EXCURSION

The northern margin of the Derbyshire carbonate platform around Castleton

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The aims of this field trip were to demonstrate the sedimentary evolution of the northern margin of the Derbyshire carbonate platform during the Asbian and Brigantian, to explain the conditions of deposition of Brigantian carbonate sand bodies associated with the shelf margin and to demonstrate the sequence of events associated with the demise of carbonate production on the Derbyshire carbonate platform. The localities visited and the stratigraphy of the area are shown in Figure 1.

1. Cave Dale (SK 149 826)

During the Asbian, the Derbyshire carbonate platform was a flat-topped shelf over which water depth during sea level highstands was probably not greater than 10 to 15m. The marginal slope of the Derbyshire carbonate platform had a depositional dip of 30-40° towards the surrounding basin in which the water was some several hundred metres deep (Broadhurst and Simpson, 1973). Cave Dale provides a section across the shelf break from limestones deposited on the shelf top to the upper part of the marginal slope of the carbonate platform (Fig. 2). The shelf top limestones in the south part of the Dale are recognised by the generally flat bedding. Near the mouth of the Dale, the dip increases abruptly from near horizontal to 25-30° northwards, representing the transition from the shelf edge to the upper part of the marginal slope of the carbonate platform. The transition from shelf top to margin was abrupt over a distance of some tens of metres. The geometry of the transition shows that the carbonate shelf was accreting vertically at this time.

2. Bradwell Dale (SK 172 805)

At the end of the Asbian, a bioclastic carbonate sand body developed at the margin of the carbonate platform. Bradwell Dale provides a section through this carbonate sand body perpendicular to the shelf edge. The shelf break is probably present within a few hundred metres to the north of the exposure. The "anticlinal" structure at the base of the cliff on the eastern side of the dale represents the crest of a large-scale submarine bedform made up of crinoidal limestone. The bedform crest trends east-west, parallel to the shelf margin (Fig. 3).

The bedform formed by initial build-up of thinly-bedded (0.05-0.1m) crinoidal limestone. The presence of small-scale cross stratification shows that the bedform surface was covered in ripples, probably caused by wave reworking. The flanks of the bedform dip some 12-14° towards the shelf and shelf margin. The style of growth then changed from vertical to lateral accretion with the development of tabular to convex-up, shelfward and basinward-dipping foresets up to 0.5m in thickness. Basinward-dipping foresets dip at 20-22° and are made

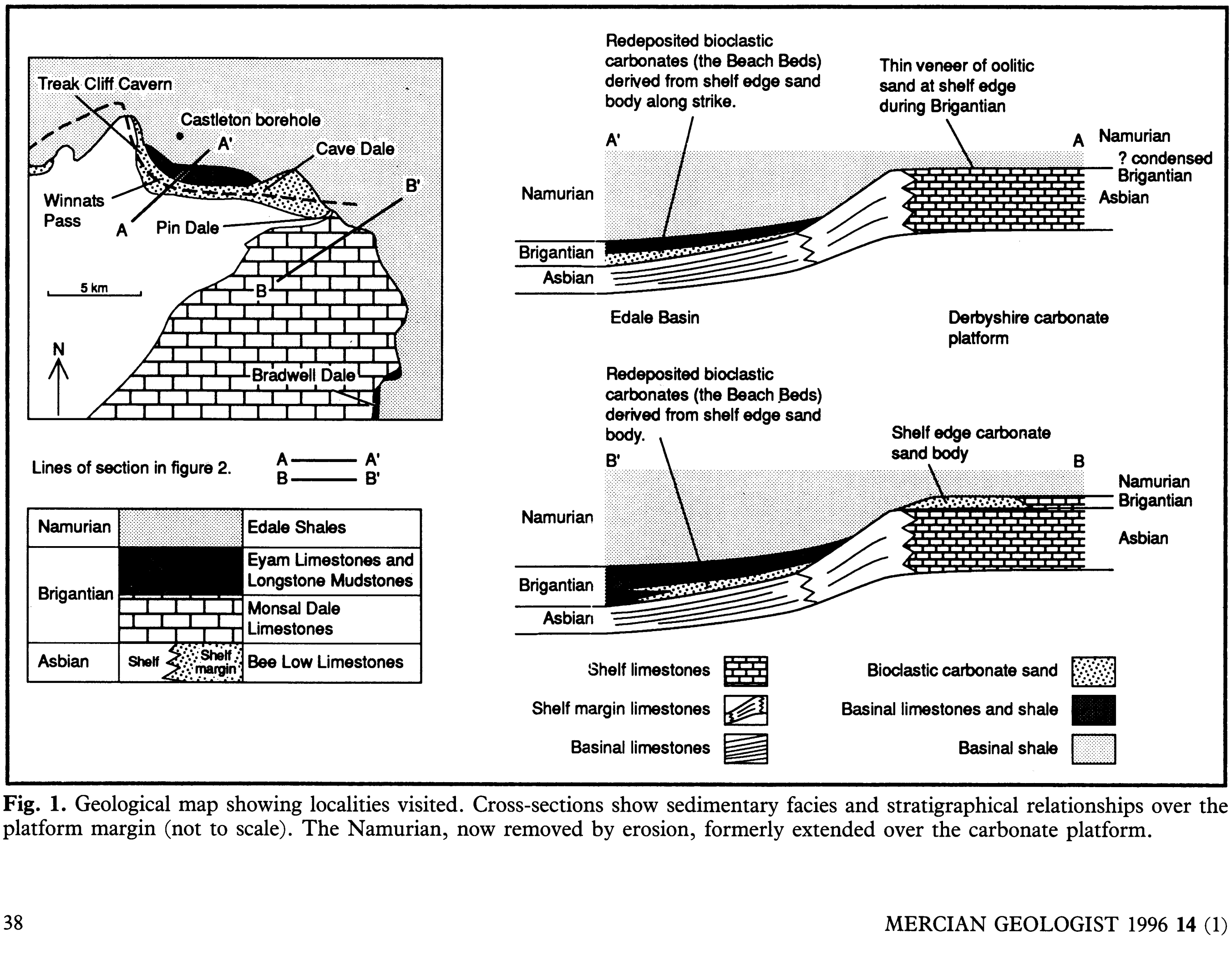

Fig. 1. Geological map showing localities visited. Cross-sections show sedimentary facies and stratigraphical relationships over the platform margin (not to scale). The Namurian, now removed by erosion, formerly extended over the carbonate platform.

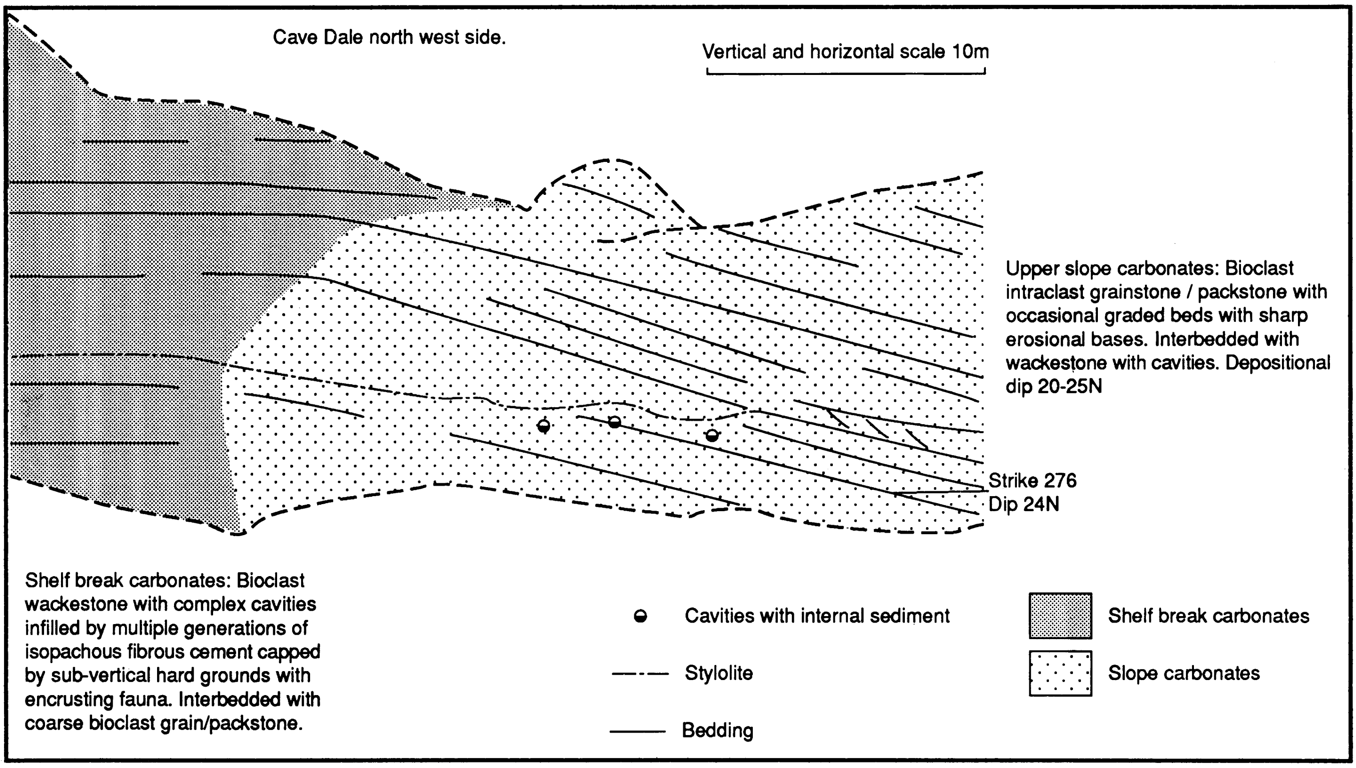

Fig. 2. Northern margin of the Derbyshire carbonate platform. Shelf to upper slope transition, western side of Cave Dale.

up of superimposed tabular cross-beds up to 0.2m thick. Similar shelfward dipping foresets dip at 8-12°. These indicate alternating shelf- and basinward transportation of carbonate sand by migrating mega-ripples which covered the large bedform. The latter accreted mainly in a shelfward direction, although some basinward accretion also took place.

3. Pin Dale (SK 160 823)

Pin Dale Quarry exposes the late Asbian/early Brigantian bioclastic carbonate sand body in a section which contains the shelf break. The main part of the quarry contains flat-bedded bioclastic limestones which were deposited at the edge of the flat-topped shelf. At the north east end of the quarry, coarse bioclastic and intraclastic limestones show increasing dip to the north-east (basinward), representing sediment spillage over the platform margin and into the basin. A large-scale submarine bedform is present. As seen in Bradwell Dale, this also shows a two stage development of initial vertical aggradation followed by basinward progradation (Fig. 4).

These carbonate sand bodies are made up of the following limestone types:
a) Micritised bioclast peloid grainstone. These limestones consist of disarticulated and rounded fossil fragments such as crinoids, brachiopods, corals, foraminifera and bryozoans. They were deposited in a high energy environment which removed any carbonate mud and other fine-grained sediment from the matrix. Most grains have been wholly or partly micritised. This process took place on the sea floor as a result of infestation of the grains by algae which bored into the grains like microscopic woodworm. When the algae died, the borings were infilled by micrite and the surrounding grain was progressively replaced by the micrite. Micritisation requires conditions of slow sedimentation or the grains become buried and cannot be colonised by algae. Abundant micritised grains therefore indicate periods of slow sedimentation, perhaps related to bedform inactivity during fairweather conditions.
b) Bioclast grainstone. These limestones also consist of disarticulated and rounded fossil fragments which were deposited in a high energy environment. The grains, however, rarely show signs of micritisation, indicating rapid deposition. They may have been deposited during bedform migration under the influence of storms.
c) Bioclast packstone/wackestone. These limestones consist of disarticulated and rounded fossil fragments together with carbonate mud, indicating deposition in low to moderate energy conditions. This sediment was deposited in more sheltered conditions down the flanks of the bedforms.
d) Bioclast wackestone. These limestones consist predominantly of carbonate mud with some reworked fossil fragments. They were deposited in low energy conditions in sheltered settings, such as troughs between bedforms, within the carbonate sand body.

The bedforms are often developed on surfaces which show evidence of karst and calcrete development and were therefore subaerially exposed. In some cases, clasts or calcrete reworked from the underlying subaerial surface are present in the bedforms. This implies that the bedforms developed following a sea level rise which flooded the exposed carbonate platform (Fig. 5). At first, sea level rose faster than the rate of sedimentation; water depth therefore increased and there was no constraint to the vertical growth of the bedforms. The initial phase of vertical accretion thus

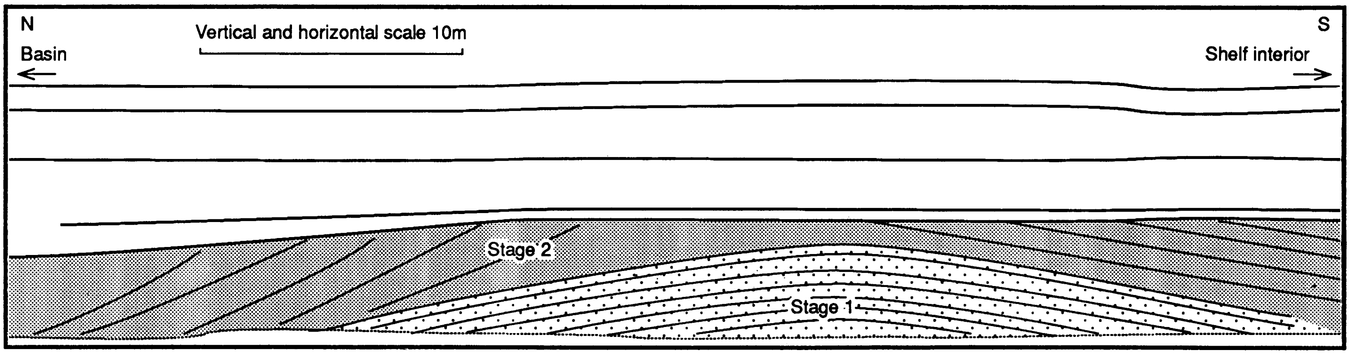

Fig. 3. East side of Bradwell Dale: Large bedform in shelf margin carbonate sand body.

took place at this time. Eventually, sea level rise slowed, allowing sedimentation to catch up. Vertical accretion of the bedforms became constrained and was replaced by lateral progradation. The predominant direction of carbonate sand transport was basinwards, with some bedforms slipping over the shelf margin into the basin.

4. Winnats Pass (SK 138 827)

The slopes to the north and east of Winnats Pass represent the exhumed marginal slopes of the Asbian carbonate platform equivalent to those in Cave Dale. Exposures on the sides of Winnats Pass show the transition from shelf to marginal slope carbonates (Fig. 6). The possible origins of Winnats Pass were reviewed by Ford (1987), who concluded that it is unlikely to represent an exhumed submarine canyon that was present during deposition. At the mouth of Winnats Pass, the Brigantian 'Beach Beds' are exposed and it is possible to show that they onlap and therefore post-date the Asbian platform margin. The 'Beach Beds' are also present in the Castleton borehole, where they comprise a series of graded, amalgamated coarse bioclastic turbidites which pass upwards into basinal shales and thinly bedded, fine-grained bioclastic turbidites. The 'Beach Beds' probably represent part of a deep-water carbonate sand apron which was draped over the lower slope of the carbonate platform margin (Gutteridge, 1991). This apron was made up of re-sedimented limestones, derived from the bioclastic carbonate sand body complex present at the shelf margin along strike to the east.

Brigantian sedimentation in the shelf-top setting above the Winnats Pass is represented by a thin veneer of superficial ooids developed around coarse sand-sized bioclastic and intraclastic nuclei. These required slow sedimentation to form and represent a period of minimal deposition in the shelf-top setting which may have lasted from the Asbian through the Brigantian. At the same time, the bioclastic carbonate sand bodies were accumulating at the shelf margin a few kilometres along strike to the east. Seismic lines crossing the platform margin to the east of the outcrop suggest that the carbonate platform prograded towards the north or northeast. Evidence from the whole length of the outcrop suggests that the northern margin of the

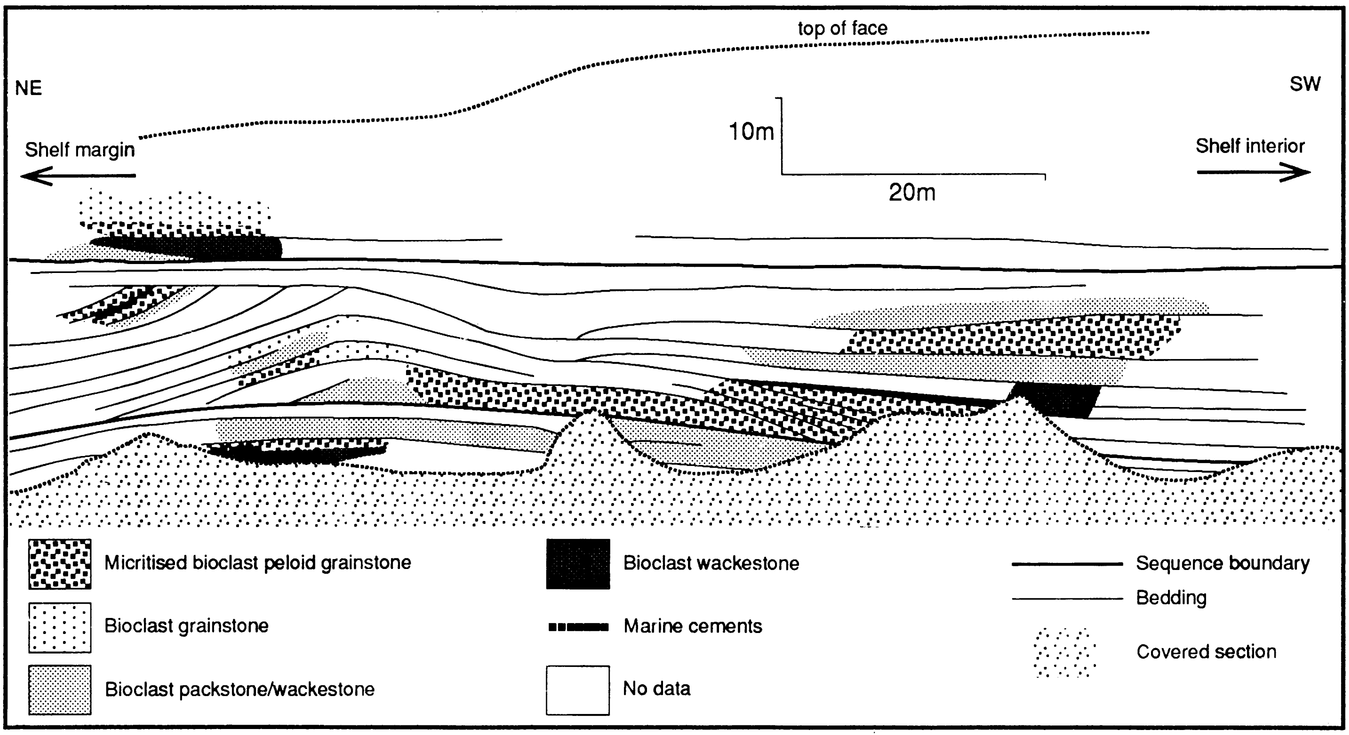

Fig. 4. Internal geometry and microfacies of the shelf margin carbonate sand body, Pin Dale (from Gawthorpe and Gutteridge, 1990).

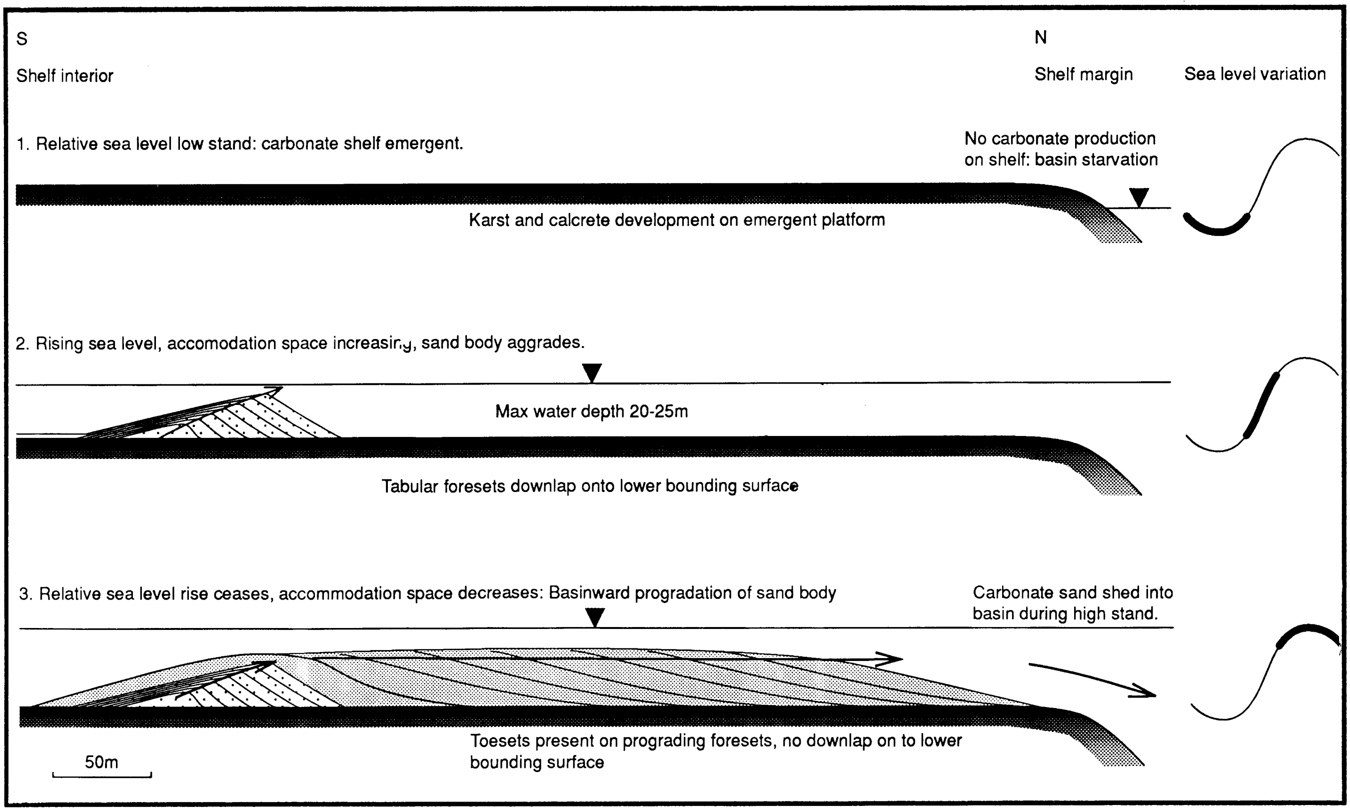

Fig. 5. Development of the shelf margin carbonate sand body. Northern margin of the Derbyshire carbonate platform (from Gawthorpe and Gutteridge, 1990).

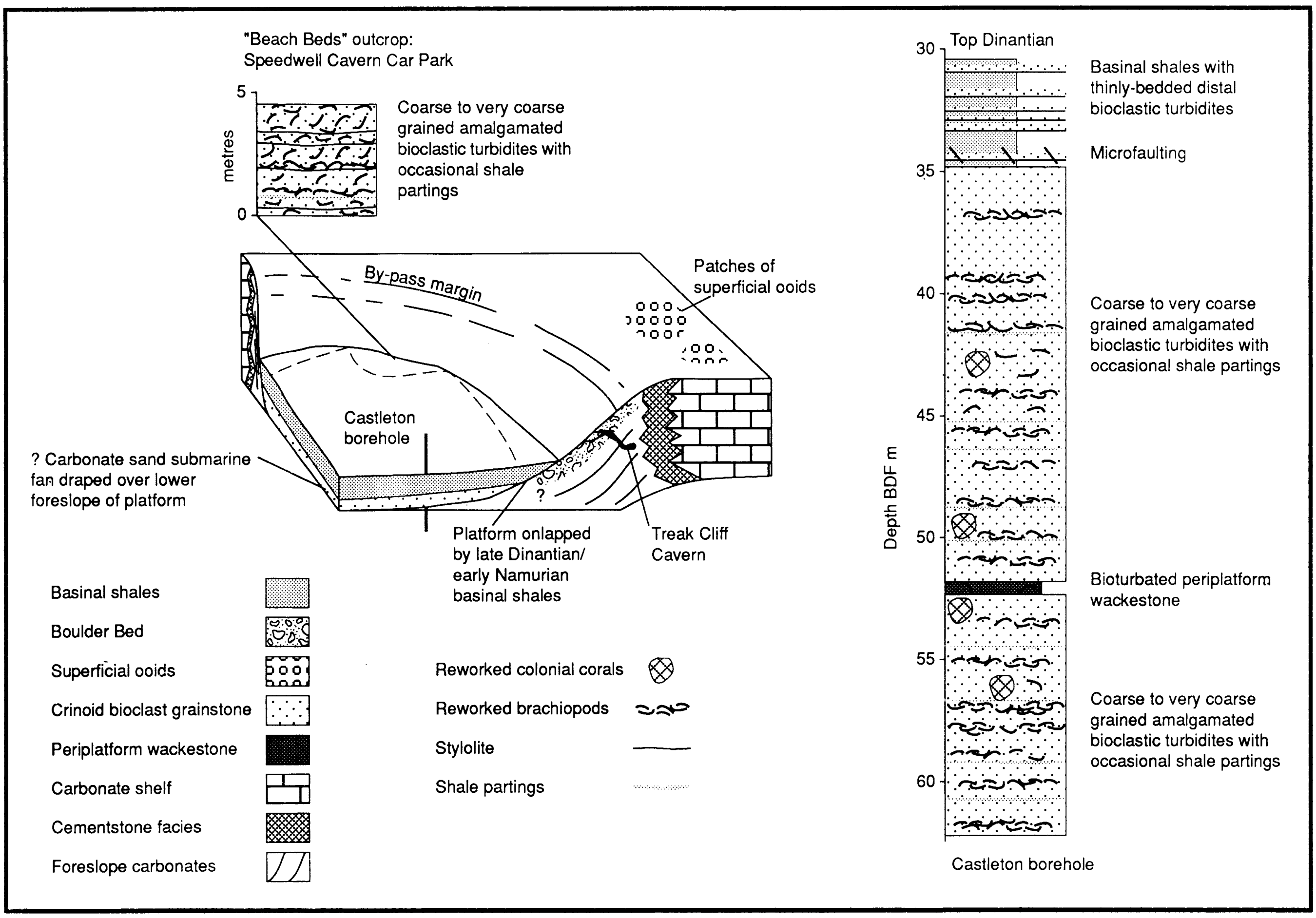

Fig. 6. Asbian carbonate shelf margin and Brigantian resedimented bioclastic carbonate sands; Winnats Pass area.

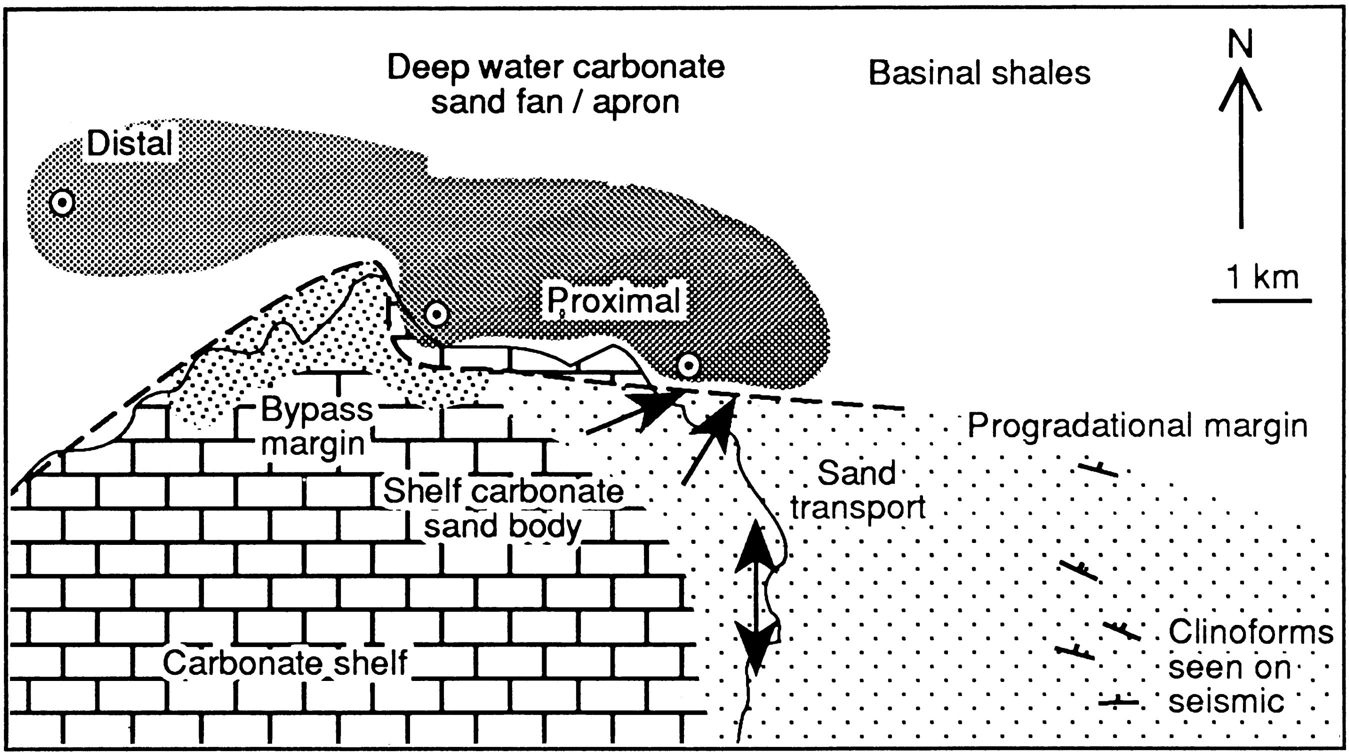

Fig. 7. Brigantian carbonate sand bodies at the northern margin of the Derbyshire carbonate platform.

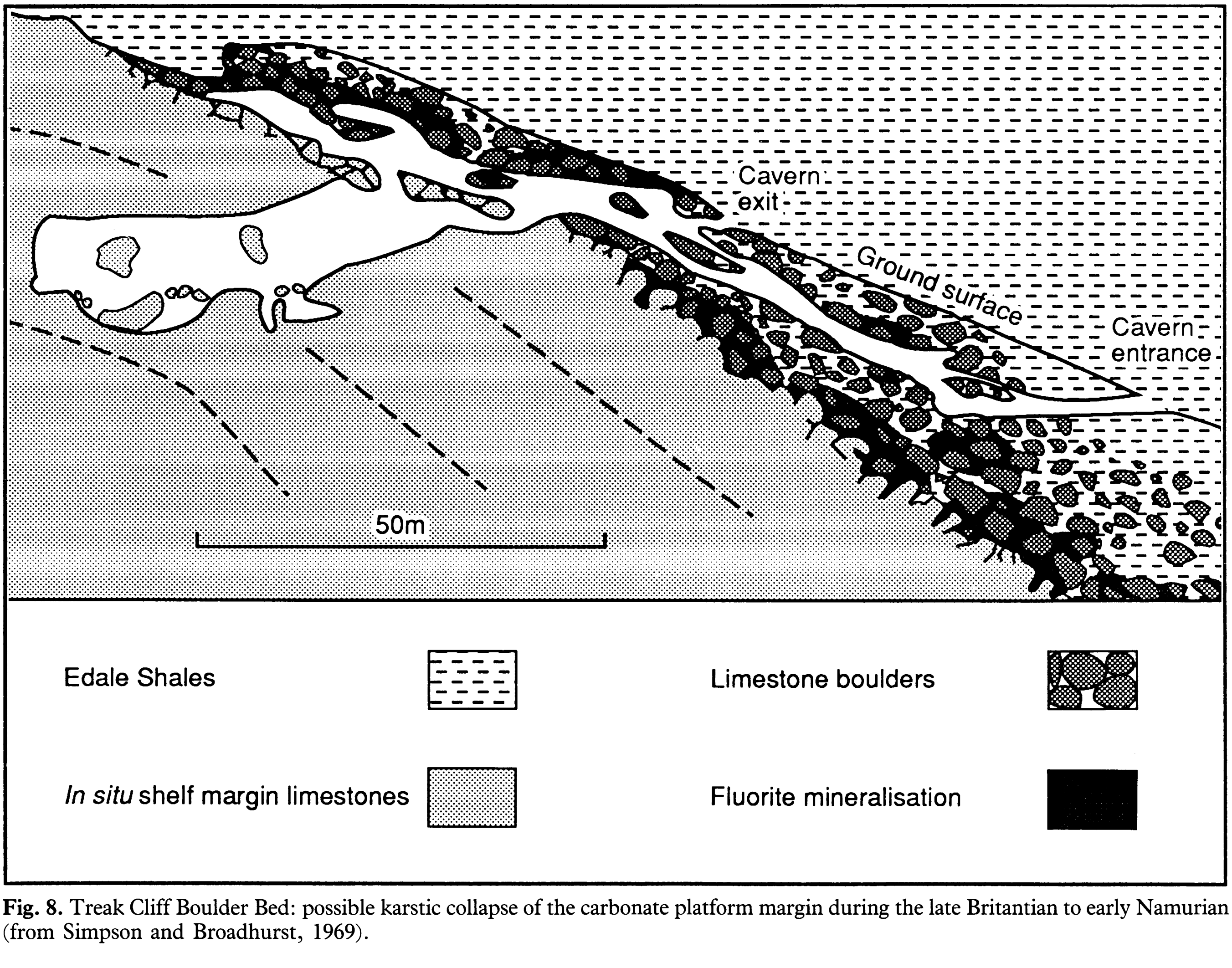

Fig. 8. Treak Cliff Boulder Bed: possible karstic collapse of the carbonate platform margin during the late Britantian to early Namurian (from Simpson and Broadhurst, 1969).

Derbyshire carbonate platform showed a marked differentiation along strike, as shown by Figure 7.

The platform margin was at its highest in the Winnats Pass area. This may have been a by-pass margin where there was minimal sediment accumulation. A bioclastic carbonate sand body showed progressive thickening along strike to the east. The offshelf transportation of carbonate sand from the shelf margin carbonate sand body formed a deep-water, submarine carbonate sand apron, represented by the "Beach Beds" draped over the lower platform margin.

5. Treak Cliff Cavern (SK 135 831)

Treak Cliff Cavern provides a unique transect through the carbonate platform margin, demonstrating the sequence of events associated with the demise of the Derbyshire carbonate platform (Fig. 8). The cave entrance is in the early Namurian Edale Shales, which represent the marine and pro-delta muds that buried the Derbyshire carbonate platform. The walls of the passage are formed by a boulder bed with pockets of Edale Shale preserved between the boulders. The boulders are composed of shelf-top and margin carbonates. They indicate collapse of the shelf margin which probably took place as a result of subaerial exposure during the late Brigantian to early Namurian. The attitude of sedimentary features in the boulders suggests that there has been little down-slope movement and implies that the boulder bed formed by *in situ* collapse. The rounding of the boulders may have been caused by dissolution between the boulders, in cavities within the limestone and also as a replacement of the limestone, probably during late Carboniferous burial. The characteristic colour of the Blue John results either from the presence of hydrocarbon inclusions or from possible lattice damage induced by radioactive decay. The back of the cavern is within *in situ* shelf margin limestones of Asbian age, with a depositional dip of 30-40° to the east indicated by the geopetal attitude of cavity infills and the alignment of crinoid stems (Broadhurst and Simpson, 1967).

References

Broadhurst, F. M. and Simpson, I. M., 1967. Sedimentary infillings of fossils and cavities in limestones at Treak Cliff, Derbyshire. *Geological Magazine*, **104**, 443-448.

Broadhurst, F. M. and Simpson, I. M., 1973. Bathymetry on a Carboniferous reef. *Lethaia*, **6**, 367-81.

Ford, T. D., 1987. The origin of the Winnats Pass, Castleton, Derbyshire. *Mercian Geologist*, **10**, 241-249.

Gawthorpe, R. L. and Gutteridge, P., 1990. Geometry and evolution of platform margin bioclastic shoals, late Dinantian (Mississippian), Derbyshire, UK. *In* Tucker, M. E., Wilson J. L., Crevello, P. D., Sarg, J. R. and Read, J. F. (Eds). *Carbonate Platforms: facies, sequences and their evolution.* Special Publication of the International Association of Sedimentologists **9**, 39-54.

Gutteridge, P., 1991. Aspects of Dinantian sedimentation in the Edale Basin, north Derbyshire. *Geological Journal*, **26**, 245-269.

Simpson, I. M. and Broadhurst, F. M., 1969. A boulder bed at Treak Cliff, north Derbyshire. *Proceedings of the Yorkshire Geological Society*, **37**, 141-151.

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