Haw Crag, North Yorkshire

[SD 913 564]

Introduction

The Haw Crag GCR site lies close to Bell Busk and some 9 km to the north-west of Skipton. This locality provides an outstanding section of the Haw Crag Boulder Bed (Arundian), resting unconformably on the underlying Thornton Limestone Member (early Chadian) (Figure 6.2). The development of these features provides spectacular evidence of a late Chadian-early Arundian episode of tectonic and sediment instability that is widely recognized in Lower Carboniferous successions throughout the Craven Basin and across much of central England. The site includes both the partially overgrown exposures seen at Haw Crag Quarry [SD 9135 5640] and the natural outcrops in the vicinity of Haw Crag summit [SD 9134 5648]. Important early works relating to the site geology are by Wilmore (1910), Hudson (1927) and Hudson and Dunnington (1944). More recent sedimentological work by Barraclough (1983) and Gawthorpe (1987a) and regional mapping by Arthurton *et al.* (1988) has led to significant improvements in our understanding of the locality. The description below derives mainly from the work of these later authors and follows the lithostratigraphical terminology of Arthurton *et al.* (1988).

Description

The exposures at Haw Crag occur on the southeastern limb of the NE–SW-trending Eshton–Hetton Anticline, close to its southern end, and just 0.5 km to the north of the Gargrave Fault a SE-trending splinter of the South Craven Fault System to the north-west. At the base of the succession are beds belonging to the Thornton Limestone. These are unconformably overlain by the Haw Crag Boulder Bed which forms the local base to what Arthurton *et al.* (1988) referred to as their 'median limestone-rich subdivision' of the Worston Shales (= Hodder Mudstone Formation of Riley, 1990a; and see (Figure 6.2)). Missing from the sequence at this unconformity is the lower part of the Worston Shales, including the Hetton Beck Limestone Member (late Chadian) and the topmost beds of the Thornton Limestone (early Chadian). In the quarry, the Haw Crag Boulder Bed overlies this highly irregular unconformity surface infilling erosional hollows scoured into the top of the Thornton Limestone.

Although no detailed description of the Thornton Limestone at Haw Crag is currently available, Arthurton *et al.* (1988) noted Its resemblance to sections of the same unit seen nearby, which they described as mainly wavy-bedded calcarenite packstones and wackestones containing corals including *Syringopora* and the diagnostic Chadian *Siphonophyllia cyclindrica.* A similar but more diverse coral fauna was recorded from these beds in the quarry by Hudson (1927).

The Haw Crag Boulder Bed comprises a limestone conglomerate with a chaotic mix of angular to subrounded limestone boulders or blocks set in a mudstone or muddy limestone matrix (Arthurton *et al.,* 1988). While blocks up to 50 m across are reported from this unit (Arthurton *et al.,* 1988), the largest seen in the quarry is about 4–5 m in diameter (Figure 6.21).

At the southern end of the quarry the conglomerate is approximately 2 m thick and dominated by boulders derived from the underlying Thornton Limestone. Traced to the north, but still within the confines of the quarry, it thickens to an 'estimated' 20 m and includes boulders of Thornton Limestone, Hetton Beck Limestone and a pale fossiliferous wackestone of a possible 'reef' origin. One particular block of bedded limestone, containing litho-clasts and the corals *Michelinia megastoma* and *Siphonophyllia* cf. *garwoodi,* closely resembles a lithofacies seen in the upper part of the Hetton Beck Limestone in a nearby borehole (Arthurton *et al.,* 1988). Farther north, the dominant boulders are of 'reef' limestone, and in the vicinity of Haw Crag summit, a 50 m block of this lithofacies near the base of the conglomerate forms an entire outcrop (Arthurton *et al.,* 1988). Earlier workers (Hudson, 1927; Hudson and Dunnington, 1944) regarded these outcrops as part of a more extensive and autochthonous development of 'reef' limestone below the unconformity surface. However, later workers recognized that at least some of these supposed 'reef' limestones are blocks of Waulsortian facies (Lees and Miller, 1985), and unpublished geopetal evidence indicates that a number of these,

including the 50 m block referred to above, are stratigraphically inverted (J. Miller, pers. comm., 2001).

Above the conglomerate, the remaining part of the Worston Shales succession (approximately 10 m thick) comprises an interbedded sequence of mudstones, siltstones and laminated muddy limestones containing graded limestone beds, slump structures and further boulders of Thornton Limestone (Barraclough, 1983; Arthurton *et al.,* 1988). Barraclough (1983) considered these boulders as part of a conglomerate sheet that thickened to the east.

Additional macrofossil records from the quarry indicate the presence of solitary rugose corals and productoid brachiopods in abundance, together with gastropods, cephalopods and trilobite remains (Wilmore, 1910). However, because this fauna was obtained from an unspecified level (or levels), its significance remains uncertain. Similar uncertainties concern the precise level(s) of foraminiferal assemblages recovered from the site by Fewtrell and Smith (1978).

Interpretation

In his revised lithostratigraphical scheme for the Worston Shale Group, Riley (1990a) considered the Worston Shales succession above the Haw Crag unconformity as Arundian in age and part of the Embsay Limestone Member, one of several newly defined members in his Hodder Mudstone Formation (= Worston Shales of Arthurton *et al.,* 1988). Similarly, beds below the unconformity are now assigned to the Thornton Limestone Member, the lowest of four new members in Riley's (1990a) re-defined Clitheroe Limestone Formation which is of early Chadian age (Figure 6.2).

Following detailed work by Gawthorpe (1986, 1987a) and Arthurton *et al.* (1988), Riley (1990a) regarded the early Chadian Thornton Limestone as a relatively shallow-water deposit that formed across the northern and central parts of the Craven Basin on a gently inclined but southward-dipping carbonate ramp. Later, crustal extension during late Chadian-early Arundian times caused this ramp to fragment, transforming what was a sea floor of low relief into one of considerable topographical expression (Gawthorpe, 1987a). Regional uplift and widespread erosion in the northern part of the basin led to the development of the Haw Crag unconformity at this time. Riley (1990a) suggested that the formation of this unconformity may be linked to the progressive erosion of a retreating submarine fault scarp moving away from the ramp's southern edge during latest Chadian times. Erosion on the unconformity surface has evidently stripped the entire thickness of the upper Chadian Hetton Beck Limestone and part of the Thornton Limestone from the sequence — the erosional remnants of these units appearing as boulders in the overlying Haw Crag Boulder Bed.

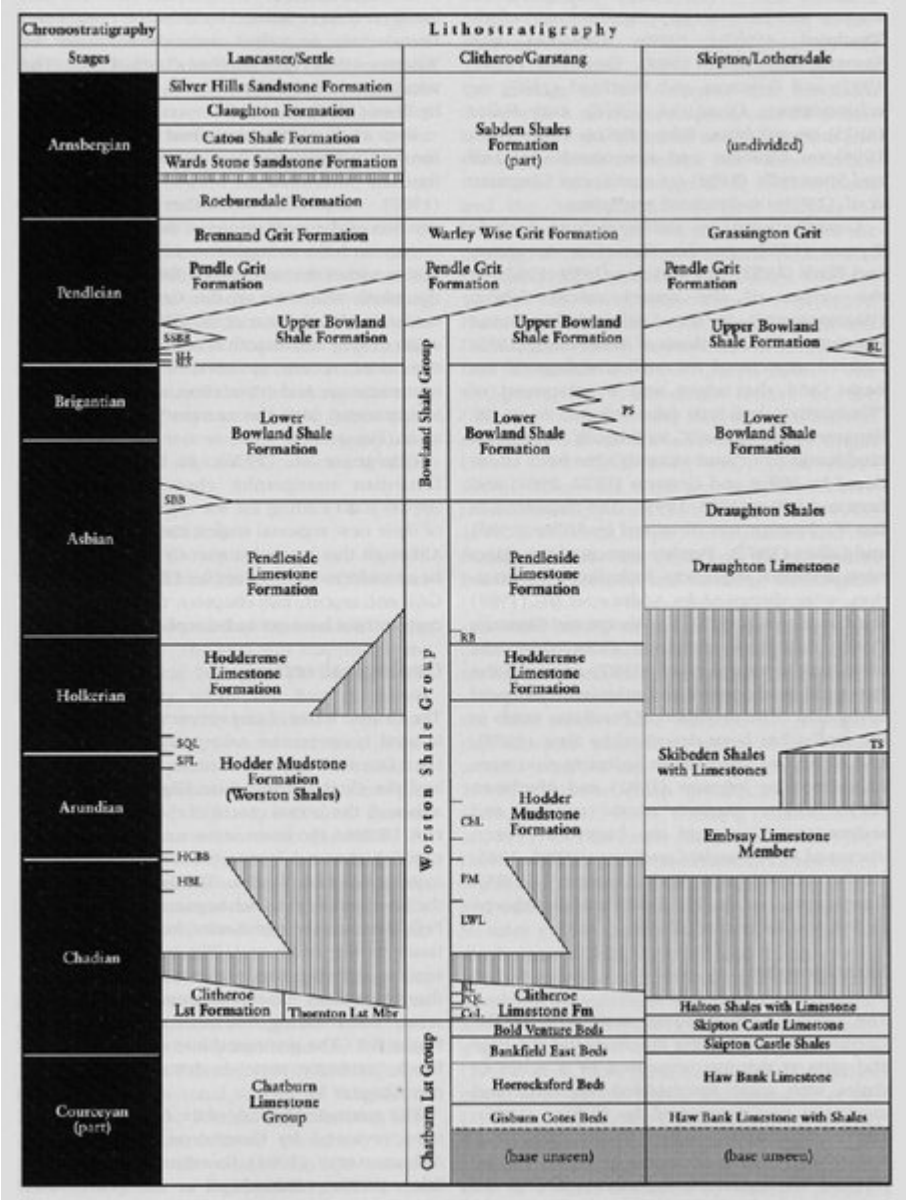
The Worston Shales sequence above the unconformity surface includes hemipelagic muds (Riley 1990a) and a heterogeneous suite of debris flows (Haw Crag Boulder Bed), gravity slides, slumps and turbidity flows (Barraclough, 1983). The sediment gravity flows were triggered from sea-floor slopes that were progressively steepening as fault blocks in the underlying basement rotated during a continuing phase of crustal extension in Arundian times (Gawthorpe, 1987a). Barraclough (1983) recognized that the steeper parts of the Haw Crag unconformity profile represented the margins of a submarine channel within which the lower of the Haw Crag debris flows was confined. Similar evidence of confinement at the base of the conglomerate sheet higher in the sequence (the younger of the Haw Crag debris flows) has not been recognized (Barraclough, 1983). The composition and size of the boulders in both flows points to their local origin. Arthurton *et al.* (1988) linked the occurrence of 'reef' limestone blocks in the Haw Crag Boulder Bed to the former existence of 'knoll reefs' in the axial zone of the Eshton-Hetton Anticline, although no trace of an in-situ 'reef' development in this area can currently be identified. However, the Waulsortian character of some of the blocks has led to speculation that they may be a remnant of a previously unrecognized autochthonous Waulsortian development, and a northerly extension of the Waulsortian mud-bank complex in the Clitheroe district (J. Miller, pers. comm., 2001; and see The Knolls, Coplow Quarry and Salthilli and Bellmanpark Quarries GCR site reports, this chapter).

Conclusions

The development of the Haw Crag unconformity marks a signicant late Chadian–early Arundian phase in the history of the Craven Basin during which the early Carboniferous sea floor was transformed from a gently inclined carbonate ramp into an area of intrabasinal highs and lows separated by steeper sea-floor slopes that facilitated the passage of gravity flows into basinal regions (see Sykes Quarries GCR site report, this chapter). The Haw Crag Boulder Bed represents a

particularly good example of a debris flow that developed in this way during early Arundian times, and is, arguably, the finest of its type in the Craven Basin.

References



(Figure 6.2) Simplified stratigraphical chart for the Lower Carboniferous succession of the Craven Basin. (HBL — Hetton Beck Limestone Member; HCBB Haw Crag Boulder Bed; SFL — Scaleber Force Limestone Member; SQL — Scaleber Quarry Limestone Member; SBB — Scaleber Boulder Bed; SLS — Sugar Loaf Shales; SLL — Sugar Loaf Limestone; SSBB School Share Boulder Bed; CoL — Coplow Limestone Member; PQL — Peach Quarry Limestone Member; BL — Bellman Limestone Member; LWL — Limekiln Wood Limestone Member; PM — Phynis Mudstone Member; ChL — Chaigley Limestone Member; FIB — Rad Brook Mudstone Member; PS — Pendleside Sandstones Member; TS — Twiston Sandstone Member; BL — Berwick Limestone.) Areas of vertical ruling indicate non-sequences. Not to scale. Compilation based on Hudson and Mitchell (1937), Metcalfe (1981), Arthurton et al. (1988), British Geological Survey (1989), Riley (1990a, 1995), Aitkenhead et al. (1992), Brandon et al. (1995, 1998).

(Figure 6.21) Exposure of the Arundian debris-flow deposit (the Haw Crag Boulder Bed) in the Hodder Mudstone Formation at Haw Crag Quarry, Bell Busk. Note that the prominent block at the foot of the crag (a boulder of the Hetton Beck Limestone Member) is approximately 5 m in diameter. (Photo: P.J. Cossey.)