The Old Red Sandstone of Great Britain

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Chapter 4

Southern Scotland and the Lake District

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INTRODUCTION

Old Red Sandstone rocks crop out in the Scottish Borders and eastern Dumfriesshire (Mykura, 1991; Trewin and Thirlwall, 2002). Situated south of the Southern Upland and Lammermuir faults, these isolated outcrops lie in the Southern Uplands Terrane (Figure 4.1; Browne *et al.*, 2002). Together with small outcrops of conglomerates fringing the Vale of Eden, these strata provide important evidence for the interpretation of the Old Red Sandstone palaeogeography of Britain. The oldest strata, which are of Late Silurian to Early Devonian age, comprise predominantly fluvial conglomerates and sandstones assigned to the Reston Group. Volcanic rocks in the Reston Group include basaltic and andesitic lavas and tuffs of the Eyemouth Volcanic Formation between St Abbs Head and Eyemouth in Berwickshire (Greig, 1988; Stephenson, 1999) and the Cheviot Volcanic Formation in Roxburghshire (Browne *et al.*, 2002). It is likely, but unproven, that the strata of the Reston Group were deposited in basins separated from those of the Midland Valley of Scotland (Browne *et al.*, 2002). One of the most extensive of the conglomerates, the Great Conglomerate Formation of the Reston Group (Davies *et al.*, 1986), crops out in the Dunbar, Lauder and Haddington areas. It comprises boulder conglomerates with wacke sandstone clasts and interbedded thin sandstones. Although no diagnostic fossils have been recorded, the strata are considered to be of Early Devonian age on the basis of correlation with pre-volcanic sedimentary rocks at Bell Hill, St Abbs (Greig, 1988; cf. Rock and Rundle, 1986).

No rocks of Mid-Devonian age are known in the Southern Uplands Terrane. Following a period of uplift and denudation at the end of the Caledonian Orogeny, alluvial basins developed in the Scottish Borders during Late Devonian times. Their fill is largely assigned to the Stratheden Group (Paterson and Hall, 1986; Browne *et al.*, 2002). The Stratheden Group rests with angular unconformity on Old Red Sandstone of Silurian to Early Devonian age or on Early Palaeozoic turbidites of the Southern Uplands. The unconformity at Jedburgh (the Jedburgh Unconformity; Figure 4.2) is a Regionally Important Geological and Geomorphological Site (RIGS).

The largest of the Late Devonian basins is the Scottish Border Basin (Leeder, 1973, 1974, 1976), which extends from Berwickshire south-westwards to Jedburgh and from there as a narrow, discontinuous belt to Kirkbean on the Solway coast. In the Eyemouth and Jedburgh districts, the Stratheden Group comprises a clastic red-bed succession of mainly fluvial pebbly sandstones, siltstones and some conglomerates. The group's thickest development (up to 200 m) is in the Langholm, Jedburgh and Cheviot districts. The conglomerates were mainly sourced from the Galloway highlands (Leeder, 1973, 1976). The sandstones provided a good source of local building material and many of the Borders abbeys and houses of the Tweeddale district are constructed of them (MacGregor and Eckford, 1946).

Nodules and beds of dolomite and chert are common in the Upper Old Red Sandstone and are particularly well-developed in Liddesdale (see **Palmers Hill Rail Cutting** GCR site report, this chapter). They are interpreted as calcretes and silcretes, indicative of contemporaneous pedogenesis. The calcrete-bearing strata are referred to the Kinnesswood Formation of the basal Carboniferous Inverclyde Group, as at Pease Bay (see **Siccar Point to Hawk's Heugh** GCR site report, Chapter 3) and at **Milton Ness** near Arbroath in the Midland Valley (see GCR site report, Chapter 3). Up to 30 m of these distinctive strata are present at Kirkbean, in Annandale and Liddesdale and at Burnmouth and Cockburnspath (Smith, 1967, 1968; Leeder, 1973, 1974; Paterson *et al.*, 1976; Browne *et al.*, 2002). At Kirkbean, and in Annandale and Liddesdale, the Kinnesswood Formation is overlain by weathered vesicular olivine basalt lavas of the Birrenswark Volcanic Formation (Stephenson *et al.*, 2003). In Berwickshire, it passes up conformably into the Ballagan Formation (Cementstone Group of Smith, 1967, 1968).

In north-west England, possible equivalents of the Reston Group on the southern margin of the Northumberland and Solway basins (Figure 4.1) include the Polygenetic Conglomerate of the Penrith and Cross Fell areas and the Mell Fell Conglomerate Formation (see **Pooley Bridge** GCR site report, this chapter) on the north-eastern flanks of the Lake District mountains (House *et al.*, 1977). The age of these conglomerates is uncertain, field relationships indicating only a post-Silurian–pre-marine Carboniferous age (Bluck *et al.*, 1992).

There is little evidence for strata equivalent to either the Stratheden Group or the overlying

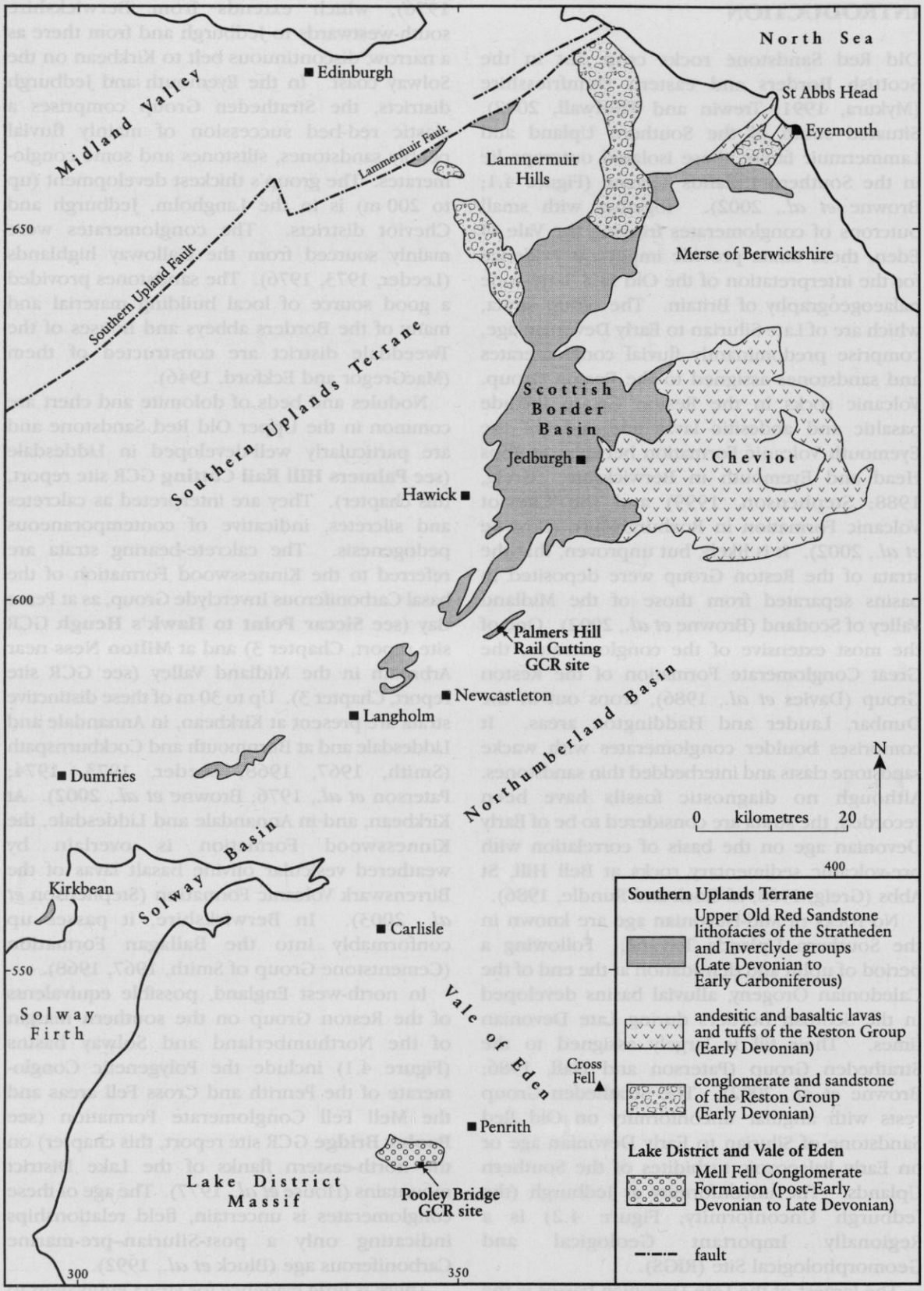

Figure 4.1 Distribution of Old Red Sandstone strata of the Southern Uplands and the Lake District.

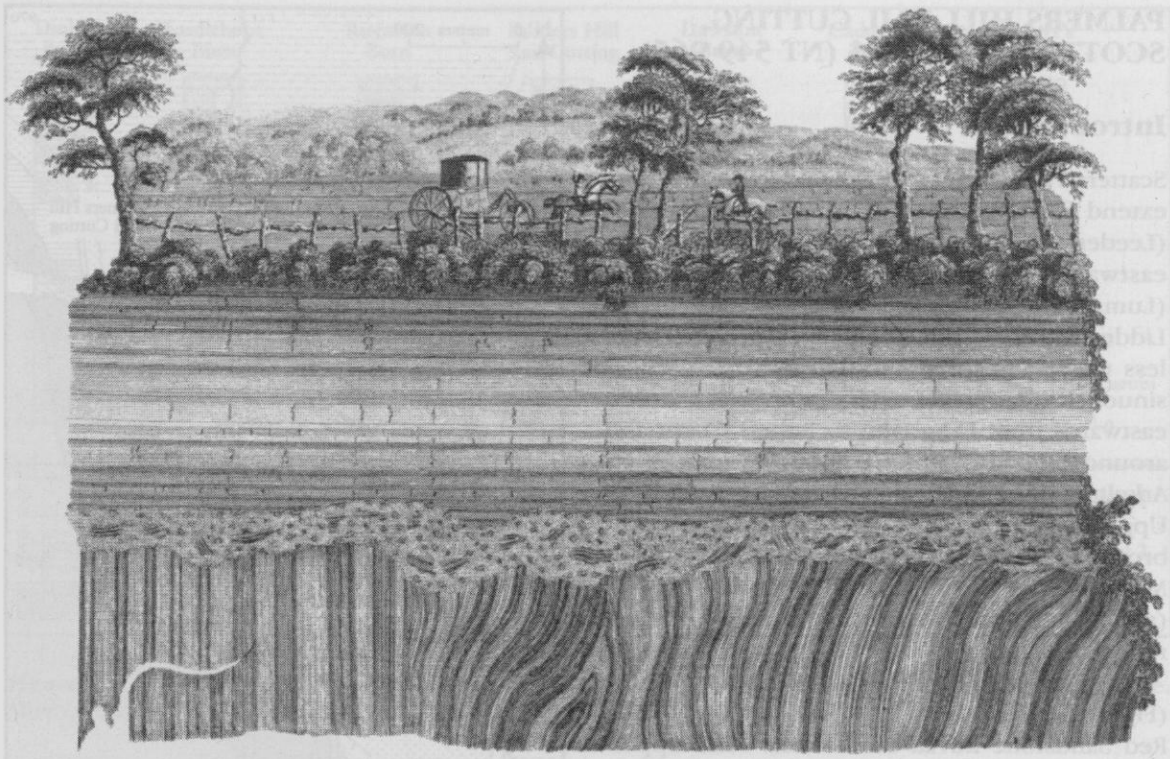

Figure 4.2 Engraving after a drawing of the unconformity at Jedburgh (NT 652 198) by John Clerk of Eldin (1787), used for Plate III of the *Theory of the Earth*, Volume 1, by James Hutton (1795). Vertical Silurian greywackes and shales are unconformably overlain by Upper Old Red Sandstone basal breccia and overlying sandstones. From Craig *et al.* (1978), reproduced by permission of Sir R.M. Clerk Bt.

Kinnesswood Formation on the margins of the Lake District Massif. Interestingly, however, Capewell (1955), in his regional study of pre-marine Carboniferous 'Basement Series' sedimentary rocks on the east side of the English Lake District, refers to characteristics in the alluvial 'Red Sandstones' of the Birk Beck valley that may be similar to those of the Ballagan Formation 'cementstone' facies of the Midland Valley of Scotland. The Birk Beck valley succession comprises Lower Conglomerates (possible correlatives of the Pinksey Gill Beds of Tournaisian age (Westoll, 1977), Red Sandstone and Upper Conglomerates, conformably overlain by Lower Carboniferous marine strata. Thus, there is local evidence in the Lake District for the development of Old Red Sandstone lithofacies of Late Devonian to Early Carboniferous age.

The transition from continental Old Red Sandstone to marine deposition may have taken place at slightly different times in the Early Carboniferous in the basins of Southern Scotland. The debate over the age of the Old Red Sandstone was fuelled by the discovery in the 19th century of fossil fishes (Jameson, 1805; Milne, 1843; Nicol, 1847; Powrie, 1870). The discovery of *Holoptychius noblissimus* Agassiz at Wauchope Burn, SSW of Jedburgh (Milne, 1843) and fish fragments believed to have come from Tudhope Quarry, Jedburgh (Nicol, 1847) resulted in the beds being assigned to the 'old red sandstone'. Powrie (1870) assigned strata with similar fish fragments at Denholm Hill, Hawick to a 'Passage Group' between the Upper Old Red Sandstone and the Carboniferous strata. Strata bearing *Holoptychius noblissimus* Agassiz at Dinley Burn, Langholm were referred to the Upper Old Red Sandstone by Peach and Horne (1903). Lumsden *et al.* (1967) noted that neither the presence of cornstone (calcrete) or *Holoptychius* was diagnostic of precise age, and that the strata now assigned to the Kinnesswood Formation could be Late Devonian or Early Carboniferous in age.

PALMERS HILL RAIL CUTTING, SCOTTISH BORDERS (NT 549 965)

Introduction

Scattered outcrops of Upper Old Red Sandstone extend from Kirkbean, south-west of Dumfries (Leeder, 1976; Leeder and Bridges, 1978) north-eastwards through Annandale to Liddesdale (Lumsden *et al.*, 1967; Leeder, 1973, 1976). In Liddesdale, the strata range in thickness from less than 15 m to over 180 m in a narrow and sinuous outcrop that extends for 20 km north-eastwards from Langholm to Robert's Linn and around the outlier of Carboniferous rocks on Arkelton Hill. To the north-east, the outcrop of Upper Old Red Sandstone fluvial sandstones broadens and extends from Jedburgh to the Merse of Berwick-shire and to Cockburnspath (see **Siccar Point to Hawk's Heugh** GCR site report, Chapter 3).

The Palmers Hill Rail Cutting in Liddesdale (Figure 4.3) exposes about 23 m of Upper Old Red Sandstone fluvial sandstones. The uppermost 7–8 m of strata contain pedogenic carbonate (calcrete) nodules and two regionally significant, mature calcrete horizons (Lumsden *et al.*, 1967; Leeder, 1976). The calcrete-bearing strata are referred to the Kinnesswood Formation of the Lower Carboniferous Inverclyde Group and the underlying strata to the Upper Devonian Stratheden Group (Paterson and Hall, 1986; Browne *et al.*, 2002). In the Palmers Hill Rail Cutting, the strata rest with angular unconformity on wacke sandstones of the Lower Palaeozoic (Wenlock) Riccarton Group (Lumsden *et al.*, 1967). They are overlain by weathered vesicular olivine basalt lavas of the Tournaisian Birrenswark Volcanic Formation.

Description

The Palmers Hill Rail Cutting lies on the north-eastern flank of Arnton Fell in Liddesdale and is one of several sections including those in the Dinley Burn, Laidlehope Burn, Riccarton Burn, Dawston Burn, Caddroun Burn and Robert's Linn (Figure 4.4) in which calcrete is recorded in the upper part of the Upper Old Red Sandstone succession. About 120 m of thinly bedded, massive and cross-bedded, brownish red, medium- to coarse-grained sandstones are exposed in Riccarton Burn, south-west of Palmers Hill Rail Cutting.

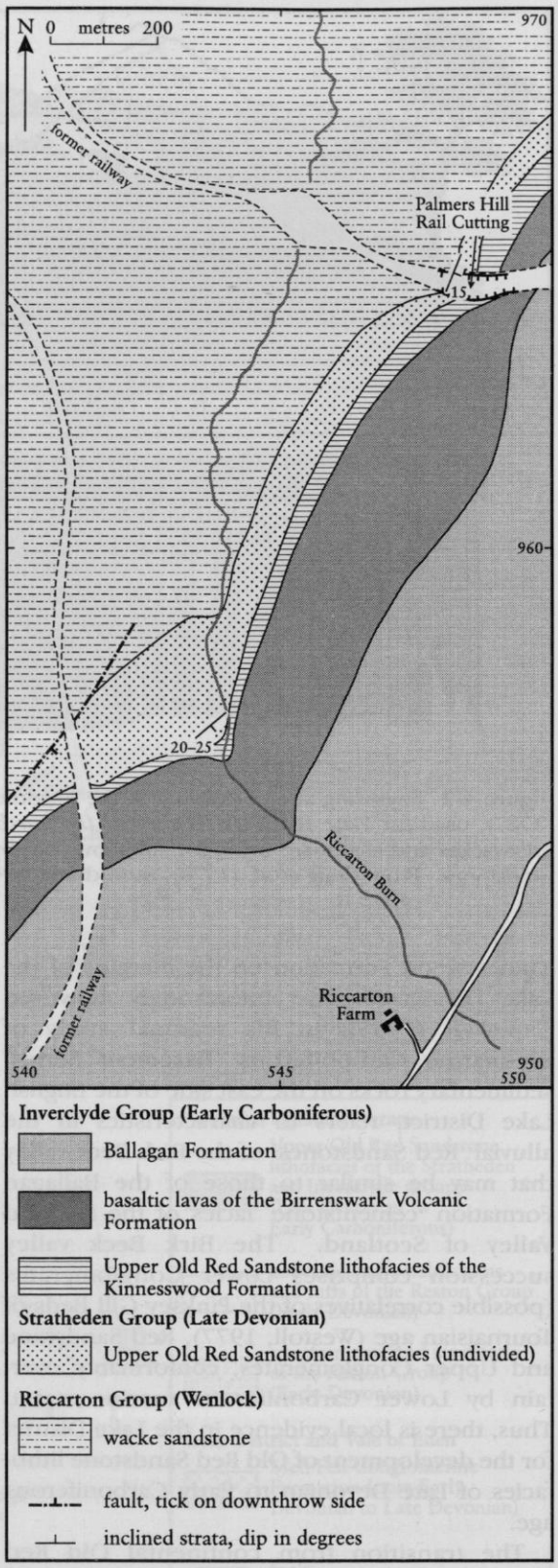

Figure 4.3 Geological map of the area around Palmers Hill Rail Cutting.

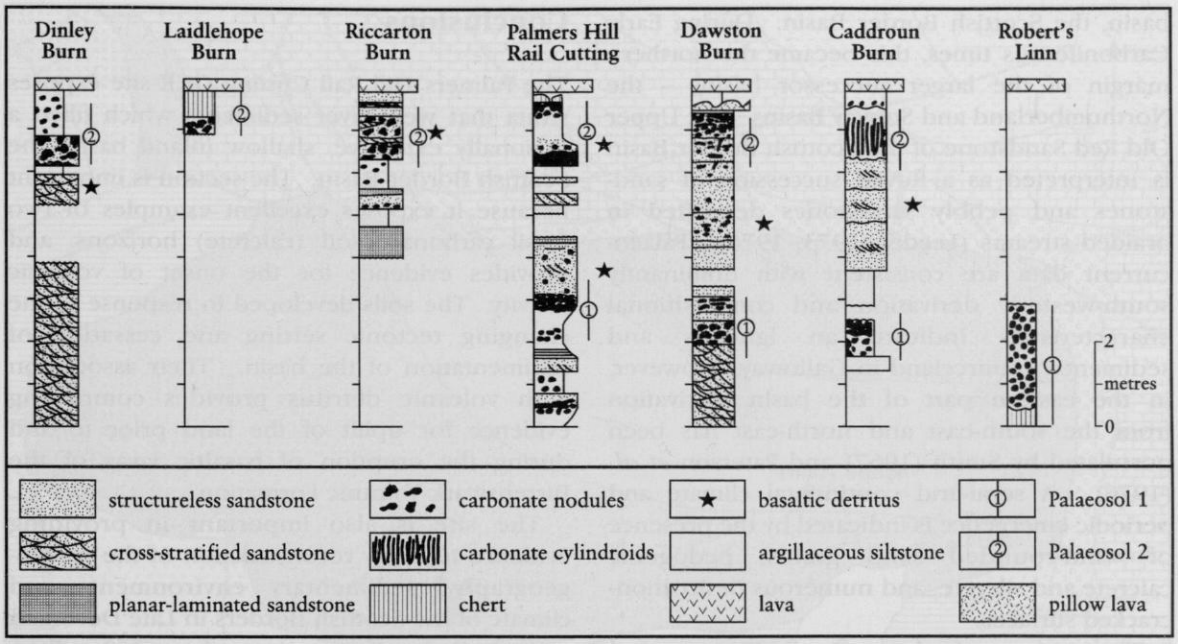

Figure 4.4 Graphic logs of the Kinnesswood Formation of Liddesdale showing the distribution of calcrete. After Leeder (1976).

The cutting exposes about 23 m of strata, which dip about 15° ESE. The lowermost 15 m are here assigned to the Stratheden Group. They comprise coarse-grained, massive, reddish brown sandstones containing well-rounded quartz pebbles and rounded clasts of deep reddish purple siltstone and silty mudstone. The lowest 1.8 m of sandstone have yielded unidentified fish scales (Lumsden *et al.*, 1967). The overlying Kinnesswood Formation is 7–8 m thick, contains nodular and massive calcrete (Leeder, 1976; the 'sandy cornstones' of Lumsden *et al.*, 1967) and is overlain by weathered lavas of the Birrenswark Volcanic Formation (Figure 4.4; Leeder, 1976). The strata comprise cross-bedded and planar-laminated sandstones interbedded with silty mudstone. The lower 4 m contain numerous carbonate nodules and a dolomitic calcrete horizon (Palaeosol 1 of Leeder, 1976) developed in a sub-arkosic sandstone. The sandstones between this horizon and a higher dolomitic calcrete (Palaeosol 2 of Leeder) are lithic-rich and contain chloritized basaltic detritus. In thin section, the calcrete is invariably seen to be a ferroan dolomite sparite exhibiting replacive and displacive fabrics of carbonate after quartz sand and silt (cf. Steel, 1974; Balin, 2000). Basaltic detritus is present above the higher calcrete, in the uppermost metre of the section, and the top few centimetres immediately below the basaltic lavas contain stringers and nodules of chert, interpreted by Leeder (1976) as silcrete.

Interpretation

The red beds of the Upper Old Red Sandstone have been variably assigned a Late Devonian and Early Carboniferous age. In the Langholm district, the presence of *Holoptychius noblissimus* Agassiz in red beds with 'cornstones' led earlier workers (e.g. Peach and Horne, 1903) to assign the strata to the Late Devonian (Lumsden *et al.*, 1967), but these criteria are not diagnostic of age. Indirect evidence of a minimum age of the strata is provided by radiometric age determinations on the overlying basalts. An olivine basalt flow of the Birrenswark Volcanic Formation at Watch Hill near Langholm and an aphyric basalt from a plug at Mellerstain Hill near Kelso have been dated by the K–Ar whole-rock method as 361 ± 12 Ma and 361 ± 7 Ma respectively, close to the Devonian–Tournaisian boundary (De Souza,1982).

The calcrete horizons and volcanic detritus in the sandstones at these other localities provide the basis for the palaeogeographical reconstruction of a shallow, alluvial, inland

basin, the Scottish Border Basin. During Early Carboniferous times, this became the northern margin of the larger successor basins – the Northumberland and Solway basins. The Upper Old Red Sandstone of the Scottish Border Basin is interpreted as a fluvial succession of sandstones and pebbly sandstones deposited in braided streams (Leeder, 1973; 1976). Palaeocurrent data are consistent with dominantly south-westerly derivation and compositional characteristics indicate an igneous and sedimentary sourceland in Galloway. However, in the eastern part of the basin, derivation from the south-east and north-east has been postulated by Smith (1967) and Paterson *et al.* (1976). A semi-arid continental climate and periodic emergence is indicated by the presence of wind-rounded sand grains, pedogenic calcrete and silcrete, and numerous desiccation-cracked surfaces.

The presence of calcretes in the Kinnesswood Formation of the Scottish Border Basin, similar to those in south Ayrshire (Burgess, 1961), indicates periodic uplift, emergence and dissection of the alluvial plains. The uplift probably took place in response to partial melting in the upper mantle, which eventually resulted in basaltic volcanism (Leeder, 1974, 1976). The first regionally recognizable calcrete (Palaeosol 1) was partially buried by lava flows during subsequent local volcanic activity, and volcanic detritus was reworked into the overlying fluvial sandstones. Further uplift resulted in the development of a second calcrete (Palaeosol 2), to be followed by the more extensive fissure eruption of basalt lavas of the Birrenswark Volcanic Formation, the outcrop of which extends discontinuously from the Kirkbean district to Kelso.

In thin section, the replacive and displacive fabrics of the dolomitic carbonate are typical of many modern and ancient pedogenic carbonates, and an analogy may be made with modern accumulations of carbonate in soil profiles of semi-arid regions (e.g. Steel, 1974; Balin, 2000). Peach and Horne (1903) noted that the cornstone (calcrete) is commonly accompanied by a lenticular red chert bed in the Riccarton area. The chert, which replaced dolomite, is interpreted as a pedogenic silicification phase (Leeder, 1976). Detailed petrological research on the origin of the dolomite at this site has yet to be undertaken.

Conclusions

The Palmers Hill Rail Cutting GCR site exposes strata that were river sediments which filled a regionally extensive, shallow inland basin, the Scottish Border Basin. The section is important because it exposes excellent examples of two fossil carbonate soil (calcrete) horizons, and provides evidence for the onset of volcanic activity. The soils developed in response to the changing tectonic setting and cessation of sedimentation of the basin. Their association with volcanic detritus provides compelling evidence for uplift of the land prior to and during the eruption of basaltic lavas of the Birrenswark Volcanic Formation.

The site is also important in providing evidence to allow reconstruction of the palaeogeography, sedimentary environments and climate of the Scottish Borders in Late Devonian to Early Carboniferous times about 362 million years ago.

POOLEY BRIDGE, CUMBRIA (NY 465 243)

Introduction

The Pooley Bridge GCR site comprises a shore section and road cutting at the northern end of Ullswater (Figure 4.5). It exposes the conglomerates of the lower part of the Mell Fell Conglomerate Formation, named after Great Mell Fell on the eastern side of the Lake District (Dakyns *et al.*, 1897; Green, 1918). The conglomerates were mentioned by early investigators, including Playfair, Otley, Sedgwick and Nicolson, all of whom referred them to the Old Red Sandstone. They form part of a 48 km-long outcrop of clastic strata on the eastern side of the Lake District from near Penrith to Ravonstonedale (Ward, 1876; Harker and Marr, 1891; Dakyns *et al.*, 1897; Oldham, 1900; Green, 1918). Originally referred to as 'Basement Beds' by Dakyns *et al.* (1897), the strata separate the Carboniferous Limestone from the underlying Lower Palaeozoic rocks. Recent studies of the Mell Fell Conglomerate Formation include those by Capewell (1954, 1955), Wadge (1978) and Kimber and Johnson (1984). The outlier has been re-mapped recently by the British Geological Survey as part of the

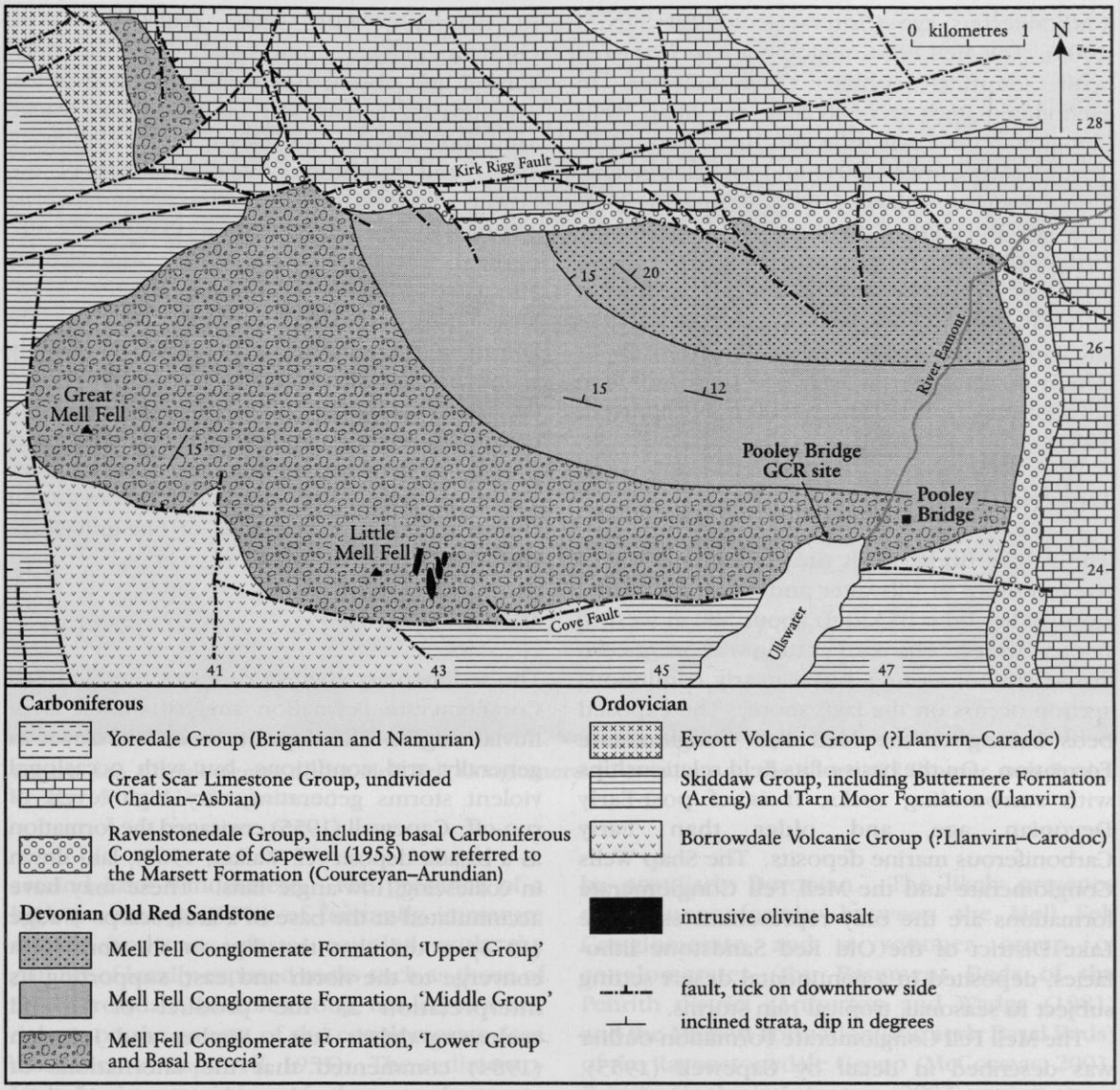

Figure 4.5 Geological map of the Mell Fells–Ullswater area. After British Geological Survey 1:50 000 Sheet 30 (England and Wales), Appleby (2003).

revision of the Appleby 1:50 000 geological sheet 30 (England and Wales) (British Geological Survey, 2003; McCormac, 2001; Millward *et al.*, 2003). Hillier and Williams (in press) provide a summary and Soper and Woodcock (2003) discuss the regional tectonic setting of the Mell Fell Trough.

The age of the Mell Fell Conglomerate Formation is uncertain, but it is thought to be Late Devonian to Early Carboniferous in age. Soper and Woodcock (2003) assign it a post-Acadian (Givetian–Frasnian) age on tectonic considerations. The Pooley Bridge site is significant in interpreting the regional geology, being the best exposed example of Old Red Sandstone lithofacies in north-west England. The conglomerates accumulated in a fault-bounded trough, the Mell Fell Trough, which covers an area of about 20 km^2 north of Ullswater. The strata rest unconformably on rocks of the Ordovician Borrowdale Volcanic Group. They are overlain unconformably by conglomerates of the Marsett Formation, the basal part of the Ravenstonedale Group of Early

Carboniferous age (British Geological Survey, 2003). The Mell Fell Conglomerate is correlated with identical cobble conglomerates in Heltondale Beck (NY 506 207), the Shap Wells Conglomerate Formation of the Shap Wells Trough (McCormac, 2001) and the 'Polygenetic Conglomerate' (Marr, 1899; Shotton, 1935). The last is confined to three outcrops in the Cross Fell Inlier (Burgess and Wadge, 1974) and one near Greystoke, west of Penrith (Arthurton and Wadge, 1981). Estimates of the thickness of the Mell Fell Conglomerate range from about 275 m (Dakyns *et al.*, 1897) to under 1000 m (McCormac, 2001) and 1500 m (Capewell, 1955).

Description

The Pooley Bridge GCR site consists of part of the foreshore of Ullswater and a cutting on the north side of the B5320 to about 500 m west of Pooley Bridge. The road cutting was overgrown at the time of writing, but a nearly continuous section occurs on the lake shore. The exposed beds belong to the Mell Fell Conglomerate Formation. On the basis of its field relationships with surrounding rocks, it is of post-Early Devonian age, and older than Early Carboniferous marine deposits. The Shap Wells Conglomerate and the Mell Fell Conglomerate formations are the only representatives in the Lake District of the Old Red Sandstone lithofacies, deposited in a continental desert setting subject to seasonal, tropical rain storms.

The Mell Fell Conglomerate Formation outlier was described in detail by Capewell (1955), who divided it into three units: (i) 'Lower Group and Basal Breccia' dominated by wacke sandstone clasts, (ii) 'Middle Group' characterized in the eastern part of the outcrop by minor acid intrusive and intermediate volcanic rocks and in the west by volcanic rocks and wacke sandstones and (iii) 'Upper Group' comprising volcanic rocks and wacke sandstones. The Pooley Bridge site provides an excellent section of the 'Lower Group'. Here, the strata consist of a very poorly sorted, dark red-brown, boulder- to cobble conglomerate (Figure 4.6) with irregular finer beds (Capewell, 1955). Rudimentary sub-horizontal to gently north-dipping bedding is seen in alignment of subangular to subrounded clasts. These range from about 0.1 m to 0.3 m in diameter, with some reaching 1.0 m. Oldham (1900) commented on the poor sorting and absence of well-rounded pebbles. The clasts consist of about 95% wacke sandstone (Harker and Marr, 1891; Capewell, 1955) and sandstone. The presence of the Lower Ludlovian graptolite *Monograptus colonus* in the clasts shows that they were derived from the Windermere Supergroup. Minor constituents of the conglomerate are lavas and pyroclastic rocks of Borrowdale Volcanic Group affinity, fine-grained, apparently unfossiliferous limestone and vein-quartz. A calcite-hematite vein cuts a wacke cobble. The matrix of smaller pebbles and coarse sand is purple-red with a calcite or iron oxide cement. There is evidence that the conglomerates infill channels, and thin interbeds of fine-gravel are cross-bedded.

Interpretation

The sedimentary characteristics of the Mell Fell Conglomerate Formation suggest that it is of fluvial origin. The deposits were laid down in generally arid conditions, but with occasional violent storms generating very high levels of run-off. Capewell (1955) envisaged the formation as a bajada deposit (cf. Walker, 1967), laid down in coalescing, low-angle fans. These may have accumulated at the base of a fault scarp. Wadge (1978) noted that the dips in the formation converge to the north and east, supporting its interpretation as the product of several coalescing debris fans. Kimber and Johnson (1984) commented that the alternations of coarse, clast-supported conglomerates with thin, well-sorted pebbly sandstones in the west and north of the Mell Fell Trough was consistent with fluvial deposition in braided channels in a mid-fan environment. A north-eastwards change, from proximal conglomerates to distal, finer-pebble conglomerates and pebbly sandstones, and palaeocurrent directions indicate north-east-flowing drainage.

The clasts in Capewell's (1955) 'Lower Group' of the Mell Fell Conglomerate Formation at Pooley Bridge consist largely of sedimentary rocks of the Windermere Supergroup. They are predominantly siltstones, mudstones, and wacke sandstones of the Bannisdale Formation and Coniston Group. The nearest present outcrops of these rocks lie about 22 km to the south

Figure 4.6 Conglomerate of the Mell Fell Conglomerate Formation on the shore of Ullswater near Pooley Bridge. (Photo: D. Stephenson.)

around Lake Windermere. The presence of a high percentage (95%) of texturally immature wacke sandstone clasts, coupled with the paucity of locally exposed rocks such as those of the Borrowdale Volcanic Group, has led to much debate on the source of the conglomerate (see discussion in Capewell, 1955). The sedimentological characteristics of the conglomerate indicate local provenance and deposition from rapid fluvial run-off from high hinterland, but the lithologies point to presently distant sources. Wadge (1978) considered that the lack of abrasion of the clasts suggested a source of Silurian and late Ordovician rocks much closer to Ullswater. McCormac (2001) noted that, although the conglomerate is texturally immature, the degree of rounding of the large clasts is unusual for such proximal deposits, and they may have been reworked from a desert regolith.

The age of the Mell Fell Conglomerate Formation has also been debated. The conglomerate contains cleaved Silurian (Ludlow) pebbles, and thus its deposition is considered to be post-Early Devonian. The likely presence of an unconformity between the Mell Fell Conglomerate and a younger group of conglomerates (the Basement Beds of the Penrith district (Arthurton and Wadge (1981) and the Marsett Formation (formerly Basal Beds) of the Ravonstonedale Group (McCormac, 2001; British Geological Survey, 2003) points to a period of uplift and erosion (Capewell, 1955). Thus Capewell (1955) favoured a pre-Late Devonian age for the Mell Fell Conglomerate, citing the evidence elsewhere in Britain for a conformable but diachronous boundary between the uppermost Old Red Sandstone and lowest Carboniferous beds. The Marsett Formation of Early Carboniferous age crops out to the north and east of Pooley Bridge. Although contact relationships are largely concealed, it is inferred that the junction with the Mell Fell Conglomerate is an unconformity, from a comparison of the regional dips of the two formations. The Marsett Formation is succeeded by strata which have yielded faunas of Chadian age (Dean, 2001). Thus the deposition of

the Mell Fell Conglomerate Formation is constrained between the Early Devonian (post-cleavage) and the Chadian. Evidence further constraining its age to the Courceyan or older is provided by the intrusive basalts of Little Mell Fell (Figure 4.5) (Capewell, 1955; Millward, 2003). These rocks, intruded into the Mell Fell Conglomerate Formation, are chemically similar to the Cockermouth Lavas (MacDonald and Walker, 1985) and are considered to be the easternmost manifestation of this volcanism (Millward, 2003). The age of the Cockermouth Lavas is tightly constrained to the Courceyan, based on the presence of CM Zone spore assemblages in overlying sedimentary rocks in Gill Beck GCR site, 4.5 km north-east of Cockermouth.

Conclusions

The Pooley Bridge GCR site exposes the Mell Fell Conglomerate Formation and provides the best section of strata of Old Red Sandstone lithofacies in north-west England. It is correlated with the Shap Wells Conglomerate Formation and the Polygenetic Conglomerate of the Penrith district and Cross Fell Inlier and provides important palaeogeographical and sedimentological evidence for the uplift and erosion of the Lake District Massif. The strata comprise poorly bedded, boulder- to cobble-grade conglomerates with some lenticular sandstone beds. The precise timing of deposition of the Mell Fell Conglomerate is uncertain but a post-Early Devonian to Late Devonian age is most likely.