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# Cracoe Knolls and Swinden Quarry, North Yorkshire

[SE 983 615], [SE 988 602], [SE 996 605], [SE 996 609], [SE 003 608], [SE 007 615], [SE 016 614], [SE 027 617]

## Introduction

The district around Cracoe and Thorpe, North Yorkshire, is a classic area for the study of late Dinantian (Asbian) knoll reefs, comprising the most easterly exposures of the Craven Reef-Belt at the margins of the Askrigg Block and Craven Basin. The term 'Cracoean', originally used as a stratigraphical unit by Bisat (1928), has been used as a facies term by Hudson and Philcox (1965) and Mundy (1994, 2000) to emphasize the distinction between this 'knoll reef' facies from the older 'Waulsortian' facies developed in areas to the south (see Salthill, Coplow and The Knolls GCR site reports, Chapter 6, and the Dovedale and Wetton to Beresford Dale GCR site reports, Chapter 7). The site embraces a number of separate localities, mostly centred on one of the reef structures. These are the working quarry at Swinden [SD 983 615], Skelterton Hill [SD 988 602], Carden Hill [SD 996 605], Butter Haw Hill [SD 996 609], Stebden Hill [SE 003 608], Elbolton [SE 007 615], Thorpe Kail [SE 016 614] and Byra Bank [SE 027 617]. Controversy about the origin of the structures has resulted in many publications on the area since the pioneering work of Tiddeman (1889, 1891). These include Marr (1899), Wilmore (1910), Garwood and Goodyear (1924), Hudson (1930a, 1932), Bond (1950a,b), Black (1954, 1958) and Mundy (1980a; 2000).

## Description

The fullest descriptions of the geology of the Cracoe area, including the localities within this site, are by Bond (1950a), Black (1958) and Mundy (1980a; 2000). Bond (1950a) produced a detailed lithostratigraphy for the area, but, because of rapid lateral facies variation in the reef complex, this has been regarded as too simplistic and unworkable by later authors (Black, 1958; Mundy, 1980a). Mundy (1980a) considered the outcrops in this area in three groups: the NE–SW-trending Swinden outcrop; the WNW–ESE-trending outcrop parallel to the Craven Fault System, including the sites of Elbolton, Thorpe Kail and Byra Bank; and the isolated outcrops to the south, including Stebden, Butter Haw, Carden and Skelterton hills. This grouping has been followed in the present description. A geological map of the central part of the area, showing the distribution of reef limestones, debris beds and later geological units, is presented in (Figure 5.24). Swinden lies partly on the British Geological Survey map of the Settle district (British Geological Survey, 1989) and has been described in the accompanying memoir (Arthurton *et al.*, 1988). The NE–SW-trending hill was thought to be a domal structure by Bond (1950a) and Black (1958), but quarrying has since revealed a northwards-younging succession (Arthurton *et al.*, 1988) complicated by locally severe fault disturbance (Mundy, 2000). Localities within the site boundary are probably all within the area of reef limestones, comprising unbedded pale-grey wackestones, though little evidence of this facies remains, the bulk of it having been removed by recent quarrying (D. Mundy, pers. comm., 2000).  $B_2$  goniatites, including *Goniatites hudsoni*, *Beyrichoceras aff. vesiculiferum* and *Bollandoceras micronotoides*, were recorded from the Swinden reef limestones by Bisat (1934).

The belt of reef limestones from Elbolton to Thorpe Kail and Byra Bank is also mostly of  $B_{2b}$  age, although at Elbolton  $P_{1a}$  limestones form flank deposits (Mundy, 1980a, 2000) banked up against the older reef structure on the southern and western sides of the hill (Figure 5.24). On Elbolton, the  $B_{2b}$  reef limestones pass from massive, on the southern side, to bedded elsewhere on the hill. Mundy (1980a) presented geopetal evidence which indicated that these bedded rocks were originally horizontal. Peloids and oncoids were also reported from these beds (Mundy, 1980a). *Gigantoproductus*, in association with large-diameter examples of *Koninckopora inflata*, occur at the top of the hill. Hudson and Cotton (1945a) recorded  $B_{2b}$  goniatites from the north-western slopes of Elbolton, but none were found in the detailed investigations of Mundy (1980a). The  $P_{1a}$  limestones are richly fossiliferous and form flanking deposits dipping at up to 35° (Mundy, 1980a).  $P_{1a}$  goniatites, including *Goniatites crenistria* and *Beyrichoceratoides truncatum*, were first described from these beds by Bisat (1928). Microbial boundstones are known from three places at Elbolton (Figure 5.24).

Although Thorpe Kail comprises entirely B<sub>2</sub> limestones, the structure is similar to that of Elbolton, with bedded limestones forming the central and northern parts of the hill, and more massive reef limestone, including local microbial boundstone, on the southern side (Mundy, 1980a). Similar structures are found eastwards along the reef-belt to Byra Bank.

Butter Haw Hill and Stebden Hill comprise reef limestones with quaquaversal dips (Bond, 1950a) in the peripheral flank limestones. Studies of geopetal infillings by Mundy (1980a) have shown that the major component of these dips is an original depositional dip. On Butter Haw Hill the reef limestones are entirely of B<sub>2b</sub> age, but P<sub>1a</sub> limestones are represented on the northern side of Stebden Hill (Figure 5.24). Goniatites of B<sub>2b</sub> age recorded from Butter Haw Hill and/or Stebden Hill include *Bollandoceras micronotum*, *Beyrichoceras rectangularum*, *B. cf. vesiculiferum*, *Beyrichoceratoides vesicus*, *B'toides implicatum*, *Bollandites castletonensis*, *Goniatites globostriatus*, *G. hudsoni*, *Nomismoceras vittiger* and *Merocanites* (Mundy, 2000). Goniatites of P<sub>1a</sub> age recorded from Stebden Hill include *B'toides truncatum* and *G. crenistria* (Mundy, 2000).

Stebden Hill was the focus of one of the most detailed palaeoecological investigations of Lower Carboniferous strata undertaken anywhere in the British Isles (Mundy, 1980a; 2000). For example, more than 13 000 shelly fossils (brachiopods and molluscs) were examined in collections from Elbolton and Stebden Hill and, in all, 206 fossil genera and 325 species were identified (Mundy, 1980a). Six biotic associations, each named after a dominant endemic component, were recognized, together with intermediate mixed assemblages (Mundy, 2000). In the B<sub>2b</sub> reef limestones these associations include the *Plicatifera* Association, developed in the oldest exposed beds, followed by three synchronous associations — the *Saharopteria*, *Conocardium* and *Koninckopecten* associations. The subsequent *Geniculifera* and *Productus* associations are of P<sub>1a</sub> age. The temporal and spatial distribution of these six faunal associations is illustrated in (Figure 5.25)a.

The *Saharopteria* Association comprises the reef framework, exposed on the summit of Stebden Hill ((Figure 5.25)b). Primary frame-builders described by Mundy (1980a, 1994, 2000) include microbial stromatolites, lithistid sponges (Rigby and Mundy, 2000), encrusting bryozoans, tabulate corals and the cemented pseudomonotid bivalve that gives its name to the association. The associated fauna includes very abundant examples of the rugose coral *Cyathaxonia cornu*, elsewhere considered to be characteristic of deeper-water Dinantian facies (Mundy, 1978). Several recent publications on Dinantian brachiopod faunas draw on specimens collected from the Craven Reef-Belt, and from Stebden Hill and Elbolton in particular (Mundy and Brunton, 1985; Brunton and Mundy, 1986, 1988a,b, 1993, 1994, 1997; Brunton *et al.*, 1994).

Despite its knoll-like shape, only small exposures of reef limestone are found on Skelterton Hill. Most of the hill comprises bedded cherty wackestones with crinoids, bryozoans and lithostrotionid corals, dipping 20° to the northeast (Mundy, 1980a). These limestones were described by Booker and Hudson (1926), who called them the 'Skelterton Limestones' and dated them as D<sub>2</sub>, equivalent in part to the Lower Bowland Shales. They were also correlated with the Scaleber Quarry Limestone Member of the Settle area, which was shown to be of Holkerian age (Ramsbottom, 1974). However, Ramsbottom (in Mundy, 1980a) reported late Asbian foraminiferal assemblages from the Skelterton Limestones; although a more recent assessment by Strank (in Mundy, 2000) considered them to be of Holkerian 'aspect'.

Limestone boulder beds of Brigantian age have been described from a number of localities along the reef-belt, for example in the Cracoe–Burnsall area by Black (1940, 1957). These comprise clasts of both reef limestones and dark Yoredale-type limestones containing *Lonsdaleia duplicata*, *Actinocyathus floriformis* and *Gigantoproductus* (Black, 1957). At this site, the lower slopes of Carden Hill are made up of boulder beds (= limestone debris beds of Mundy, 1980a) (Figure 5.24). The boulder beds are difficult to distinguish from in-situ reef limestone, but can be recognized by the varied attitude of geopetal infillings (Mundy, 1980a, 2000). Clasts within the boulder beds here are entirely of reef limestone. The majority of these limestone debris beds are assigned to the Pendleside Limestone Formation (Mundy, 2000).

Hudson (1932) described an unconformable relationship between the Bowland Shales and the reef limestones. This relationship was further studied by Black (1940) who noted the way the shales onlap the limestone surface. Stebden Hill is completely encircled by the lowland Shales (Figure 5.24) and the summit of the hill is at about the level of contact between the Grassington Grit and the Bowland Shales. According to Black (1940), the lowest Bowland Shale around Stebden is of P<sub>1b</sub>, (Brigantian) age; the mudrock succession extending up into the E<sub>1</sub> Zone (Pendleian). Within the area

of the sites described here, Bowland Shales of E<sub>1</sub> age are exposed in Thorpe Beck on the south-east side of Elbolton [SE 011 614] (Bond, 1950a).

## Interpretation

Most of the debate about the geology of the Cracoe area has focused on the origin of the reef structures. Tiddeman (1889) advanced the idea that they were original depositional structures made by mounds of animal debris. Rival theories stressed the importance of structural processes, and Marr (1899) suggested that the knolls were entirely tectonic in origin, but this fails to account for the observed facies variations. Hudson (1930a, 1932) took up Tiddeman's idea that these were original depositional structures and suggested that there may have been a continuous reef-belt along the line of the Middle Craven Fault. He further suggested that this reef-belt was faulted and eroded prior to deposition of the Bowland Shales. Bond (1950a,b) developed Hudson's ideas by suggesting that many of the dips in the reef limestones indicated pre-Bowland Shales folding as well as faulting.

Black (1958) analysed the structure of the area in detail and concluded that there was undoubtedly an original knoll topography along the reef-belt, but that while this was more-or-less symmetrical in the case of Stebden Hill, Elbolton and Thorpe Kail showed a high degree of asymmetry. According to Black (1958), this original knoll topography was then buried gradually by deposition of Bowland Shales, which, as a result, rest conformably on nearby shelf limestones and onlap the reef structures. Some uplift and erosion occurred at this time to account for the formation of the boulder beds. Black (1958), therefore, regarded many of the dips in the reef limestones as primary depositional dips, but was unable to conclusively demonstrate this.

Black's ideas were further developed by Mundy (1980a) who used geopetal structures to distinguish depositional from tectonic dips. He confirmed that the reef-belt from Elbolton to Byra Bank is essentially marginal to the shelf to the north, comprising an apron reef with depositional dips into the Craven Basin on the southern side, but passing into horizontal shelf limestones on its northern side. The reef limestones of Stebden and Butter Haw, however, are separated from this continuous reef-belt. Both show bedded flanking limestones with quaquaversal dips and would seem to be true knoll reefs as envisaged by Tiddeman (1889). Mundy (1980a) inferred an original topography of 110 m for Stebden Hill in upper B<sub>2</sub> times. According to Mundy (2000), the top of Stebden Hill is 30 m below the base of the Grassington Grit. The reef was thus covered by Bowland Shales in P<sub>1b</sub>, (Brigantian) times.

The reef at Swinden seems to be a special case. Its north-east to south-west orientation indicates that it is not part of the WNW–ESE-trending marginal reef complex. It has been suggested by Mundy (1980a) that reef limestones here developed as an elongate structure along an embryonic fold line — that of the Hetton Anticline. The development of embryonic fold structures in this region during Early Carboniferous times is considered further by Arthurton (1984).

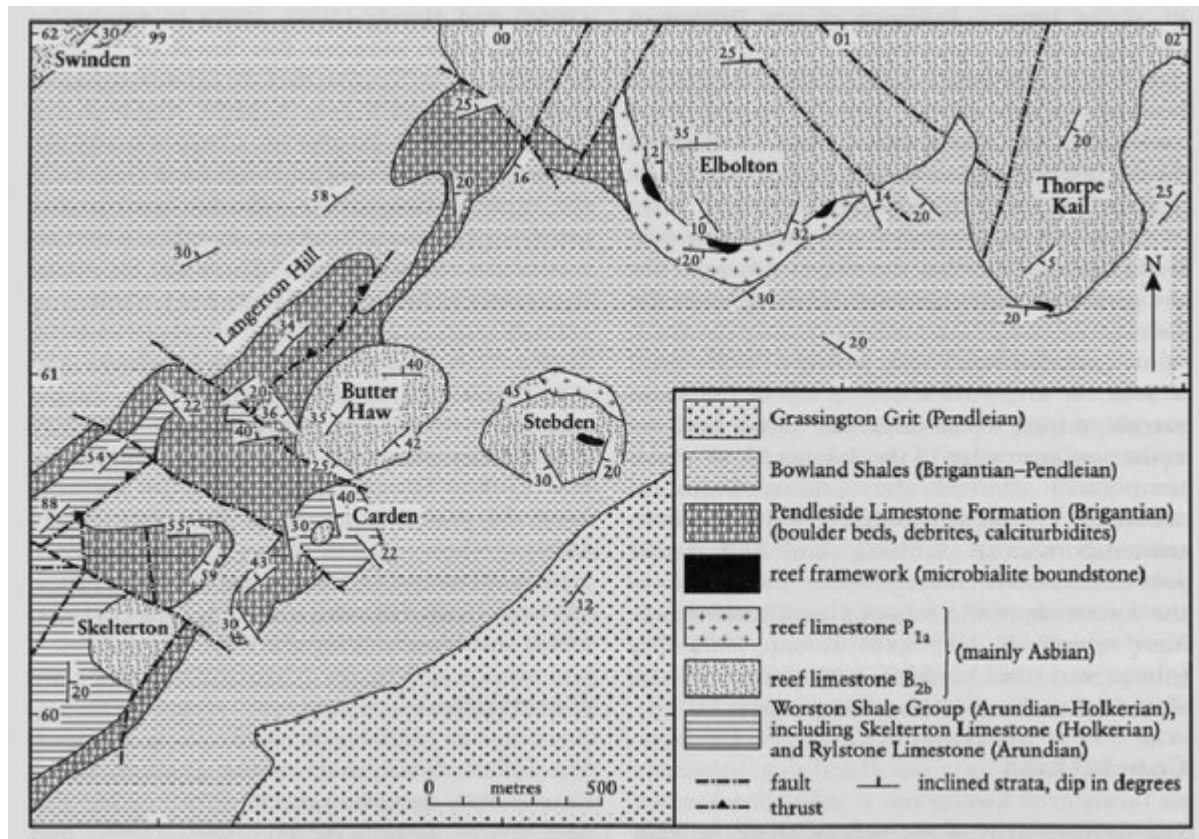
The biotic associations of Mundy (1980a, 2000) reflect both temporal and spatial variations in the reef environment. The oldest limestones (B<sub>2b</sub>) exposed at Stebden Hill contain a *Plicatifera* Association, interpreted as having developed in marginal reef slope sediments on a soft substrate. Of the three subsequent synchronous (B<sub>2b</sub>) associations, the framework *Saharopteria* Association developed in the shallowest water and passes down the reef slope via mixed assemblages into first the *Conocardium* Association and then the *Koninckopecten* Association. The P<sub>1a</sub> *Genfculifera* Association developed on the middle and lower reef slopes. The subsequent *Productus* Association (late P<sub>1a</sub>) is thought to represent re-colonization in shallow water after intra-P<sub>1a</sub> uplift and emergence (Mundy, 1980a, 2000). Independent evidence for this phase of uplift is provided by the breccia beds of this age and by fissuring and vadose cement fabrics at the summit of Stebden Hill (Mundy, 1980a, 2000).

## Conclusions

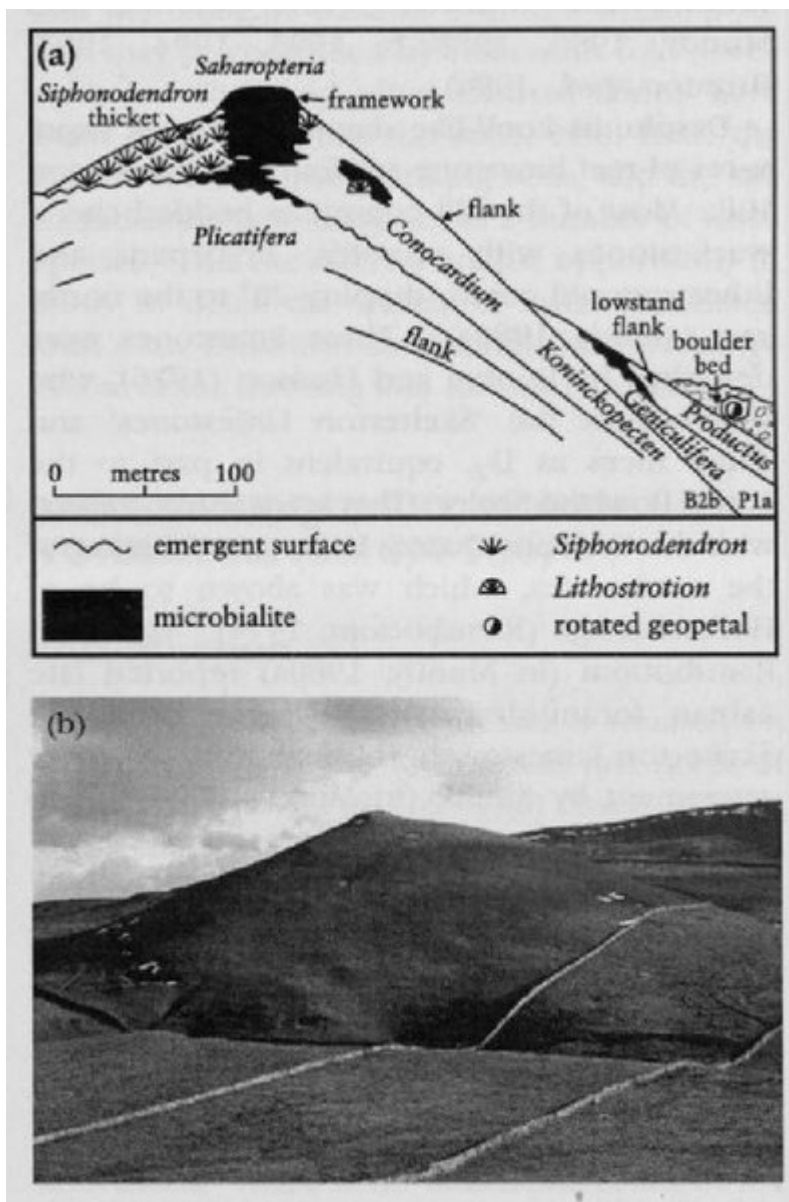
The district around Cracoe is one of the classic areas for British Lower Carboniferous geology. Late Dinantian reef limestones (Cracoean facies) are particularly well displayed here and it is possible to study their relationships with laterally equivalent and overlying beds. The area is invaluable for showing three different types of contemporaneous reef occurrence: the marginal reef along the line of the Middle Craven Fault, the isolated knolls of Stebden and Butter Haw,

and the elongate bank of Swinden whose position may be controlled by embryonic fold development. Rich and often unusual faunas have been described from the reefs, both from the framework and from flanking beds, and the site includes the type localities of a number of fossil species. This site offers a unique opportunity to study in detail the variety of facies associated with a late Dinantian shelf margin and is a major resource for teaching and for future research.

## References



(Figure 5.24) Geological map of the Cracoe-Thorpe district. Minor faults and mineral veins omitted. After Mundy (1980a, 2000).



(Figure 5.25) (a) Schematic section through the reef mound at Stebden Hill illustrating the temporal and spatial relationships between reef associations. Approximate orientation is from south (left) to north (right). Vertical height from the top of the microbialite framework to the base of the boulder bed is 120 m. After Mundy (2000). (b) The distinctive outline of the Asbian reef mound at Stebden Hill near Cracoe, viewed from the north-west. The crest of the mound is in framework facies whereas the sloping ground immediately below the reef crest is in flank facies. Fields in the lower ground are underlain by Namurian Bowland Shales. (Photo: D. Mundy, reproduced here by kind permission of the Yorkshire Geological Society)