REVISION OF THE MONSAL DALE/EYAM LIMESTONES BOUNDARY (DINANTIAN) IN DERBYSHIRE

by

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Summary

Carbonate mud buildups which occur in association with the Monsal Dale/Eyam Limestones boundary have been regarded as part of the Eyam Limestones Formation. A sedimentological study of this boundary shows that these carbonate mud buildups are separated from the overlying Eyam Limestones by a stratigraphical break which represents a period of subaerial emergence. The base of the Eyam Limestones is therefore redefined so that the carbonate mud buildups are included within the Monsal Dale Limestones.

Introduction

The stratigraphical boundary discussed is between the Monsal Dale Limestones Formation (below) and the Eyam Limestones Formation (above); both of which are of Brigantian (late Dinantian) age (Fig. 1). According to Aitkenhead & Chisholm (1982) the numerous carbonate mud buildups which occur in association the Monsal Dale/Eyam Limestones boundary are included within the Eyam Limestones. Sedimentological studies of these carbonate mud buildups by Adams (1980) and Gutteridge (1983) have shown that they rest comfortably on the underlying Monsal Dale Limestones and are separated from the overlying Eyam Limestones by a stratigraphical break which represents a period when much of the Derbyshire carbonate platform was emergent. The objectives of this paper are to describe the stratigraphical relationships of these carbonate mud buildups and to revise the base of the Eyam Limestones so that the carbonate mud buildups are placed within the underlying Monsal Dale Limestones.

This revision of the Monsal Dale/Eyam Limestones boundary is concerned only with sections in which carbonate mud buildups are present. The position of the boundary in the four type sections defined by Aitkenhead & Chisholm (1982) is not affected as these sections do not contain carbonate mud buildups.

Stratigraphical position of the carbonate mud buildups

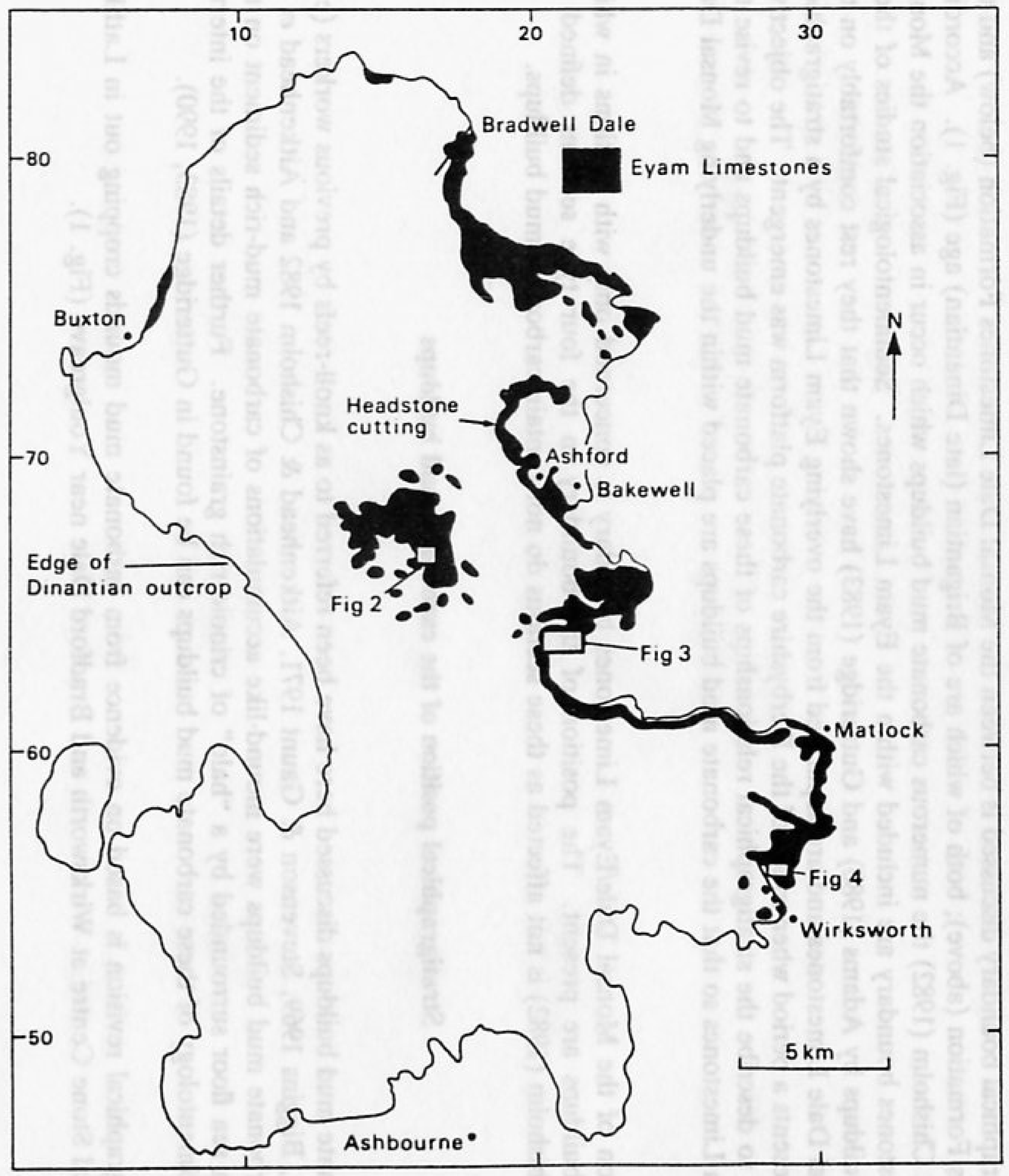
The carbonate mud buildups discussed here have been referred to as knoll-reefs by previous workers (e.g. Smith *et al.* 1967, Biggins 1969, Stevenson & Gaunt 1971, Aitkenhead & Chisholm 1982 and Aitkenhead *et al.* 1985). These carbonate mud buildups were mound-like accumulations of carbonate mud-rich sediment on the former Dinantian sea floor surrounded by a "halo" of crinoid-rich grainstone. Further details of the internal structure and sedimentology of these carbonate mud buildups can be found in Gutteridge (1983, 1990).

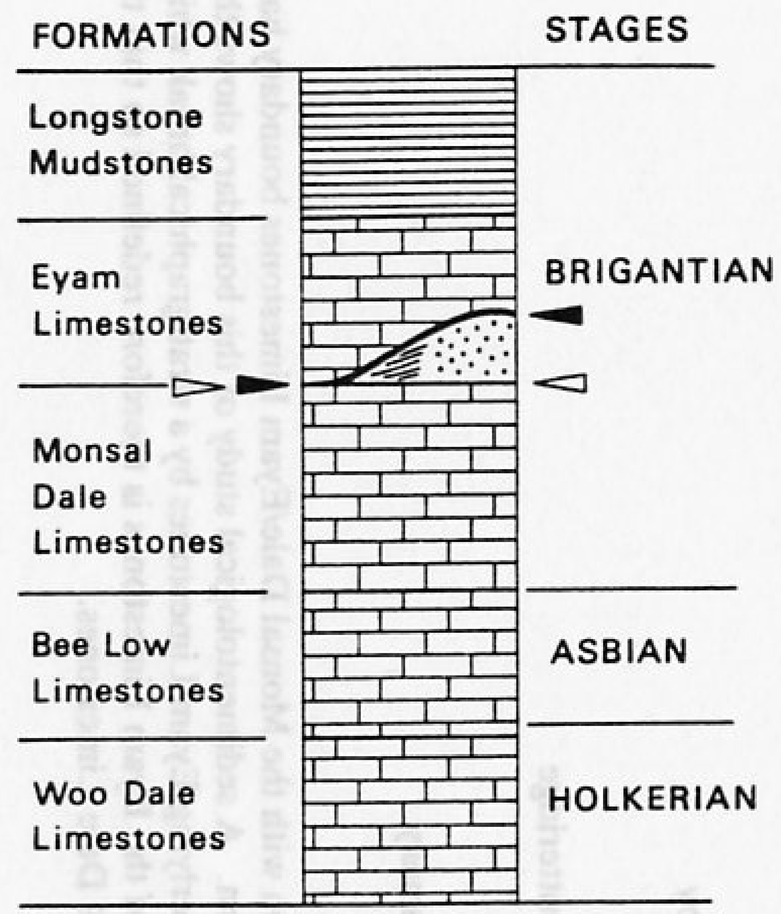
This stratigraphical revision is based on evidence from carbonate mud mounds cropping out in Lathkill Dale, the National Stone Centre at Wirksworth and Bradford Dale near Youlgreave (Fig. 1).

(a) Lathkill Dale

Carbonate mud buildups are present at the western end of Lathkill Dale (SK1666) and are exposed around Ricklow Quarry (SK164661), (Fig. 2).

The base of the carbonate mud buildups seen in the sides of Lathkill Dale is marked by a conformable transition from thickly-bedded pale bioclast peloid packstone upwards into medium-bedded bioclast





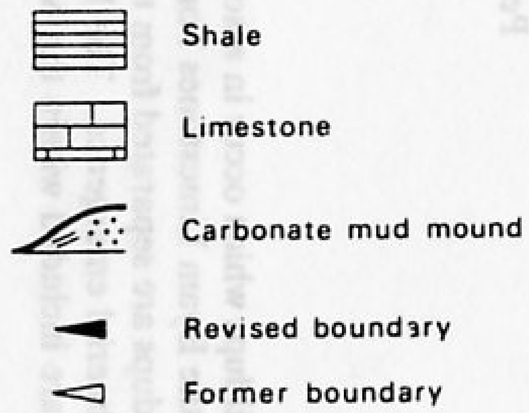


Fig. 1. Outcrop of the Eyam Limestones on the Derbyshire carbonate platform (from Aitkenhead & Chisholm 1982). Stratigraphical column indicates position of Monsal Dale/Eyam Limestones boundary (open arrow) defined by Aitkenhead & Chisholm (1982), and the revised position of the boundary where carbonate mud buildups are present (solid arrow). Localities referred to in the text: 1. Lathkill Dale, 2. Ricklow Quarry, 3. National Stone Centre, Wirkworth and 4. Bradford Dale.

wackestone/packstone. The latter facies contains several tabular mud-mounds up to 1 m in thickness which represent the initial stage of carbonate mud buildup growth. There is no evidence of an unconformity between the Monsal Dale Limestones and these carbonate mud buildups as determined by Shirley (1959).

The top surface of the carbonate mud buildups is marked by a calcrete profile (Adams 1980) which can be traced onto the top surface of the laterally-equivalent Monsal Dale Limestones. These carbonate mud buildups contain vadose cements and fissures which are partly infilled with speleothem cements (Adams 1980, Gutteridge 1983). These speleothem deposits contain calcrete clasts and are overlain by sediment derived from the overlying Eyam Limestones. This demonstrates that these vadose cements formed during the episode of subaerial exposure before deposition of the Eyam Limestones.

Where carbonate mud buildups are absent, the top of the Monsal Dale Limestones is marked either by a calcrete horizon or a palaeokarstic surface. At the base of the overlying Eyam Limestones, an impersistent, fenestral wackestone interpreted as a peritidal deposit is present which is overlain by a medium bedded, medium grey bioturbated bioclast wackestone deposited in a subtidal environment (Gutteridge 1983, 1984).

The sequence of events associated with the Monsal Dale/Eyam Limestone boundary in Lathkill Dale is interpreted as follows:

1. Deposition of the Monsal Dale Limestones in marine subtidal conditions.
2. Growth of carbonate mud buildups in a subtidal setting.
3. Subaerial exposure of the carbonate mud buildups and the surrounding Monsal Dale Limestones. This resulted in calcrete development on the carbonate mud buildups and the top surface of the Monsal Dale Limestones together with vadose cementation of the carbonate mud buildups.
4. Deposition of the Eyam Limestones, which initially took place in a peritidal environment which was followed by establishment of a subtidal environment as sea level rose.

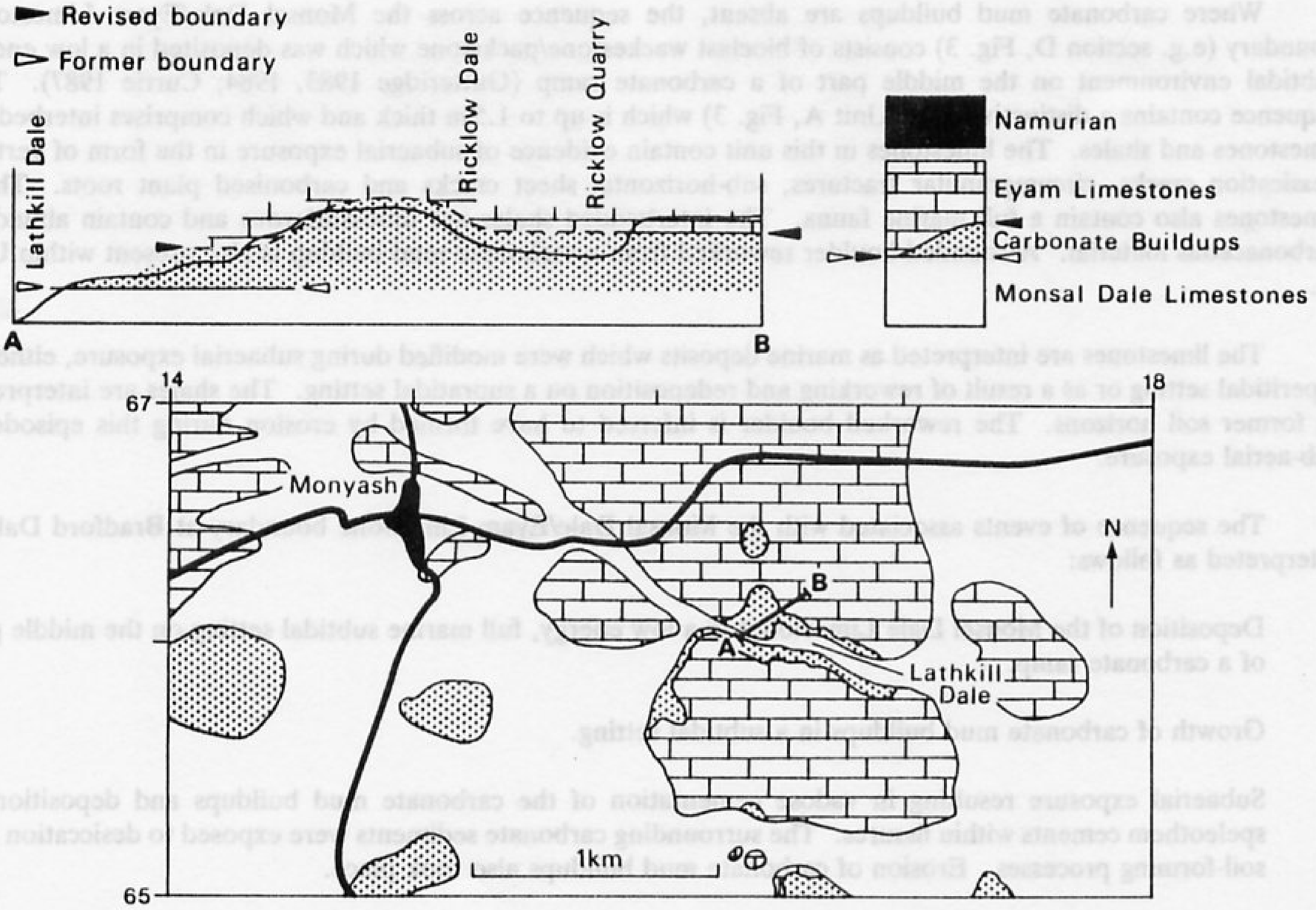


Fig. 2. Stratigraphical relationships in Ricklow Quarry (SK16456615).

(b) Wirksworth

The Monsal Dale/Eyam Limestones boundary is exposed in a series of disused quarries immediately to the north of Wirksworth (the National Stone Centre SK2855). See Fig. 4, p. 77.

The contact between the carbonate mud buildups and the underlying Monsal Dale Limestones shows no evidence of any significant stratigraphical break. These carbonate mud buildups contain vadose cements and fissures which are infilled with speleothem cements similar to those seen at Lathkill Dale. There is also an impersistent calcrete developed on the top of these carbonate mud buildups. The contact between the Monsal Dale Limestones and the Eyam Limestones away from the carbonate mud buildups is not exposed. These carbonate mud buildups are buried by bioclast (mainly crinoidal) grainstone which was deposited in a bioclastic shoal complex associated with the southern margin of the Derbyshire carbonate platform (Gawthorpe *et al.* 1990).

The sequence of events associated with the Monsal Dale/Eyam Limestone boundary near Wirksworth is interpreted as follows:

1. Deposition of the Monsal Dale Limestones in marine subtidal conditions.

2. Growth of carbonate mud buildups in a subtidal setting.

3. Subaerial exposure, which resulted in calcretisation together with vadose cementation of the carbonate mud mounds.

4. Deposition of the Eyam Limestones as a result of relative sea level rise. In this case, the depositional environment was a high energy crinoidal grainstone shoal developed in association with the southern margin of the Derbyshire carbonate platform.

(c) Bradford Dale

The succession across the Monsal Dale/Eyam Limestone boundary, together with several carbonate mud buildups is exposed in Bradford Dale (SK215642), (Fig. 3). The carbonate mud buildups contain vadose cements and fissures which are partly infilled with speleothem cements indicating an episode of subaerial exposure immediately after deposition.

Where carbonate mud buildups are absent, the sequence across the Monsal Dale/Eyam Limestones boundary (e.g. section D, Fig. 3) consists of bioclast wackestone/packstone which was deposited in a low energy subtidal environment on the middle part of a carbonate ramp (Gutteridge 1983, 1984; Currie 1987). This sequence contains a distinctive unit (Unit A, Fig. 3) which is up to 1.5 m thick and which comprises interbedded limestones and shales. The limestones in this unit contain evidence of subaerial exposure in the form of vertical dessication cracks, circumgranular fractures, sub-horizontal sheet cracks and carbonised plant roots. These limestones also contain a full marine fauna. The interbedded shales are unfossiliferous and contain abundant carbonaceous material. A rounded boulder reworked from a carbonate mud buildup is also present within Unit A.

The limestones are interpreted as marine deposits which were modified during subaerial exposure, either in a peritidal setting or as a result of reworking and redeposition on a supratidal setting. The shales are interpreted as former soil horizons. The reworked boulder is inferred to have formed by erosion during this episode of sub-aerial exposure.

The sequence of events associated with the Monsal Dale/Eyam Limestone boundary at Bradford Dale is interpreted as follows:

1. Deposition of the Monsal Dale Limestones in a low energy, full marine subtidal setting on the middle part of a carbonate ramp.

2. Growth of carbonate mud buildups in a subtidal setting.

3. Subaerial exposure resulting in vadose cementation of the carbonate mud buildups and deposition of speleothem cements within fissures. The surrounding carbonate sediments were exposed to desiccation and soil-forming processes. Erosion of carbonate mud buildups also took place.

4. Deposition of the Eyam Limestones in a low energy, full marine subtidal setting on the middle part of a carbonate ramp as a result of relative rise in sea level.

(d) Summary of stratigraphical evidence

These three areas demonstrate a consistent stratigraphical relationship between the Monsal Dale Limestones, carbonate mud buildups and the Eyam Limestones:

1. Carbonate mud buildups rest conformably upon the Monsal Dale Limestones.
2. Features indicative of subaerial exposure, such as calcretes and vadose cements, are present within the carbonate mud buildups.
3. Calcrete profiles, palaeokarsts and palaeosols are present on the top surface of the Monsal Dale Limestones where it is overlain directly by the Eyam Limestones.
4. The sub-aerial features developed at the top of the Monsal Dale Limestones and within the carbonate mud mounds represent the same episode of sub-aerial exposure.

An important stratigraphical break is thus present between the carbonate mud buildups and the Eyam Limestones. The inclusion of these carbonate mud buildups within the Eyam Limestones Formation is therefore inconsistent with the stratigraphical evidence and a modification of the Monsal Dale/Eyam Limestones boundary is proposed such that the carbonate mud buildups are removed from the Eyam Limestones and placed within the Monsal Dale Limestones.

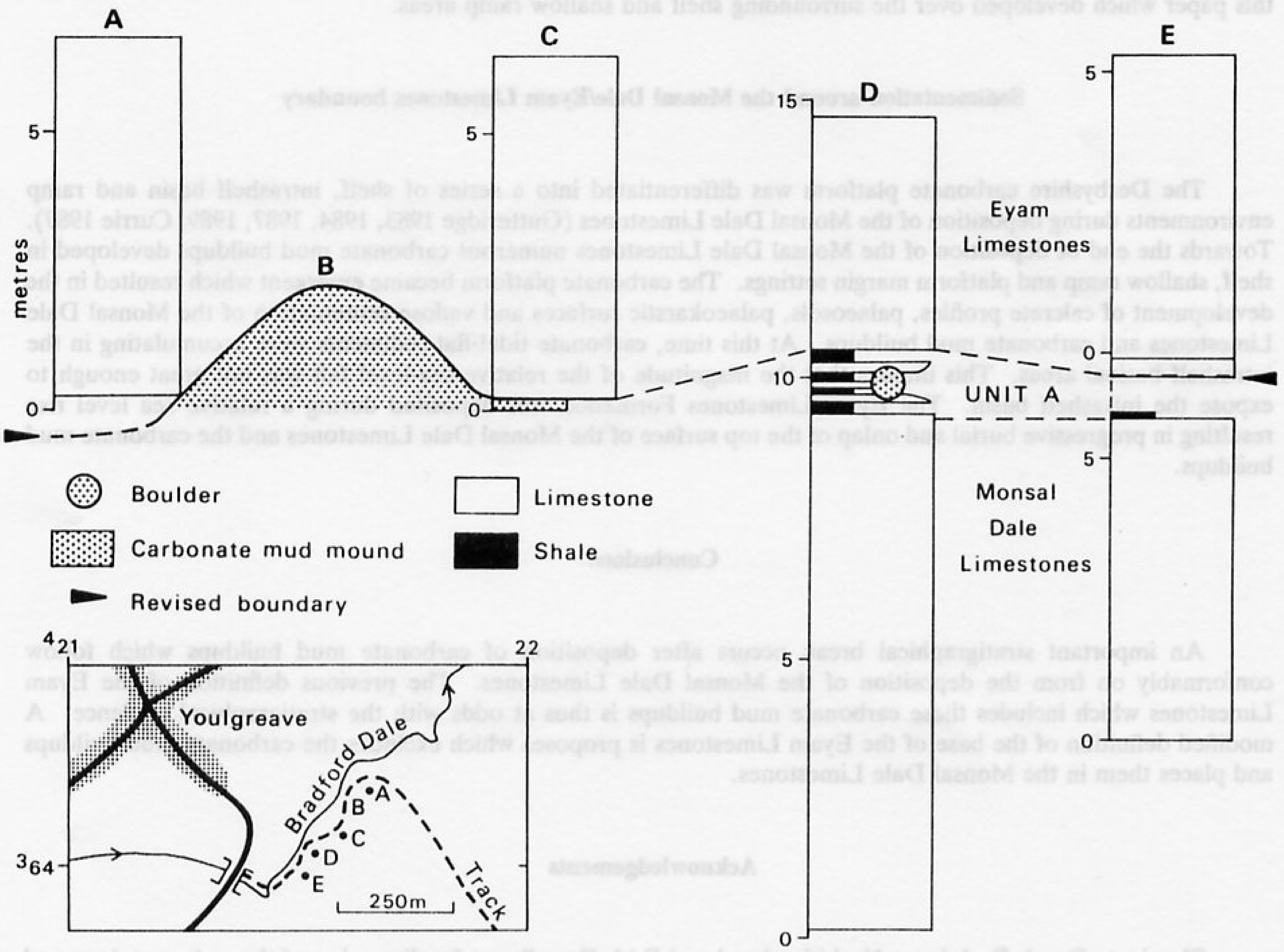


Fig. 3. Stratigraphical relationships of the Monsal Dale Limestones, Eyam Limestones and carbonate mud buildups in Bradford Dale. Solid arrow indicates revised position of Monsal Dale/Eyam Limestones boundary.

The Monsal Dale/Eyam Limestones boundary elsewhere in Derbyshire

(a) Bradwell Dale

At the northern margin of the Derbyshire carbonate platform the Monsal Dale/Eyam Limestone boundary is best exposed in Bradwell Dale (SK173807). Both the Monsal Dale and Eyam Limestones were deposited in a bioclastic grainstone facies (the "flat-reef" facies of previous workers) which developed in a bioclastic shoal complex associated with the northern margin of the Derbyshire carbonate platform (Gawthorpe & Gutteridge 1990).

Shirley & Horsfield (1940) and Stevenson & Gaunt (1971) placed the base of the Eyam Limestones in Bradwell Dale at an inferred erosion surface overlying an E-W trending "anticlinal" structure. This "anticline" was reinterpreted by Gawthorpe & Gutteridge (1990) as the crest of a large-scale sedimentary bedform. The overlying discordance is thus inferred to have been produced by sedimentological factors which influenced bedform development and is unlikely to be of stratigraphical significance. Further work is needed to determine the precise position of the Monsal Dale/Eyam Limestone boundary in this section.

(b) Ashford/Bakewell area

This area represents a former intrashelf basin within the Derbyshire carbonate platform in which dark-coloured limestones were deposited in a relatively deep-water, sheltered setting (Butcher & Ford 1973, Aitkenhead *et al.* 1985 and Gutteridge 1989). Aitkenhead & Chisholm (1982) drew the Monsal Dale/Eyam Limestones boundary at the base of a dolomitised laminated limestone (the Headstone Laminite of Gutteridge 1989) in Headstone Cutting (SK188714). This laminite was interpreted by Gutteridge (1989) and Fowles (1989) as a tidal flat deposit and is inferred to be the time-equivalent of the emergence surface described previously in this paper which developed over the surrounding shelf and shallow ramp areas.

Sedimentation around the Monsal Dale/Eyam Limestones boundary

The Derbyshire carbonate platform was differentiated into a series of shelf, intrashelf basin and ramp environments during deposition of the Monsal Dale Limestones (Gutteridge 1983, 1984, 1987, 1989, Currie 1987). Towards the end of deposition of the Monsal Dale Limestones numerous carbonate mud buildups developed in shelf, shallow ramp and platform margin settings. The carbonate platform became emergent which resulted in the development of calcrete profiles, palaeosols, palaeokarstic surfaces and vadose cementation of the Monsal Dale Limestones and carbonate mud buildups. At this time, carbonate tidal-flat sediments were accumulating in the intrashelf basinal areas. This implies that the magnitude of the relative sea-level fall was not great enough to expose the intrashelf basin. The Eyam Limestones Formation was deposited during a relative sea level rise resulting in progressive burial and onlap of the top surface of the Monsal Dale Limestones and the carbonate mud buildups.

Conclusions

An important stratigraphical break occurs after deposition of carbonate mud buildups which follow conformably on from the deposition of the Monsal Dale Limestones. The previous definition of the Eyam Limestones which includes these carbonate mud buildups is thus at odds with the stratigraphical evidence. A modified definition of the base of the Eyam Limestones is proposes which excludes the carbonate mud buildups and places them in the Monsal Dale Limestones.

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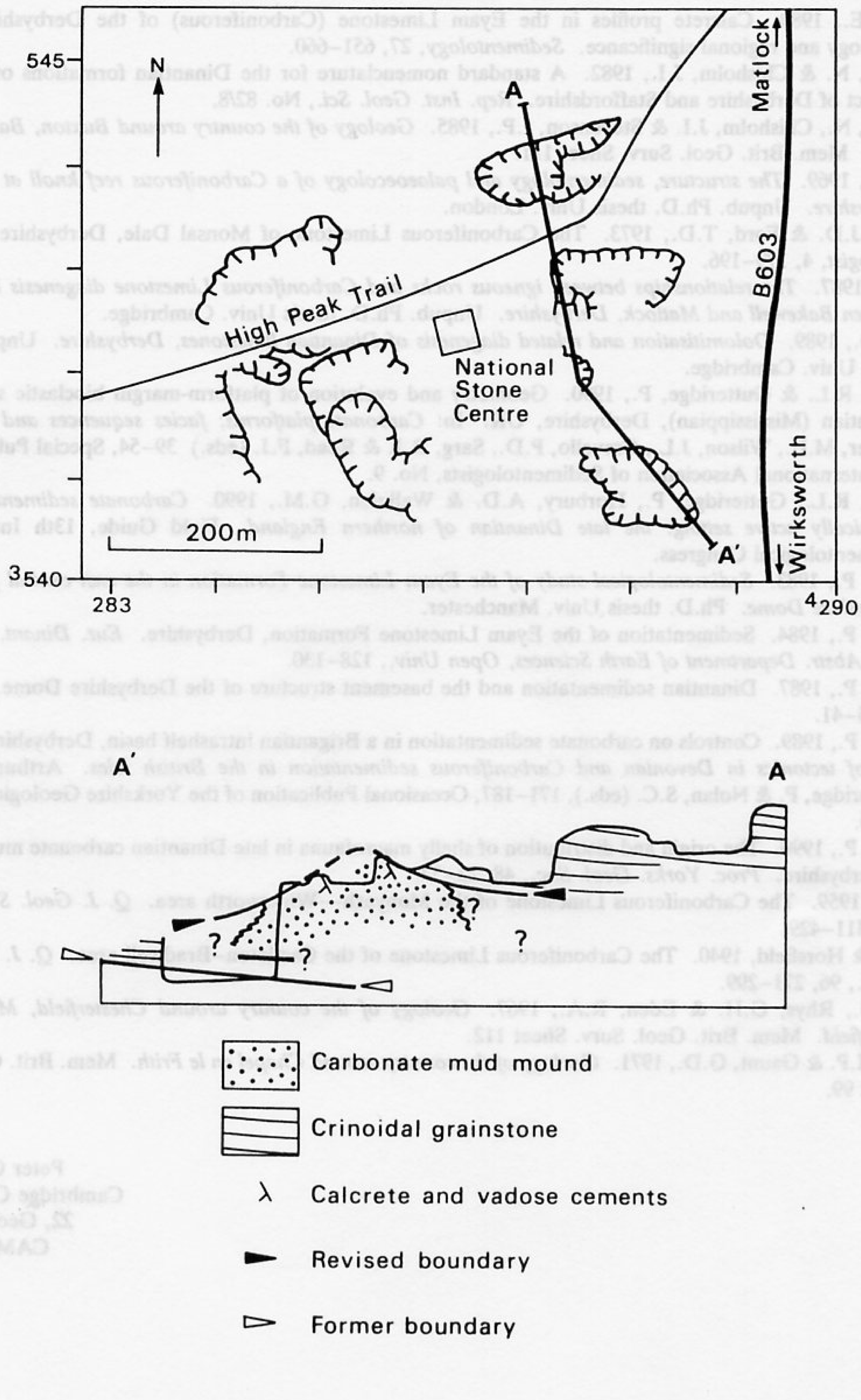

Fig. 4. Stratigraphical relationships of the Monsal Dale Limestones, Eyam Limestones and carbonate mud buildups in National Stone Centre near Wirksworth. Figure modified from (Gawthorpe *et al*. 1990). Solid arrow indicates revised position of the Monsal Dale/Eyam Limestones boundary.

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