British Cambrian to Ordovician Stratigraphy

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Chapter 5

Cambrian rocks of England

A. W. A. Rushton

INTRODUCTION

In England, Cambrian rocks mainly occur in association with Precambrian volcanic rocks in small inliers in the Welsh Borderlands and the English Midlands.

The Welsh Borderland

Inliers of Cambrian and Precambrian rocks are brought up along the Church Stretton Lineament and the Malvern Line (Brasier *et al.*, 1992b), the principal outcrops being in the Comley and Wrekin areas of south Shropshire and the Malvern Hills of Worcestershire and Herefordshire. In these areas the successions are mainly of quartzitic and glauconitic sandstones of the Comley and St David's series, overlain by thin black mudstones of the Merioneth, and in all areas there are significant breaks in deposition. The sediments accumulated in shallow water in areas close to active fault-complexes. Apart from the basal strata, most of the succession in the Comley and Wrekin areas is very badly exposed, and practically all the details of the stratigraphy had to be elucidated by trenching (Cobbold, 1927; Cobbold and Pocock, 1934). The accepted succession (summarized by Rushton, 1974) is given in outline in Figure 4.1. In the Malvern Hills the Cambrian is better exposed but the sequence is badly disrupted by faulting. Groom (1902) assembled the general succession, also shown in Figure 4.1.

The Wrekin Quartzite and basal lower Comley Sandstone are exposed in the Ercall Quarry, where both radiometric age-dating and biostratigraphy contribute to the relatively good dating of the early Cambrian transgression. The approximately correlative Malvern Quartzite is exposed in the Gullet Pass Pit, where it is fossiliferous. The interesting contacts between the top of the lower Comley Sandstone, the Comley Limestones and the base of the upper Comley Sandstone are present in the Comley Quarry site and the associated 'Excavation No. 2', but none of the overlying divisions is well-enough exposed to have been selected for the GCR site series.

English Midlands

In contrast to the Welsh Borderland, the Cambrian of the English Midlands has substantial sandstone formations only in the lower parts of the Lower Cambrian, as seen in the Nuneaton Inlier of Warwickshire and in the Charnwood Forest area. The Lickey Quartzite, south-west of Birmingham, was formerly referred to the Cambrian but is now regarded as Ordovician (Old *et al.*, 1991). At Nuneaton the sandstones of the Hartshill Formation are overlain by thick mudstone divisions of the Stockingford Shale Group, which range in age from early to late Cambrian and accumulated in a relatively stable intra-cratonic shelf setting. There may be stratigraphical breaks in the Hartshill Formation, but in the Stockingford Shale such breaks are confined to a single trilobite zone. These Cambrian divisions are partly exposed in the Nuneaton area and have been encountered widely in boreholes. The general succession is described by Brasier *et al.* (1978), Taylor and Rushton (1972) and Bridge *et al.* (1998), as shown in Figure 4.1.

There are few good natural exposures, but the Hartshill Formation was studied when well-exposed in several working quarries (Brasier *et al.*, 1978). The base of the succession is seen at Boon's Quarry, and the upper part, from the Jee's Member to the base of the overlying Purley Shale Formation, is represented at Woodlands Quarry. The overlying formations are in general very badly exposed, and all the overlying divisions are best known from borehole cores (Taylor and Rushton, 1972), though the richly fossiliferous Abbey Shales are present at Illing's Trenches. None the less, where lamprophyric intrusions have been quarried, some parts of the Outwoods Shales Formation are available for study, and representative exposures that exemplify the thickest division of the Stockingford Shale Group are exposed at the Mancetter Quarries, which are described as a potential GCR site. The chapter ends with brief notes on two Lower Cambrian sites in the Brand Group of Charnwood Forest; the importance of these sites in Cambrian stratigraphy has only recently emerged (Bland and Goldring, 1995), and they are described fully in the companion volume on the Precambrian rocks of England and Wales (Carney *et al.*, in prep).

ERCALL QUARRY (SJ 644 097)

Introduction

Ercall Quarry is of national importance, being the best and most complete exposure of the Wrekin Quartzite and showing important uncon-

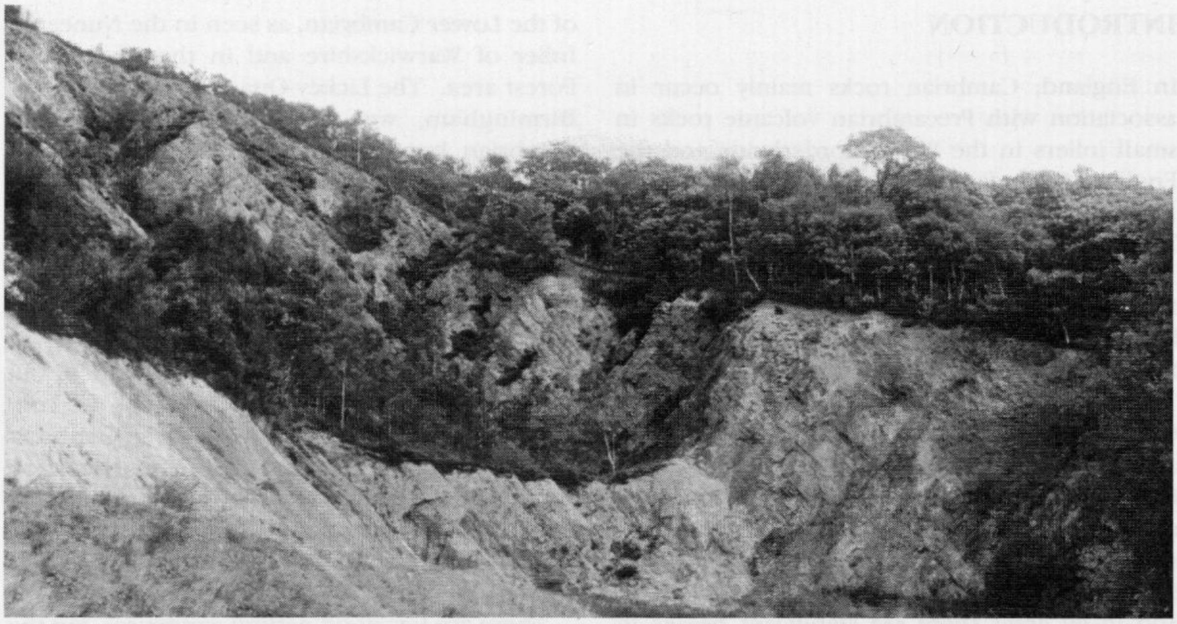

Figure 5.1 Ercall Quarry (Quarry 3 of Toghill and Beale, 1994), looking north-east. The Ercall Granophyre (Precambrian), is the pale, non-bedded rock on the far left of the photograph. The Wrekin Quartzite, centre, is pale and thickly bedded, and is overlain on the right by a darker cliff of Lower Comley Sandstone. (Photo: C. D. Prosser.)

formities with the underlying Precambrian Uriconian volcanic rocks and the Ercall Granophyre. Local radiometric dates and fossils provide the best constraints for the age of the Cambrian transgression in the Welsh Borderlands.

The Wrekin (Latin *Uriconium*) is a large hill made up of Precambrian volcanic rocks (Uriconian Group); its northerly extension, the Ercall, is intruded by a granophyre. The south-east flank of both hills is covered by the Wrekin Quartzite and Comley Sandstone. Early workers regarded the Wrekin Quartzite as altered Caradoc Sandstone, but Callaway (1877, p. 653) identified it with the Hollybush Sandstone at Malvern, of known Cambrian age (see the Gullet Pass Pit site report). The geology and main rock types of the Wrekin area were described by Pocock *et al.* (1938), who also included a summary of earlier work.

The Ercall Quarry assumed particular importance when quarrying operations exposed the base of the Cambrian lying unconformably on the Ercall Granophyre. Previously their stratigraphical relationships were uncertain and the possibility that the Ercall Granophyre was intruded into the Cambrian had been entertained by some workers (see Cope and Gibbons, 1987, p. 58). Radiometric dating of the granophyre and microfloral study of part of the Wrekin Quartzite were reported by Wright *et al.* (1993). Hamblin and Coppack (1995) give a general account of the geology of the area, and Toghill and Beale (1994) give a detailed guide to the Ercall and neighbouring quarries.

Description

The rhyolitic and basaltic lavas and tuffs of the Uriconian Volcanic Group are exposed in quarries 300 m south-west of the summit of the Ercall. Intruded into these is the Ercall Granophyre, exposed in the Ercall Quarry, the north face of which reaches almost to the summit of the hill. The granophyre has given a U-Pb age of 560 ± 1 Ma (Tucker and Pharaoh, 1991), which is regarded as the date of intrusion. A Rb-Sr whole-rock date of 533 ± 12 Ma represents a resetting event that preceded the local Cambrian marine transgression (Patchett *et al.*, 1980; Wright *et al.*, 1993).

The unconformably overlying Wrekin Quartzite is 34 m thick and fully exposed (Figure 5.1). It consists of pale grey fine-grained quartz sand with a siliceous cement, ocurring in thick beds, some of which have rippled upper surfaces, and is considered to have formed in a shallow coastal environment. Wright *et al.* (1993) gave a description and logged the section. Cope and Gibbons (1987) described the unconformity with the Ercall Granophyre and identified rare pebbles of the granophyre in the basal conglomerate. A bed of shale 6 m above the base of the Wrekin Quartzite contains an acritarch microflora that Downie (in Wright *et al.*, 1993) correlated with a flora that had been assigned a mid-Tommotian age. In the Siberian standard succession, the Tommotian Stage underlies the trilobite-bearing rocks of the Atdabanian Stage and may correlate with or below the non-trilobite zone of the Comley Series (Figure 2.2).

The Wrekin Quartzite is succeeded abruptly but conformably (at 6445 0955) by the lower Comley Sandstone, consisting of coarse to fine, commonly glauconitic, sandstone. The lowest 15 cm contains a neritic shelly fauna including *Obolella? groomi* Matley, species of *Micromitra,* and some *Mobergella* (Figure 5.2a, b) that were recorded as *M.* cf. *turgida* Bengtson (by Bengtson, 1977, p. 10) and as *M.* cf. *radiolata* Bengtson (in Hamblin and Coppack, 1995, p. 9). This fauna is correlated with the upper part of the Tommotian Stage. Elsewhere in Shropshire the lower Comley Sandstone, capped by the Comley Limestones, contains diverse faunas of the higher Comley Series, of later early Cambrian age (Cobbold and Pocock, 1934; Rushton, 1974).

Interpretation

Ercall Quarry exposes stratigraphical contacts critical for understanding the Cambrian transgression in Shropshire. The nature of the contact between the Ercall Granophyre and the Wrekin Quartzite, formerly uncertain, is here clearly exposed as unconformable. The Ercall Granophyre below the unconformity gives significant radiometric dates, and the Wrekin Quartzite and lower Comley Sandstone above the unconformity yield fossils that provide better biostratigraphical correlation with the Tommotian Stage than any other site in the Welsh Borderlands. It appears from the available evidence that the Wrekin Quartzite at the Ercall is younger than the lower parts of the Hartshill Formation at Nuneaton (see site reports for Boon's Quarry and Woodlands Quarry), suggesting that the early Cambrian marine transgression reached the Welsh Borderlands somewhat later than the English Midlands.

The base of the Cambrian is now defined internationally at Fortune Head in south-east Newfoundland (Brasier *et al.,* 1994), and the age for this base is estimated at 544 Ma (Isachsen *et al.,* 1994) or 543 Ma (Grotzinger *et al.*, 1995). An age of 531 ± 1 Ma is recorded for early Cambrian strata in New Brunswick that can be correlated with strata in Newfoundland which have been regarded as pre-Tommotian (Landing,

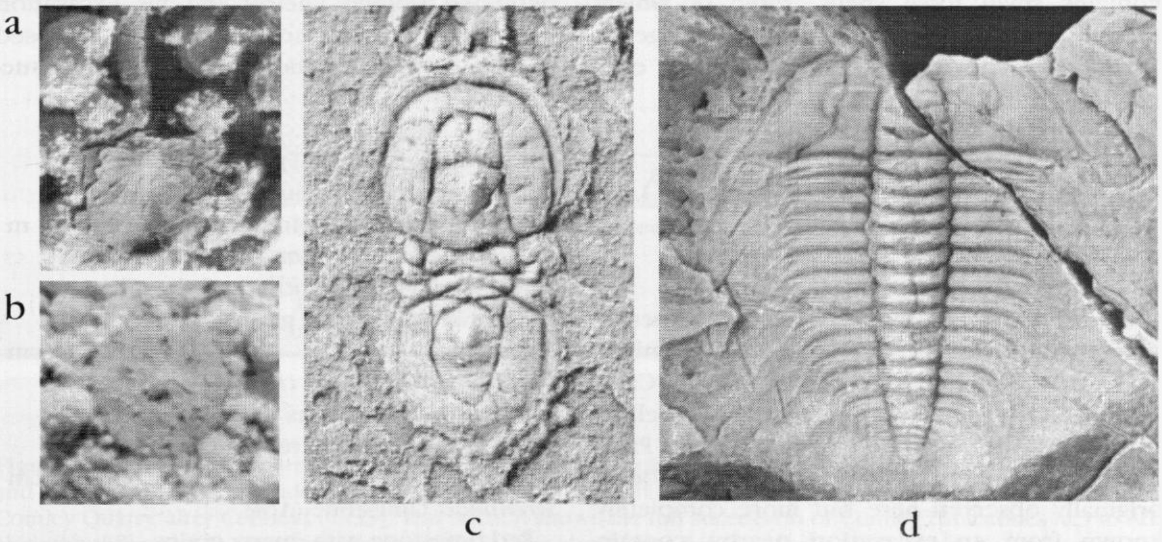

Figure 5.2 Cambrian fossils from English sites. (a, b) *Mobergella* cf. *radiolata* Bengtson, ×12, from the basal Comley Sandstone (Comley Series, Tommotian) of Ercall Quarry. (c) *Tomagnostus fissus* (Linnarsson), ×10, from the Abbey Shales (St David's Series), Illing's trenches, at Hartshill Hayes. (d) *Olenus gibbosus* (Wahlenberg), ×6, from the Outwoods Shales (Merioneth Series), Purley Quarry.

1994), but their correlation with the Tommotian Stage of Siberia is contentious (Rozanov, 1995)

The section in Ercall Quarry shows strata of mid- to late Tommotian age overlying the Ercall Granophyre, which provides a minimum age of 533 ± 13 Ma. This falls well within the constraints offered by Isachsen *et al.* (1994) and shows that the basal part of the Cambrian in Shropshire is considerably younger than the base of the system as defined at Fortune Head and also indicates that the upper part of the Tommotian is likely to be younger than about 533 Ma. However, if the Ercall Granophyre was intruded at 560 ± 1 Ma, it pre-dates the defined base of the Cambrian, which accordingly falls within the hiatus represented by the local Precambrian–Cambrian unconformity. Even though co-ordination of the Tommotian with radiometric time-scales is still insecure, evidence from the Ercall Quarry section shows the magnitude of the hiatus beneath the local basal Cambrian transgression.

Conclusions

Ercall Quarry shows a unique view of Cambrian history in Shropshire. A granitic rock (the Ercall Granophyre) that solidified 560 million years ago is overlain unconformably by beach sands (Wrekin Quartzite) younger than about 533 million years old that were deposited from a deepening sea. The overlying Comley Sandstone contains small fossil shells, some of which, though known from beds of similar age in Scandinavia and Siberia, are not known elsewhere in Britain.

COMLEY QUARRY (SO 4845 9647)

Introduction

Comley Quarry is a historic locality of international significance. It shows a Comley–St David's (traditionally Lower–Middle Cambrian) contact, where strata with olenellids (*Callavia*) are overlain by beds with Paradoxididae. The intervening Comley Limestones, originally observed here but more completely known from an excavation nearby, contain *Protolenus* faunas of debated Lower–Middle Cambrian age and are the type strata for numerous genera and species, some of which are of wide or intercontinental distribution. Several non-sequences or paraconformities have been detected within a mere 2–3 m of strata.

The Cambrian rocks around Comley and Caer Caradoc are poorly exposed. They are famous, however, for their faunal succession, worked out by Cobbold by means of excavations (Cobbold, 1927, p. 553) and described in several papers (listed in Rushton, 1974, p. 115). The starting point for Cobbold's investigations was Comley Quarry (4845 9647), which is one of the few permanent exposures of the Cambrian in the Comley area and which shows a contact between the Comley and St David's Series (Lower and Middle Cambrian).

In the 1880s, at the time when the debate about the relative ages of Olenellid and Paradoxidid faunas was being resolved, Lapworth (1888, 1891) reported the Olenellid trilobite *Callavia callavei* (Lapworth) from Comley Quarry and later described *Paradoxides groomi* Lapworth from the same place. To clarify the stratigraphical relationships of these two trilobite occurrences, Cobbold investigated Comley Quarry in detail and also made an excavation (his 'Excavation No. 2') some 200 m along strike to the south. He collected large faunas from the various beds encountered and described the results in a series of papers (Cobbold, 1910, 1911, 1921, 1931, 1936). An important result was the identification of a *Protolenus* fauna stratigraphically between *Callavia* and *Paradoxides*. In 1933 Cobbold described Comley Quarry and his Excavation No. 2 as they appeared when best exposed (Figure 5.3), giving the following general succession.

Quarry Ridge Grit (Ba1)	
Coarse quartzose glauconitic sandstone, calcareous and conglomeratic at base	6 m
Lapworthella Limestone (Ad)	
Very dark-grey, composed of phosphatic material with quartz grains; locally thinning out	up to 15 cm
Protolenus Limestone (Ac5)	
Pale-grey fossiliferous limestone, dark and phosphatic where fossils are rarer	about 15 cm
Strenuella Limestone (Ac4)	
Red limestone with quartz grains and a phosphatic matrix	about 25 cm
Eodiscus bellimarginatus Limestone (Ac3)	
Phosphatic sandy limestone	about 55 cm

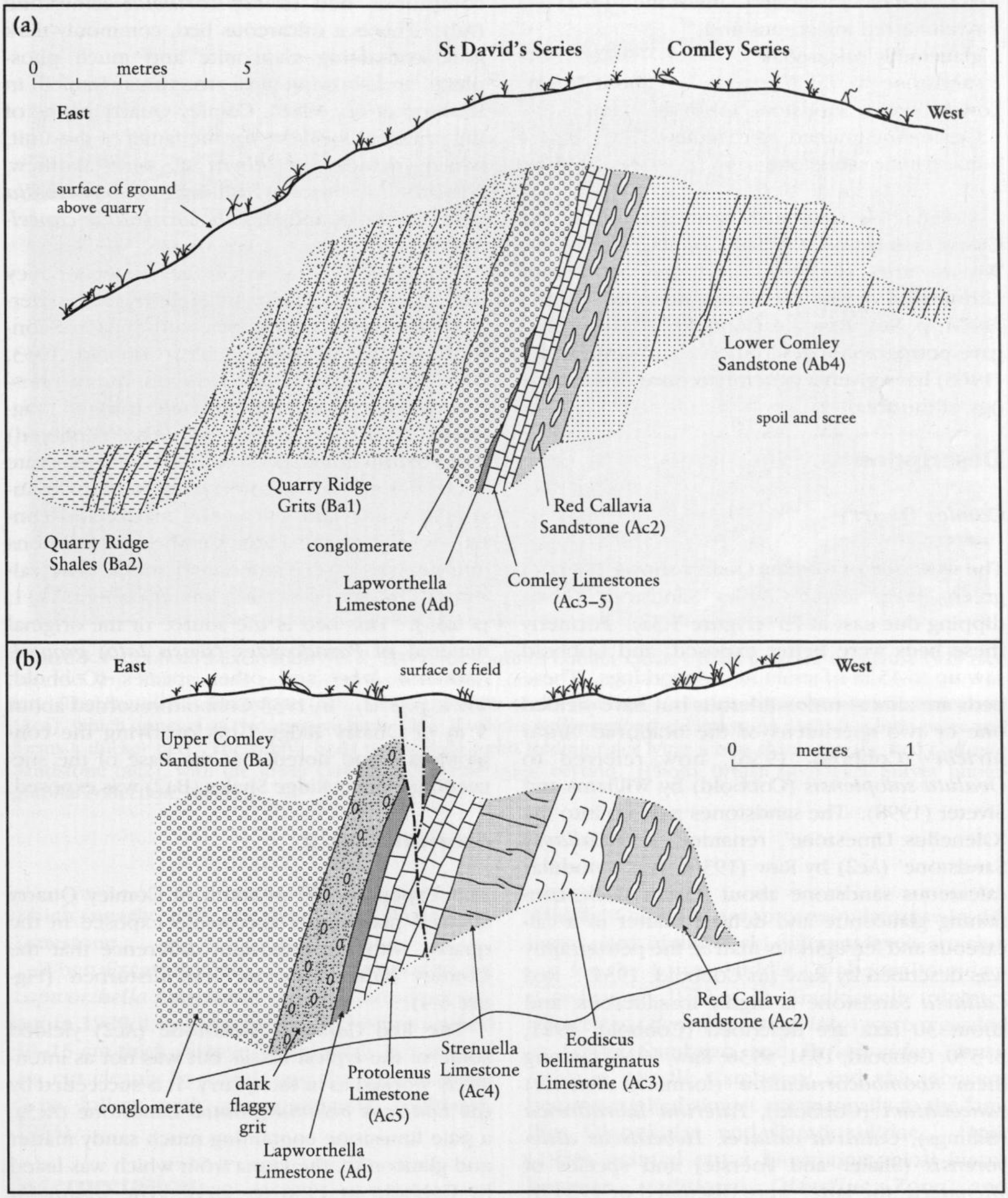

Figure 5.3 (a) Comley Quarry, looking south, showing the rock succession as drawn by Cobbold between 1906 and 1914. (b) Lower to Middle Cambrian succession seen in 1933 in Cobbold's 'Excavation No. 2', south of Comley Quarry, after Cobbold (1933). This section shows the full succession of Comley Limestones Ac3 to Ad. Note the difference in scale between (a) and (b). See also Figure 5.4.

Red *Callavia* Sandstone ('Limestone') (Ac2)

Nodular red micaceous and glauconitic calcareous sandstone	about 75 cm

Lower Comley Sandstone (Ab4)

Green, fine-grained, micaceous glauconitic sandstone	> 15 m

Comparable sequences were detected at the Cwms, a location SSW of Comley, and in the Wrekin area (Cobbold and Pocock, 1934). Lithological details are summarized in Rushton (1974, p. 96), Raw (in Cobbold, 1931, p. 502) gave petrographic descriptions, and Greig *et al.* (1968) have given a general account of the geology of the area.

Description

Comley Quarry

The west side of Comley Quarry shows 2–3 m of green, flaggy lower Comley Sandstone (Ab4), dipping due east at 73° (Figure 5.3a). Formerly these beds were better exposed, and Cobbold saw up to 15 m of strata in old workings. These beds are almost unfossiliferous but have yielded one or two specimens of the bradoriid *'Aluta ulrichi'* (Cobbold, 1936), now referred to *Ovaluta salopiensis* (Cobbold) by Williams and Siveter (1998). The sandstones pass up into the 'Olenellus Limestone', renamed 'Red *Callavia* Sandstone' (Ac2) by Raw (1936). It is a nodular calcareous sandstone about 75 cm thick, containing glauconite and detrital matter in a calcareous and ferruginous matrix; the petrography was described by Raw (in Cobbold, 1931). Red *Callavia* Sandstone is highly fossiliferous, and about 30 taxa are described (Cobbold, 1921, p. 370; Cobbold, 1931, 1936; Raw, 1936), among them *Rhombocorniculum* (formerly *Helenia*) *cancellatum* (Cobbold), *Paterina labradorica* (Billings), *Callavia callavei, Hebediscus attleborensis* (Shaler and Foerste) and species of *Micmacca*; the latter were discussed in 1934 by Lake (1906–1946, p. 172).

Overlying the Red *Callavia* Sandstone are beds of the Comley Limestones, Ac3, Ac4 and Ac5, together about 0.5 m thick. Apparently all three units are present and have yielded a few of their typical fossils, but the section is disturbed by faulting and a better section is available at Excavation No. 2 (see below). Adhering to the top of the Comley Limestones is the thin, discontinuous bed of *Lapworthella* Limestone (Ad). This is a calcareous bed, commonly dark grey, containing glauconite and much phosphate, and showing algal structures (Danielli in Rushton *et al.*, 1988). Comley Quarry is one of the principal localities for the fauna of this unit, which includes *Acrothyra* cf. *sera* Matthew, *Hyolithellus micans* Billings, *Lapworthella nigra* Cobbold, and *Rhombocorniculum cancellatum.*

The lowest division of the upper Comley Sandstone, the Quarry Ridge Grits (Ba1), overlies the Comley Limestones with apparent conformity. The base is variable (Cobbold, 1933, p. 473) and may include a discontinuous phosphatic layer 1–2 cm thick with trilobite fragments (*Kootenia [Dorypyge] lakei* (Cobbold) and *Paradoxides* sp.). A basal conglomerate about 0.5 m thick follows: it has a coarse glauconitic sandy and calcareous matrix and contains clasts of the older Cambrian formations and pebbles of Precambrian(?) rocks. The calcareous matter occurs as 'clots' (Cobbold, 1911, p. 283). This bed is the source of the original material of *Paradoxides* (*sensu lato*) *groomi, Kootenia lakei* and other species (Cobbold, 1921, p. 372). In 1933 Cobbold recorded about 5 m of Quarry Ridge Grits overlying the conglomerate and noted that the base of the succeeding Quarry Ridge Shales (Ba2) was exposed.

Excavation No. 2

This exposure 180 m south of Comley Quarry showed part of the succession exposed in the quarry, with the important difference that the Comley Limestones are less disturbed (Figure 5.4).

The Red *Callavia* Sandstone (Ac2) yielded some of the typical fossils but was not as intensively worked as in the quarry. It is succeeded by the *Eodiscus bellimarginatus* Limestone (Ac3), a pale limestone containing much sandy matter and glauconite, the fauna from which was listed by Cobbold in 1936 (p. 233). The *Strenuella* Limestone (Ac4), which follows, is a reddish limestone with a fine detrital component, glauconite and phosphate, and the overlying *Protolenus* Limestone (Ac5) is a pale bioclastic limestone with glauconite and much phosphate, but little detrital matter. The faunas from the latter units were listed by Cobbold (1921, p. 371). Excavation No.2 was the principal source for all these faunas, amounting to about 50 taxa, of

Figure 5.4 Cobbold's Excavation No. 2, 200 yards south of Comley Quarry, photographed in August 1929 (see Figure 5.3b). The hammer rests on the *Lapworthella* Limestone (Ad), with the upper Comley Sandstone to the left. The *Protolenus* Limestone (Ac5) lies to the right of the hammer, underlain by the *Strenuella* Limestone (Ac4), which appears as two massive beds. The *Eodiscus bellimarginatus* Limestone (Ac3) is a little paler and forms a thicker bed. The rubbly beds to the right (with folding ruler lying across them) are the Red *Callavia* Sandstone (Ac2), with the lower Comley Sandstone (Ab4) beyond. (Photo: British Geological Survey photographic collection, A4857.)

which nearly half are from the *Protolenus* Limestone.

When Excavation No. 2 was first opened the *Lapworthella* Limestone (Ad) was not detected, but in 1929 it was revealed as a continuous bed 10–15 cm thick (Figure 5.3b). Both Ac5 and Ad are cut cleanly by a fault and the Quarry Ridge Grits follow with paraconformity (Cobbold, 1933).

Interpretation

The strata at Comley Quarry and Excavation No. 2 represent slow intermittent deposition in shallow-water environments. Successive units show a decrease in clastic input and an increase in phosphates; each unit contains a distinct fauna and is separated from contiguous units by hiatuses in deposition.

The meaning of the terms 'Lower' and 'Middle' Cambrian are uncertain, because in different parts of the world different levels are chosen for the Lower–Middle Cambrian Boundary (Cowie *et al.*, 1972, p. 7). Traditionally trilobites referred to *Olenellus* (*sensu lato*) were regarded as Lower Cambrian and *Paradoxides* (*sensu lato*) as Middle Cambrian, and this concept became applied almost axiomatically to the families Olenellidae and Paradoxididae. Öpik (1966) pointed out a biostratigraphical hiatus between traditional *Olenellus* Zone and *Paradoxides*-bearing strata, discussed the classification of the intervening *Protolenus* Zone and *Paradoxides*-bearing strata, and considered the classification of the intervening *Protolenus* Zone and Ordian Stage. Subsequently Geyer (1990) summarized evidence showing that in Morocco olenellids (but not *Olenellus* itself) range higher than the level at which Paradoxididae (but not *Paradoxides* itself) appear.

It was to avoid applying the ambiguous terms 'Lower' and 'Middle' Cambrian to British strata that Cowie *et al.* (1972) introduced the regional terms 'Comley Series' and 'St David's Series'. The former refers particularly to the faunal succession in Shropshire; the latter commences with correlatives of the *Paradoxides oelandicus* zonal group of the Scandinavian succession, following Westergård (1936).

At Comley, the Comley–St David's boundary is unambiguous. It is placed above the *Lapworthella* Limestone (Ad). The Red *Callavia* Sandstone (Ac2) and *E. bellimarginatus* Limestone (Ac3) are also unambiguously Lower Cambrian: their faunas are correlated with the *Callavia* Zone in the lower Brigus Formation of south-east Newfoundland (Cobbold, 1921, p. 370; Hutchinson, 1962), approximately equivalent to the upper Atdabanian of the Siberian sequence. Similarly, the Quarry Ridge Grits (Ba1) are Middle Cambrian by any standard, a species like *Paradoxides groomi* being known from the base of the Swedish *oelandicus* beds (Westergård, 1936, p. 43). The intervening strata represent a long period, as implied by the faunal changes seen in the *Strenuella, Protolenus* and *Lapworthella* Limestones, as well as the overstepping of the former two units by the *Lapworthella* Limestone and the tectonic episode between the deposition of the *Lapworthella* Limestone and the Quarry Ridge Grits (Cobbold, 1927, p. 569). Geyer (1990) correlated the *Strenuella* Limestone with his interpretation of the Lower–Middle Cambrian boundary in Morocco, making the *Protolenus* Limestone Middle Cambrian. Hutchinson (1962) correlated the *Protolenus* Limestone with a poorly known *Protolenus* fauna at the top of the Brigus Formation and below the base of the Middle Cambrian, as he recognized it. The *Protolenus* Limestone corresponds partly with the Toyonian (latest Lower Cambrian of the Siberian succession, but regarded by Geyer as Middle Cambrian). Cobbold assigned the *Lapworthella* Limestone to the Lower Cambrian on account of its faunal and stratigraphical relationships, whilst recognizing that the fauna was not highly diagnostic.

Conclusion

Comley Quarry, interpreted with information from Excavation No. 2 nearby, is an internationally important site. A few metres of beds represent a long period of time during which several fossiliferous limestone beds formed, with pauses in deposition – and even periods of erosion – between individual beds. Each limestone bed has an individual fauna, and the site is the type locality for a great number of species. Ultimately, after a period of uplift and erosion, a new cycle of deposition commenced, with coarse, shallow-water sands containing a Middle Cambrian fossil community.

GULLET PASS PIT (SO 7598 3798)

Introduction

At Gullet Pass Pit a clear exposure of fossiliferous shoreface sandstones allows approximate correlation of the basal Cambrian transgression in the Malvern area with that in the Wrekin area, where the dating is better constrained.

Groom (1899, 1902) described the general succession of Cambrian rocks in the Malvern Hills, distinguishing the Malvern Quartzite from the previously described Hollybush Sandstone of Phillips (1848).

White-leaved Oak Shale	Merioneth
	(St David's not recognized)
Hollybush Sandstone Malvern Quartzite	} Comley

This sequence was adopted by Rushton (1974) and Worssam *et al.* (1989), who each summarize more recent work on the district.

The Malvern Quartzite occurs in faulted inliers, although at one place the base has been seen resting, probably unconformably, on the Malvernian Complex (R. Jones *et al.*, 1969). Because outcrops are small and generally faulted, the total thickness of the formation is unknown but may attain as much as 100 m in all (Groom, 1902, p. 93).

The lithology varies from pale-grey, even-grained quartzose sandstone to brown, sandy conglomerate. The petrology was described by Sweeting (1927). Cross-bedding is recorded, but trace fossils are not. Groom (1902, p. 91) described strata transitional to the overlying dark-green Hollybush Sandstone. The fauna recorded is of low diversity: *Paterina phillipsii* (Holl), *Obolella? groomi* Matley and rare hyolithids, including '*Hyolithes*' (*sensu lato*) *pri-*

maevus Groom. These indicate an early Cambrian age (Comley Series).

Description

Gullet Pass Pit is a small quarry 100 m southwest of the Gullet Quarry (7598 3798). It exposes a small part of the outcrop of Malvern Quartzite, which locally may represent as much as 60 m of beds (Worssam *et al.*, 1989). The quarry exposes about 5 m of hard, brittle, even-grained quartzose sandstone, cemented by silica, forming beds around 10 cm thick; these are interbedded with conglomeratic layers containing rounded pebbles of quartz and rocks derived from the Malvernian Complex. The strata dip north at 32°. Certain sandstone layers contain numerous fragments of the brachiopods *Paterina phillipsii* and *Obolella? groomi*, together with the problematical *Sunnaginia* cf. *parva* Brasier. Humphreys (195-, undated) also recorded *Micromitra labradorica* (Billings), *Kutorgina? anglica* Cobbold and Pocock, *Obolella crassa* (Hall) and *Hyolithes primaevus.*

Interpretation

The Malvern Quartzite is interpreted as an early Cambrian shoreface sand that formed beside a landmass from which Malvernian rocks were being eroded. Although the formation rests unconformably on the Malvernian, the contact at the present locality is considered to be faulted (Worssam *et al.*, 1989). Shells of a low-diversity shallow-water fauna, reworked and broken by currents, are preserved in some beds.

The principal brachiopods recorded, *P. phillipsii* and *O?. groomi*, are known also from the lowest beds of the lower Comley Sandstone (Cobbold, 1921), for example at the Ercall Quarry (see site report, above) in the Wrekin area (Hamblin and Coppack, 1995, p. 9), and these suggest correlation with the Tommotian Stage of Siberia and part of the Comley Series (non-trilobite Zone of Cowie *et al.*, 1972). *Sunnaginia parva* Brasier (1986) was described from the Home Farm Member at Nuneaton (see site report for Woodlands Quarry, below), which is correlated with the Tommotian Stage. One of the fossils recorded by Humphreys (195-, undated), *Paterina labradorica*, occurs at Comley, Shropshire, at a higher horizon, namely at the base of the Comley Limestones (Cobbold, 1921), although as his other fossils are more suggestive of the older, low Comley Sandstone, horizon, Humphreys did not attempt to effect a correlation of the Malvern Quartzite with either level in the lower Comley Sandstone.

Conclusions

This quarry shows beds of shallow-water or beach sands that represent the transgression of the Lower Cambrian sea onto the Precambrian of the Malvern Hills. The sands contain brachiopods known from beds of the same age in Shropshire.

BOON'S QUARRY (SP 329 947)

Introduction

Boon's Quarry (formerly known also as Man-Abell's Quarry) shows the transgressive local base of the Cambrian where it rests unconformably on the Precambrian Caldecote Volcanic Formation. It is the type and only locality for the Boon's Member, the lowest division of the Hartshill Sandstone Formation, which represents a fan-delta derived from the erosion of an irregular local topography.

Lapworth (1898) originally divided the Hartshill Quartzite into three: the Park Hill, Tuttle Hill and Camp Hill quartzites. Brasier *et al.* (1978) subdivided the Camp Hill division into three members, and when Carney (1992a) redescribed the sequence he referred the lowest 19 m of the Park Hill Member in the area of Boon's Quarry to a newly identified 'Boon's Member'. The present divisions of the Hartshill Formation are as follows.

Woodlands Member
Home Farm Member
Jee's Member
Tuttle Hill Member
Park Hill Member
Boon's Member

Away from Boon's Quarry, as at Judkins' Quarry (343 932), the Boon's Member is not developed, and the Park Hill Member rests directly on the Caldecote Volcanic Formation. General accounts of the geology are given in Bridge *et al.* (1998), Carney (1992b), and Carney and Pharaoh (1993).

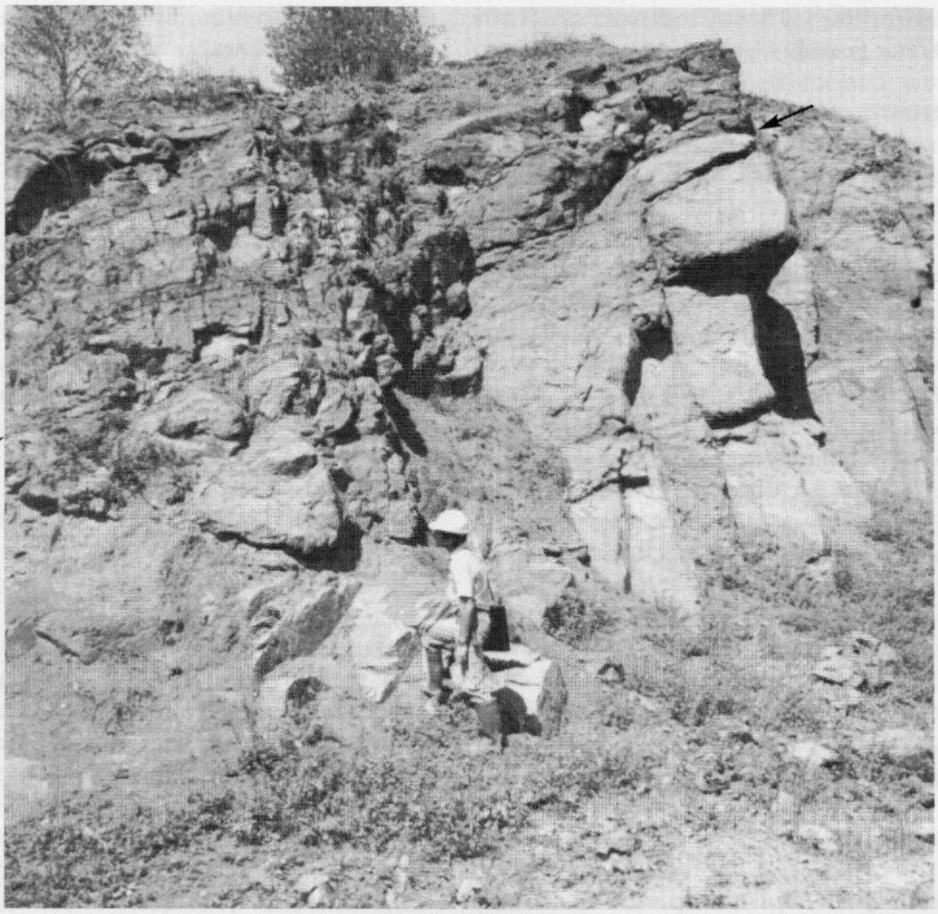

Figure 5.5 Boon's Quarry, north-west of Nuneaton. Spheroidally weathered Precambrian tuffs of the Caldecote Volcanic Formation overlain unconformably (at arrows) by immature conglomeratic sandstones of the Boon's Member of the Hartshill Formation (Lower Cambrian). (Photo: British Geological Survey photographic collection, A14973.)

Description

Boon's Quarry is a western extension of the older Hartshill Quarries and shows the Caldecote Volcanic Formation and the basal parts of the Hartshill Sandstone Formation (Figure 5.5). The Caldecote Volcanic Formation consists of crystal-lapilli tuffs, vitric tuffs, tuffaceous sandstones and mudstones, showing evidence of deposition under water. The upper metre or two are reddened by subaerial weathering prior to the deposition of the Boon's Member.

The Boon's Member comprises red to dark-maroon medium- to coarse-grained sediments, divisible in ascending order into three units A–C as follows (Bridge *et al.*, 1998).

C. Pink or grey sandstones, more than 7 m thick, rarely with planar cross-bedding and with relatively few breccia layers. Some upwardly coarsening beds have undulating upper surfaces indicative of wave or current action.

B. Red, massive to planar-bedded lithic sandstones at least 9 m thick, with thin layers of matrix-rich breccia. Thin beds of mudstone drape the breccia layers, and one of these yielded sphaeromorph acritarchs. The proportion of breccia decreases in the upper layers. The sandstones include large proportions of subrounded quartz grains and Precambrian volcanic detritus.

A. More than 3 m of planar-bedded granulestones with intercalated lenses of massive breccio–conglomerates that include boulders up to 2 m in diameter of Precambrian crystal–lithic tuffs.

The base of the succeeding Park Hill Member is exposed in the south-eastern part of Boon's Quarry (3312 9442) and is taken as the lowest bed showing significant cross-bedding; it has a rippled top. This level coincides with the appearance of detrital glauconite. The only fossils recorded from the Boon's Member are acritarchs. They are of no precise stratigraphical significance but indicate a marine depositional environment (Bridge *et al.*, 1998, p. 29).

Interpretation

Boon's Quarry gives a unique view of the early Cambrian history and geography of the Midland Platform because the Hartshill Sandstone Formation illustrates the initial phase of deposition during the early Cambrian marine transgression. Although the lower parts of the Hartshill Sandstone Formation are not precisely dated, the succession of lithofacies and trace-fossil associations matches that of the Random Formation in south-east Newfoundland (Brasier, 1989), which is of Tommotian and possibly pre-Tommotian age. The Hartshill Formation is referred to the early Cambrian Comley Series, and Brasier (1986) has correlated the higher parts with the Tommotian Stage in Siberia, based on the fauna of small shelly fossils in the Home Farm Member (see site report for Woodlands Quarry, below).

Prior to the early Cambrian transgression, the eroded Precambrian topography appears to have been subject to subaerial spheroidal weathering, resembling in part the lateritic weathering that takes place in tropical climates today. Following a late Precambrian rifting event, the coarse immature beds in the lowest part of the Boon's Member were deposited by mass-flow down south-west-facing palaeoslopes, and these are interpreted as erosional debris derived from fault scarps. Their angular clasts and mineral composition imply transport over short distances with minimal reworking. A mudstone in the overlying unit contains acritarchs that indicate that the depositional environment was marine, and the presence of turbidite beds suggests a fan-delta environment. Sediments in the uppermost unit are more mature, suggesting a more subdued source-area, with sediment being reworked tidally along a shoreline.

The succeeding Park Hill Member is interpreted as a shoreface sand deposit, representing a further cycle of deposition that covered the former rifted topography and transgressed the fan-delta of the Boon's Member.

Conclusions

Boon's Quarry is a unique site that shows the transgression of an early Cambrian sea onto the Midlands landmass: it is the type locality for the Boon's Member, the residue of a delta of coarse detritus that was eroded from the underlying Caldecote volcanic rocks and is overlain by shallow-water marine sandstones of the Park Hill Member.

WOODLANDS QUARRY (SP 3245 9473)

Introduction

Woodlands Quarry is the type locality for the Home Farm Member of the Hartshill Sandstone Formation, a regionally significant division for correlation of the Cambrian. The strata contain a rich fauna of 30+ species of small shelly fossils and microfossils of correlative value, with algal stromatolites. It is the type locality for at least eight species. The quarry also exposes the base of the overlying Purley Shales.

Lapworth (1898) recorded a calcareous unit, the '*Hyolithes* Limestone' or 'Hyolite Limestone', in the upper or Camp Hill Quartzite division of the Hartshill Quartzite. He listed a fauna from the 'Hyolite Limestone' that he referred to the Lower Cambrian, and correlated it with a fauna from Comley, Shropshire. Lapworth's (1898) stratigraphical nomenclature was adopted by Illing (1913), Eastwood *et al.* (1923), Allen (1968) and Rushton (1974). Cobbold (1919) described the fauna and inferred that it was older than any from the Comley Limestones.

Brasier *et al.* (1978) revised the succession and named three members, together equivalent to the Camp Hill Quartzite, in ascending order the Jee's, Home Farm and Woodlands members. The Home Farm Member is equivalent to Lapworth's '*Hyolithes* Limestone' and from it Brasier (1984, 1986) described many further taxa.

The Home Farm Member is principally exposed in quarries, and much detailed information has been derived from working quarries (Bridge *et al.*, 1998, pl. 6); but as these are subject to change, the type section was taken at the

Figure 5.6 Woodlands Quarry, Hartshill, Nuneaton area. Photograph taken in 1913, looking north. The calcareous Home Farm Member of the Hartshill Formation forms a bedding plane on the right, above the right-hand skip. The massive sandstones overlying are the Woodlands Member, succeeded by the basal beds of the Purley Shale Formation, which extend to the quarry floor behind the white-shirted quarryman. The massive rocks forming the left-hand quarry face are a lamprophyre intrusion. (Photo: British Geological Survey photographic collection, A1635.)

permanent exposure in the disused Woodlands Quarry. General accounts of the geology are given in Bridge *et al.* (1998), Baldock (1991) and Brasier *et al.* (1978).

Description

The quarry is now landscaped and rather overgrown, but Figure 5.6 shows it at a time when it was much clearer. The lowest beds now visible are the uppermost few metres of the Jee's Member, consisting of alternations of maroon, buff or green sandstones with shales dipping south-west at about 40°. The sandstones are planar bedded or cross-bedded, extensively bioturbated, and the tops may show pebbly winnowed lags (Bridge *et al.*, 1998, p.27). Foresets seen at the north end of the quarry contain the trace fossils *Arenicolites, Didymaulichnus, Isopodichnus, Planolites* and *Rusophycus*?.

Overlying the Jee's Member with disconformity and a sharp erosive base is the Home Farm Member, about 2 m thick. The succession is as follows:

3. '*Hyolithes* Limestone', about 1 m thick. Maroon to grey sandy limestones, sometimes nodular, with subordinate siltstones, shaly mudstones, within which Brasier (1986) has recognized 12 beds, many of them separated by hardground discontinuities. The fauna of over 30 taxa includes Brachiopoda, Hyolitha, Mollusca, protoconodonts, tommotiids and problematical tubular fossils such as *Coleoloides* and *Hyolithellus*; the fauna of Bed 10iii is particularly diverse. Many of the hardgrounds are encrusted with algal stromatolites. The base of Bed 2 is an eroded hardground resting on a phosphatized limestone conglomerate (Beds 1i–1v) with a fauna that includes species of *Paterina, Coleoloides, Hyolithellus, Torellella, Sunnaginia, Camenella* and a few Hyolitha.
2. Calcareous micaceous sandstone, glauconitic and bioturbated, up to 0.5 m thick.
1. Basal quartzose conglomerate, less than 0.5 m

thick. The fauna includes *Paterina phillipsii* (Holl), *Coleoloides typicalis* Walcott, and species of *Hyolithellus, Sunnaginia* and *Turcutheca*?.

The succeeding Woodlands Member consists of dark-grey, glauconitic, subarkosic sandstones with subordinate mudstone, up to 14 m thick. Some beds show cross-bedding and some have thin mudstone drapes and rippled tops. Brasier (1989) recorded scarce *Coleoloides* and *Torellella*.

The Purley Shale Formation, consisting of red to maroon blocky mudstones with a few calcareous concretions, is seen to a thickness of about 10 m. At Woodlands Quarry the base rests sharply on the Woodlands Member, but at Hartshill Quarry to the south-east there is mixing of the sediment of the two divisions at their contact (Bridge *et al.*, 1998). Rushton (1966) described trilobite fragments, possibly *Callavia,* from 0.3–1 m above the base of the Purley Shale at Woodlands Quarry and from the same horizon elsewhere along strike, and Brasier (1989) reported *Coleolides,* tubes of *Platysolenites antiquissimus* Eichwald and *Teichichnus* burrows.

Interpretation

The Hartshill Sandstone Formation was deposited during a marine transgression on to eroded Precambrian rocks on the margins of the Midlands Platform (see site report for Boon's Quarry, above). The lowest unit at Woodlands Quarry, the Jee's Member, represents deposition in a wave-agitated environment, signifying shallower water than was associated with the underlying parts of the Hartshill Formation (Bridge *et al.*, 1998). The upper part of the Jee's Member may have been eroded before deposition of the Home Farm Member.

The Home Farm Member represents deposition during a relative rise in sea level. The sources of sandy detritus were flooded, allowing a condensed carbonate sequence to form slowly and intermittently, interpolated by episodes of submarine scouring. Brasier *et al.* (1992a) compared records of stable isotopes from the Home Farm Member with those from correlative beds in Newfoundland and suggest that during the period of their formation the shelf sea was shallowing from subtidal to peritidal depths.

The Woodlands Member is interpreted as a wedge of shallow-water sediment deposited during a lower stand of sea level. Subsequently, deepening caused the arenaceous source to move landwards, and minor condensed bioturbated sequences formed at the top of the unit, upon which the Purley Shales formed in an outer-shelf environment.

Brasier (1986, 1989) correlated the Hartshill Sandstone Formation with the Tommotian and basal Atdabanian of the Siberian succession. The fauna of small shelly fossils in the Home Farm Member, in particular the first appearances of such taxa as *Allatheca degeeri* (Holm) and *Rhombocorniculum insolutum* Missarzhevsky and Mambetov, indicates a correlation with the upper Tommotian and with the *Camenella baltica* Zone developed in the Fosters Point Formation (formerly part of the Smith Point Limestone) of south-east Newfoundland. The presence of trilobite fragments at the base of the Purley Shale Formation is suggestive of an Atdabanian age, whilst the occurrence about 70 m higher of a fauna with the trilobite *Serrodiscus bellimarginatus* (Shaler and Foerste) suggests correlation with a level near the Atdabanian–Botomian boundary and with the *S. bellimarginatus* fauna in the Brigus Formation of south-east Newfoundland (Rushton, 1966).

Conclusions

Woodlands Quarry is nationally important because it is the only permanently exposed site where the fossil communities of the Home Farm Member are preserved. They represent the oldest diverse shelly assemblages known at outcrop in Britain and enable correlation with similar faunas known elsewhere from Siberia and Newfoundland.

ILLING'S TRENCHES, HARTSHILL HAYES (SP 3240 9423)

Introduction

Illing's Trenches are the type locality for the Abbey Shales Formation and are the only place where practically the full thickness of the formation has been examined. The strata contain a rich fauna and this site is internationally important, being the type locality for over 20 taxa of trilobites. The succession of trilobites is the best-documented for the mid St David's Series in

Britain, making this an important biostratigraphical site.

Illing (1916) distinguished the Abbey Shales as a succession of variegated, mainly grey, shaly mudstones, sometimes pyritous, that differ in their darker colour and greater fissility from the underlying Purley Shale Formation and from the overlying division, now known as the Mancetter Shale Formation. Although the Abbey Shale Formation is very poorly exposed, Illing was able to map the outcrop from Atherstone in the north-west to near Stockingford in the south-east, and recent mapping has confirmed his work, with minor adjustments near Stockingford (British Geological Survey, 1994a). Along the outcrop the thickness of the formation varies from about 10 m to 40 m. General accounts of the geology are given by Bridge *et al.* (1998) and by Taylor and Rushton (1972), who also described part of the succession seen in Merevale No. 3 Borehole. Cook (1977) described a temporary exposure of Abbey Shale Formation near Stockingford.

Description

As there are no significant natural exposures of the Abbey Shale Formation, Illing caused trenches about 40 m long to be dug across the outcrop at Hartshill Hayes, where the formation is about 30 m in thickness and dips south-west at around 60°. The basal beds were not revealed, but a subsidiary section at Purley Park Lane (3101 9610) showed the lowest 3 m of the formation and the passage down into the Purley Shale Formation.

Illing (1916, p. 391) described the lithological succession minutely, and the overgrown state of the trenches at present is such that nothing further can be added. The 'calcareous glauconitic conglomerate' at the top of the succession is poorly visible where it is overlain by smooth, greenish-grey, micaceous mudstones of the Mancetter Shale Formation.

Illing recorded 22 fossil-bearing horizons, which yielded sponge spicules, brachiopods including *Linnarssonia*, hyolithids, *Stenotheca*, and more than 50 species of trilobites, including 32 of Agnostoidea (e.g. Figure 5.2c). He described all the trilobites and tabulated their occurrences bed by bed (Illing, 1916, pp. 402–403). Rushton (1979) reviewed the agnostid fauna and Lake (1906–1946) revised most of the other taxa.

Interpretation

The Abbey Shale Formation is thought to have been deposited on a fairly shallow marine shelf during a period of relatively low oxygenation of the sea floor, when dark pyritous muds could accumulate. There were periods, however, when the influence of tidal currents (Allen, 1968, p. 35) deposited thin beds of glauconitic sandstone. The varying bottom-conditions led to colonization by a diversity of benthic trilobites.

Illing grouped the successive assemblages of trilobites into six faunas, which Rushton (1979) correlated approximately with the Scandinavian zonal succession (Table 5.1).

This succession of faunas formed an important component of the biostratigraphical synthesis by Thomas *et al.* (1984, fig. 3) and has been

Table 5.1 The trilobite faunas recognized by Illing, correlated with the Scandanavian zonal succession (Rushton, 1979).

Horizons	**Faunas**		**Biozones**
G1–G3	Upper	*Paradoxides*	*Ptychagnostus punctuosus*
F1–F3	Lower	*davidis* Fauna	*Hypagnostus parvifrons*
E1–E3	*Hartshillia* (passage) Fauna		?
D1–D3	Upper	*Paradoxides*	
B1–C3	Lower	*hicksii* Fauna	*Tomagnostus fissus*
A4	*Paradoxides aurora* Fauna		? *Ptychagnostus gibbus*

used as a standard for correlation with other successions, such as those of the St David's area in South Wales (Illing, 1916, p. 38), St Tudwal's Peninsula in North Wales (Nicholas, 1916; Young *et al.*, 1994) and Manuel's Brook in south-east Newfoundland (Howell, 1925). Although the succession at Porth-y-rhaw is better exposed, the faunal succession revealed by Illing's Trenches was documented in greater detail. Illing (1916, p. 401) showed that part of the fauna was facies-controlled and mentioned one example, but other instances (Illing 1916, p. 450) were never described.

The site of Illing's Trenches is the type locality for at least 22 taxa of trilobites. Illing had 12 new species or subspecies of agnostid, to which two subspecies have since been added, and he described five new polymerid species, to which Lake added three more. Even though some synonyms have been detected, the Abbey Shales fauna exceeds 50 valid taxa. Illing (1916, p. 397) recorded the presence of juvenile forms of several species, but, with minor exceptions (Rushton, 1979, p. 56), these remain undescribed.

Illing's Trenches are not only a key site for the contributions that their faunas make to understanding the biostratigraphy of the mid-part of the Middle Cambrian in Britain and the Acado-Baltic realm: they also hold potential for ontogenetic studies of certain trilobites and the analysis of benthic faunas in relation to fluctuating environments in a Cambrian shelf sea.

Conclusions

Illing's Trenches are the only place in England where the rich trilobite assemblages of the mid-part of the Middle Cambrian Period has been seen. They are the type locality for several trilobite species. The succession of trilobite zones is used as a standard for precise dating of rocks of similar age elsewhere in Britain and abroad.

MANCETTER QUARRIES (SP 304 963–SP 311 949)

POTENTIAL GCR SITE

Introduction

Mancetter Quarries show by far the best exposures of the Stockingford Shale Group, which itself is the most complete representation of the Cambrian System (above its lowest parts) in England. They have the only large exposure of Upper Cambrian rocks in England.

Lapworth (1886) distinguished the middle part of the Stockingford Shales as the 'Oldbury Shales', which he referred to the Upper Cambrian. Illing (1913, 1916) recognized four subdivisions of the Oldbury Shales, in ascending order the Abbey Shales, the Outwoods Shales, the Moor Wood Flags and Shales, and the Monks Park Shales. He showed that the Abbey Shales is Middle Cambrian (see site report for Illing's Trenches) and recorded Upper Cambrian fossils from the Outwoods Shales. Taylor and Rushton (1972) described boreholes that penetrated almost the whole thickness of the Oldbury Shales and in the light of these reviewed the whole succession, which they showed to have the fullest sequence of Upper Cambrian trilobite zones in Britain. They separated a further subdivision at the base of the Outwoods Shales – the Mancetter Grits and Shales. Rushton (1978) showed that this unit is of latest Middle Cambrian age, the base of the Upper Cambrian lying close to the base of the Outwoods Shales. Rushton (1983) described the trilobite fauna of the Outwoods Shales. Bridge *et al.* (1998) reviewed the geology of the Nuneaton area and formalized the subdivisions of the Stockingford Shale Group as formations.

Description

Mancetter Quarries exploit the Oldbury Sill, the largest of the lamprophyre sills intruded into the Stockingford Shales in the Nuneaton area. Purley Quarry in the north is being worked, but Jubilee Quarry, the site of the Merevale No. 3 Borehole, is now filled in and landscaped. Oldbury Quarry, to the south, having been much extended since Taylor and Rushton (1972) described it, is now (1998) worked out.

Besides the Oldbury Sill, which thickens from 30 m in the north to 50 m in the south and dips at about 20° to the south-west, these quarries afford strike sections through the middle parts of the Outwoods Shale Formation below and above the sill. The Outwoods Shale consists of pale-grey and dark-grey mudstones interbedded on a scale of millimetres to metres, together with thin, silty and micaceous beds and lamellae. The dark mudstones are organic-rich, pyritous and unburrowed; the pale mudstones are commonly burrowed. Taylor and Rushton (1972, p. 10) described the lithologies in detail and illustrated representative sections about 30 m thick both below and above the sill, which bakes the mudstones for about 7 m below and 5 m above it.

Fossils, although not abundant, occur at several horizons (Taylor and Rushton, 1972, p. 15). In Purley Quarry the section below the sill yielded the monotype of *Modocia anglica* Rushton 25 m below the sill and *Proceratopyge* cf. *nathorsti* Westergård about 3 m higher. The appearance of *Olenus gibbosus* (Wahlenberg) (Figure 5.2d), *Glyptagnostus reticulatus* (Angelin) and *Homagnostus obesus* (Belt) 10 m below the sill marks the base of the *gibbosus* Subzone, the lowest division of the *Olenus* Zone, and these taxa range to 6 m above the sill. *Olenus austriacus* Yang (Rushton, 1983, p. 125) was found 10 m above the sill, and the occurrence of *O. truncatus* (Brünnich) and *O. transversus* Westergård about 5 m higher indicates the base of the *truncatus* subzone.

In Oldbury Quarry *Olenus truncatus* occurs 25 m below the sill and is overlain, 17 m below the sill, by *O. wahlenbergi* Westergård, which indicates the succeeding *wahlenbergi* subzone. Above the sill *O. cataractes* Salter, *Proceratopyge tullbergi* Westergård and *P.* cf. *rectispinata* (Troedsson) were collected, and Rushton (1983) referred these to his *cataractes* subzone. Other, longer-ranging, taxa are *Homagnostus obesus*, '*Grandagnostus*' *falanensis* (Westergård) (now referred to *Peratagnostus* by Robison, 1994, p. 66), phosphatocope arthropods described by Williams and Siveter (1998), including *Cyclotron lapworthi* (Groom), and sponge spicules, hyolithids and lingulid brachiopods.

Interpretation

The Stockingford Shale Group is considered mainly to have been deposited in a quiet outer-shelf setting in no great depth of water. The dark and pale mudstone alternations of the Outwoods Shale Formation are taken to represent more or less poorly oxygenated conditions, and the general lack of sandstone beds suggests quieter conditions than obtained during the better-oxygenated conditions of the Mancetter and Moor Wood formations, each characterized by the presence of sandstone beds. Dysaerobic conditions became much more marked when the condensed black Monks Park Shale Formation was formed (Taylor and Rushton, 1972).

Evidence from Merevale No. 3 Borehole shows that the lowest 9 m of the Outwoods Shale Formation is referable to the *laevigata* Zone, the highest zone of the Middle Cambrian, and that the succeeding 58 m are in the lowest Upper Cambrian *pisiformis* Zone (Rushton, 1978). Only the uppermost part of the latter zone is known from outcrop at the present site. At Mancetter Quarries all four of the locally recognized subzones of the *Olenus* Zone are present in sequence in the 60–70 m of shales exposed above the *pisiformis* Zone. The full thicknesses of the *gibbosus* subzone (14 m), *truncatus* subzone (10 m) and *wahlenbergi* subzone (about 20 m) are, or were, exposed but only the lower 10–20 m of the *cataractes* subzone, whose total thickness is estimated as nearly 100 m (Rushton, 1983). At Purley Quarry the sill is in the *gibbosus* Zone, whereas in Oldbury Quarry (and Jubilee Quarry) it lies between the *wahlenbergi* and *cataractes* subzones; this shows that the sill transgresses across more than 30 m of beds between Purley and Jubilee quarries (Taylor and Rushton, 1972, p. 15).

Conclusions

Mancetter Quarries show the only large exposures of the rocks of Merioneth Series in England and are the only good fossiliferous representatives of the Stockingford Shale Group now exposed.

CHARNWOOD FOREST AREA, ENGLISH MIDLANDS

In addition to the sites in the Welsh Borderlands described above, two sites in the Charnwood Forest area expose strata conventionally assigned to the Charnian Supergroup, which is predominantly of Precambrian (Neoproterozoic) age. These sites are in the Brand Group at the top of the Charnian Succession. Following the development of new criteria for recognizing early Cambrian rocks, coupled with the discovery of Cambrian-type trace fossils, the strata are now referred to the Placentian Series at the base of the Cambrian System. The discovery of Cambrian trace fossils in the Swithland Formation (Bland and Goldring, 1995) has added significantly to the extent of Cambrian rocks in the Midlands. Though now considered representative of part of the Cambrian, these two sites will be described fully with the other sites in Charnwood Forest in the companion volume on *Precambrian Rocks of England and Wales* (Carney *et al.*, in prep.). However, Dr J.N. Carney has kindly supplied brief notes on these sites for inclusion here.

STABLE PIT, BRADGATE PARK (SK 5340 1000)

Stable Pit exposes part of the Brand Hills Formation, a division of the Brand Group and supposedly the oldest Cambrian rocks in the Charnwood Forest area. McIlroy *et al.* (1998) suggest a correlation with the lower part of the Hartshill Formation at Nuneaton (see site report for Boon's Quarry, above).

THE BRAND (SK 537 121)

The Brand exposes part of the Brand Hills Formation and part of the overlying mud-rich turbidites of the Swithland Formation. The latter formation elsewhere contains the trace fossil *Teichichnus* (Bland and Goldring, 1995), which is considered indicative of a Cambrian rather than Precambrian age. McIlroy *et al.* (1998, fig. 6) indicate a correlation of the Swithland formation with the higher parts of the Hartshill Formation and the lower part of the overlying Purley Shale Formation (see site report for Woodlands Quarry, above).