# River Belah, Cumbria

[NY 799 123]

## Introduction

The River Belah section exposes the Penrith Sandstone, showing aeolian and fluvial facies interbedded with alluvial fan conglomerates. The Penrith Sandstone is overlain by the Eden Shales, which consist of fluvial and continental sabkha deposits. The Belah Dolomite contains a marine fauna and represents an incursion of the late Permian Bakevellia sea. This is therefore an important site for the study of Permian palaeogeography and palaeoenvironmental change.

The petrology of the Penrith Sandstone has been described by Versey (1939) and Waugh (1965, 1970a,b, 1978), the Eden Shales, including the Belah Dolomite, have been described by Eccles (1870–1871), Meyer (1965), Burgess and Wadge (1974), Burgess and Holliday (1974, 1979), Arthurton *et al.* (1978), Macchi and Meadows (1987, pp. 76–9), and Macchi (1990).

## Description

Several localities in the vicinity of the River Belah, in the southern part of the Vale of Eden (Figure 2.21), have exposures with sections through the Permian succession (Figure 2.27) and (Figure 2.28); the best sites include Belah Bridge [NY 7935 1210] and Belah Scar [NY 7965 1215]. The Belah Scar exposure is cut by a series of major and minor faults that may be syndepositional.

### Sedimentology

The Penrith Sandstone is a brownish-red, texturally mature orthoquartzite, with some yellowish bands and mottles (Versey, 1939), and interbedded grey, green, or brown siltstones. The sandstones are coarse-grained and well sorted, and are cemented by secondary quartz that occurs as overgrowths in optical continuity with the generally well-rounded grains. The overgrowths may be unicrystalline or polycrystalline, and may include fragments of derived vein quartz, metaquartzite, gneiss, and schist. Grains are dominantly quartz (90% to 95%), with minor feldspar (5% to 8%) and lithic fragments (2% to 5%). Rarely, the orthoclase and microcline feldspar grains have feldspar overgrowths. Accessory minerals, such as zircon, tourmaline, rutile, garnet, limonite, and magnetite, are also present. Many of the quartz grains have frosted surfaces. Ventifacts occur sporadically (Waugh, 1970a,b, 1978).

Sedimentary structures are clearly defined and well preserved in the Penrith Sandstone. Large-scale cross-bedded units occur, mostly with sets of high-angle wedge-planar cross-bedding, but also with some tabular-planar and lenticular trough cross-strata. The angle of inch- nation of the foresets ranges from 20° to 33° (Waugh, 1970b).

The exposure at Belah Bridge comprises 1 m of parallel-bedded sandstones overlain by a 2.5 m-thick bed of poorly sorted conglomerate (Figure 2.27), part 1). The sandstone sequence contains thin, laterally discontinuous beds of gritty or pebbly, dolomitized limestone conglomerate overlying erosion surfaces. The breccio-conglomerate facies (the brockram) is clast-supported, and consists of granule- to boulder-sized fragments of Carboniferous Limestone and reddish sandstone in a matrix of red, medium- to coarse-grained sand and clay.

North of Belah Bridge, *c.* 1 m of breccio-conglomerates, with erosional or channelled bases (Burgess and Holliday, 1979), is overlain by *c.* 2 m of sandstones (Figure 2.27), part 2). In the sandstones, a lower unit has a basal breccia overlain by parallel and sub-parallel bedded sands. It is succeeded by a second sandstone unit, also with a basal breccio-conglomerate, but with well-preserved cross-bedding structures, with several re-activation surfaces overlain by tangential foresets. Downcurrent, the tangential foresets are replaced by foresets with asymptotic bases. Grain sizes on the foresets have a bimodal distribution typical of fine- and coarse-grained alternating laminations. The foresets dip at 27° towards the west. It is likely that these sandstones are the lateral equivalents of the rudaceous sediments at Belah Bridge

(Macchi and Meadows, 1987).

Above the Penrith Sandstone, *c.* 12 m of the Eden Shales are seen and comprise brown and green siltstones, with thin sandstone interbeds and a prominent collapse breccia at their base. These siltstones are overlain by the Belah Dolomite, *c.* 5 m of thinly bedded, pale grey or yellowish dolomite and dolomitic limestone; the upper part of this unit contains solution cavities and calcite veins (Burgess and Holliday, 1979).

At Belah Scar [NY 7965 1215], the Penrith Sandstone interfingers with brockram ((Figure 2.27), part 3). The sandstones are dark red in colour, medium- to coarse-grained, and moderately well-sorted. They are massive or parallel-laminated; individual beds have sharp planar or erosive boundaries. Many of the erosion surfaces support a thin drape of argillaceous material. Small limestone pebbles commonly occur in the lower parts of the sandstone beds. At the eastern end of Belah Scar ((Figure 2.27), part 4) these become more common, occur through a greater thickness, and may show evidence of soft-sediment deformation (sub-vertical and vertical casts). Lenses, thin beds, and desiccation horizons of red mudstone occur throughout the sandstone sequence (Macchi and Meadows, 1987).

The conglomerates in the upper part of the section are poorly sorted and show crude horizontal bedding; their boundary with the underlying sandstone is sharp and has considerable erosional relief, with conglomerate commonly infilling deep scours and incised channel-margin contacts. The beds fine upwards, and basal lags are common. Clasts show evidence for imbrication, but are more commonly aligned parallel to the inferred current direction (Macchi and Meadows, 1987).

The uppermost part of the Permian section exposed around the River Belah comprises the Eden Shales, and includes the Belah Dolomite. The Eden Shales are red and grey sandstones and mudstones with discontinuous beds of evaporites. The Belah Dolomite is a carbonate horizon with marine fossils (Arthurton *et al.,* 1978).

### Palaeontology

Fossils are rare in the Belah Dolomite, but a restricted marine fauna, including an alga (cf. *Calcinema permiana*), foraminifera (cf. *Glomospira* sp.), bivalves (*Liebea squamosa, Schizodus obscurus*), ostracods (possibly bairdiids), and calcispheres, has been recovered from the River Belah section at[NY 8008 1225] (Burgess and Holliday, 1979, p. 69).

## Interpretation

The succession along the River Belah (Figure 2.27) may be correlated with that at Hilton Beck by noting the position of the Penrith Sandstone-Eden Shales contact, and of the Belah Dolomite. The latter unit was formerly identified as the 'Magnesian Limestone' (e.g. Meyer, 1965), but lateral comparisons with sections farther north in the Vale of Eden Basin allow the evaporite units A-D to be employed as markers. Anhydrite unit D lies immediately above the Belah Dolomite, which allows this dolomite unit to be traced extensively through the basin.

The Penrith Sandstone accumulated in continental desert environments. The well-sorted nature of the sediments, and the presence of frosted grains and ventifacts are characteristic features of aeolian sedimentation and erosion processes. The large-scale cross-bedded units have unidirectional foreset slopes, and in places the foreset surfaces are smoothly curved and concave, features consistent with formation in crescentic barchan dunes. Palaeowind directions were dominantly from the east or southeast (Waugh, 1970b). The cross-bedded sediments exposed at Belah Bridge and in the middle of Belah Scar are the only confirmed aeolian facies at this locality The remainder originated as aeolian sands, but were reworked by fluvial activity (Macchi and Meadows, 1987).

The arenaceous facies of the Penrith Sandstone is interbedded with coarse-grained breccias, the 'brockram'. These wedge-shaped units of rudaceous sediments, with planar and lenticular trough cross-bedding, are the products of ephemeral flash floods on alluvial fans and in wadis at the margins of the Vale of Eden sedimentary basin (Waugh, 1970b). Their distribution and geometry indicate that the wadi channels were steep-sided, long, and aligned ENE–WSW. Sedimentary structures, such as imbricated pebbles, indicate that sediment transport was from the north-east (Macchi and Meadows, 1987).

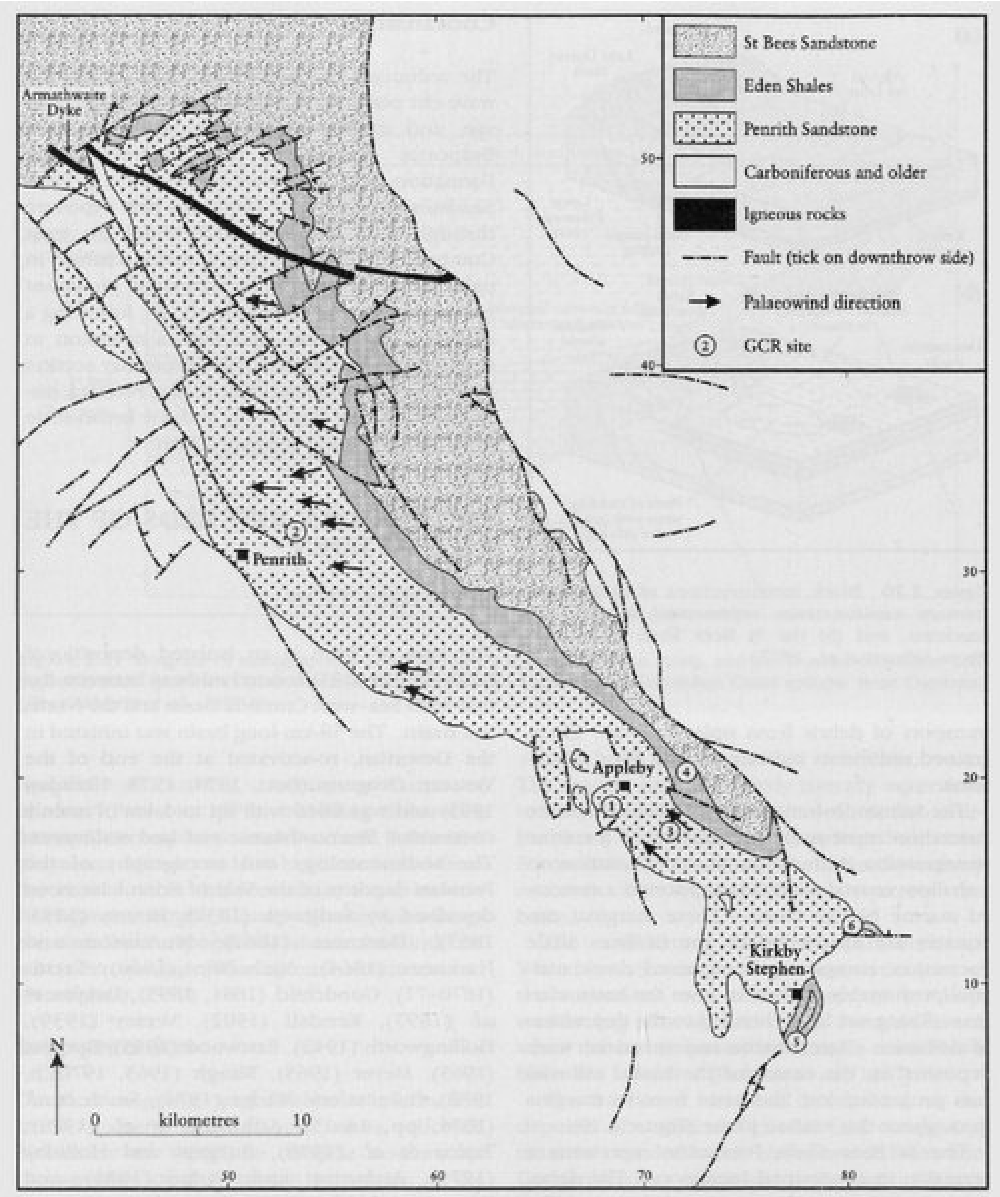
The Belah Dolomite represents a period of marine deposition, caused by a marine incursion, possibly from the east, through the Stainmore Depression. The associated sediments of the Eden Shales were deposited under dominantly terrestrial conditions, in lagoons or on sabkha flats (Arthurton *et al.,* 1978).

The fossil assemblage confirms that the Belah Dolomite is a marine unit and provides important evidence for correlation: the assemblage of *Liebea, Schizodus,* and *Calcinema* (Burgess, 1965; Pattison, 1970) indicates a correlation with the Seaham Formation (cycle EZ3) of the Durham Zechstein sequence.

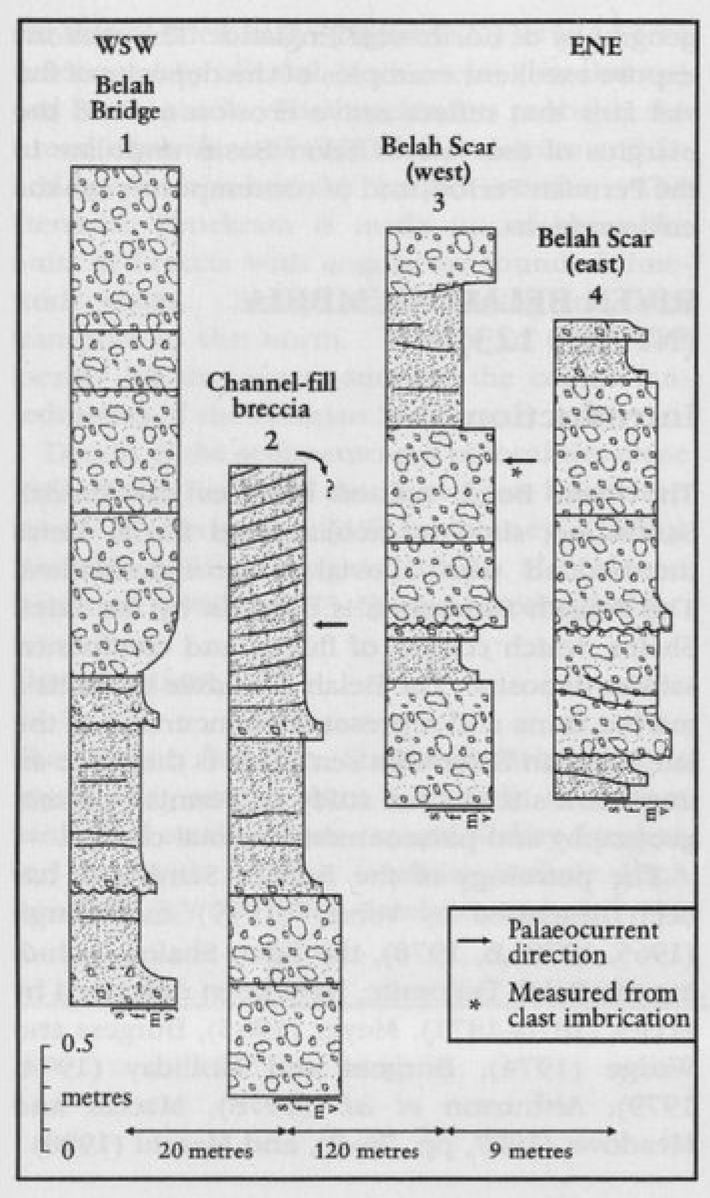
## Conclusions

The Permian sediments in the vicinity of the River Belah provide important information on palaeoenvironmental and palaeogeographical change. Sandstones and conglomerates were deposited in and around large alluvial fans. The sandstones were deposited by aeolian processes, although many of the resulting sand dunes were then reworked by rivers. The conglomerates were deposited on the alluvial fans and in wadis. The overlying Eden Shales were deposited under sabkha-type conditions, with the Belah Dolomite representing a period of marine incursion.

**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 2.27) Sections through the Penrith Sandstone exposed between Belah Bridge (1) and Belah Scar (4). (After Macchi and Meadows, 1987.)

(Figure 2.28) Permian sediments on Belah Scar: Penrith Sandstone with brockram lenses cut by an extensional fault downthrowing to the west. The cliff is about 6 m high. (Photo: P. Turner.)