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HIGH SMITHSTONE QUARRY SITE OF SPECIAL SCIENTIFIC INTEREST AND REPLACEMENT SITE

Geology and Landscape Scotland

Open Report OR/09/038



BRITISH GEOLOGICAL SURVEY

GEOLOGY & LANDSCAPE SCOTLAND

OPEN REPORT OR/09/038

HIGH SMITHSTONE QUARRY SITE OF SPECIAL SCIENTIFIC INTEREST AND REPLACEMENT SITE

Timothy Kearsey and Michael Browne

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Front cover **Exposure of the
Ayrshire Bauxitic Clay
Member at Lugton Water at
Sevenacres Mill.**

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1 Introduction

This report was commissioned by Scottish Natural Heritage (SNH) to consider the options for the replacement of the existing Special Site of Scientific Interest (SSSI) for the Carboniferous, Namurian to Westphalian age Ayrshire Bauxitic Clay Member of the Passage Formation (Clackmannan Group). The bauxitic clay is an unusual lithofacies and is only found in northern and parts of central Ayrshire on the western side of the Midland Valley of Scotland terrane. The existing site at High Smithstone Quarry has an extant planning permission for landfilling and the owner has exercised that right with the result that many of the features for which the quarry was noted are no longer visible. Whilst recognising that it was unlikely that any other site would demonstrate all the features, the British Geological Survey was asked to recommend the best available alternative exemplar site for SSSI status for the Ayrshire Bauxitic Clay Member

2 Site Details

2.1 High Smithstone Quarry GCR/SSSI

High Smithstone Quarry is the currently designated Geological Conservation Review (GCR) site for the Ayrshire Bauxitic Clay Member. Of the original exposures described in the High Smithstone Earth Science Site Documentation Report and in the GCR review (Cleal and Thomas, 1996), none of the described sections is still exposed. There remains one small outcrop in a grassy bank [NS 27969 45723] showing a 2–3 m high cliff exposure at the north-west margin of the site. Here the clay's exposed surface weathers into the modern soil profile.



Figure 1 High Smithstone Quarry as exposed in 1997. Of the exposures seen in this photo only the Outcrop 2 remains.

There is a small exposure of coal/carbonaceous mudstones (the Raise Coal at the base of the Scottish Lower Coal Measures Formation) on the eastern (right) edge of outcrop 2 (see Figure 1 and exposed in Figure 2A and C). However, this carbonaceous mudstone is within the modern soil profile and is very weathered and it also shows laminations/ bedding which may have been reoriented by glacial deformation movement during the Quaternary ice ages. The exposed outcrop of the Ayrshire Bauxitic Clay Member contains several obvious subdivisions. The top bed is 1.06 m thick and is light grey-green and has clay pisoliths (~1 mm). Below this is a 2.30 m thick bed which is darker than the overlying bed and lacks pisoliths and contains numerous vitrainous plant fragments. Below this is another 20 cm of pisolith rich clay which appears to pinch in and out.



Figure 2 Three different views of outcrop 2, the only remaining exposure at High Smithstone Quarry. A) was taken in 1997, B) was taken in 2007 after the quarry had started to be backfilled. The arrow marks the outcrop. C) is the outcrop in 2009.

Of the marine mudstone immediately overlying the basaltic lavas reported by Cleal and Thomas (1996) (Figure 3) and essential in the interpretation that the clays were mainly transported weathering products (Monro *et al.*, 1983), there is now no exposure. Nor is there any exposure remaining of the associated coal seams at least one of which had been mined on the site in the past by stoop and room techniques. There are isolated exposures of an overlying Lower Coal Measures sandstone at the very top of the old section 1, although they are likely to be covered shortly by infilling which was in progress at the time of visit in June 2009.



Figure 3 Section 1 described by Cleal and Thomas (1996) as viewed in 2007. In 2009 only the top of the uppermost sandstone was visible and the site was actively being back filled thus none of this outcrop is going to be left exposed.

2.2 Potential Replacement Sites

Following a literature search and map review, five potential replacement sites for High Smithstone were identified for field inspection (Table 1 below). However one of these (Dubbs) was discarded because SNH were aware that it had already been subject to landfilling. In addition un-filled abandoned opencast workings just to the east of the steading at High Smithstone were also included in the field search in case any remaining sections in the Ayrshire Bauxitic Clay Member were available. This turned out not to be so, exposure being entirely of Scottish Lower Coal Measures strata, and in any case active restoration work was taking place.

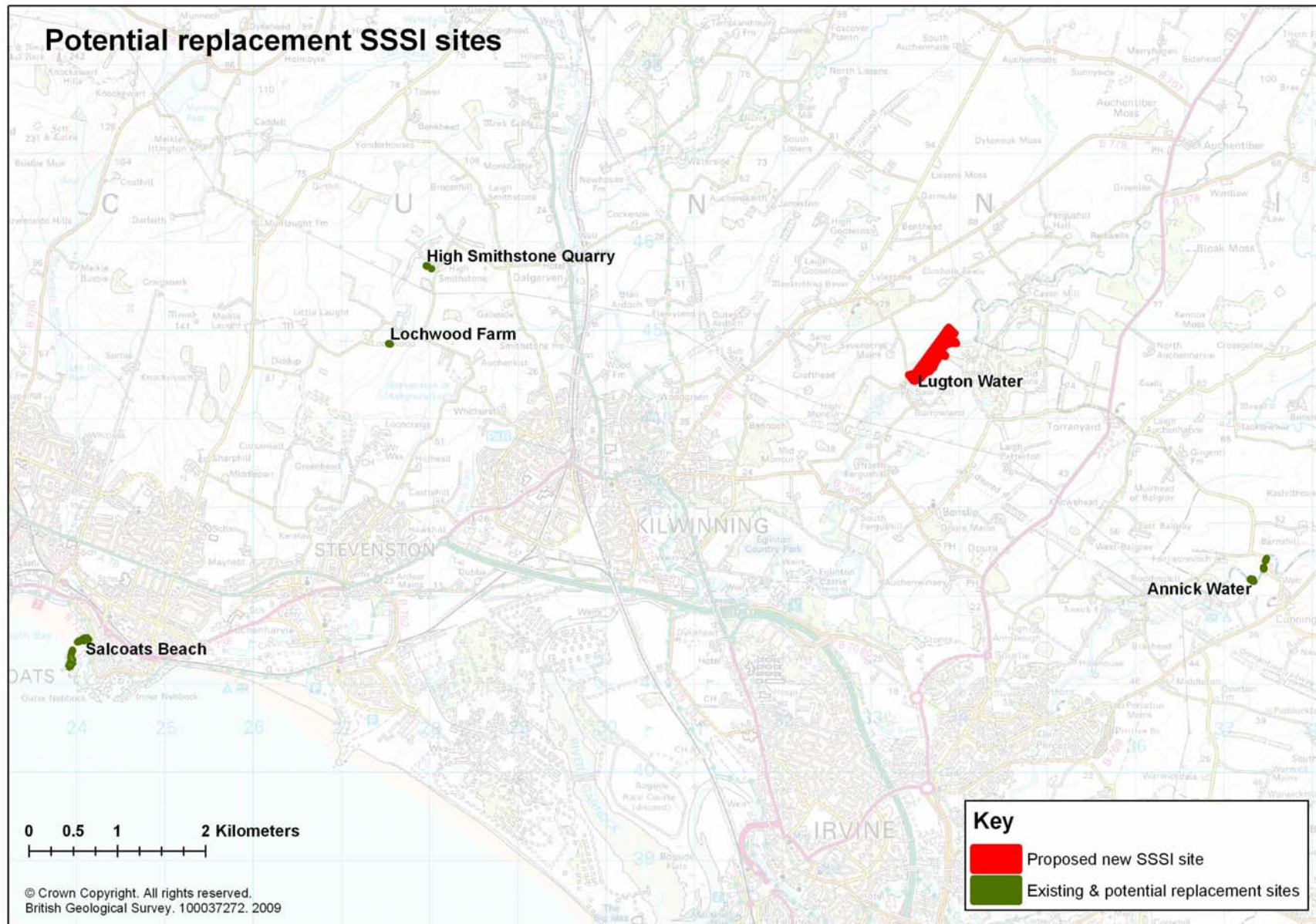


Figure 4 Map of Potential Replacement Sites

Location	Grid Ref.	Exposure	Nature of Ayrshire Bauxitic Clay (ABC)	Geological context	Access	Recommended as replacement
Annick Water at Cunninghamehead Bridge	NS 37492 42438	In river cliffs, the largest 4 m high and in the river bed	Has three distinct units, showing fossil roots, pisoliths and carbonaceous rich beds at base above the weathered basalts; sand filled cracks Total thickness 3.75 m	The best exposure of the ABC but only a small exposure of the weathered Troon Volcanic Member lavas at the base. Downstream there are exposures of the Troon Volcanics/ABC contact, although of poorer quality of the ABC	Very Accessible all sections are maximum 300 m from the road and can be accessed by a well used fisherman's path	Second Choice This has a good exposure of the ABC but lacks the upper context of the coal measures at Lugton Water
Lochwood Farm nr. Ashgrove Loch	NS 27545 44837	In a grassy bank, 5.59 m exposed but very overgrown and impossible to log	Sphaerosiderite grains and pisolith structures were identified in the top 1m of exposure	Some carbonaceous mudstone present in the hillside	Relatively easy access. Access is though cattle fields but section is 150 m from a road	
Saltcoats South Beach	NS 24116 41518	Low bench exposure in beach below HWM mainly covered in barnacles.	The bauxitic clay has two distinct layers; include pisoliths and sphaerosiderite and has a semi-conchoidal fracture. Is less than 1 m thick	Exposure of both the weathered Troon Volcanic Member lava below and the carbonaceous mudstones of the coal measures at the position of the Raise Coal above. Also evidence of later faulting and dyke emplacement	Very Accessible all sections exposed on public beach at Saltcoats, However much of the outcrop is only exposed at low tide	
Lugton Water at Sevenacres Mill	NS 33535 44529	In river cliff – best exposure is 6 m high and other exposures in the access path on hillside nearby	Has three distinct units, including sphaerosiderite at base and nodules of coarser material and occasional root fossils; is 2 m thick. However no evidence of pisoliths found.	Has best context of any replacement section studied, the underlying weathered Troon Volcanic Member lavas are exposed and so are the overlying carbonaceous mudstones and sandstones of the Scottish Lower Coal Measures Formation	Relatively hard access. The exposure is 1.3 km from the best access road. Although there is a path for 1km from the road the last 300 m is off path and accessed from the eastern bank	First Choice This has the best context and a significant exposure of the ABC and is thus recommended as the replacement.
Dubbs Quarry	NS 28297 42410	Old quarry working now used as a landfill no exposure left	None left due to being covered by landfill.			

Table 2 Potential Replacement Sites.

2.3 Notes on Potential Replacement Sites

2.3.1 Annick Water near Cunninghamhead Bridge

5 m north of the bridge at Cunninghamhead on the west bank of the Annick Water [NS 37492 42438] is a 20 m long and 5 m high exposure of the Ayrshire Bauxitic Clay Member (Passage Formation, Clackmannann Group).



Figure 5 Best exposure of the Ayrshire Bauxitic Clay Member at Annick Water.

Exposure: Three beds of the Ayrshire Bauxitic Clay Member are exposed (Figure 4). The upper most bed is partially covered by vegetation and there is evidence of modern soil deformation in the top 0.50 m. It is a blocky jointed clay which weathers red/Fe stained and is 1.30–1.40 m thick. It also contains possible sphaerosiderite. The presence of vertical branching fossilised roots in this bed suggests the clay formed in situ rather than being transported. Below is a grey more crumbly less blocky clay 0.40–0.45 m that sits on (with sharp contact) clay which contains pisoliths. The lower most unit is white green (weathered) clay and extends 1.9 m into the river bed. It becomes very hard at the base of the section. At the very base of section in the stream bed (in the river on day of fieldwork) there is a possible highly weathered basic lava (Troon Volcanic Member).

On the fisherman's track to the south of the bridge on the western bank, just opposite Cunninghamhead Mill [NS 37448 42314] is an exposure of the Troon Volcanic Formation in the river bed which underlies the Ayrshire Bauxitic Clay Member. Here the lava is well jointed, hard, relatively unweathered and generally fine-grained

The Ayrshire Bauxitic Clay Member is exposed again 300 m south of Cunninghamhead Bridge in the south bank of the stream [NS 37325 42164] although this outcrop is vegetated to the point that bed contacts cannot be seen. The weathered top of the Troon Volcanic Member is observed in the north bank in the stream bed in close proximity to clay. Directly overlying the volcanic rocks is a dark, carbonaceous mudstone containing possible vitrainous plant fragments and roots in the south bank of the river. The carbonaceous mudstone interfingers with the overlying bauxitic clay. This bauxitic clay in turn also has pockets of somewhat micaceous (muscovite), fine to medium-grained sandstone which may represent desiccation crack infills or sedimentary dykes.

In none of the exposures is the top of the Ayrshire Bauxitic Clay seen or the overlying Scottish Lower Coal Measures Formation strata.

Access: The main section is a few metres north of Cunninghamhead Bridge (as marked on OS map) and is accessible by a gate on the south western corner of the bridge and then passing down on a fisherman's path and passing under the bridge itself. The auxiliary sections are also accessible via the fisherman's path along the edge of a field.

2.3.2 Lochwood Farm near Ashgrove Loch

This exposure is described by Wilson (1922) and records an exposed thickness of 5.59 m.

Exposure: This outcrop was located [NS 27545 44837]. It now only consists of 5 m of broken exposure in a grass bank (Figure 5). Sphaerosiderite grains and pisolith structures were identified in the top 1 m of exposure and there is now not enough unweathered section to measure an accurate section. Some carbonaceous mudstone is present in the modern soil profile on the hillside.

Access: Access is best by parking at a space by a gate at a sharp kink in the road north of the locality and then passing through two cattle fields; the section is 150 m from this road.



Figure 6 Section of the Ayrshire Bauxitic Clay Member at Lochwood Farm.

2.3.3 Saltcoats South Beach

This exposure is described by Wilson (1922); Weedon (1992) and Monro (1999).

Exposure: The outcrops of the Ayrshire Bauxitic Clay Member exposed at Saltcoats South Beach are exposed between the high-water mark (HWM) [NS 24116 41518](Figure 7) and the low water mark (LWM) [NS 23917 41191]. All outcrops include a package of weathered lava of the Troon Volcanic Member, the bauxitic clay and carbonaceous mudstones/coal exposed in low profile benches (rock reefs) on the beach.

The weathered lava at the top of the Troon Volcanic Formation is sphaerosiderite rich. The overlying bauxitic clay is ~1 m thick at the HWM, but thins to 0.25 m at the LWM. The bauxitic clay has distinct two layers; the lower 0.60 m includes pisoliths and sphaerosiderite, while the upper layer is rooted and has a semi-conchoidal fracture. Overlying the bauxitic clay are carbonaceous shales with occasional vitrinite bands at the horizon of the Raise Coal (Scottish Lower Coal Measures Formation). Towards the LWM from [NS 23938 41299], the bauxitic clay is cut by three minor faults with a maximum lateral displacement of 30 m and at least two altered basaltic dykes up to 3 m wide. Below HWM the outcrops are largely covered in barnacles and seaweed and the only way to identify the bauxite is to by hammering off fresh specimens.

Access: All sections are exposed on the public South Beach at Saltcoats; however some of the outcrop is only exposed at low tides



Figure 7 The section exposed at Saltcoats South Beach near the high water mark.

2.3.4 Lugton Water at Sevenacres Mill

This outcrop was described by Wilson (1922), *Monro et al.* (1983) and *Monro* (1999). *Monro* (1999) describes it as being a typical example of the Ayrshire Bauxitic Clay Member on a palaeo-high south of the Dusk Water Fault. The best exposure at this section is in a river cut cliff [NS 33535 44529] Figure 8.

Exposure: At the base (in river bed) is highly weathered lava (0.10 m or more). Above this is siltstone and mudstone (0.40 m) now almost totally covered in moss and vegetation. Above this is 0.30 m of sulphurous mudstone interbedded with siltstone and sandy siltstone. This unit contains some plant fragments. Overlying this is bed is 0.90 m of mudstone which is grey brown at base, but becomes increasingly red towards the top of the bed. This bed has a subconchoidal fracture and the reddening may be a result of baking caused by the overlying lava. This lava sits directly on top of the reddened mudstone and consists of 0.90–1.20 m of highly weathered basalt which also shows spheroidal onion skin weathering. Above this is a 0.20 m thick cream fine-grained rock with sphaerosiderite. This may be extremely weathered lava. The next unit is the Ayrshire Bauxitic Clay Member, which can be divided into three units. There is a lower, more massive blocky bauxitic unit 0.30–0.70 m thick. This unit also contains 8 cm wide nodules which contain sub-millimetre siderite grains. The middle unit consists of 0.50–0.70 m of less blocky bauxitic clay. Finally the upper division of the bauxitic clay is 0.32–0.50 m thick and contains occasional root traces.

Overlying the Ayrshire Bauxitic Clay is 0.20–0.30 m of carbonaceous mudstone with vitrinite bands all of which are weathered. This in turn is overlain by 0.10 m of paler grey siltstone/mudstone which is carbon rich. The final package of rocks, exposed high in the cliff

include, at the base a 0.30–0.60 m thick off-white medium to fine-grained sandstone, which weathers orange. This unit is lens shaped and had an erosive base but no evidence of ripple structures in the base. Above this is 0.30 m of grey siltstone/sandstone, 0.30 m of sandstone and in the very top of the outcrop is another poorly exposed sandstone 0.30 m thick with a gap between in which no strata could be seen.

Access: The site is best accessed from a good path which runs just outside the southern edge of the grounds of Montgreenan (Hotel). Follow this path for 1 km till the woods that immediately surround the Lugton Water are reached. The section described can be reached either by wading along the river bed or by keeping close to the field boundary on the south-east side of the Lugton Water and descending down to the section when the trees thin to reveal a meadow on a river meander (Figure 9) in the second field along. Note in summer the vegetation is dense enough to hide the cliff from view.

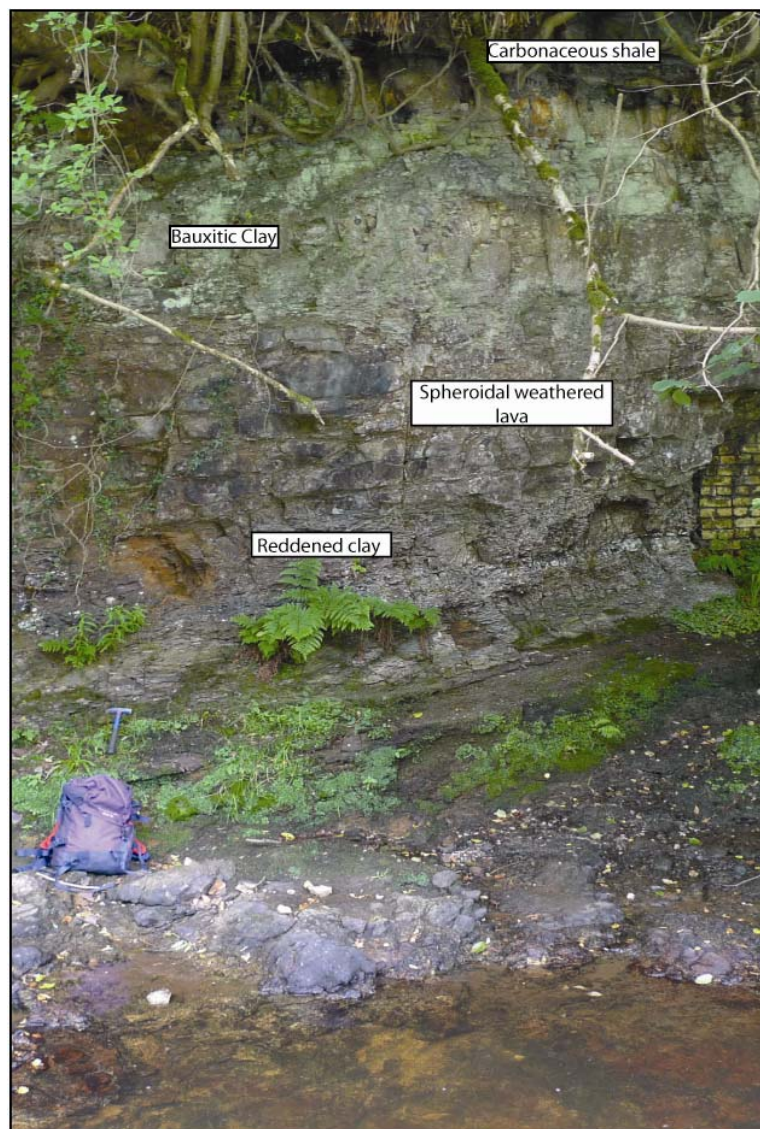


Figure 8 The best exposure of the Ayrshire Bauxitic Clay Member at Lugton Water at Sevenacres Mill.



Figure 9 The view across the flood meadow of the Lugton Water to the site described largely hidden by the trees.

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4 GCR Statement of Site Value – Sevenacres, Lugton Water

Intrinsic Scientific Value: The Ayrshire Bauxitic Clay Member of the Passage Formation (Clackmannan Group) is a distinctive thin suite of Namurian to basal Westphalian (Langsettian) age sedimentary rocks (probably just over 315 million years old), and was previously known as the Ayrshire Bauxitic Clay Formation. It is best exposed in the Lugton Water, North Ayrshire. The bauxitic clay is thought to be a product of deep weathering of the basalts that underlie it and as such it is thought to be a fossilised soil horizon (paleosol). This gives key insights into the environment and the climate in the Carboniferous in Scotland around the Mississippian-Pennsylvanian boundary (mid-Carboniferous break). The exposure at Lugton Water includes both the Ayrshire Bauxitic Clay Member and the Troon Volcanic Member (Passage Formation) below it from which the Bauxitic Clay is thought to derive. Above the Bauxitic Clay is the Raise Coal (and associated carbonaceous paleosols and mudstones) at the base of the Scottish Lower Coal Measures Formation (Scottish Coal Measures Group) above which is evidence of a soil surface. The bauxitic clay shows several internal sub-divisions and is variably rich in sphaerosiderite. Equally the lava directly below the bauxitic clay has distinctive spheroidal weathering suggesting it was weathered in situ and supporting the conclusion that the bauxitic clay represents a soil developed in a humid tropical forest (Oxisol).

4.1 GCR Site Report

4.1.1 Lugton Water at Sevenacres Mill [NT 33535 44529]

Highlights

The Lugton Water at Sevenacres Mill is the best exposed locality for the Ayrshire Bauxitic Clay Member Passage Formation). The exposure also includes the decayed lavas of the Troon Volcanic Member (Passage Formation), and the coals, carbonaceous mudstones and sandstones of the Scottish Lower Coal Measures Formation which provide context for the Ayrshire Bauxitic Clay Member.

Introduction

The river cliff [NS 33535 44529] is 500m NE of Sevenacres Mill, about 3 km north-east of Kilwinning, North Ayrshire, Scotland shows the most extensive section of the Ayrshire Bauxitic Clay Member still exposed at the surface. Also exposed is the Troon Volcanic Member and Raise Coal (Munro, 1999) providing the geological context for the bauxitic clay. The site is mentioned by Wilson (1922), Munro (1999) as being a typical example of the Ayrshire Bauxitic Clay Member south of the Dusk Water Fault.

Description

The exposed sequence here is about 7 m thick (Figure 11). At the base there is highly weathered lava overlain by siltstones and mudstones up to 1.7 m thick, some of which are sulphurous and

contain plant fragments. Overlying this is a weathered lava 0.90–1.20 m thick which shows distinct spheroidal onion skin weathering (Figure 13) which suggests it was weathered in situ. This lava has also baked the underlying mudstone making it a distinctive red colour. Munro (1999) suggests that this lower succession is interdigitation of sedimentary rocks of the Troon Volcanic Member.

Directly overlying the lava is a thin bed containing relic lava structures and abundant sphaerosiderite (Figure 14). This has been used to suggest the overlying bauxitic clay may be an allochthonous deposit and had been derived from the underlying basalt (Munro *et al.* 1983; Munro, 1999). Above this is 1.12–1.90 m of bauxitic clay which makes up the Ayrshire Bauxitic Clay Member at this locality. The lower section of the clay is massive and blocky and contains 8 cm wide nodules which include sub-millimetre siderite grains. Above this is a layer of less blocky bauxitic clay that merges into blockier bauxitic clay which contains occasional root traces (Figure 15) and plant fragments. This is a typical exposure of the bauxitic clay on the 'high' south of the Dusk Water Fault, although it lacks the pisoliths observed in other sections (Munro, 1999). Those sections south of the Dusk Water Fault are significantly reduced in thickness compared to those in the north, such as High Smithstone (Munro 1999).

The BGS Lexicon gives the following description for the Ayrshire Bauxitic Clay Member:

Pale grey to buff clayrock, of massive habit with conchoidal fracture, hard and compact. Texture ranges from fine-grained to ooidal, pisolitic and coarsely clastic. Mineralogically, the deposit is "bauxitic in the chemical sense of containing more Al_2O_3 than can be accommodated with SiO_2 to give kaolinite". The bauxitic clay may be considered a flint clay. The member may also contain sphaerosiderite, plant fragments and tree trunks and include beds of seatrock, coal and mudstone (<http://www.bgs.ac.uk/lexicon/home.html>)

Overlying the bauxitic clay is carbonaceous mudstone with vitrinite bands which has been identified as the horizon of the Raise Coal (Munro 1999). Overlying this are several channelized cross-bedded buff sandstones of the Scottish Lower Coal Measures Formation. A thicker unit of sandstone (>5 m) is exposed in contact with a thin basic sill 100 m south [NS 3354 4444] of this cliff section.

4.1.2 Interpretation

This is the best available exposure of the Ayrshire Bauxitic Clay Member in the Namurian of the Ayrshire coalfields. Its occurrence is limited to north and parts of central Ayrshire. The site has context of both the underlying weathered basic lavas and the overlying Raise Coal position being well exposed. With the infilling of the High Smithstone Quarry SSSI, this section may now be taken as the type locality. It is the thickest development of the member that can be seen in surface outcrop. Also, and more significantly, it shows the weathered contact with the underlying lavas and the presence of root traces in the bauxitic clay. The presence of both suggests that the bauxitic clay is an allochthonous deposit (Munro *et al.* 1983). The presence of these features are indicative of a fossil soil (paleosol) developed in a humid tropical forest. Such paleosols (classified as Oxisols) have thick clayey weathered horizons that can be bauxitic and have little soil structure apart from pisoliths and it is observed that roots do not penetrate the infertile substrate (Retallack 2001).

4.1.3 Comparison with other localities

The Ayrshire Bauxitic Clay Member is also exposed at High Smithstone [NS 27969 45723]; Annick Water [NS37492 42438]; Lochwood Farm [NS 27545 44837] and Saltcoats north beach [NS 24116 41518]. Although Annick Water, High Smithstone and Saltcoats beach all include pisoliths which are not observed at Lugton Water none of these sections has good exposures of

both the Troon Volcanic Member and the horizon of the Raise Coal and overlying strata of the Scottish Lower Coal Measures Formation,

5 Conclusions

The Lugton Water at Sevenacres Mill is the best locality for a distinctive suite of Namurian to early Westphalian age (probably just over 315 million years old) sedimentary strata known as the Ayrshire Bauxitic Clay Member of the Passage Formation (Clackmannan Group). The clay is set in the context of the underlying Troon Volcanic Member (Passage Formation) and the overlying Raise Coal horizon at the base of the Scottish Lower Coal Measures Formation. The bauxitic clay represents an oxisol paleosol developed in a humid tropical forest. By contrast with the existing SSSI, this section is much thinner, lacks the interbedded coal seams and the underlying marine band reported at High Smithstone.

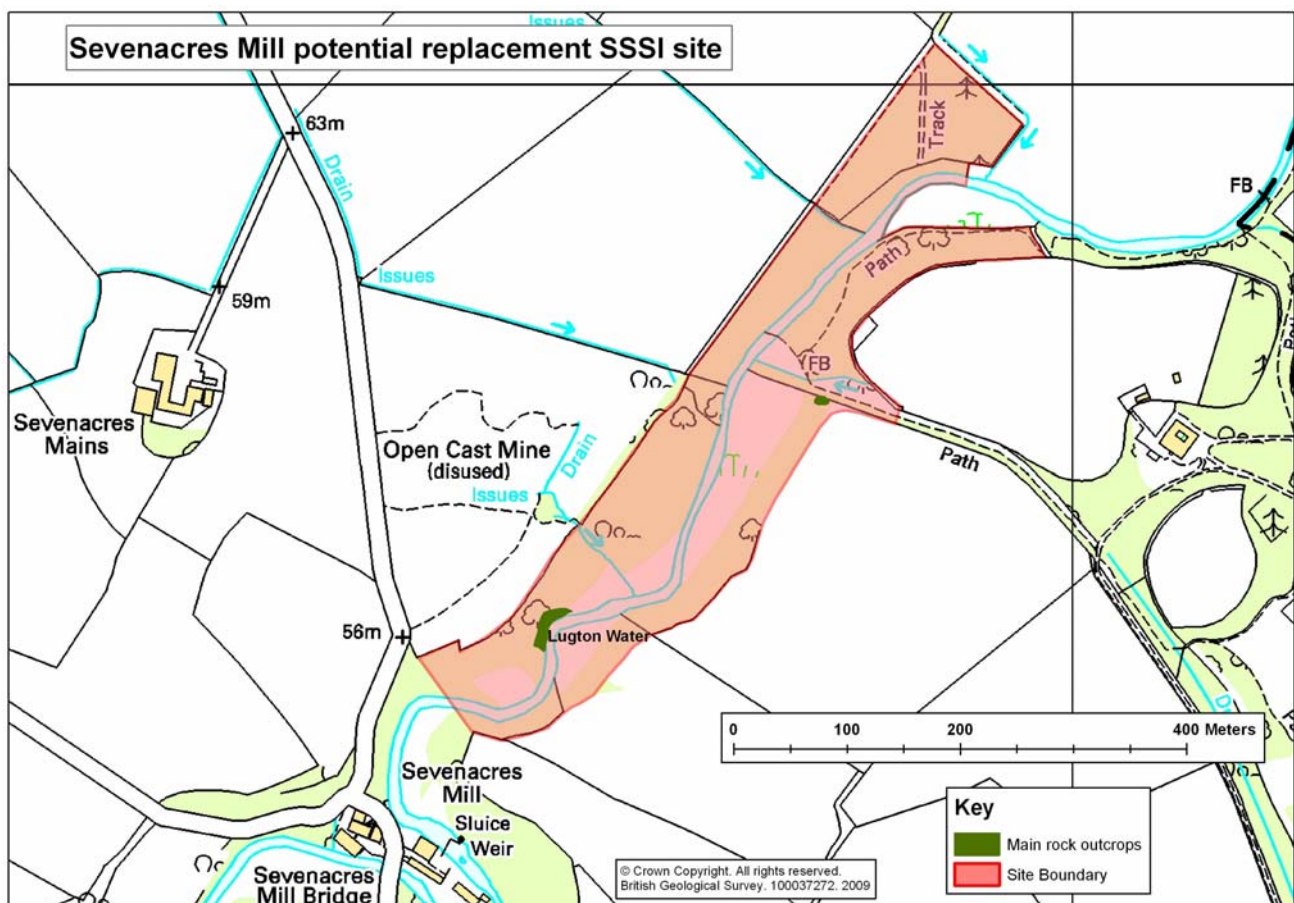


Figure 10 Sevenacres Mill potential replacement site boundary

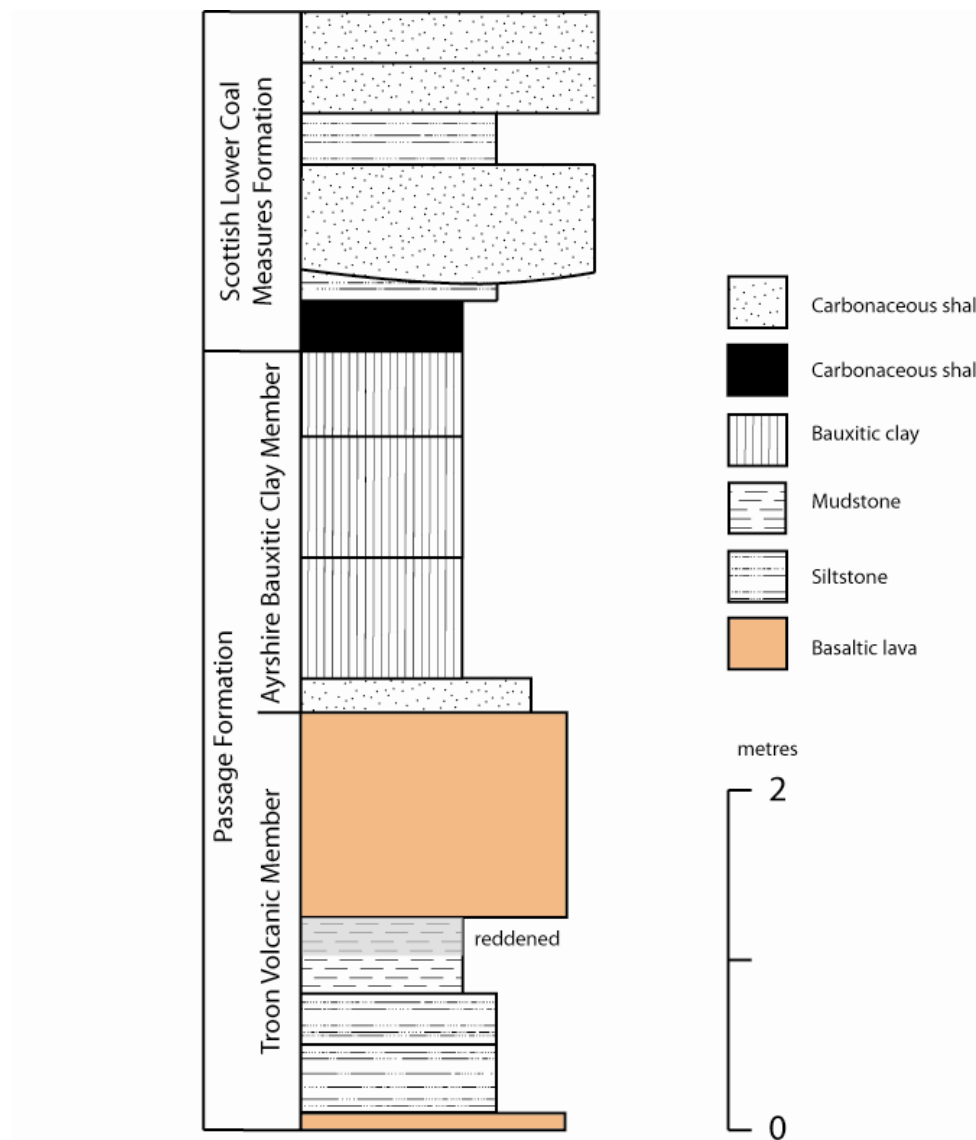


Figure 11 Bauxitic Clay member and associated strata present at Lugton Water nr. Sevenacres Mill.

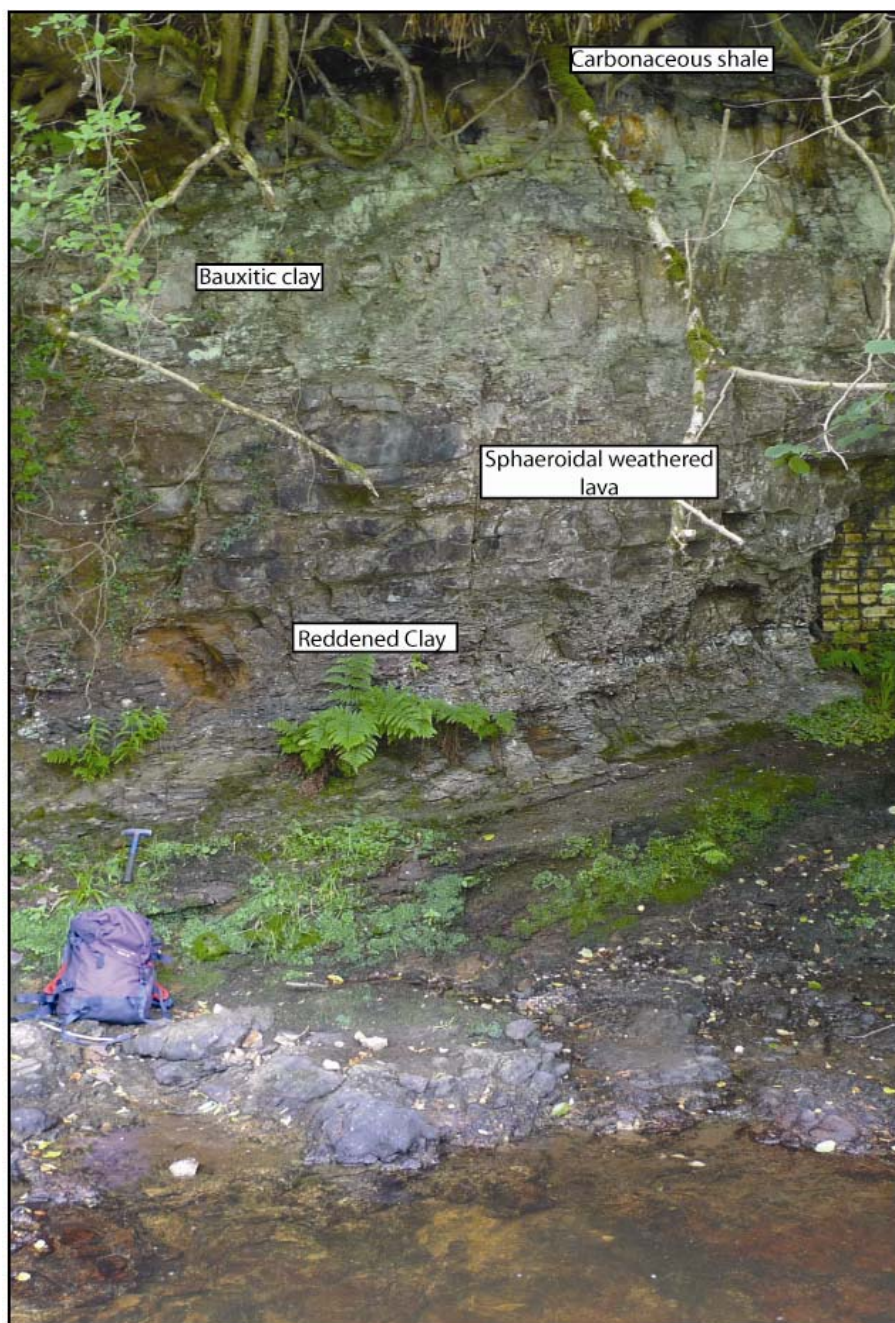


Figure 12 The section exposed at Lugton Water at Sevenacres Mill.



Figure 13 Distinctive spheroidal/onion skin weathering in the lava directly below the Bauxitic Clay Member.



Figure 14 Highly weathered lava at base of Bauxitic Clay Member containing abundant sphaerosiderite.



Figure 15 Carbonised root trace seen in the top of the Bauxitic Clay Member.

6 References B

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