River Ure Cliff, Ripon Parks

[SE 3073 7526]–[SE 3083 7517]

Highlights

The low river cliff at Ripon Parks (box 1 in (Figure 4.2)) is one of the few exposures of the Edlington Formation in Yorkshire and is unique in containing thick beds of gypsum. The thickest gypsum lies at the base of the sequence and is only gently folded, but overlying thinner-bedded mudstone, siltstone, dolomite and gypsum is spectacularly tightly folded and fractured; these higher beds also contain many conspicuous veins of white fibrous gypsum.

Introduction

The river cliff lies on the west bank of the River Ure at Ripon Parks, about 3 km north of Ripon; it is partly concealed by vegetation and the base of the cliff is almost constantly washed (and undermined) by the fast-flowing river. Except for a mantle of red-brown boulder clay, all the strata seen in the cliff are thought to be part of the Edlington Formation, here in the floor of the narrow fault-bounded Coxwold–Gilling Trough. Strata in the cliff comprise several metres of gently folded gypsum overlain by a somewhat thinner, but partly strongly folded and faulted, sequence of thin-bedded mudstones, siltstones and dolomites. These upper beds contain many veins, lenses and sheets of secondary fibrous gypsum, and, at the southern end of the face, are separated from the underlying gypsum by a low-angle slip plane. Foundered beds of the Brotherton Formation lie in the bed of the river at the southern end of the main cliff.

The section has been known to geologists for well over a century, having been mentioned by Sedgwick (1829), Tute (1868a, b, 1870, 1884), Cameron (1881) and Fox-Strangways *et al.* (1885) in the last century. More recently the section has been described and illustrated in greater detail by

Table 4.1 Main geological features of the marine Permian GCR sites in the Yorkshire Province of the English Zechstein.

Yorkshire Province	**Site**	**Interest**
Cycle 1 / Cycle 2		
Ellington Formation	River Ure Cliff, Ripon	The only permanent surface exposure of Permian evaporites in north-east England; much gypsum after anhydrite, partly strongly internally folded; many satin-spar veins; foundered limestones of Brotherton Formation (Cycle 3) with *Calcinema*
Cycle 1		
Cadeby Formation (Sprotbrough Member), transitional to Edlington Formation	Quarry Moor, Ripon	Unevenly interbedded algal-laminated dedolomitized ooid grainstones and evaporite dissolution residues; expansion structures; algal-laminated dolomite ooid grainstones
Sprotbrough Member on Wetherby Member	Micklefield Quarry, New Micklefield	Typical dolomitized ooid grainstones of sandwave facies rests on full sequence of peritidal Hampole Beds; fenestral ('birds' eye') fabric; Hampole Discontinuity

	Cadeby Quarry, Cadeby	Typical dolomitized ooid grainstones of sandwave facies rests on atypically thick Hampole Beds; Hampole Discontinuity with relief of 3 m+; Wetherby Member with unusually tall patch-reefs and thick dolomite domed algal laminites
Wetherby Member	Wood Lee Common, Maltby	Selectively eroded dolomitized bryozoan patch-reefs form tors on grassy slope
	South Elmsall Quarry	Dolomitized bryozoan–algal patch-reef in peloidal and oncoidal shelf grainstones; stromatolite domes
	Ashfield Brick-clay Pit, Conisbrough	Dolomitized bryozoan patch-reef in dolomitized ooid grainstones, on bedded skeletal grainstones and rudstones (coquinas), on dolomitic siliciclastic mudstones
	Newsome Bridge Quarry, North Deighton	Dolomitized inferred patch-reef in peloidal and oncoidal shelf grainstones lies on eminence in Carboniferous Permian unconformity; rock litter
Wetherby Member on Basal Permian Sands	Bilham Quarry	Basal shelf dolomite mudstones/wackestones of the Cadeby Formation on incoherent marine-redistributed aeolian sand-rock
	Ashfield Brick-clay Pit, Conisbrough	Basal dolomitic siliciclastic mudstones on atypically pebbly red friable sandstone

Kendall and Wroot (1924), Forbes (1958) and James *et al.* (1981). Sedgwick was unsure whether the gypsum at Ripon Parks formed part of the 'lower marl and gypsum' (now the Edlington Formation) or of the 'lower part of the upper red sandstone' (now the Roxby Formation), but Tute (1870, p. 5) favoured the former. Kendall and Wroot (1924) adopted the alternative (later) age and this view was accepted by visiting parties (e.g. Hudson *et al.,* 1938, p. 369) and by Forbes (1958). Smith (1974a, b, 1989), however, reverted to Tute's view on the evidence of increased knowledge of the local rock sequences and this interpretation has been accepted by James *et al.* (1981), Cooper (1986, 1987a, 1988) and Powell *et al.* (1992).

Description

The position of the River Ure Cliff is shown in (Figure 4.3). The section is about 500 m long and 6–9 m high, but the main interest centres on the central 220 m where rock exposures are almost continuous.

The general appearance of the central part of the section is well documented in the literature and, despite indisputable evidence of rapid recession (James *et al.,* 1981), changed relatively little between 1923/24 (Kendall and Wroot, 1924), and 1956/57 (Forbes, 1958, fig.2, reproduced here as (Figure 4.4)) and 1980 (James *et al.,* 1981, plate 22).

Correlation of the various beds present is somewhat uncertain because of lateral variation and the presence of many folds and minor faults, but Forbes (1958, p. 353) tentatively reconstructed an 8.4 m sequence about 140 m north of the southern end of the main exposure and Cooper and Powell (in Cooper, 1987a, pp. 50–53, and Powell *et al.,* 1992, p. 14) measured a 13.7 m sequence in the central section as a whole; Forbes' measured sequence coincides with the upper part of that given by Cooper and overall agreement is good. The section measured by Cooper and Powell and Powell *et* al. and supplemented by observations by Forbes (1958) and Smith (1974b and unpublished notes) may be summarized thus:

	Thickness (m)
Mudstone, dull red, pink and grey, partly dolomitic, with laminae and thin beds of grey argillaceous dolomite and thick mainly concordant lenses and sheet-veins of white fibrous gypsum; some thin siltstone beds	*c.* 2.1+
Dolomite mudstone, grey to grey-buff, thinly interbedded with subordinate grey to pink mudstone and dolomitic mudstone and with concordant lenses and sheet-veins of white fibrous gypsum	*c.* 1.0
Mudstone, green-grey, grey and dull red, partly silty, blocky to laminated, with thin beds of argillaceous siltstone, silty sandstone, dolomitic mudstone and argillaceous to gypsiferous dolomite mudstone; abundant, mainly concordant lenses and sheet-veins of white fibrous gypsum	*c.* 1.2
Mudstone, grey to pink-grey and grey-pink, partly dolomitic, with subordinate grey argillaceous siltstone and scattered to abundant, concordantly-elongated, grey to pink and orange gypsum nodules and a few mainly concordant lenses and sheet-veins of white fibrous gypsum	*c.* 1.5
Gypsum, mainly grey, alabastrine to coarse grained, evenly to undulatedly thin-bedded to laminated at several levels, with a few thin grey and red mudstone beds and laminae; a few to abundant mainly concordant lenses and sheet-veins of white fibrous gypsum	7.6+

The thick gypsum at the base of this sequence forms most of the southern part of the cliff (Figure 4.5), but mixed strata dominate the remainder. Sedimentary structures in the siliciclastic beds include ripple lamination in some of the thin sandstones and desiccation cracks in some of the mudstones; casts of halite crystals also occur in some of the mudstones (Smith, 1974b). The basal layer of the gypsum is commonly porphyroblastic, especially adjoining gypsum veins and carbonate layers. Petrographic examination by Forbes (1958) showed that relic anhydrite is widespread and locally abundant in the bedded gypsum but there are few clues to the primary sulphate crystal fabric. Forbes identified dolomite as the dominant carbonate mineral in these rocks but noted that there is also a little widespread calcite, and he also recorded small amounts of celestite, some as a vein mineral.

The lenses and sheet-veins of white fibrous gypsum are up to 0.12 m thick and some may be traced for more than 15 m (Forbes, 1958); they form up to 40% of some of the higher beds in the section, but are less abundant below. Shorter 'feeder' veins connect the main sheets and locally contribute to a reticulate network; many veins and sheets are compound, with evidence of several phases of opening, movement and filling. Crystal fibres are sub-vertical in the extensive sheet-veins, and parallel with the axial planes of the folds elsewhere (Forbes, 1958); many are curved, in response to movement of the walls of the veins during crystal growth. Forbes concluded that much of the fibrous gypsum was emplaced after most of the folding and faulting but that some of the thicker fibrous veins and sheets must have been formed before faulting was completed.

Folds at Ripon Parks (Figure 4.6) occur on a wide range of scales and an element of overfolding towards the north is common; they are tightest and most common in the upper half of the sequence, and Forbes (1958) recorded a plane of accommodation (decollement) between the relatively competent gypsum and the less competent overlying beds. Forbes also noted that the axes of the folds in the strongly contorted part of the cliff lie between west to east and north-west to southeast but that those in the more northerly faces trend between north-west to south-east and NNE to SSW. Polished (slickensided) surfaces abound in the contorted sequence, and are a feature of the walls of many of the veins.

Interpretation

The River Ure Cliff is one of the few places in Britain where thick evaporite rocks are preserved in a surface exposure and is also by far the best and most instructive natural section in the Edlington Formation. Although not yet fully understood, the dislocation of strata in the upper part of the section is a superb example of a type of disturbance commonly associated with evaporite rocks that have been deeply buried and subsequently exhumed.

Abundant evidence in the Ripon area points to relatively rapid subsurface dissolution of gypsum in the Edlington Formation (e.g. Tute, 1870; Smith, 1972, 1974b; Cooper, 1986, 1987a, 1988) and estimates by James *et al.* (1981) suggest that surface dissolution of the gypsum has been the main cause of Ure cliff recession averaging about 1 m in every 10–20 years between 1853 and 1956. Much higher rates of dissolution were calculated and observed for detached gypsum blocks. Given these high rates of dissolution, the preservation of the Ure river cliff gypsum is remarkable and can probably best be accounted for by a combination of the unusually great primary thickness (up to 30 m) of the gypsum (and its anhydrite precursor) in the Ripon area, protection by its cover of relatively impermeable mudstone and siltstone, and by only fairly recent exposure to river attack, perhaps as a result of meander migration. Even so, the presence of steeply tilted foundered strata of the Brotherton Formation at river level at the southern end of the GCR site (Smith, 1974b; Cooper, 1987a) shows that dissolution rates have been capable of,removing most or all of the gypsum there, perhaps indicating that other special factors accounted for the preservation of the gypsum cliff a few metres to the north.

The gypsum of the Ure cliffs is now thought likely to be the hydrated equivalent of anhydrite that is extensive at the base of the Edlington Formation (Smith, 1974a, b; James *et al.,* 1981; Cooper, 1987a) and which locally makes up more than half of the formation; this unit is tentatively correlated with the Hayton Anhydrite of English Zechstein Cycle lb age (Smith, 1974b, 1980a, 1989; James *et al.,* 1981), but no direct connection can be demonstrated and it seems more likely to be an approximate age equivalent than part of a continuous rock body. Primary fabrics having been obliterated by hydration, the gypsum of the Ure river cliffs offers few clues to its original depositional environment and, even in the subsurface, the equivalent anhydrite is almost entirely of the mosaic type with a dolomite net; thisnfabric, too, may be secondary and hence may throw little light on the rock's early history. Farther north, however, equivalent sulphate beds in the Edlington Formation on Teesside were shown by Goodall (1987) to have been formed subaqueously in a stratified, hypersaline lagoon complex subject to oscillating brine levels and shorelines, and Smith (1989, fig. 8) envisages a generally comparable, but more extensive, lagoonal setting for the Ure river cliff sulphates.

The mainly siliciclastic rocks above the gypsum in the river cliff are typical of more marginal deposits, perhaps formed when the area lay near the shoreline and sedimentation was on an extensive, brine-soaked coastal plain or sabkha that was periodically extensively inundated and subaerially exposed as the lagoon expanded and contracted. The dolomite in the upper part of the measured section may be a feather-edge of the Kirkham Abbey Formation, but this supposition, like the correlation of the anhydrite, is difficult to prove and the rock may be of lagoonal rather than marine origin. Thin dolomite beds are widespread in much of the comparable inner shelf/lagoon area of the Edlington Formation (Smith, 1974a, b, 1989, fig. 9). Halite, too, is widespread in the Edlington Formation in a NNW to SSE belt through York and may formerly have extended into the Ripon area but has since been dissolved.

The cause and locus of the dislocation in the higher parts of the section remains controversial, and both deep and shallower settings have their proponents. The latter setting, favoured by James *et al.* (1981), Cooper (1987a) and Powell *et al.* (1992), ascribes the dislocation to pressures created during the hydration of the precursor anhydrite, theoretically involving a 63% increase in volume. Most gypsum beds formed from anhydrite elsewhere are not strongly folded, however, and the most strongly dislocated beds here apparently contained less anhydrite than the relatively undeformed massive beds at the base of the section. Forbes (1958), moreover, commented that his petrographic evidence from the Ure river section tended to show that the anhydrite-gypsum transition took place at depth on a volume for volume basis. Though not venturing a positive opinion on the cause of the folding, Forbes nevertheless remarked on the readiness of gypsum to flow under stress, implying a deep-seated cause. The writer sympathizes with this view, believing that the initial phases of deformation may have taken place at considerable depth (perhaps before hydration) and resulted from plastic flow of the evaporites (including halite) caused by differential loading; in this interpretation the pressure differential could have arisen during the Coxwold–Gilling faulting episode or early phases of evaporite dissolution, and the initial dislocation was probably augmented by foundering related to continuing evaporite dissolution during the current cycle of uplift.

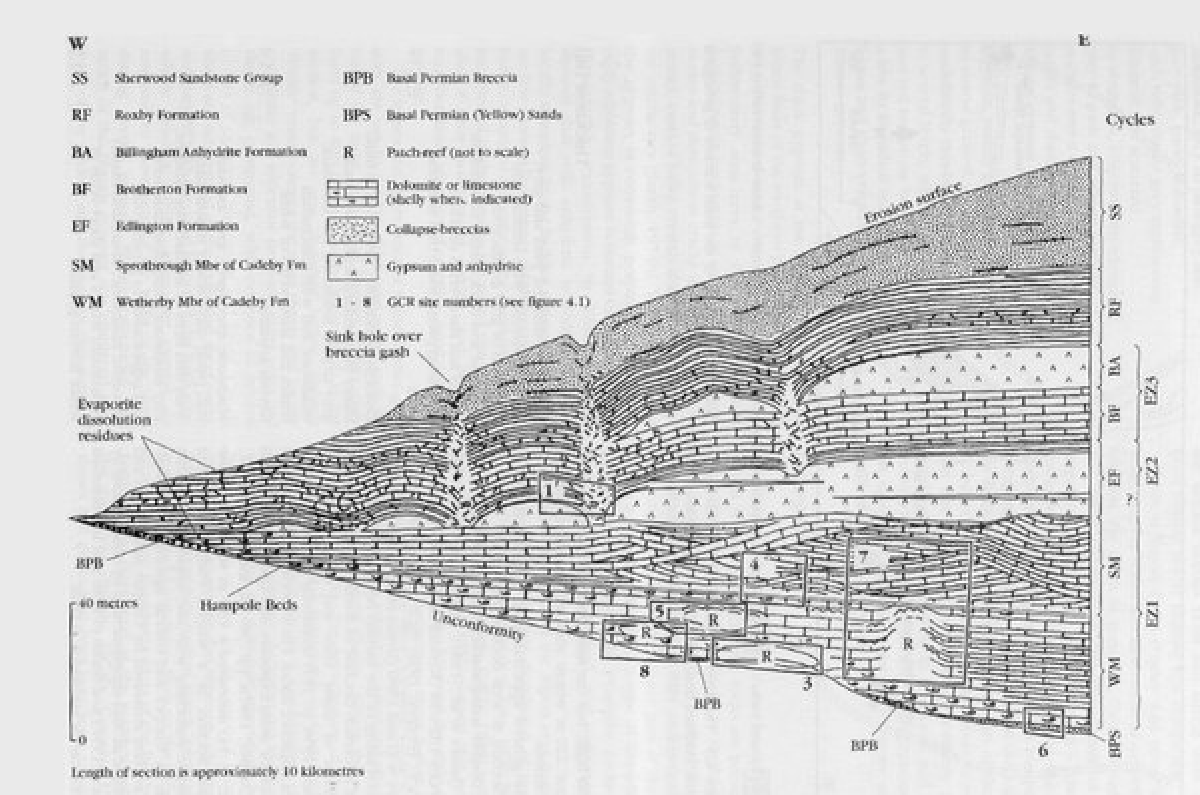
Future research

As one of the few remaining surface exposures of the Edlington Formation, the main value of this spectacular section lies in its general appearance and as an excellent example of what evaporites look like in the field. The petrology of secondary gypsum rocks is now reasonably well understood so that research into this aspect might not be fruitful. The crucial problem of what caused the dislocation of higher strata in the section remains unsolved, however, and awaits satisfactory resolution.

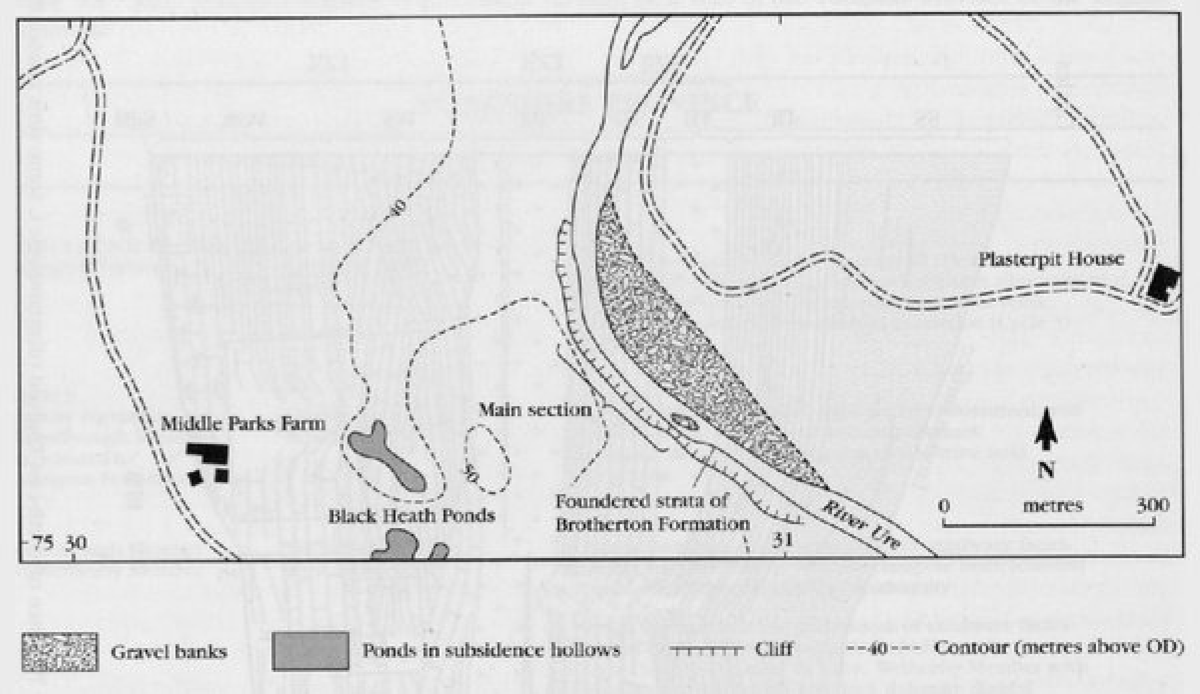
Conclusions

This is the only GCR site in which the Edlington Formation is exposed, and one of the few exposures of this formation in Yorkshire. The site is unique in that the sequence contains gypsum interfolded with associated mudstones and dolomites. The gypsum of the River Ure Cliff is considered to be the hydrated equivalent of precursor anhydrite, and as such, affords little evidence on the original environment of formation. The deformation of the gypsum has resulted from the plastic flow of the evaporites under pressure, probably at depth and perhaps in association with halite (rock salt). The preservation of evaporite rocks is also unusual, because in most parts of England only relic texture, evidence of foundering, and insoluble residues survive as reminders of their former presence.

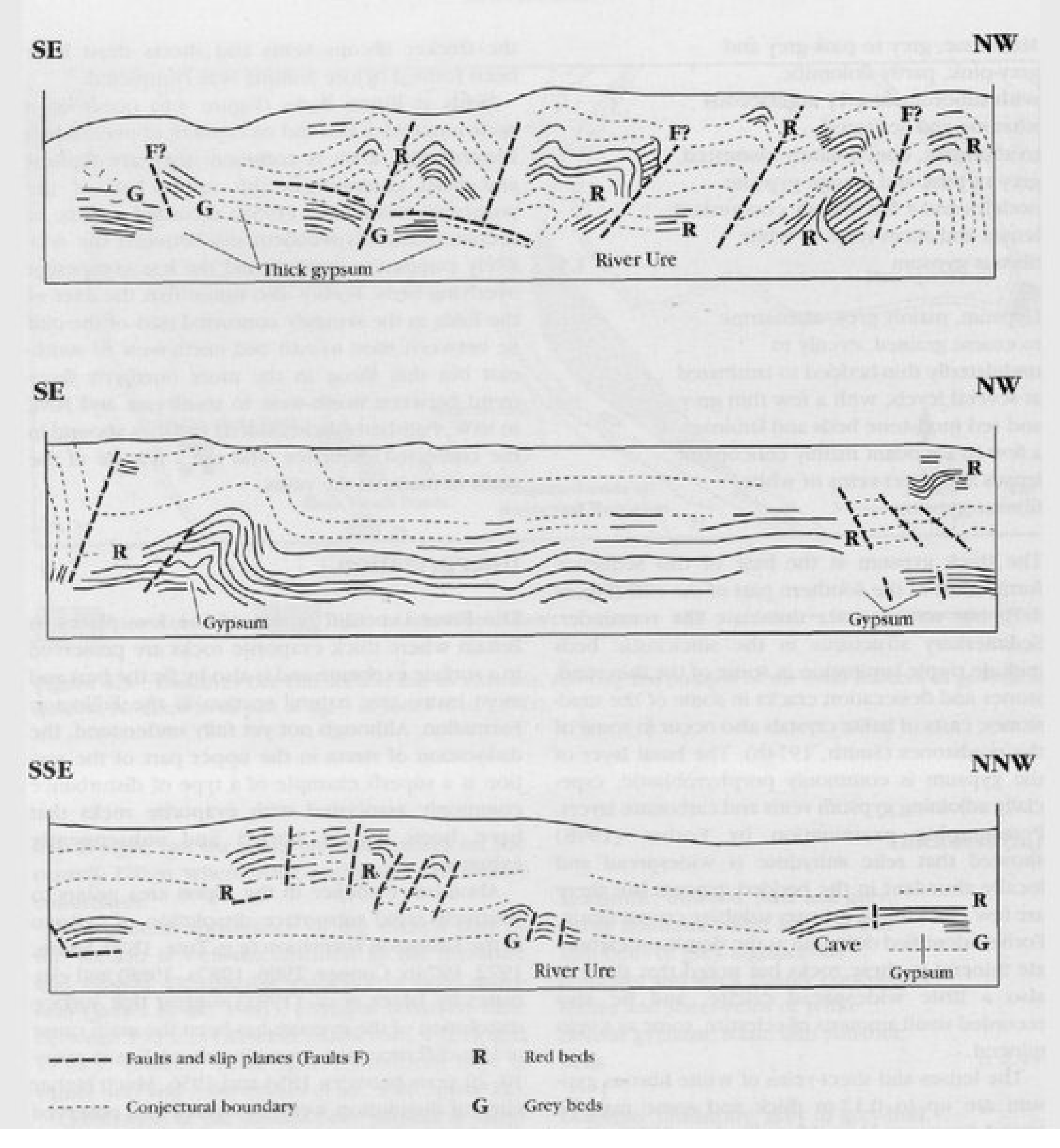
References



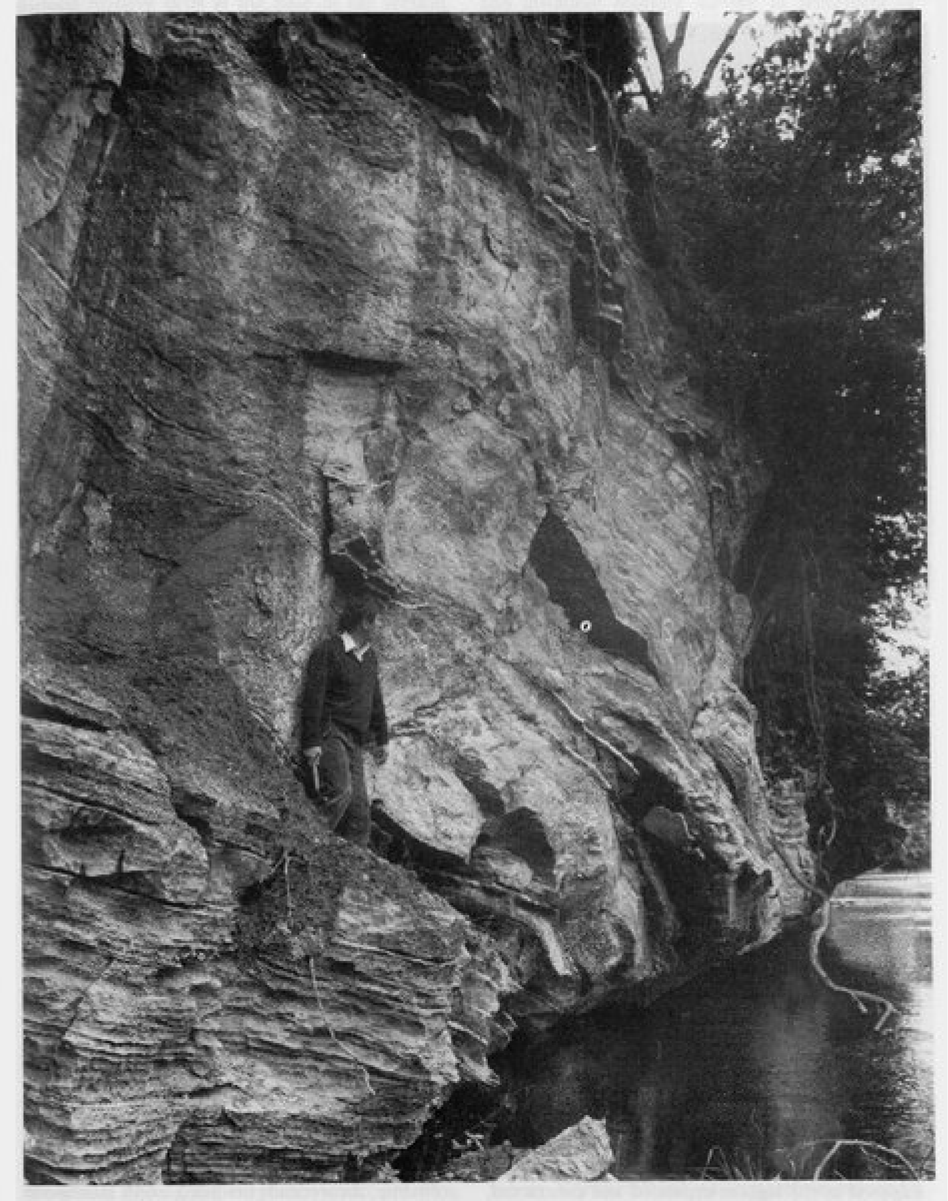
(Figure 4.2) Approximate stratigraphical position of marine Permian GCR sites in the Yorkshire Province of north-east England (diagrammatic). Some sites cannot be shown on this line of section and have been omitted.



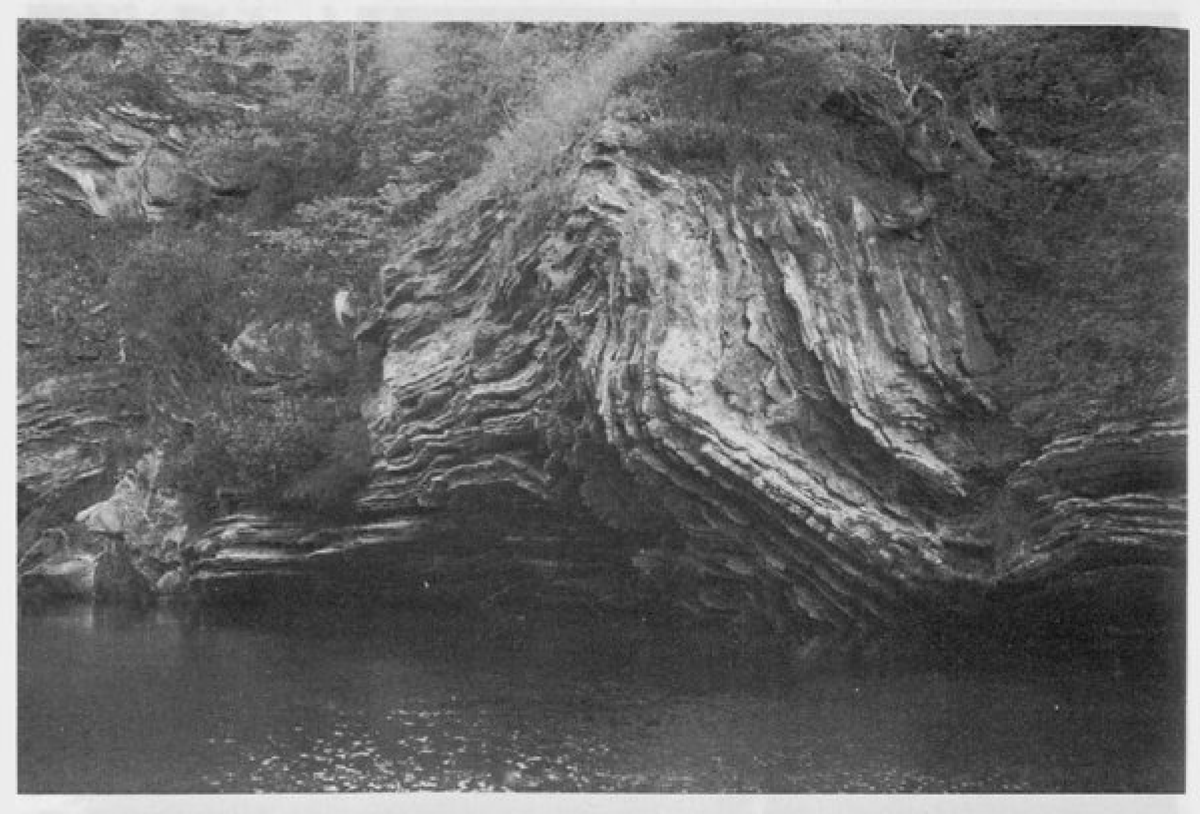
(Figure 4.3) The River Ure cliff section and its environs, showing the position of the main features of geological interest. Modified from part of fig. 3 of James et al. (1981).



(Figure 4.4) Sketch (top left to bottom right) of the main face of the River Ure Cliff, showing the principal geological features; slightly modified from Forbes (1958, fig. 2). Gypsum lies mainly at the base of the cliff except at the southern end. Total length of section shown is about 220 m, height about 7.5 m.



(Figure 4.5) Gypsum, possibly equivalent to the Hayton Anhydrite, forming most of the river cliff at the southern end of the main rock section at Ripon Parks. Note the abundant sub-concordant sheet-veins of fibrous gypsum (white) in the upper part of the section. (Photo: A.H. Cooper.)



(Figure 4.6) Sharp fold in mainly siliciclastic strata of the Edlington Formation with bedded gypsum (?=Hayton Anhydrite) at the base, and with many sub-concordant sheet-veins of fibrous gypsum (white). The fold is still recognizable at the southern end of the middle sector in Forbes' drawing of 1958 (Figure 4.4). The cliff is about 6 m high at this point. (Photo: A.H. Cooper.)