The Permian red beds of the Vale of Eden

Introduction

The Vale of Eden is an isolated depositional basin (Figure 2.21) located midway between the East Irish Sea–west Cumbria Basin and the North Sea Basin. The 50-km-long basin was initiated in the Devonian, re-activated at the end of the Variscan Orogeny (Bott, 1974, 1978; Holliday, 1993) and was filled with up to 1 km of mainly continental Permo-Triassic red bed sediments. The sedimentology and stratigraphy of the Permian deposits of the Vale of Eden have been described by Sedgwick (1832), Binney (1855, 1857), Harkness (1862), Murchison and Harkness (1864), Nicholson (1868), Eccles (1870–71), Goodchild (1881, 1893), Dakyns *et al.* (1897), Kendall (1902), Versey (1939), Hollingworth (1942), Eastwood (1953), Burgess (1965), Meyer (1965), Waugh (1965, 1970a,b, 1978), Burgess and Wadge (1974), Smith *et al.* (1974, pp. 14–15), Arthurton *et al.* (1978), Taylor *et al.* (1978), Burgess and Holliday (1979), Arthurton and Wadge (1981), and Younger and Milne (1997).

The Vale of Eden succession includes a complex series of continental sediments, the continental breccias ('Brockrams') and water-laid and aeolian (Penrith) sandstones (Figure 2.22), which share broad characters with the red beds of the southern Scottish basins (see above). Breccias and water-laid sandstones are the dominant rock types near the margin of the basin, and they interdigitate with aeolian sands and marginal marine evaporite and dolomite units towards its centre.

The Penrith Sandstone comprises two distinct facies: in the northern part of the basin it is mainly a coarse, dune-bedded, red sandstone, while in the south and around the margins of the basin it interfingers with the brockrams and more poorly sorted fluvial sediments. The maximum exposed thickness is 460 m, but the unit probably reaches a thickness of 900 m in the centre of the basin (Bott, 1974). The Penrith Sandstone is mainly an aeolian facies, attributed to crescentic barchans moving through a large sand sea (erg). Palaeowinds blew mainly to the west (Figure 2.21), except in the south of the basin where they blew to the north-west. Silicified layers occur throughout, and these may be incipient silcretes, desert soils (Waugh, 1970a; Younger and Milne, 1997). Reptilian footprints from high in the aeolian facies near Penrith are of Permian aspect (Hickling, 1909), although they are hard to match precisely with those from the south of Scotland (see above).

The lowermost Penrith Sandstone south of Appleby, and around Kirkby Stephen (Figure 2.21), is a breccia known colloquially as the 'brockram'. This is typically a clast-supported breccia, with a few red, cross-bedded, channel sandstones (Macchi, 1990). Clasts are mainly limestone, and range from 10 to 400 mm in diameter. The clasts and the medium-grained sand matrix are reddened. Small channel fills, up to 0.5 m thick, are composed predominantly of lithic fragments, and fine upwards from a conglomerate lag into sandstones. Both the breccias and the sandstones are extensively cemented by calcite.

The Eden Shales overlie the Penrith Sandstone and comprise shales, siltstones, and sandstones, with several beds of evaporite and a thin dolomite (Arthurton, 1971). They include some marginal breccias, such as the Stenkrith Brockram, which continued to be deposited through late Permian times. In central areas of the basin, alternating continental and estuarine marine sediments (red beds, evaporites, carbonates, grey clastics) were deposited, and reached a total thickness of 160 m, but thin to 0 m at the margins (Figure 2.22). The Vale of Eden Basin was occupied during late Permian times by an elongate, almost flat, sedimentary plain flanked by slightly elevated rocky desert; from time to time the sub-facies of the plain included alluvial fans, continental sabkhas, deflation surfaces, playas, and minor dunefields.

The Late Permian marine transgression was apparently accompanied by a change in climate from arid to more humid, and the spread of plants over the land surface. Abundant plant remains are found in grey lagoonal clastic deposits at the southern end of the trough, and represent vegetation that apparently stabilized the uplands, since wind-blown clastic debris diminishes sharply at this level in the sequence. The plants are similar to those from the lower Zechstein succession on the eastern side of the Pennines (Stoneley, 1958), and the grey plant-bearing sediments are conventionally dated as Mid Permian (Wordian–Ufimian) in age (Smith *et al.,* 1974). One unit, the Hilton Plant Beds, immediately overlying the Penrith Sandstone in Hilton Beck, is especially rich in plant debris.

Correlation of the succeeding divisions of the Eden Shales (Figure 2.22) is based on matching individual evaporite units, termed A to D. However, the evaporites are poorly exposed, and are seen best in boreholes (Burgess and Holliday, 1974). The evaporite units are generally 1 to 30 m thick, and are typically separated by 10 to 60 m of variegated purple, green, and grey laminated mudstones, with thin stringers of gypsum, anhydrite, and dolomite. The evaporite units have been correlated tentatively with the Zechstein succession on the east side of the Pennines, on the assumption that they formed in response to wide-ranging climatic changes (Smith *et al.,* 1974, p. 15). Some additional evidence comes from a restricted fauna from the Belah Dolomite, which is correlated tentatively with the Seaham Formation of east Durham and the Brotherton Formation of Yorkshire (Burgess, 1965; Pattison, 1970; Burgess and Holliday, 1979), both of which units occur at the base of the Teesside Group or cycle EZ3 (Smith, 1995). The Belah Dolomite apparently marks the only marine incursion into the Vale of Eden Basin, when the Zechstein Sea entered the southern part of the basin.

The Belah Dolomite is succeeded by two continental units. The first, more than 30 m of brick-red, massive sandstone and blocky, argillaceous siltstone, was probably deposited by aeolian processes on the damp surface of an inland sabkha. The second, comprising 20–30 m of brick-red, finely cyclic mudstones, siltstones, and sandstones, was probably deposited on an alluvial plain. These sediments are comparable with the St Bees Shale Formation of the west Cumbria coast (see above).

The Vale of Eden Basin is confluent to the north with the Carlisle Basin, a branch of the East Irish Sea Basin that runs under the Solway Firth. Brockram deposits in the south-eastern margin of the Carlisle Basin are overlain by aeolian sandstones of Penrith Sandstone-type, which were redistributed by water action in their uppermost 10 m, and pass up by interdigitation into the St Bees Sandstone Formation of the Sherwood Sandstone Group (Triassic System).

Six GCR sites have been selected to illustrate the varied sedimentary conditions in the Vale of Eden: Burrells Quarry for the basal Penrith Brockram, Cowraik Quarry and George Gill for the Penrith Sandstone, Hilton Beck for the Hilton Plant Beds, Stenkrith Beck for the Stenkrith Brockram, and the River Belah section for the Belah Dolomite. The GCR coverage is detailed because of the long geological interest in this unusual small basin, and in order to represent the diversity of the geological units; the marine sequences of Bakevellia and Zechstein provinces are described in detail elsewhere in the GCR Series (Smith, 1995).

Burrells Quarry, Cumbria

Cowraik Quarry, Cumbria

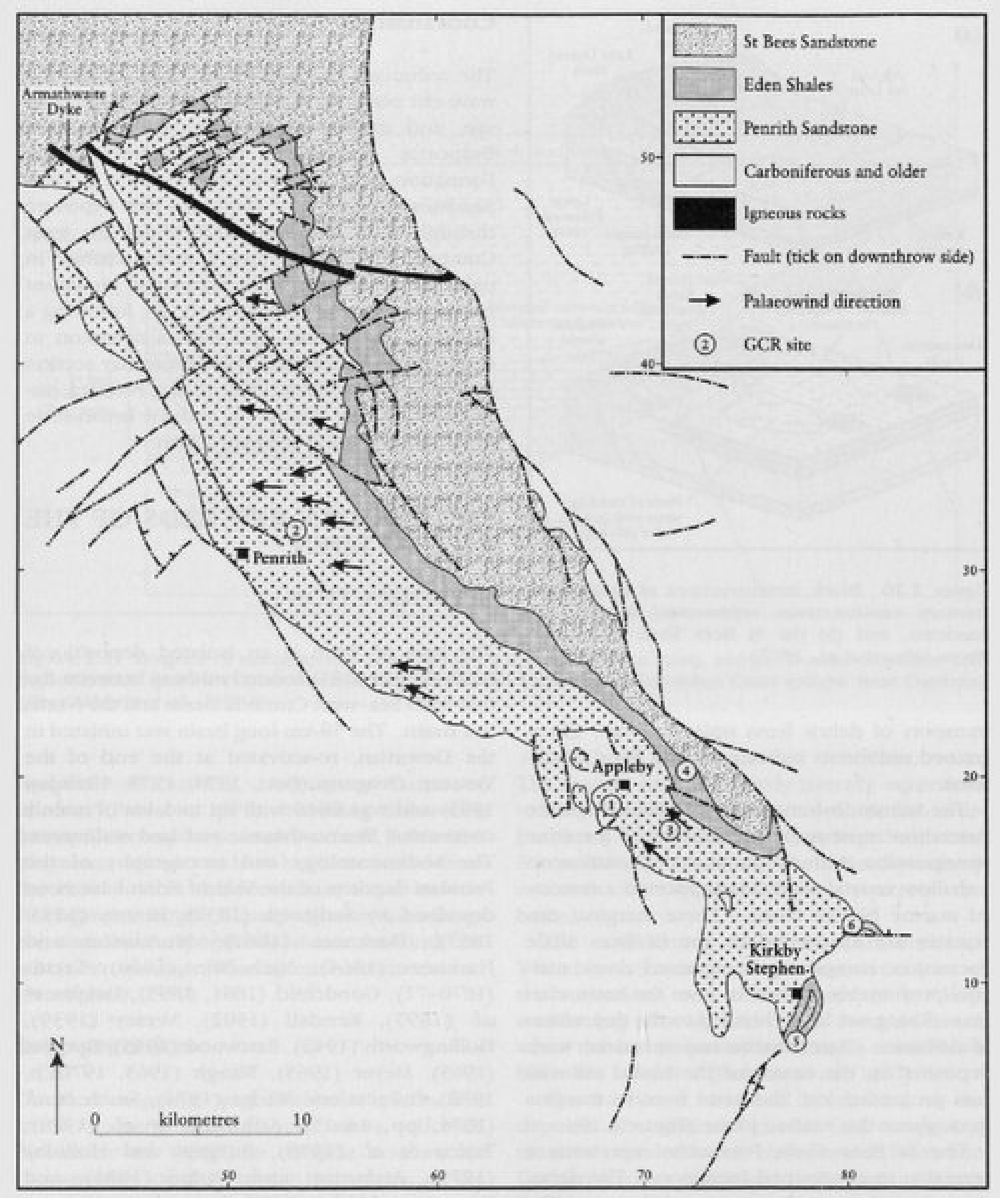
George Gill, Cumbria

Hilton Beck, Cumbria

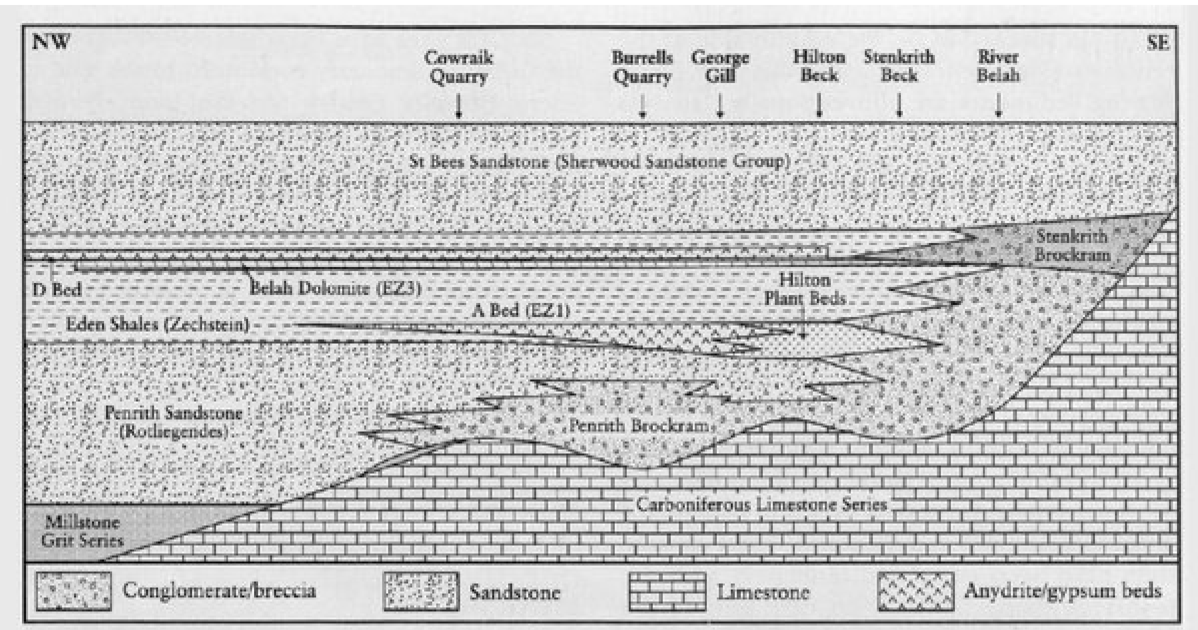
Stenkrith Beck, Cumbria

River Belah, Cumbria

References



(Figure 2.21) Simplified geological map of the Vale of Eden and the surrounding area, including palaeowind directions for the Penrith Sandstone. GCR localities are: (1) Burrells Quarry; (2) Cowraik Quarry; (3) George Gill; (4) Hilton Beck; (5) Stenkrith Beck; (6) River Belah. Based on Waugh (1970b), Burgess and Holliday (1974), and Younger and Milne (1997).



(Figure 2.22) Diagrammatic NW–SE section through the Vale of Eden basin, showing the Permian succession. The section is about 55 km long. (After Arthurton et al., 1978.)