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# Harthwaite Sike

[NY 702 247]–[NY 708 248]

## Introduction

Harthwaite Sike, coupled with the adjacent Billy's Beck, provides important information on both the stratigraphy of the Dufton Shale Formation and the geological history of the late Ordovician of northern England. Harthwaite Sike includes the best and most accessible section showing the local volcanoclastic basal facies of the Dufton Shale Formation and also contains the longest section of the Woolstonian and Marshbrookian parts of the formation. The nearby section in Billy's Beck includes younger parts of the Dufton Shale Formation, including the Billy's Beck Member, and shows that the base of the Swindale Limestone, when traced northwards, cuts down onto progressively older parts of the Dufton Shale Formation.

Nicholson and Marr (1891) and Dean (1959a) termed the relatively coarse-grained basal development of the Dufton Shale the '*corona* Beds', after the brachiopod *Trematis corona*, but Burgess and Holliday (1979) renamed it the '*corona* facies' as it does not constitute a mappable unit. These Longvillian tuffaceous sandy beds are succeeded by more typical mudstones of the Dufton Shale Formation, extending up into the most extensive section of the Woolstonian and Marshbrookian substages in the Cross Fell Inlier.

An important complementary section is seen in the upper reaches of Billy's Beck, 500 m to the north [NY 708 253]–[NY 712 256], where the uppermost parts of the Dufton Shales are exposed. The Purgillian and lower Cautleyan strata there contain a significant component of quartz sand and were termed the Billy's Beck Member by Kneller *et al.* (1994, p. 239); this term supersedes the '*Diacalymene* Beds' used by Dean (1959a) for the Cautleyan strata, following comparisons with equivalent levels in the Cautley area to which that name had been applied by King and Williams (1948). At Billy's Beck, the younger Ashgill strata belong to the latest Cam-leyan to earliest Rawtheyan Swindale Limestone.

Schematic maps of the sections in Harthwaite Sike and Billy's Beck were published by Dean (1959a) and more detailed maps by Burgess and Holiday (1979). Both papers include extensive, well-localized lists of the diverse shelly faunas.

## Description

The Dufton Shale Formation in Harthwaite Sike dips SSW at about 65° (Figure 11.9). At the eastern end of the site, tuffs of the Borrowdale Volcanic Group exposed south of Harthwaite Cottage are overlain in the stream section by tuffaceous sandstones containing calcareous shelly fragments and large lingulid brachiopods. These sandstones mark the base of the Dufton Shale Formation and its '*corona* facies', the overlying tuffaceous siltstones of which contain the typical fauna including the brachiopod *Trematis corona* Davidson (Figure 11.10)a, b. The overlying grey mudstones extend up through probable Woolstonian into the Marshbrookian Substage, although precise recognition of the substage boundaries is not possible where diagnostic taxa are not present.

Marshbrookian strata also occur 500 m to the north-west, in the lower part of Billy's Beck (Burgess and Holliday, 1979, p. 12; Dean, 1959a, fig. 3). Woolstonian shales are faulted against the Borrowdale Volcanic Group in the upper reaches of Billy's Beck and two fault-bounded areas there expose the uppermost parts of the Dufton Shale Formation (Burgess and Holliday, 1979, fig. 7). These comprise the Billy's Beck Member and show a conformable Purgillian–Cautleyan boundary. Like the basal parts of the formation, they have a significant arenaceous component, but they differ in that the sand-grade material is quartz. Another fault-bounded area in the upper part of Billy's Beck contains outcrops of the Swindale Limestone.

## Interpretation

The tuffaceous material in the *corona* facies at the base of the formation was probably derived from the underlying Borrowdale Volcanic Group. Kneller *et al.* (1994, p. 229) noted that this facies is analogous to the volcanoclastic Longsleddale Member of the Stile End Formation, which marks the local but much younger (early Cautleyan) transgressive base of the Dent Group over the Borrowdale Volcanic Group in the south-eastern Lake District.

As stated by Burgess and Holliday (1979, p. 12), the placing of the substage boundaries in the Dufton Shale Formation at Harthwaite Sike is problematical. The *corona* facies is undoubtedly Longvillian in age, but beds immediately overlying include the brachiopod *Bancroftina cf. typa* (Bancroft), which is suggestive of the Longvillian (=Lower Longvillian of Burgess and Holliday and earlier authors), with *Bancroftina robusta* (Bancroft) and the trilobite *Broeggerolithus nicholsoni longiceps* (Bancroft), which indicate the overlying Woolstonian (=Upper Longvillian) Substage. The base of the overlying Marshbrookian is difficult to identify in places where diagnostic taxa such as *Broeggerolithus transiens* (Bancroft) are not found, but the site includes some of the best faunas from the substage in the Cross Fell Inlier.

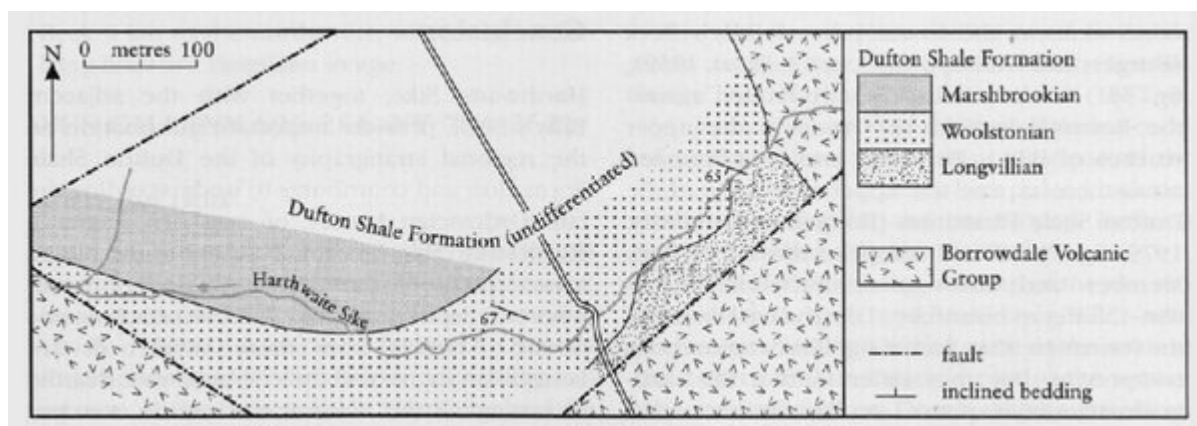
Although the Swindale Limestone in Billy's Beck is fault-bounded, the presence of Cautleyan strata in other faulted blocks here indicates that the base of the formation rests on younger strata than in Swindale Beck (see site report), 3 km to the north-west, where the uppermost part of the Dufton Shale Formation is Pusgillian in age.

## Conclusions

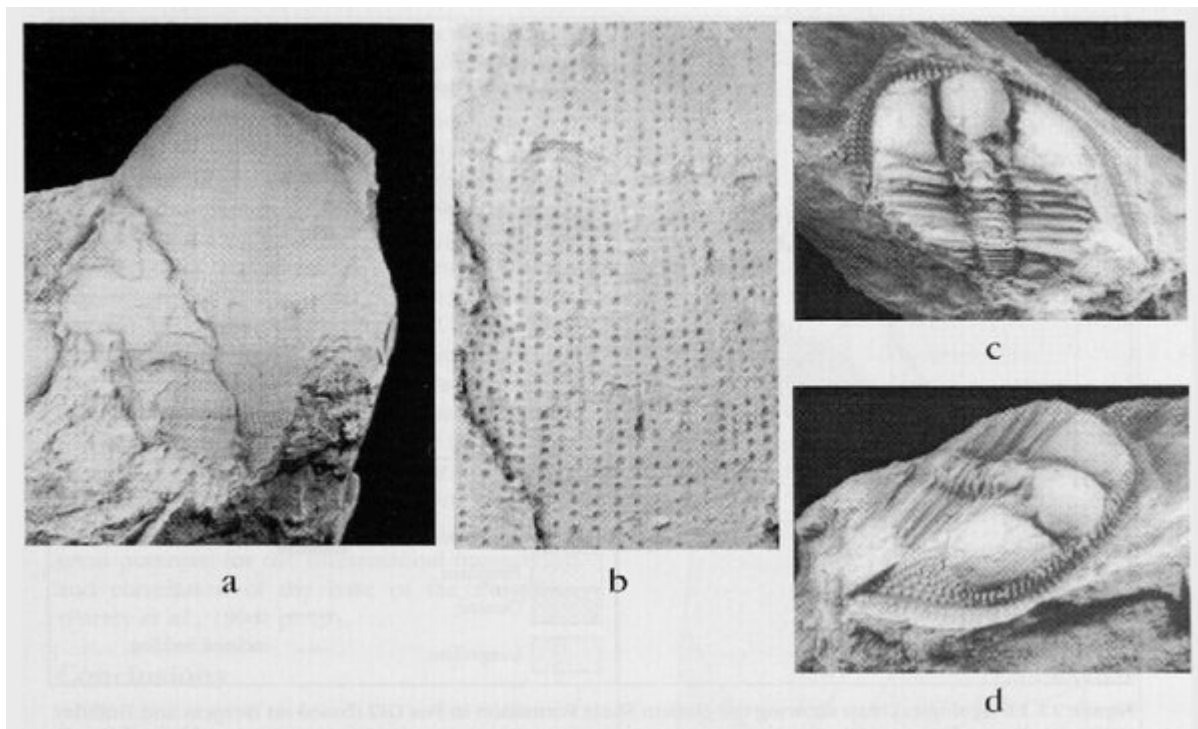
Harthwaite Sike, together with the adjacent Billy's Beck, provides important information on the regional stratigraphy of the Dufton Shale Formation and contributes to understanding the late Ordovician history of northern England. Harthwaite Sike has the best exposure of the lowest parts of the Dufton Shale Formation where it rests on the Borrowdale Volcanic Group. Fossils from these basal beds are Longvillian in age and thus demonstrate that the drowning of the volcanic succession was not contemporaneous over northern England, as the corresponding strata in the Lake District are younger, being mid-Ashgill in age.

Overlying shales in Harthwaite Sike include the best outcrops of the Woolstonian and Marshbrookian substages in the Cross Fell Inlier. The adjacent Billy's Beck includes the uppermost parts of the formation together with the Swindale Limestone Formation, which here overlies younger parts of the Dufton Shale Formation (earliest Cautleyan) than in Swindale Beck 3 km to the north-west, where the underlying beds are Pusgillian in age.

## References



(Figure 11.9) Geological map showing the Dufton Shale Formation in Harthwaite Sike, based on Burgess and Holiday (1979, fig. 6) and Dean (1959a, fig. 3).



(Figure 11.10) Fossils from the Dufton Shale Formation in Pus Gill. (a, b) A brachiopod of the corona facies (Longvillian), *Trematis corona* Davidson, x3, with enlargement of sculpture, x8. (c, d) Two views of the Pusgillian trilobite *Petaspis moeldenensis* Cave (*sensu lato*), x 2.