Balmae Coast

[NX 676 465]–[NX 724 433]

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Introduction

The Balmae Coast site occupies about 8 km of the cliffs and foreshore of the northern coast of the Solway Firth and eastern side of Kirkcudbright Bay. Occurring a few kilometres to the south and south-east of Kirkcudbright itself, the rocks included stretch from just north of the Lifeboat Station to the eastern end of White Port (Figure 4.62).

The strata over the whole site have a general strike of ENE–WSW, and are exposed in a number of blocks that are bounded by five major faults. Of these faults, the four to the north and west have a generalized NE–SW trend, whilst that farthest to the east trends approximately NW–SE. These fault blocks contain exposures of strata now recognized as belonging to the Raeberry Castle and Ross formations, which are Wenlock in age (White *et al.,* 1992; Cocks *et al,* 1992). Both these formations (Kemp and White, 1985; Kemp, 1986; Cocks *et al.,* 1992), or just the Raeberry Castle Formation (White *et al.,* 1992), have been recently considered to comprise the Riccarton Group. The NE-trending fault farthest to the north, just south of the Lifeboat Station, in addition brings exposures of the Hawick Group to feature at this site; this group is now believed to be partly of Wenlock and partly of Llandovery age.

The stratigraphical problems imposed by this tract of land were recognized as long ago as 1851 by Murchison, but the general geology of the area was first described by Lapworth (1878). The latter author recognized the structural complexity of the Southern Uplands as a whole, and although only making brief reference to the Kirkcudbright area, stated that the Riccarton Beds were of Wenlock age. Peach and Horne (1899) summarized Lapworth's work; they too considered that the Riccarton Beds more or less equated with the whole of the Wenlock, and they believed that the Hawick Rocks and Queensberry Group below were of Llandovery age, and the Raeberry Castle Beds were of Ludlow age (Figure 4.63). The much later stratigraphical schemes of Craig and Walton (1959) and Clarkson *et al.* (1975) differed radically from earlier ones; in particular, the Raeberry Castle Beds were considered as the oldest and the Hawick Rocks as the youngest units in this area. More recent studies (Kemp, 1985; Kemp and White, 1985; White *et al.,* 1992) have brought general agreement about the stratigraphical order and age of the major lithostratigraphical divisions, the differences being more about questions of stratigraphical terminology rather than stratigraphical relationships (Figure 4.63). The different opinions and the resolution of the problems stemmed from the recognition of the true age relationships of the major groups of rocks preserved in this general area as determined from graptolite biostratigraphy, and through detailed sedimentological and structural analysis.

This Balmae Coast site, and that of Meikle Ross (Borgue Coast) 5 km to the west (see site report), have major geological importance for two particular reasons. The first is that both are important historically, since they played a part in the many interpretations of the complex stratigraphy and structural history of the Lower Palaeozoic rocks of the Southern Uplands. Secondly, they illustrate the effect on a sedimentary sequence of the subduction that finally destroyed the Iapetus Ocean, as Laurentia and Avalonia approached and finally docked. In addition, the Balmae site includes the type section (Kemp, 1986) of the Raeberry Castle Formation.

Description

At the north-west end of the section, the Ross Formation is faulted against the Hawick Group along the structurally important Riccarton Line (Kemp, 1986). To the south and then east, alternating sections of the Ross and Raeberry Castle formations occur with faulted contacts as far as the middle of Mullock Bay. Beyond this to White Port, a stratigraphical section upwards from the Ross to Raeberry Castle formations may be traced; the latter is eventually overstepped to the east by Lower Carboniferous rocks (Clarkson *et al.,* 1975).

The Ross Formation, which is considered (White *et al.,* 1992) to form the upper part of the Hawick Group is more fully described in this chapter in the Meikle Ross site report, its type locality to the west. The formation comprises (Kemp, 1986) various turbidite facies (Figure 4.64). Monotonous thin- to medium-bedded calcareous sandstones of the turbidite facies C and D predominate. Massive facies B sandstones up to 10 m in thickness occur occasionally, and lithologies of larger grain size are very rare. Slumped units of Facies F occur up to a maximum thickness of 3 m. The hemipelagite units are usually 0.1 to 3 m beds in Facies C mudstones and siltstones, and they also occur as rather thinner units in Facies D units.

The Raeberry Castle Formation is characterized by a diverse association of turbidite facies, including:

1. Coarse rudites and arenites of Facies A and B, which occur in channels, and are associated with thinly bedded overbank siltstones and mudstones of Facies E. The coarser sediments (sandstones and conglomerates) contain bioclasts of coral, bryozoan and brachiopod fragments, and rarely limestone boulders, and sandstone clasts, which because of the occurrence in them of haematite are identical to the lithology of the Hawick Rocks.
2. Classic turbidites of Facies C and D.
3. Hemipelagic-dominated, Facies E sediments.

Extensive collection and identification of the graptolite faunas from the area led White in Kemp (1986), to the conclusion that the *murchisoni* and *riccartonensis biozones* could be identified at a number of localities in the Riccarton Group. The following graptolite species were identified there (British Library Supplementary Publication No. 24023, Kemp (1985)): *Cyrtograptus linnarssoni, Cyrtograptus* cf. *rigidus cautleyensis, Cyrtograptus* sp., *Monograptus capillaceus, Monograptus flemingii flemingii, Monograptus flexilis flexilis, Monograptus flexilis belophorus, Monograptus firmus sedberghensis, Monoclimacis flumendosae, Monograptus radotinensis inclinatus, Monograptus riccartonensis, Monograptus* cf. *retroflexus, Plectograptus bouceki, Pristiograptus dubius, Pristiograptus pseudodubius, Pristiograptus meneghinii meneghinii* and *Monoclimacis vomerina basilica.* More recently White *et al.* (1992), on the basis of graptolite and new acritarch evidence, have proposed that the Ross Formation is of *centrifugus* to upper *riccartonensis* Biozone age, whilst the Raeberry Castle Formation is of upper *riccartonensis* to *lundgreni* Biozone age.

Interpretation

Peach and Horne (1899) summarized the earlier work of Lapworth (1878). Compared to his study, some of the subsequent research suggested that the Silurian sequence was in fact reversed (Figure 4.63). For example, Craig and Walton (1959) considered that the stratigraphical interval represented by the sequence now believed to be of uppermost Llandovery to Wenlock in age, spanned the Llandovery to Ludlow, with the Raeberry Castle Beds oldest, and Hawick Rocks youngest. Clarkson *et al.* (1975), with some revision of stratigraphical terminology, had the same order of stratigraphy as Craig and Walton (1959), but with the Silurian sequence encompassing a greater time interval (Figure 4.63). More recently, stratigraphical schemes much closer to that of Peach and Horne (1899) have been proposed (Kemp and White, 1985; Kemp, 1986). In these schemes, the Hawick Rocks were considered oldest and entirely of Llandovery age, whilst the Riccarton Group (embracing the Ross and Raeberry Castle formations) was of earliest Wenlock to mid- or late Wenlock (*ellesae* to *lundgreni* Biozone) age. The stratigraphical scheme proposed by White *et al.* (1992) was similar to that of the earlier proposals of Kemp (1985) and Kemp and White (1985); it differs in that the Ross Formation was now considered to comprise the upper, early Wenlock part of the Hawick Group, with a stratigraphical range of *centrifugus* to upper *riccartonensis* biozones. The Raeberry Castle Formation was equated by White *et al.* (1992) with the entire Riccarton Group, and correlated with the uppermost *riccartonensis* to *lundgreni* biozones. The stratigraphy and stratigraphical range for the sequence which Cocks *et al.* (1992) illustrated, differed from that of Kemp and White (1985) in having the Hawick Group with a stratigraphical range of middle Telychian to lower Wenlock, and being partly a lateral equivalent of the lowest part of the Riccarton Group, the base of which was coincident with the base of the Wenlock; their Riccarton Group embraced the whole of the Ross Formation and the Raeberry Castle Beds (Figure 4.63).

There are at present two major types of geotectonic model for the evolution of the rocks of the Southern Uplands. The work of McKerrow *et al*. (1977) and Leggett *et al*. (1979a, b, 1982), which was based in part on the rocks exposed at this site, resulted in the formulation of the 'accretionary prism' model, whilst Stone *et al.* (1987) proposed that the rocks

comprising the Southern Uplands region were deposited in a back-arc basin. Both of these models include the development of an imbricate thrust stack, but involving a sedimentary sequence deposited in different geotectonic positions. During the later Ordovician and the Silurian, the area lay on the northern margin of the Iapetus Ocean, which finally closed along a NE–SW line through the Solway Firth (Cope *et al.,* 1992). In these two models, the Southern Uplands Massif as a whole is composed of a series of NE–SW trending fault blocks; in general, from north-west to south-east, each block shows rocks of successively younger age, yet within each block the younging direction is to the north-west (Figure 3.68). As a variation on these models Moseley (1977, 1978) considered that the Iapetus Ocean had been closed by the end of the Ordovician, so that there was no subduction in the Southern Uplands during the Silurian.

In this, the Kirkcudbright area, the Raeberry Castle Formation comprises three internally coherent tectonic units separated by relatively narrow (< 50 m) shear zones (Kemp, 1986). These three units probably represent successively accreted (underthrust) packets of sediment, which had accumulated on the northern margin of the Iapetus Ocean in the final stages of the ocean's existence. The 0.8 to 1.2 km thickness of these packets accords with the dimensions inferred from some modern active margins, such as in the Amlia sector of the Aleutian Trench (McArthy *et* al, 1984). Thus, the northern subduction, which finally destroyed Iapetus as Laurentia and Avalonia approached, was responsible for the stratigraphy now displayed. Kemp (1987) has integrated sedimentological and structural information to try to understand the control on the sequence by the interaction and interdependence of these two aspects.

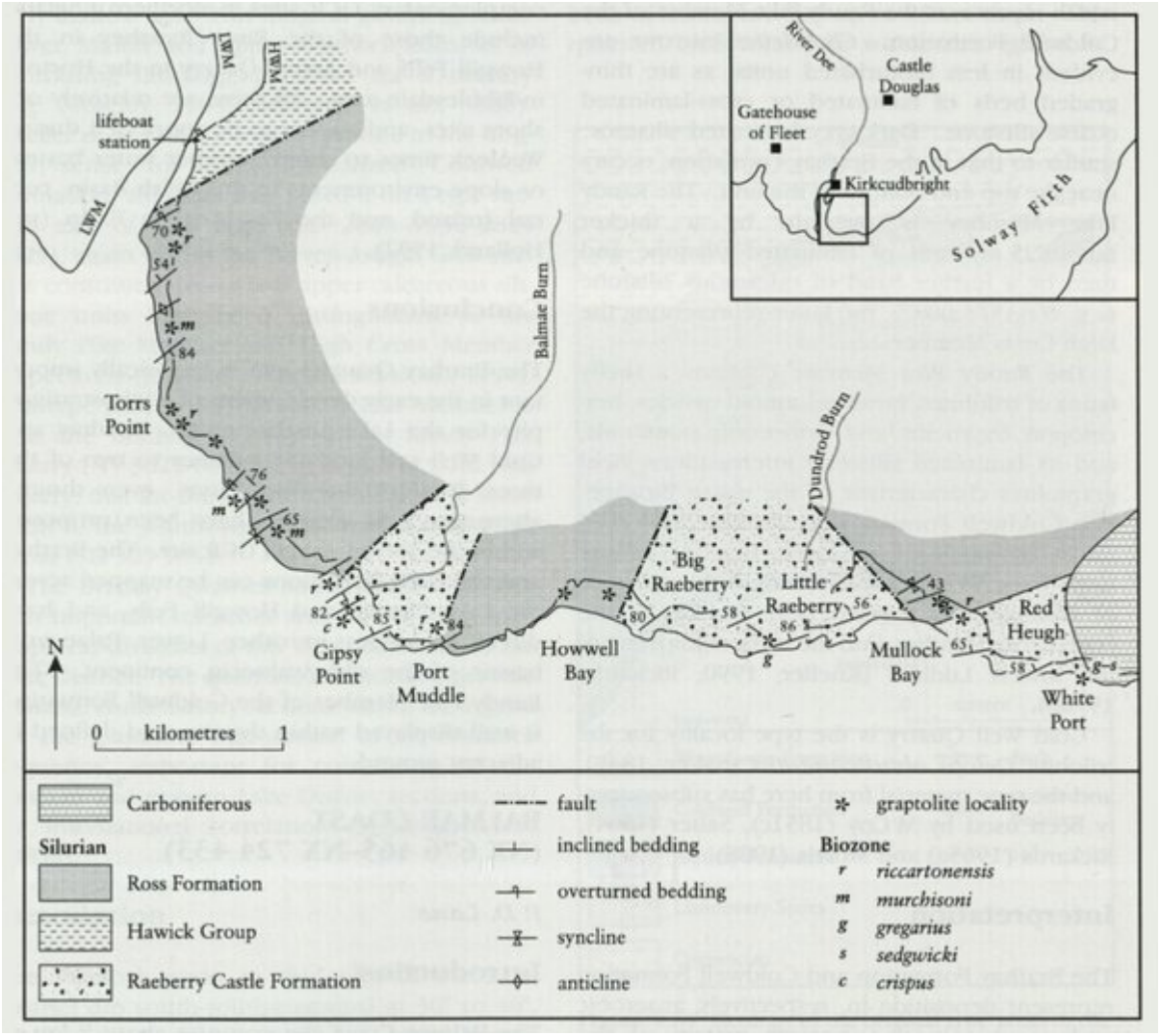
The imbricate stack model of Leggett *et al.* (1982) is that which is now generally accepted as the most plausible for the Southern Uplands. It has been shown to hold for the Balmae Coast site and also for the Kirkcudbright area in general, particularly following a refinement of the graptolite biostratigraphy (Rushton *et al.,* 1996). This model, however, does not explain the sequences seen in the whole of the Southern Uplands tract. Some 100 km to the north-east in the Peebles–Hawick area the greywacke sequence, which is of the same general age as the sequence in the Kirkcudbright area, conforms to the imbricate stack model only in its lowest and the uppermost parts. In the northeast part of the Southern Uplands, however, in the middle part of the greywacke sequence (mid-to late-Llandovery in age), out-of-sequence thrusting has been recognized, which has been attributed to the presence of some obstacle to simple forward-thrust propagation (Rushton *et al.,* 1996).

The Balmae Coast site is the stratigraphical, structural and sedimentological complement of its sister site, Meikle Ross (Borgue Coast). Particularly in exhibiting a fully marine, graptolitic sequence, the Balmae Coast site contrasts with other Scottish Silurian sites showing rocks of similar age, but of contrasting tectonostratigraphical position. To the north, in the Midland Valley of Scotland, sites in the Pentland Hills (Lyne Water and Lynslie Burn), the Hagshaw–Lesmahagow area (Ree Burn–Glenbuck Loch), and in the eastern part of the Girvan area (Knockgardner), all illustrate the early onset of non-marine conditions at about the Llandovery–Wenlock boundary interval, or at the latest in early Wenlock times.

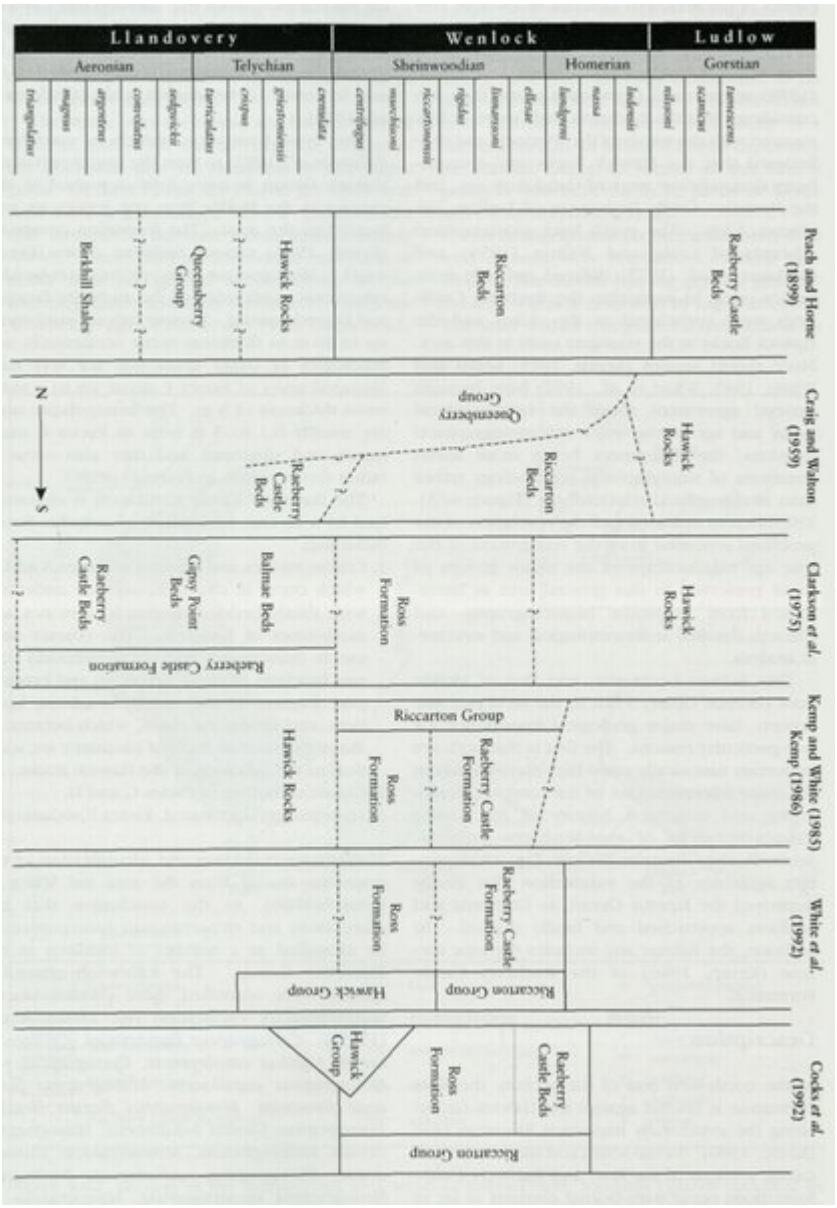
Conclusions

This site (and its sister site of Meikle Ross) has much historical importance. The difficulties of the structural interpretation of the Scottish Southern Uplands, including this area, were first recognized in the mid-19th century by Murchison, and have been under detailed study since that time. The site is crucial for understanding the structural development of the Southern Uplands, and its impact on the details of the progressive closing of the Iapetus Ocean during the Silurian. The regular southward-propagating thrust model, which has been demonstrated at this site contrasts with the less regular, partly out-of-sequence thrust model developed in rocks of similar age and facies in the Peebles–Hawick area about 100 km to the north-east. 'These thrust models have been largely constrained by the fine-scale biostratigraphy that has been performed on the graptolites and acritarchs preserved in this and nearby sections. In addition the sediments, which are well exposed in these coastal sites, afford fine examples of all facies of classical Lower Palaeozoic turbidite sedimentation in a deep marine environment. The contrast with the mainly non-marine, red-bed Wenlock sequences of sites in the Midland Valley serves to illustrate the complex Lower Palaeozoic history shown by the rocks of southern Scotland.

References

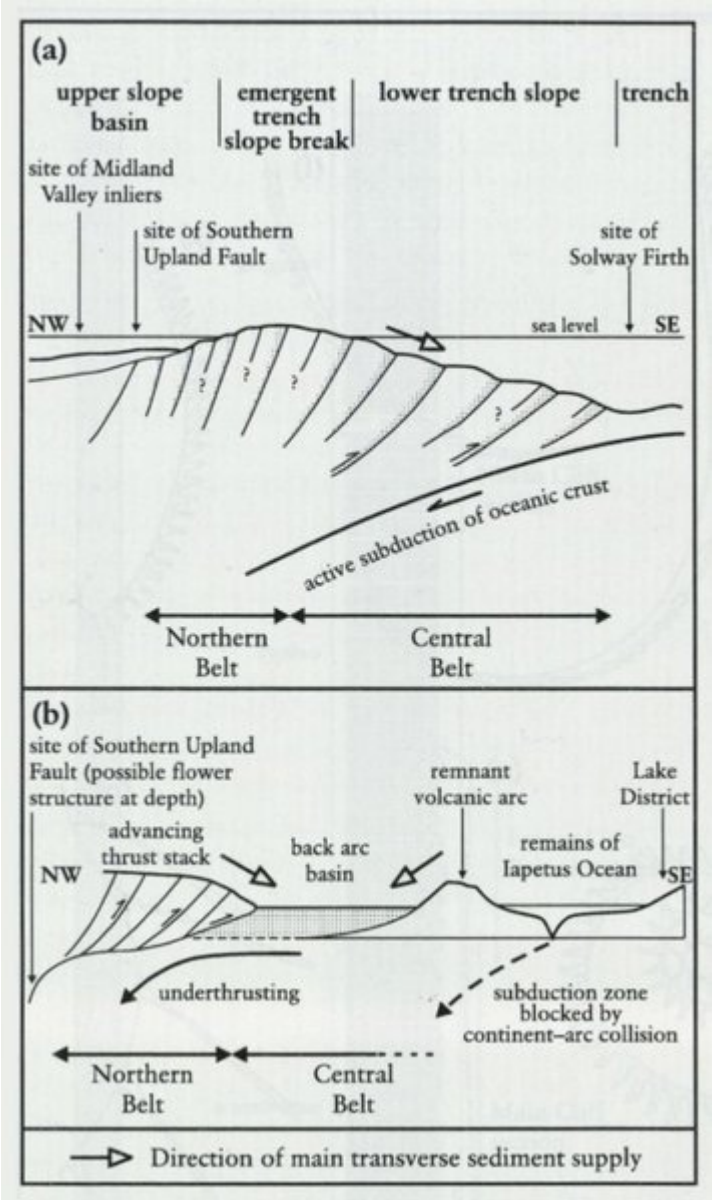


(Figure 4.62) Geology of the Balmae coast area, south of Kirkcudbright, Southern Uplands (modified from Clarkson et al., 1975, with minor revision of lithostatigraphical terminology after White et al., 1992).



(Figure 4.63) Stratigraphical schemes for Silurian strata occurring in the Balmac coast area, south-east of Kirkcudbright, Southern Uplands (after quoted published sources).

(Figure 4.64) Balmae Coast. Turbidites of the Ross Formation, Riccarton Group, Wenlock Series, south-cast of Torrs Point, Kirkcudbright Bay, Southern Uplands. (Photo: Derek J. Siveter.)



(Figure 3.68) Two models accounting for the structural and stratigraphical development seen in the Southern Uplands (from McAdam et al., 1992). (a) accretionary prism model of Leggett et al. (1979a); (b) back-arc basin model of Stone et al. (1987).