PORT SCHUCHAN TO DUNURE CASTLE

G. Durant

OS Grid Reference: NS247152–NS252159

Introduction

Lower Old Red Sandstone volcanic rocks crop out along the Ayrshire coast at Dunure, Culzean and Turnberry where they occupy a total area of approximately 40 km². The Dunure coastal exposures are part of the Carrick Hills outcrop; those of Culzean and Turnberry are smaller down-faulted inliers (see the Culzean Harbour and Turnberry Lighthouse to Port Murray GCR site reports) (Figure 9.34). The Ayrshire coast volcanic rocks conformably overlie the local Lower Old Red Sandstone succession of sandstones, conglomerates and cornstones and are in turn overlain unconformably by Upper Old Red Sandstone sedimentary rocks. The volcanic rocks are predominantly calc-alkaline andesites, suggested by Thirlwall (1981a) as being the product of subduction-related volcanism. The basal lavas are interbedded with the topmost beds of the sedimentary succession and sedimentary intercalations occur throughout the volcanic sequence suggesting that the volcanic rocks are the same general age as the sedimentary rocks.

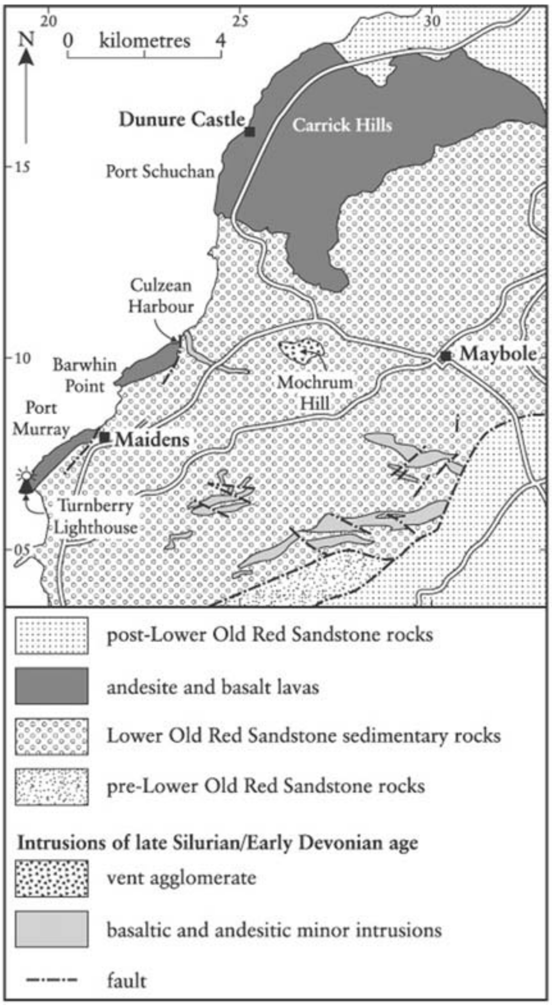

Figure 9.34: Map of the Ayrshire coast outcrops of Lower Old Red Sandstone volcanic rocks.

Smith (1910) estimated that the volcanic rocks of the Dunure area are approximately 130 m thick in total, although a much higher figure of 300 m was given by Eyles *et al*. (1949). This section is important because of the complex relationship between volcanic rocks and

© JNCC 1980–2007

intercalated sedimentary rocks, which has led to the suggestion that much of the sequence consists of subvolcanic sills rather than lava flows (Kokelaar, 1982). The volcanic units will therefore be referred to as 'sheets' in the following accounts. Petrographically the volcanic rocks are augite-, enstatite-, and pyroxene-olivine andesites with rare basalts near to the base of the sequence. The andesites are commonly markedly feldspar-phyric and also highly vesicular. The vesicles are filled by a variety of secondary products, but it is the agates described by Smith (1910) that makes this section of the coast popular with collectors (see Heddle, 1901; Macpherson, 1989).

Description

A well-exposed sequence of andesite sheets with minor intercalations of sedimentary rock is exposed in the low cliffs, the sea stacks and on the wave-cut platform between Port Schuchan and Dunure. A porphyritic, vesicular andesite forms the wave-cut platform immediately west of Port Schuchan and two prominent sea stacks, the Two Sisters, are isolated outliers of the 7 m-thick overlying andesite sheet. At the base of the south-easterly of the Two Sisters (2468 1523), a highly distinctive pillow of vesicular andesite has cut into the finely laminated sandstone between the andesite sheets (Figure 9.35). The lamination within the sandstone remains close to that of the regional dip even when remnants are isolated by the pillowed andesite. Thin sandstone 'dykes' (up to 2 cm wide) cut through the massive central part of the andesite sheet which forms the stacks. The sandstone between the andesite sheets is intimately mixed with the volcanic rock in places; it can infill vesicles or occur within the andesite as irregular structureless patches, some of which are traceable back to larger more laminated patches. This is well displayed in outcrops near the top of the shore just to the east of the south-easterly of the Two Sisters stacks.

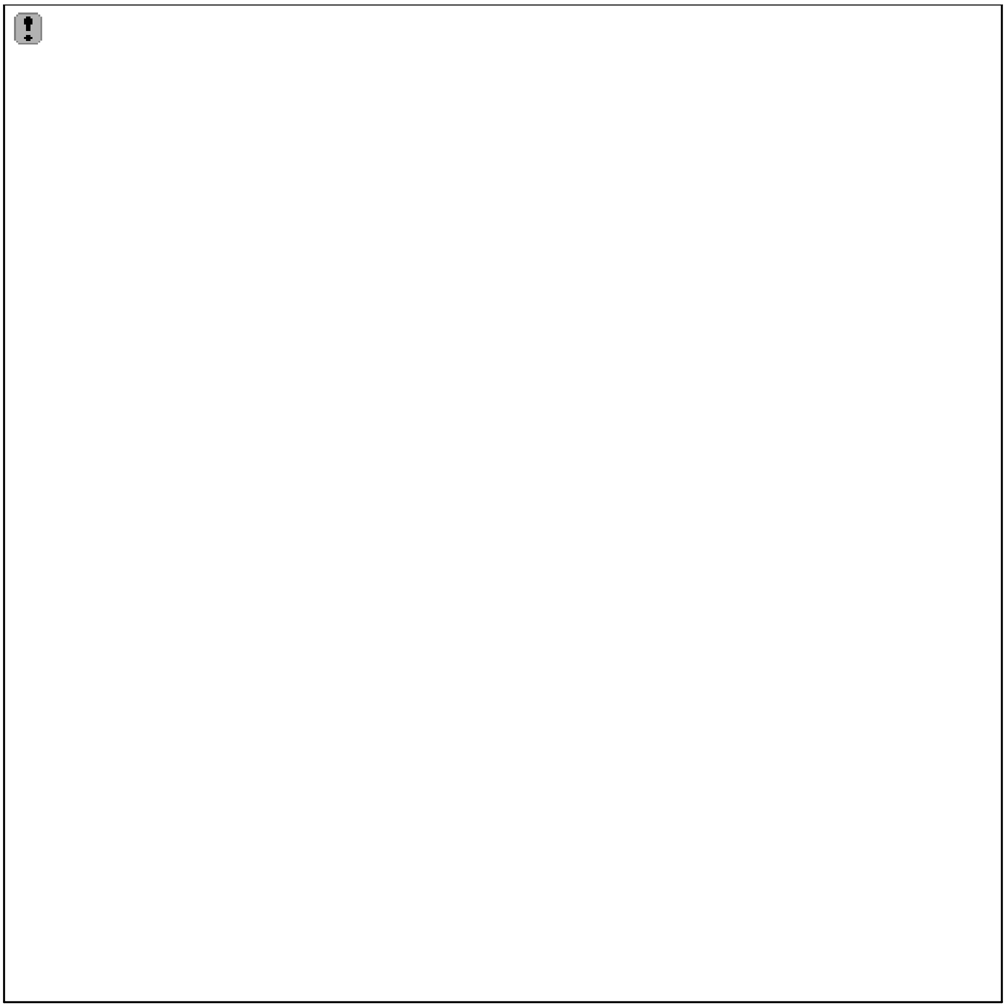

Figure 9.35: Pillowed lobe of vesicular andesite in laminated sandstone at the base of the south-easterly of the Two Sisters stacks, Port Schuchan (2468 1523). (Photo: G. Durant.)

The 12 m-thick andesite sheet forming the distinctive cliff at Dunure Point (2473 1532) to the NE of the Two Sisters, is cut by numerous thin sandstone ‘dykes', which follow broadly curving paths from the bottom to the top of the sheet. Where the andesite sheet is seen in horizontal section on the wave-cut platform, the sandstone ‘dykes' can be seen to be part of a branching, pseudohexagonal network. The sandstone within the dykes has been hardened and often stands proud, being more resistant than the andesite. This is well displayed to the NE of Broad Crag (2500 1569) and on the shore just below Dunure Castle (2517 1582).

The bases and tops of individual sheets are often markedly amygdaloidal, the original vesicles having been infilled with quartz, agate and calcite. Minor amounts of galena, pyrite, manganese and baryte have been reported as associated minerals (Smith, 1910). Larger irregular masses of quartz and agate also occur within the andesites. A 75 × 50 cm oval mass of quartz occurs near the summit of Mackerel Rock (2471 1544), a low-lying stack north of the Two Sisters and a popular roost for sea-birds. Vertical veins of agate (up to 1 cm wide) also occur, a good example being seen in the stack below Dunure Castle.

Critical exposures for the re-interpretation of the andesite sheets as sill-like intrusions rather than lava flows occur in the low cliffs south of Dunure Castle. A good example of a typical contact between two andesite sheets occurs immediately to the east of Mackerel Rock (2482 1544). In this low cliff section the pillowed and highly vesicular upper contact of the lower andesite sheet encloses and is partially overlain by sandstone, which is laminated in places and structureless elsewhere. Pillows at the base of the upper andesite sheet cut down into the sandstone and sandstone ‘dykes' traceable back to this sedimentary enclave run upwards through the upper sheet. This exposure has been figured by Kokelaar (1982, fig. 4B). A good example of the complex upper surface of one of the andesite sheets occurs in a low cliff at the top of the shore to the SE of Scart Rock (2494 1553). Protrusions of andesite from the main mass, penetrate upwards into laminated sandstone. The laminations within a diagonally orientated remnant wedge of sandstone are absent within 2 cm of the contact with andesite (see Kokelaar, 1982, fig. 4C). Such observations led Kokelaar (1982) to postulate a process of sediment removal by fluidization as the lobes of andesite burrowed into wet, unconsolidated sediment. The wet sediment into which the magma was intruded is now preserved in part as vesiculated sandstone. This feature can be seen on the shore just south of Dunure Castle (2518 1583).

Dunure Castle sits on top of a raised sea stack composed of enstatite andesite (Tyrrell, 1913) which shows a marked internal fabric parallel to the base of the flow. Loose wave-polished blocks beneath the castle show that this fabric is an internal feature caused by textural differences within the intrusion. Such internal textural differences and consequent differential erosion are also responsible for the pseudo-brecciated appearance of the andesite forming Scart Rock (2800 1560). At the base of Dunure Castle (2519 1586) numerous monolithological blocks of andesite occur within light-coloured calcareous sedimentary rock that form the enclaves between intrusive sheets. A fossil arthropod, *Kampercaris tuberulata*, was found by Smith (1909) in rocks close to Dunure Castle, and was subsequently described by Brade-Birks (1923). Rolfe (1980) places the discovery of these arthropod fossils and tracks in an overall evolutionary setting.

Interpretation

The relationship between the sedimentary rocks and the andesites has interested a number of authors over a considerable period since it was first noted in the Geological Survey Memoir for Sheet 14 (Geikie *et al*., 1869). The survey authors noted vertical veins of sandstone traversing the ‘lavas' and suggested ‘that the veins were due to sand being washed into the irregular star-shaped cracks of cooled lava before the flow was covered by the next stream of molten matter'. Smith (1892) who discovered fossil arthropod tracks in the fine-grained sedimentary rocks was sceptical about this interpretation. The tracks figured by Smith (1909) are preserved in fine detail ‘owing evidently to the fact that in the quiet recesses within the lavas, there would be no commotion to disturb the surfaces of the sedimentary laminae after the markings had been made on them'. A critical observation by Smith (1909) is that ‘the lava has sometimes scoured away portions of the sedimentary beds. This is well demonstrated as sometimes a series of footprints will extend right up to the side of a lava ... where one row had been cut by it and the other left'. Heat blisters identified by Smith (1909) also demonstrate that the wet sediment was baked by the heat of the intruding magma.

Geikie (1897) viewed the lava–sediment relationships somewhat differently, believing that the sediments had entered the fissures from above but in a subaqueous environment. However, he also indicated thoughts of another possible explanation (op. cit., p. 283) ‘the first and natural inference which a cursory examination suggests is that the molten rock has caught up and carried along pieces of already consolidated sandstone'. He countered this observation with another, ‘that the lines of stratification in the sandstone, even in what appears to be detached fragments are marked by a general parallelism and lie in the same general plane with the surface of the bed of the lava in which the sandy material is enclosed'.

Tyrrell (1913) believed that the sediment infilled fissures in cooled lavas and hence that the lavas were subaerial. Eyles *et al*. (1949) also believed that the constancy of the alignment of the bedding of the sedimentary rock within the lavas is due to the sediment having been washed into position, ‘the sediment infilling fissures was then greatly hardened possibly because the surrounding lava was still hot when the detritus was deposited in the cavities'.

Micaceous fine-grained sandstones occur as thin and impersistent intercalations between the igneous sheets and as a series of irregular vertical dykes and fissure fillings. They are commonly finely bedded and this bedding is mostly consistent with the regional dip. However, as was pointed out by Kokelaar (1982), the bedding is absent immediately adjacent to the volcanic rock and is now interpreted as being the original bedding of the sediment into which the magma burrowed, in so doing removing most of the unconsolidated wet sediment by fluidization. The bedded sedimentary rock that is observed in fissures within the andesite is therefore the last remaining vestige of a much greater mass of sediment that has been removed by the proposed fluidization process. This re-interpretation of the lava flows as high-level andesite sills emplaced into unconsolidated wet sediment (Kokelaar, 1982) means that the arthropod trackways found by Smith (1909) were probably formed in fine-grained sediment on the bottom of a shallow lake, prior to eruption, a suggestion which is in keeping with the findings of Pollard and Walker (1984), Pollard (1995) and E.F. Walker (1985) based on detailed examination of the fossil tracks.

The presence of multiple andesite sheets, requires a repetition of the conditions that resulted in the burrowing of magma into wet sediment rather than eruption at the surface. This argues for eruption into an actively subsiding sedimentary basin marked by a lake in which sediment accumulation took place in conditions quiet enough to preserve the arthropod trackways. The fine-grained nature of the sediment suggests that there was low relief around the margins of the lake, which was situated in a generally arid environment (Bluck, 1978b). In spite of the high degrees of vesiculation, the andesite magma seems to have been erupted relatively quietly, possibly from fissures. An earlier, possibly more explosive phase of volcanic activity is indicated by the presence of a breccio-conglomerate exposed at Barwhin Point at the SW end of the Culzean inlier (2185 0946), which contains volcanic rock fragments generally more siliceous than any found elsewhere within the overlying Ayrshire coast volcanic sequence (see the Culzean Harbour GCR site report).

Oxygen isotope studies of agates from both Dunure and Turnberry (Fallick *et al.*, 1985) support the idea of a low temperature (*c.* 50°C) origin for the agates from fluid having at least a component of meteoric water.

Conclusions

The Port Schuchan to Dunure coastal section has engaged the minds of geologists for more that 100 years. This section is of national and international importance because of the complex relationship between volcanic rocks and intercalated sediments. The volcanic rocks, predominantly pyroxene andesites, were originally interpreted as subaqueous flows (Geikie, 1897) or subaerial lavas (Tyrrell, 1913). A re-interpretation of the andesites as intrusions into wet, unconsolidated sediment (Kokelaar, 1982) relied on evidence from this section. Fossil arthropod trackways found in the laminated sedimentary rocks between the volcanic units furnish evidence of life in a Siluro-Devonian freshwater lake and Dunure agates, which form amygdales in the andesites, have been much prized by collectors since Victorian times. This is an enjoyable and instructive section, which has an important part to play in the understanding of Lower Old Red Sandstone times and volcanic processes.

Reference list

Bluck, B. J. (1978b) Sedimentation in a late orogenic basin: the Old Red Sandstone of the Midland Valley of Scotland. In *Crustal Evolution in Northwestern Britain and Adjacent Regions* (eds D. R. Bowes and B. E. Leake), *Geological Journal Special Issue* No. **10**, pp. 249–78.
Brade-Birks, S. G. (1923) Notes on Myriapoda XXVIII. *Kampecaris tuberculata* n.sp. from the Old Red Sandstone of Ayrshire. *Proceedings of the Royal Physical Society*, *Edinburgh*, **20**, 277–80.
Eyles, V. A., Simpson, J. B. and MacGregor, A. G. (1949) Geology of Central Ayrshire. *Memoir of the Geological Survey of Great Britain*, Sheet 14 (Scotland).
Fallick, A. E., Jocelyn, J., Donnelly, T., Guy, M. and Behan, C. (1985) Origin of agates in volcanic rocks from Scotland. *Nature*, **313**, 672–4.
Geikie, A. (1897) *The Ancient Volcanoes of Great Britain*, Macmillan, London.
Geikie, A., Geikie, J. and Peach, B. N. (1869) Ayrshire: southern district. *Memoir of the Geological Survey of Great Britain*, Sheet 14 (Scotland).
Heddle, M. F. (1901) *The Mineralogy of Scotland*. D. Douglas, Edinburgh.
Kokelaar, B. P. (1982) Fluidization of wet sediments during the emplacement and cooling of various igneous bodies. *Journal of the Geological Society of London*, **139**, 21–34.
Macpherson, H. (1989) *Agates*, British Museum (Natural History) and the National Museums of Scotland.
Pollard, J. E. (1995) John Smith's discoveries of trace fossils from Old Red Sandstone and Carboniferous rocks of Southwest Scotland. In *John Smith of Dalry*, *Geologist*, *Antiquarian*

and Natural Historian, Ayrshire Archaeological and Natural History Society, Darvel, pp. 30–39.

Pollard, J. E. and Walker, E. F. (1984) Reassessment of sediments and trace fossils from Old Red Sandstone (Lower Devonian) of Dunure, Scotland, described by John Smith (1909). *Geobios*, **17**, 567–76.

Rolfe, W. D. I. (1980) Early invertebrate terrestrial faunas. In *Terrestrial Environment and the Origin of the Invertebrates* (ed. A. L. Panchen), Academic Press, London and New York, pp. 117–157.

Smith, J. (1892) From the Doon to the Girvan Water, along the Carrick shore. *Transactions of the Geological Society of Glasgow*, **10**, 1–12.

Smith, J. (1909) *Upland Fauna of the Old Red Sandstone Formation of Carrick*, *Ayrshire*. Cross.

Smith, J. (1910) *Semi-Precious Stones of Carrick*. Cross.

Thirlwall, M. F. (1981a) Implications for Caledonian plate tectonic models of chemical data from volcanic rocks of the British Old Red Sandstone. *Journal of the Geological Society of London*, **138**, 123–38.

Tyrrell, G. W. (1913) A petrographical sketch of the Carrick Hills, Ayrshire. *Transactions of the Geological Society of Glasgow*, **15**, 64–83.

Walker, E. F. (1985) Arthropod ichnofauna of the Old Red Sandstone at Dunure and Montrose, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, **76**, 287–97.