few miles west of the Petrockstow Basin at Shebbear (Freshney *et al.*, 1979).

An excellent detailed review (in French) of all the above localities, plus a number of other minor occurrences is given in Coque-Delhuille (1987), who attributed them to a period of silcrete formation in the Eocene.

Further east, the sarsens of southern England are now generally accepted (Small, 1980 and Summerfield and Goudie, 1980) to be silcreted formed at some time in the Palaeogene.

### SILCRETES WEST OF THE BOVEY BASIN

Figure 1 shows all the occurrences where silcrete development may have taken place. The following four locations have been selected for description:

- Ringslade ball clay pit
- Higher Brimley
- Ramshorn Down
- The area between Lounston and Higher Sigford

#### *Ringslade ball clay pit*

Bristow and Hughes (1971) described Devonian slate thrust over the Bovey Formation on the south side of Ringslade pit. Since then the pit has developed further back into the hill and a large drag fold in the Bovey Beds under the thrust fault is now well displayed on the south side of the pit.

However, a puzzling feature has been the appearance of a number of large boulders, up to 3 m in diameter just below the sole of the thrust [SX 845 726].

These boulders are made up of a matrix-supported breccia which consists of angular clasts of ferricrete or some kind of siliceous material ranging in size from a few millimetres to several centimetres, set in a dark coloured siliceous/ferruginous matrix. In places the material is mainly siliceous and in other places mainly ferruginous. This, according to Ollier, is best interpreted as a silcrete or ferricrete breccia. If this identification is correct it suggests that the silcrete/ferricrete boulders could have been brought up along the thrust from somewhere in the vicinity of the Palaeogene/Palaeozoic unconformity.

#### *Higher Brimley*

Adjacent to the western boundary fault of the Bovey Basin, beside the lane west of Higher Brimley [SX 799 769], a large boulder several cubic metres in size shows the same kind of brecciated texture as the Ringslade material. The breccia is in places cemented by silica and in other places by iron oxide. Further east in the area of Brimley Copse and the fields below, this material is quite widespread. A sample from the east side of Brimley Copse [SX 798 770] shows that the breccia is made up of clasts of what appears to be Lower Carboniferous chert, set in a fine-grained siliceous matrix, with sporadic iron staining. Thin sections of the breccia show chert fragments set in a matrix composed of iron oxide, microcrystalline silica and some chalcedonic silica. Small veins in the clasts were clearly formed before the material was brecciated, suggesting that the breccia post-dates the Variscan orogeny.

The siliceous rocks in Brimley Copse can be classified into three components:

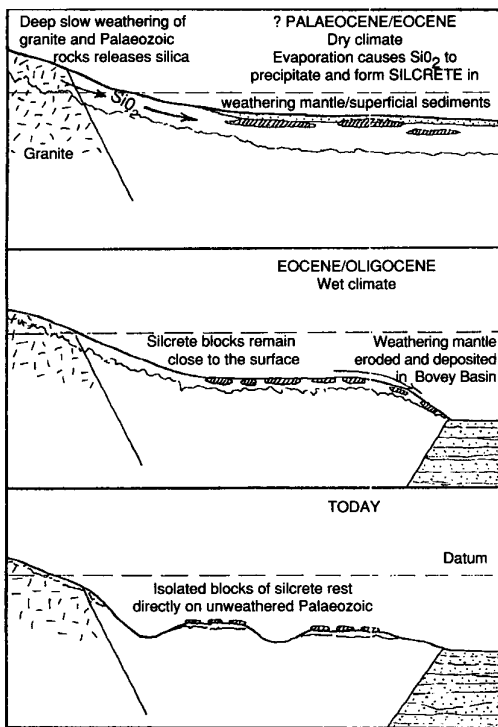


Figure 2: A series of sketch sections to illustrate a possible scenario for the formation of the silcretes in the area west of the Bovey Basin.

- (1) Towards the base, thinly bedded chert similar to the Lower Carboniferous cherts seen elsewhere in south Devon.
- (2) The brecciated material as described above.
- (3) The uppermost part of the outcrop is made up of highly siliceous material with voids, resembling a massive structureless brown or grey quartzite, without any visible bedding.

In places in the Cope itself the breccia rests directly on the Carboniferous chert, in other places a transition can be seen, with a growth of secondary silica and ferruginous material in veins, following an earlier north-south fracture cleavage, gradually expanding until the rock is broken up into a breccia-like mass. In other places a transition directly from the Carboniferous cherts into the Type 3 material is seen.

At the foot of the slope below Brimley Cope and in the short lane leading up to the fields [SX 799 771], there are a large number of large boulders of mainly ferruginous brecciated material, again often showing a transition to the Carboniferous host rock.

### Ramshorn Down

Rora and Ramshorn Downs make up one of the most extensive areas of Lower Carboniferous radiolarian chert in South Devon. The cherts are well exposed in a roadside quarry [SX 790 740] and were formerly also exposed in another quarry on Rora Down [SX 798 747], now unfortunately largely infilled.

About 100 m south-east of the quarry on Ramshorn Down [SX 792 739], scattered large boulders of siliceous material ranging up to several cubic metres in size occur on the surface. In the same area a clitter of Lower Carboniferous radiolarian chert fragments, similar in character to the chert seen in the two quarries, is also seen.

There is a considerable variety of textures in these boulders of siliceous material on the surface, ranging from a vague sort of brecciated texture, to other boulders which seem to show a colloform texture, similar to those seen in classic silcretes, including those described by Isaac from the Sidmouth area. Other boulders show the more definite kind of brecciated texture seen at Higher Brimley, and reminiscent of those silcretes growing on Palaeozoic cherts in Australia figured by

Ollier (p.154, 1991a).

Much of the material looks rather like a brown quartzite with irregular ramifying veins of silica. The silica in these veins can be quite coarse at times, with crystals up to several mm in diameter in some cases. Late-stage microcrystalline quartz veins cut the breccia and the brown quartzite-like material in places.

There is a wide range of textures in this surface clitter of siliceous boulders, but it must be emphasised that there is no trace whatsoever of any of these lithologies in the two quarries on Rora and Ramshorn Downs, which contain only Lower Carboniferous radiolarian cherts; so it must be concluded that we are dealing with a surface scatter of siliceous boulders, apparently unrelated to the underlying geology.

### Lounston - Higher Sigford

Moving now to the area between Lounston and Higher Sigford, we enter the area where the writer's mapping in 1961-2 revealed an extensive scatter of boulders of unusual siliceous rocks. The underlying rock is the fairly uniform bluish-black pyritic slate of the Sigford Beds and, resting on this unit, is a group of siliceous rocks including rocks described in 1962 as 'cherts, quartzites and breccias' totally unlike any of the Carboniferous cherts. To quote the writer's 1962 description:

"These fragmentary rocks appear to be made up of silty or slaty fragments in a siliceous matrix composed of intergrown quartz grains. The fragments are angular and, under the microscope, appear to have been silicified around their margins. In the clitters these fragmental breccias' and cherts are associated with quartzites and sandstones."

No wholly convincing location where the siliceous material appeared to be *in situ* could be found. It seemed to represent a scatter of blocks up to 1 m in diameter resting almost directly on unweathered Palaeozoic slates. Much of this material is similar to the Type 3 material at Higher Brimley. Some of the material found on Ramshorn Down is also rather similar.

Besides the four occurrences described above there are a great number of other occurrences of similar siliceous rocks in the area between Ilsington, Higher Brimley, Liverton and Bickington, which are indicated on Figure 1. Most of the occurrences lie between 150 and 200 m above O.D.

### DISCUSSION

In summary, the features of this scatter of surface related siliceous material appear to be:

- (1) The siliceous material mainly occurs as loose blocks lying on the present land surface and does not appear to be part of the Lower Carboniferous sequence.
- (2) In spite of extensive recrystallisation, many of the textures associated with silcretes appear to be present, including brecciated and colloform types.
- (3) In a few places the siliceous material can be seen to have invaded and grown on the Lower Carboniferous cherts.
- (4) There are transitions from silcrete towards ferricrete-like material in places.
- (5) These occurrences of siliceous material are closely associated with the most extensive outcrop of radiolarian cherts in South Devon.
- (6) Nearly all the occurrences lie between 150 and 200 m above sea level.

The most reasonable interpretation of this material would appear to be that we are dealing with the remnants of a silcrete/ferricrete duricrust formed at some time in the past; but when might it have been formed?

Faced with no direct means of dating these silcretes, the obvious analogy must be with the silcretes in East Devon, which Isaac tentatively suggested were Palaeocene or Early Eocene in age. The silicification in the Woolley Grit, which Blyth and Shearman (1962) dated as Late Cretaceous or early Tertiary, is another pointer to a similar age, especially as Woolleigh lies only 3 km away from Higher Brimley. Further east we have the analogy with the sarsens of southern England, which are silcretes presumed also to be of Palaeogene age. The

occurrences at Shebbear, west of the Petrockstow Basin, reported by Freshney (1979) also appear to be similar, as well as the occurrences in the Taunton area reported by Prudden (1987) and others.

If we accept that the most likely age for the formation of these silcretes is Palaeocene/Early Eocene, then a scenario as set out in Figure 3 suggests itself.

In the Palaeocene, under a warm, but not excessively wet climate; deep weathering of the Dartmoor granite and the Palaeozoic rocks took place, possibly with a landscape with much less relief (Ollier, 1992) than today. Silica released by the chemical weathering of aluminium silicates migrated downslope, to an area where the concentration of silica in the soil water rose to the point where deposition of silica started to take place, possibly aided by a fairly alkaline Ph. The source of the silica could have been from the weathering of the feldspars and micas in the granite, or the clay minerals of the Palaeozoic rocks. The regional association between the silcretes and the Palaeozoic cherts suggests that much of the silica could have been mobilised from this source; some silica could also have been mobilised from within the soil profile. This mobilised silica would then have been precipitated in the weathering mantle, or in associated early Tertiary sandy sediments, or even in the upper part of the underlying unweathered Palaeozoic rocks. This became the silcrete.

The formation of the silcrete was particularly strong in and around the area where the radiolarian cherts occurred. In places the silcrete grew directly on the cherts and invaded them, producing the brecciated textures we have noted.

In mid-Eocene times, as Isaac (1979) pointed out, uplift and faulting commenced and the long period of slow deep weathering came to an end. The weathering mantle began to be rapidly eroded due to uplift and a wetter climate, and it was transported away to fault-formed basins such as the Bovey Basin. New immature weathering profiles developed, but were swept away almost as fast as they formed. The silcrete, much of which was in the form of large blocks, remained behind as it was too massive to be removed by erosion.

Following the climax of the Alpine movements and the closure of the Bovey Basin, erosion continued and valleys were cut in the old Tertiary surface leaving the remnants of the silcrete duricrust now as isolated boulders scattered over the hilltops between 150 and 200 m above O.D. This sequence is similar to that envisaged by Coque-Delhuille (1987, pp. 413-429) for the formation of silcretes elsewhere in Devon; and with the dating proposed by Small (1980) and Summerfield and Goudie (1980) for the formation of the various surface-related silcretes (including sarsens) in southern England.

Whilst this scenario would appear to be the most likely and fits most of the observed facts, it must be emphasised that there is at present no secure way of dating the formation of these silcretes, which could be older, or younger, than the early Palaeogene age proposed above. However, the quartz veins running through the silcrete and the coarsely crystalline nature of much of the silcrete are features which suggest that there has been extensive recrystallisation of the silcretes, which may be an indication of an older, rather than a younger age. It is just possible that this could have been in the Mesozoic, when the Cornubian island was almost certainly a land area of low relief. The silcretes may also have been formed by more than one episode of silcrete formation.

The existence of these silcretes would seem to be an indication that the land surface west of the Bovey Basin has not been greatly lowered since the early Tertiary. Further work on the mineralogy and chemistry

of these silcretes may help to clarify the timing and manner of formation of these intriguing rocks, and could provide valuable information on the early geomorphological evolution of the Cornubian peninsula.

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