Ardrossan to Saltcoats Coast, North Ayrshire

[NS 246 409]–[NS 224 417]

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Introduction

South Bay, between Ardrossan and Saltcoats on the north Ayrshire coast (Figure 5.9), is flanked by promontories formed by resistant igneous rocks, products of Late Palaeozoic basic extrusive and intrusive activity. At Saltcoats, Coal Measures strata, resting on the Namurian Ayrshire Bauxitic Clay Member and lavas of the Troon Volcanic Member, have been intruded by the Inner Nebbock Sill of analcime-dolerite ('teschenite) and most notably by the Saltcoats Main Sill, a composite intrusion of analcime-dolerite and picrite. The latter has much in common with the better known and more studied Lugar Sill (see Lugar GCR site report) some 39 km to the SSE. Also of note, in the intertidal platform between the two sills, are fossil tree stumps of sigillarian type (Yuill, 1963). The headland of Castle Craigs, Ardrossan is also formed from a composite sill of dolerite and picrite which may be an extension of the Main Sill, displaced by a WNW-trending fault. On the north (inland) side of this fault, a separate sill of analcime basanite extends northeastwards to form Castle Hill; it is intruded into Visean lavas, tuffs and sedimentary rocks. The area is cut by NW-trending basaltic and andesitic dykes of Palaeogene age.

Some of the sills were described by Geikie (1897) and Falconer (1907), and they were all described in relation to other intrusions in the north Ayrshire area in Geological Survey memoirs (Richey *et al.,* 1930; Monro, 1999). A detailed account of the petrography and geochemistry of the Saltcoats Main Sill was given by Patterson (1945, 1946). The area is frequently visited by field parties and features in excursion guides (Bassett in Bluck, 1973; Weedon in Lawson and Weedon, 1992). A K-Ar determination on the Castle Craigs Sill yielded an Early Permian age of 272 ± 7 Ma (*c.* 278 Ma using new constants) (De Souza, 1979), but a re-determination of the same sample by Ar-Ar gave a more precise, significantly older, Stephanian age of 298.3 ± 1.3 Ma (A.A. Monaghan and M.S. Pringle, pers. comm., 2002).

Description

Namurian volcanic rocks

Near low-water mark, west of the Saltcoats Bathing Pool [NS 241 411], there are poor exposures of the Ayrshire Bauxitic Clay and the underlying Troon Volcanic Member, which together form the main part of the Passage Formation at the top of the Namurian Series in north Ayrshire (Monro, 1999).

The Troon Volcanic Member is over 50 m thick in the Saltcoats area but only the highly decomposed topmost few metres are exposed within the GCR site. Less altered samples from neighbouring localities have been identified as being composed dominantly of olivine basalt similar in character to the 'Dalmeny'-type basalt of the Visean Clyde Plateau Volcanic Formation.

The Ayrshire Bauxitic Clay Member varies in thickness up to about 20 m. On the Saltcoats shore it consists of approximately 1.2–1.5 m of massive light-grey to buff-coloured kaolinitic clayrock with ooliths and pisoliths that grades downwards into altered basalt. The highly oolitic upper portion passes downwards into a pale-brown to reddish clayrock containing specks of sphaerosiderite. Fragmentary plant remains are common. This is one of the few natural sections of this member available for study.

Saltcoats Main Sill

The Saltcoats Main Sill crops out on the foreshore south of the bathing pool, where it is about 18 m in thickness. It dips to the southeast in conformity with the Coal Measures strata. The base is in contact with the Kilwinning Main Coal that has been baked to a columnar coke (Figure 5.10). The outcrop can be subdivided into four distinct units (Figure 5.11) that occur in downwards succession from southeast to north-west as follows (Patterson, 1945, 1946):

1. **The top flow-banded analcime-dolerite** ('teschenite'), which varies in thickness from about 1.8 m to 2.7 m, is generally fine grained with microphenocrysts of titanaugite and serpentinized olivine. The groundmass consists largely of microlites and laths of plagioclase, brown amphibole and abundant interstitial analcime. The rock has a characteristic brown colour on exposed surfaces and has well-developed flow-banding roughly parallel to the upper contact. The overlying fissile mud-rocks have been baked and hardened. Xenoliths of hornfelsed mudrock occur towards the top of the unit indicating that they were broken off during intrusion. Some xenoliths of mudrock and coal occur near the bottom of the unit where it is in contact with the underlying biotite analcime-dolerite. There appears to be some marginal chilling of the base of the flow-banded analcime-dolerite close to the lower contact.

2. **The upper biotite analcime-dolerite** ('biotite-teschenite') is a little less than 3 m in thickness. It crops out as smooth rounded masses of black rock with cross-cutting segregation veins and patches rich in pale-pink analcime. The rock consists essentially of labradoritic plagioclase laths up to 2 mm in length, and titanaugite with lesser amounts of red-brown amphibole, and analcime. Biotite occurs as numerous small flakes moulded on feldspar and titanaugite. Olivine is variable in abundance but usually in small amounts and is invariably altered to 'serpentine'. There are a few small euhedral crystals of nepheline.

The segregation veins contain elongate crystals of alkali amphibole, euhedral titan-augite and sparse flakes of biotite; plagioclase, zoned from oligoclase to albite, has largely been replaced by secondary analcime and chlorite. Within the veins there are also patches of analcime, vestiges of K-feldspar and a little nepheline. Similar veins occur in the Lugar Sill, where they have been termed lugarite' (see Lugar GCR site report), but at Saltcoats the rock is richer in potassium.

It would appear that the underlying picrite has penetrated the base of the dolerite, prising off slabs, from which it has been concluded that the picrite was intruded after the dolerite (Patterson, 1946). However lugaritic' segregation veins originating in the alkali dolerite penetrate the picrite in a few instances – an indication that the picrite was intruded prior to the complete solidification of the dolerite.

3. The central picrite, about 9 m in thickness, is composed essentially of abundant serpentinized olivine with somewhat lesser amounts of alkali amphibole (red-brown barkevikite), augite and much-altered plagioclase. Patches of analcime may be primary in origin or may in part be derived from the breakdown of plagioclase. Biotite and opaque oxides occur as accessory minerals along with rare prisms of apatite.

Both the upper and lower contacts with biotite analcime-dolerite are abrupt although neither the picrite, nor the units above and below, show signs of chilling. At both contacts there is a marginal gradation of the picrite into picrodolerite, marked by a decrease in the abundance of olivine and an increase in the proportion of feldspathic minerals. An 8 cm-thick 'lugaritic' vein, 60 cm below the upper contact, differs from those cutting the upper biotite analcime-dolerite in the presence of olivine and lack of biotite. Primary plagioclase has been replaced to a major extent by analcime, thomsonite and prehnite.

4. The lower biotite analcime-dolerite ('biotite-teschenite'), about 3.5 m in thickness, is intensely altered to yellowish 'white trap' for about 1.5 m above the lower contact as the result of carbonation by fluids produced by the thermal metamorphism of the underlying coal (Figure 5.10). Dark slabs of coal, prised off during intrusion, occur within the 'white trap'. Above this the unit is composed of much fresher rock, similar to the upper biotite analcime-dolerite, with analcime-rich patches and 'lugaritic' segregation veins.

The Inner Nebbock Sill

A substantial sill of 'teschenitic' alkali dolerite forms the south-west side of Saltcoats Harbour at the Inner Nebbock [NS 245 409]; similar rock occurs offshore as the Outer Nebbock islet. Sedimentary rocks above the sill are noticeably hornfelsed. Although the sill is largely concealed by the harbour wall (New Pier) it is exposed in a railway cutting about 1 km to the north-east where it is seen to consist of three layers, each 3–4 m thick; a central picrite is flanked above and below by analcime-dolerite. At a quarry nearby, in the same intrusion, the coarse-grained picritic layer was at one time worked for 'osmond stone', a term used to denote rock suitable for the soles of bakers' ovens (Richey *et al.,* 1930). The sill can be traced inland to Stevenston as a topographical feature and still farther east in boreholes.

The Castle Craigs Sill

The low rocky promontory of Castle Craigs [NS 228 415] at Ardrossan is formed by a composite layered intrusion (Falconer, 1907). A lower, marginal layer of 'olivine-feldspar rock' is overlain by coarse-grained amphibole-bearing picrite. The upper part comprises a thin layer of amphibole-bearing dolerite overlain by finer-grained banded biotite analcime-dolerite. The latter becomes less olivine-rich upwards and develops alkali amphibole as it passes up into a metre-thick margin of analcime-basalt.

Another small alkali dolerite sill occurs on the beach about 400 m to the north-east of Castle Craigs.

Interpretation

Namurian volcanic rocks

The outcrop of the Troon Volcanic Member at Saltcoats is the north-western limit of a 40 km-wide Namurian volcanic field in north Ayrshire. Borehole evidence indicates a maximum thickness of about 160 m north of Troon. The resulting volcanic land surface that emerged from the surrounding deltaic environment, is much decomposed, consistent with the near-equatorial tropical latitude that has been inferred for this part of the Scottish crust at this time.

The Ayshire Bauxitic Clay Member, which rests directly on top of the weathered surface of the Troon Volcanic Member, is considered to have resulted from a prolonged period of post-volcanic subaerial lateritic weathering under wet tropical conditions. Although in some areas a complete gradation of the claystone downwards into underlying lava is indicative of residual weathering *in situ,* the claystone is commonly interbedded with other sedimentary rocks including coal and laminated mudrock. It is thus considered that much of the deposit has resulted from transport of the products of weathering and their deposition in shallow pools on the uneven surface of the underlying lavas (Monro *et al.,* 1983; Monro, 1999).

Sills

A reconstruction of the order of intrusion of the various units of the Saltcoats Main Sill by Patterson (1946) suggested that the top flow-banded analcime-dolerite (unit 1) was intruded first. A viscous, volatile-poor magma was intruded along a horizon at or just above the top of the Kilwinning Main Coal, with xenoliths of sedimentary rocks being incorporated into the basal and upper parts of the intrusion; the flow-banding is consistent with this. There was insufficient heat to cause major alteration of the underlying coal. This may be explained, at least in part, if the intrusion took place mainly in the fissile mudrock immediately above the coal. This first unit had probably completely solidified when further alkali basalt magma was intruded below it, but still above the partly disturbed coal, forming a sill over 6 m in thickness (units 2 and 4). The greater thickness of the second intrusion provided a more long-lasting heat source which led to the destructive distillation of the coal at its base to produce carbonate-rich volatiles that altered the base of the intrusion to 'white trap'. As the magma solidified, a volatile-and alkali-rich fraction became segregated to form the lugaritic' veins.

While it was still hot, and before there had been time for complete solidification, the biotite analcime-dolerite of units 2 and 4 was intruded by a third and final pulse of magma. Picritic magma (unit 3) split the dolerite a little more than halfway up, along the plane of weakness that would have existed where it was not yet entirely solidified. Some xenoliths detached from the dolerite contained still unconsolidated patches of alkali-rich differentiates, some of which penetrated the picrite. The high temperature of the enclosing rock delayed the cooling of the picrite, hence the lack of internal chilled margins between the units. The picritic magma was already partly solidified at the time of emplacement and was thus intruded as a mush of crystals. The crystallization of the ground-mass led to a concentration of alkalis in the volatile-enriched residual liquid. This led to a further set of 'lugaritic' segregation veins. As the intrusion cooled, hydrothermal fluids expelled from the residual liquid attacked the olivine, converting most of it to 'serpentine'.

The clear evidence that the picrite was intruded soon after the alkali dolerite and the similarity of their respective residual liquids suggest a close genetic relationship. It is thus likely that they were each derived from the same parent magma by gravitational separation of olivine prior to intrusion of the resulting differentiated fractions (Patterson, 1946). However, the relationship of the flow-banded analcime-dolerite to the rest of the intrusive complex is unclear.

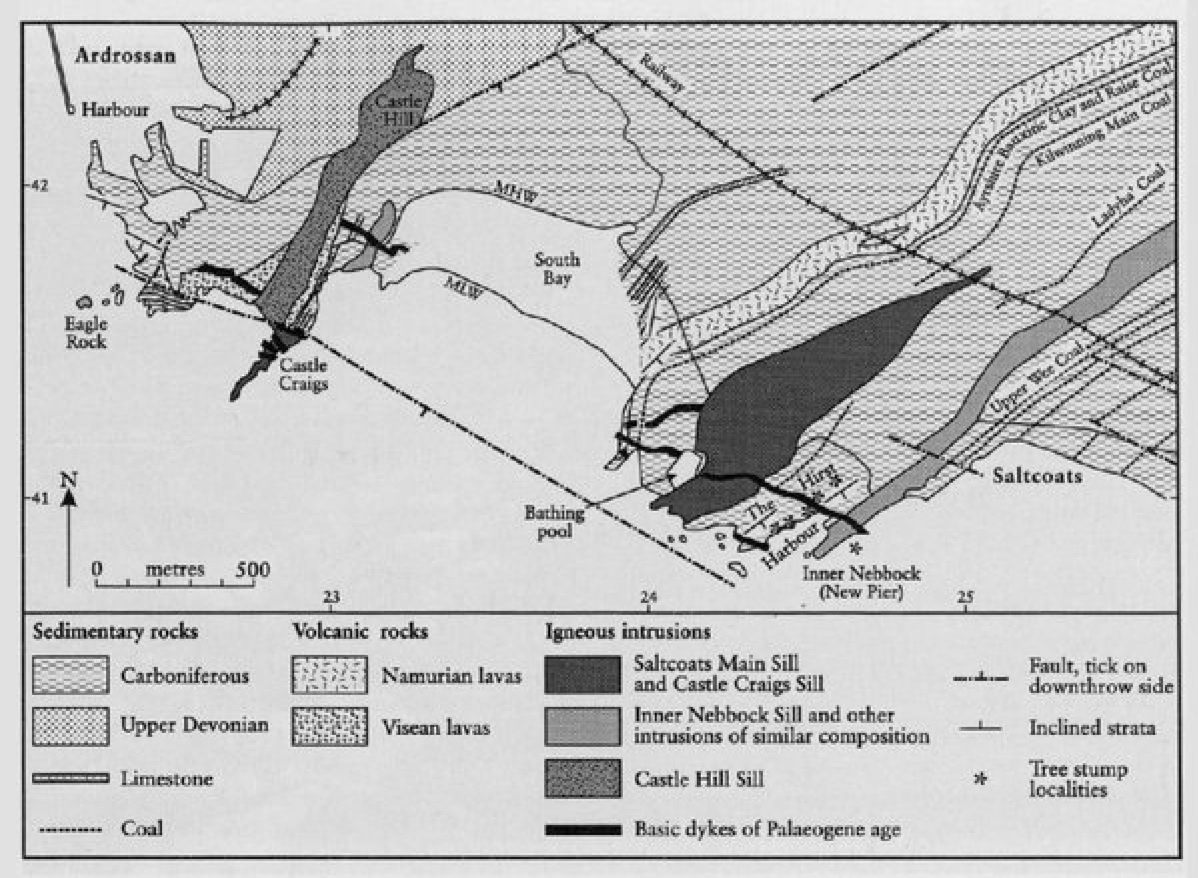
Evidence for successive intrusion of pulses of genetically related magmas to form composite sills is also found in the Inner Nebbock and Castle Craigs sills. The similarity of the main lithologies in the latter to those in the Saltcoats Main Sill, in particular the biotite analcime-dolerite and the amphibole-bearing picrite, led Richey *et al.* (1930) to suggest that the two outcrops are part of the same sill displaced by the WNW-trending Ardrossan Harbour Fault. However, the arrangement of the units is not directly comparable and Falconer (1907) considered that the doleritic facies was emplaced later than the picrite at Castle Craigs, which is the opposite to the order deduced for the Main Sill. A re-investigation of the field relationships and petrogenesis of the intrusions is clearly needed to resolve this and several other outstanding problems.

Conclusions

The Saltcoats Main Sill is representative of the analcime-dolerite ('teschenitic) varieties of Late Carboniferous to Early Permian basic alkaline sills in the west of the Midland Valley of Scotland and is an excellent example of a composite mafic to ultramafic intrusion. It provides evidence of successive pulses of magma that are likely to have had a common origin. Other basic sills within the area of the Ardrossan to Saltcoats Coast GCR site are also composite, but they all differ in detail from other sills of the same age and petrographical affinity (e.g. see Lugar GCR site report). In addition to a variety of mafic and ultramafic rock-types, the exposures show excellent examples of internal contacts between separate intrusive phases and external contacts with country rocks. Mudstones are baked, coal seams are reduced to coke, and volatiles expelled from the coals have altered the margins of some sills to a pale rock termed 'white trap'.

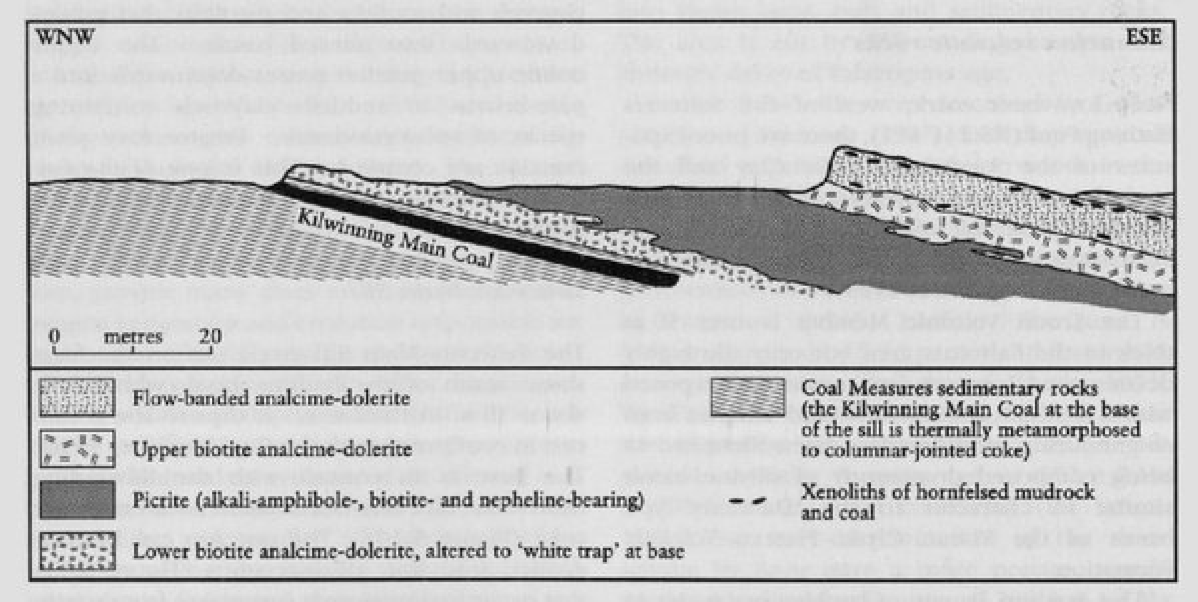
The site is also representative of the Troon Volcanic Member, the most extensive product of Namurian volcanism in the western Midland Valley (see 'Introduction' to Chapter 4). Exposures of these rocks are poor, but the basalt lavas exhibit evidence of deep weathering under wet tropical conditions soon after they were erupted. They grade upwards into the Ayrshire Bauxitic Clay Member, a pale aluminium-rich clayrock derived partly *in situ* and partly by accumulation of the products of weathering in hollows on the lava surface. This is one of few places where these deposits can be studied in natural sections.

References



(Figure 5.9) Map of the area around the Ardrossan to Saltcoats Coast GCR site. After Bassett (in Bluck, 1973).

(Figure 5.10) The contact between the base of the Saltcoats Main Sill (pale weathering) and baked coal-bearing sedimentary rocks (dark). The sill has been altered to form 'white trap' adjacent to the coal. The hammer is 28 cm long. (Photo: C. MacFadyen.)



(Figure 5.11) Diagrammatic cross-section of the Saltcoats Main Sill below the bathing pool. After Patterson (1946).