British Cambrian to Ordovician Stratigraphy

A.W.A. Rushton
Palaeontology Department, Natural History Museum,
London, UK

A.W. Owen
Division of Earth Sciences, University of Glasgow, UK

R.M. Owens
Department of Geology, National Museum of Wales, Cardiff, UK

and

J.K. Prigmore
Equipoise Solutions Ltd, Croydon, UK

GCR Editor: **L.P. Thomas**

JOINT NATURE CONSERVATION COMMITTEE

Chapter 10

Arenig to Caradoc of Shropshire

A. W. Owen, R. M. Owens
and A. W. A. Rushton

INTRODUCTION

The Ordovician rocks of Shropshire form two contrasting sequences that are separated by the Precambrian rocks of the Longmynd block (Figure 10.1). Both are of great importance. The Caradoc area to the east is the original site of Murchison's (1839, p. 216) 'third Formation, or Caradoc Sandstone', and because the Caradoc Series has traditionally been based closely on the succession in this area, it has been the focus of much subsequent work. The sequence in the Shelve area to the west of the Longmynd is much thicker and the rocks exposed extend through all of the lower half of the Ordovician. They constitute a stratigraphical standard of great value, in particular for correlation between shelf and basin successions.

SHELVE AREA

The Shelve area in west Shropshire (and part of Powys) exposes a succession about 4 km thick at the eastern edge of the Welsh Basin. This ranges virtually continuously from low in the Tremadoc to the Soudleyan Substage in the mid-Caradoc (Figure 10.2). The area (or 'inlier') is bounded to the south-east by the Linley–Pontesford Fault; east of the fault the Ordovician rocks of Pontesford are related to those of the Caradoc area (Dean and Dineley, 1961), and the Pontesford Lineament is, together with the Church Stretton Fault belt, accepted as marking the eastern edge of the Welsh Basin (Woodcock, 1984; Bluck *et al.*, 1992). Though much of the succession is representative of deep-shelf conditions, it includes shallow neritic environments at some levels, and there are Llanvirn volcanic edifices that show evidence of shallow-water erosion. It is evident therefore that there was subsidence on the Pontesford Lineament contemporaneous with deposition during the earlier half of the Ordovician.

Although Murchison (1839) described localities in the Shelve area, it was Lapworth who recognized the stratigraphical importance of the succession (Lapworth and Watts, 1894), containing as it does alternations and mixtures of shelly and graptolitic faunas. Whittard extended Lapworth's work by mapping the area and mak-

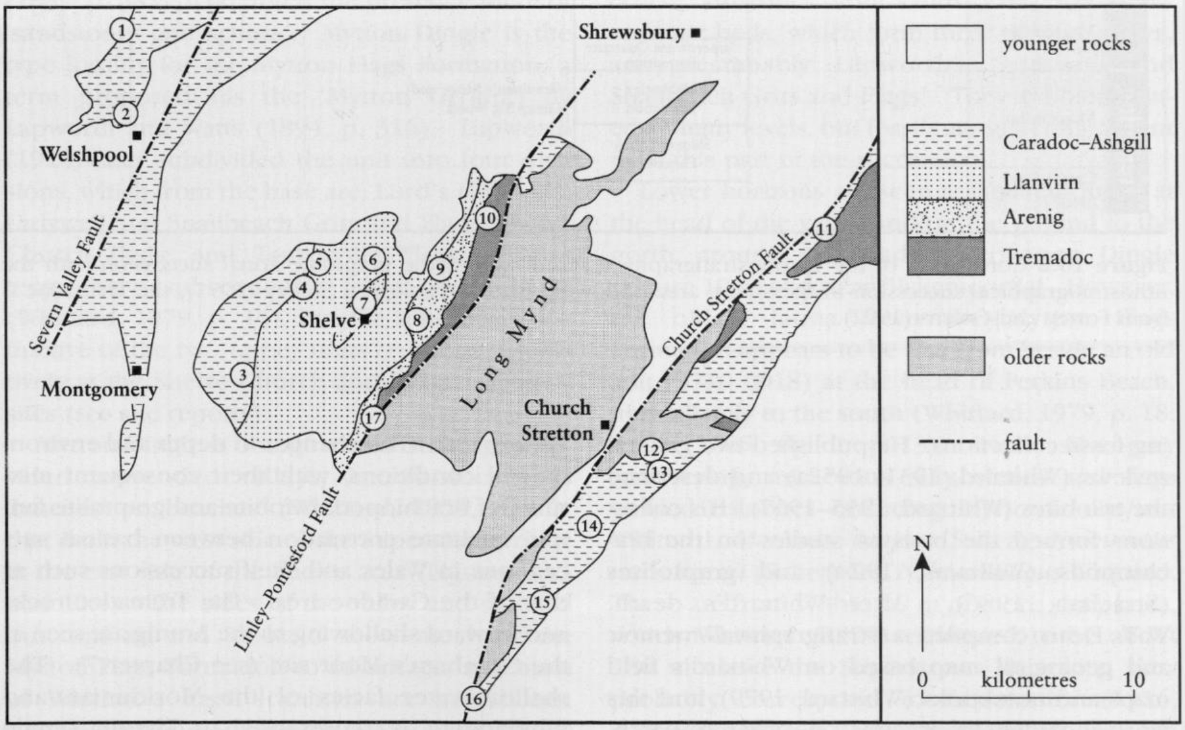

Figure 10.1 Map showing the distribution of Ordovician rocks in south Shropshire and eastern central Wales, from British Geological Survey (1994c). GCR sites as follows: 1, Gwern-y-brain; 2, Trilobite Dingle; 3, Spy Wood and Aldress dingles; 4, Meadowtown; 5, Betton Dingle; 6, Hope Valley; 7, Shelve Church; 8, Bergam Quarry; 9, Mytton Dingle; 10, Granham's Moor (Tremadoc, see Chapter 7); 11, Coundmoor Brook (Harnage); 12, Hope Bowdler; 13, Soudley Quarry; 14, Marshwood; 15, Onny River; 16, Coston Farm; 17, Linley Big Wood (Tremadoc, see Chapter 7).

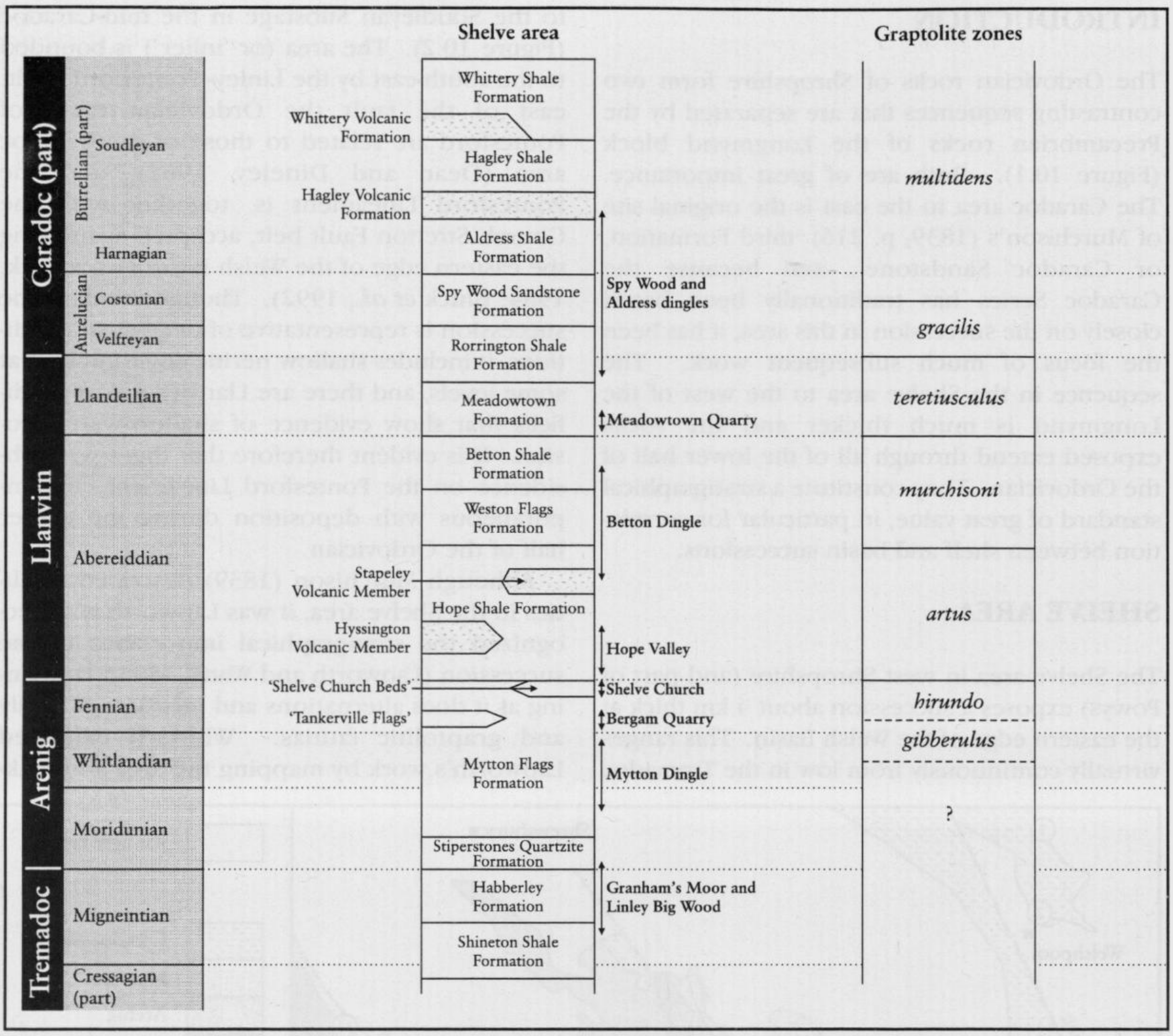

Figure 10.2 Correlation of the chronostratigraphical standard and the graptolite zonal succession with the lithostratigraphical succession in the Shelve area, following British Geological Survey (1991); the Tremadoc is from Fortey and Owens (1992).

ing fossil collections. He published two general reviews (Whittard, 1931, 1952a) and described the trilobites (Whittard, 1955–1967). His collections formed the basis of studies on the brachiopods (Williams, 1974) and graptolites (Strachan, 1986). After Whittard's death, W. T. Dean compiled a stratigraphical memoir and geological map based on Whittard's field maps and notebooks (Whittard, 1979), and this work includes an account of earlier research. The British Geological Survey (1991; 1994b; Cave and Hains, in press) published a more detailed map and modified the stratigraphy slightly.

The stratigraphical succession is shown in Figure 10.2. The changes in depth and environmental conditions, with their consequent mixtures of brachiopod, trilobite and graptolite faunas, facilitate correlation between basinal successions in Wales and shelf successions such as that of the Caradoc area. The Tremadoc rocks and upward shallowing to the Arenig are seen at the Granham's Moor site (see Chapter 7). The shallow-water facies of the Moridunian and Whitlandian is represented at Mytton Dingle whereas the Fennian is seen at Bergam Quarry and Shelve Church. The lower Abereiddian is present in a deeper-water, partly graptolitic, facies in Hope Valley and the upper Abereiddian in a shallower facies at Betton Dingle. The

Llandeilian is developed in a varied, partly calcareous, facies at Meadowtown Quarry. The sequence at Spy Wood and Aldress dingles exposes a long section in lower Caradoc graptolitic rocks, punctuated by the input of clastic and volcanic units, both of which locally contain shelly fossils.

MYTTON DINGLE AND SNAILBEACH (SJ 365 005–SJ 374 006 AND SJ 378 023–SJ 380 024)

Introduction

This site is important in having exposures of much of the Mytton Flags Formation, a predominantly shallow-water development that characterizes the Arenig Series in the Shelve area. It has also furnished the type specimens of several species of trilobites (particularly trinucleids), brachiopods, a bivalve, a rostroconch and a crinoid.

Mytton Dingle (also referred to as Mytton Batch and Myttonbeach) and nearby Crowsnest Dingle were mentioned briefly by Murchison (1839, p. 285), who noted the presence there of 'sandstones and schists'. Mytton Dingle is the type locality for the Mytton Flags Formation, a term proposed (as the 'Mytton Group') by Lapworth and Watts (1894, p. 316). Lapworth (1916) later subdivided the unit into four divisions, which from the base are: Lord's Hill Beds; Ladywell and Snailbeach Grits and Flags; Shelve Church Beds; and Tankerville Flags. These terms have subsequently fallen into disuse (Whittard, 1979, p. 16), but the lithologies distinctive of the two upper units crop out respectively at the Shelve Church and Bergam Quarry sites (see site reports).

Mytton Dingle is one of several striking steep-sided unwooded valleys, known locally as 'batches' or 'beaches' (Whittard, 1979, p. 17), that drain the west side of the Stiperstones ridge at the east side of the Shelve area (Figures 10.3 and 10.4). The sides of the valley and isolated outcrops around its head show much of the Mytton Flags Formation to advantage, and most of Whittard's fossil localities are hereabouts. The area around Snailbeach is more affected by faulting, but provides several important fossil localities, for which reason it is included within this site. The lack of continuous sections means that the stratigraphy of the Mytton Flags has to be assembled from such isolated exposures. The whole area contains many old mine workings, and the majority of the mineral veins (galena, blende, barytes) in the Shelve area occur in fault fissures within the Mytton Flags Formation (Whittard, 1931, p. 325; 1979, p. 17).

Description

Mytton Dingle cuts an east–west cleft between Green Hill on the south and Oak Hill on the north (Figure 10.3). Its line is clearly fault-controlled (British Geological Survey, 1991), and there are old mine shafts and an adit at the head of the valley. The best exposures are on the north side and cover the greater part of the succession, although the lowest strata are largely obscured by talus and scree at the foot of the Stiperstones ridge. The beds dip steeply to the north-west, and Whittard (1952a, p. 158) gave a total thickness of about 3000 ft (900 m) for the formation, much in excess of Lapworth's (1916) estimate of 1600 ft (< 500 m). The exposures in the north side of Mytton Dingle are in massive, greyish-weathering, blue-hearted siltstones, flags and sandstones, with laterally impersistent coarse siltstones and sandstones; the more resistant beds, which form three distinct ridges, are presumably Lapworth's 'Ladywell and Snailbeach Grits and Flags'. They are bioturbated at many levels, but fossils are generally absent from this part of the succession.

Lower horizons are seen at isolated points at the head of the valley and on the ground to the north, around the head of Crowsnest Dingle (Figure 10.4) and near Blakemoorflat. However, the oldest fauna from the Mytton Flags Formation appears to be that from beside an old adit (3710 0018) at the head of Perkins Beach, immediately to the south (Whittard, 1979, p. 18: locality 805, fig. 7, p. 13). Here, silver-grey weathering, micaceous silty shales and flags yielded trilobites including *Myttonia confusa* Whittard, *Merlinia major* (Salter), *Neseuretus murchisoni* (Salter) and *N. brevisulcus* Whittard. These are from within 60 m of more shaly beds, which Whittard (1979) estimated to be about 180 m above the Stiperstones Quartzite; they probably correspond to Lapworth's (1916, p. 37) 'Lord's Hill Beds'. Similar beds are seen at the head of Mytton Dingle alongside the steep path to Blakemoorflat (3736 0059), where they have yielded a fauna like that at Perkins Beach, with the addition of the trilobites *Ampyx* cf. *reyesi* Benedetto and Malanca, *Neseuretus com-*

Figure 10.3 View eastwards along Mytton Dingle. The Mytton Flags Formation, cropping out on the north side of the valley, dips steeply towards the viewer and strikes obliquely south-west. The ridge on the left is Blakemoorflat; Green Hill, on the right, slopes down into Perkins Beach. (Photo: Cambridge University Collection of Air Photographs, BM 13: copyright reserved.)

planatus Whittard (type locality) and the brachiopod *Monobolina plumbea* (Salter); the type locality for the crinoid *Aethocrinus murchisoni* Donovan is probably hereabouts. Yet another outcrop, at the head of Crowsnest Dingle (3719 0087), has a similar fauna, comprising the trilobites *Myttonia multiplex* Whittard and *Neseuretus parvifrons* (M'Coy) and the brachiopods *M. plumbea* and *Palaeoglossa myttonensis* Williams. The type locality for *Neseuretus brevisulcus* Whittard is nearby. From a slightly higher level, 305 m above the Stiperstones Quartzite, Whittard (1955–1967) reported *Cyclopyge grandis* (Salter) in yellowish siltstones 530 m NNE of Blakemoorflat (3769 0127).

Exposures to the NNE, around Lord's Hill, show further examples of the horizon seen at the head of Mytton Dingle, as, for instance, at the entrance to Yewtree Level (3800 0183), which is the type locality for the trilobite *Myttonia confusa,* here occurring with the brachiopod *Paralenorthis* cf. *proava* (Salter) and the bivalve *Pensarnia*. At Lord's Hill, or there-

Figure 10.4 Scarp of the Mytton Flags Formation on the east side of Hope Valley, looking north-east. The lower ground is occupied by the Hope Shale Formation, the road following the Mytton—Hope boundary quite closely. The white tip-heap is spoil from Snailbeach Mine. The next nearer cleft is Crowsnest Dingle. (Photo: Cambridge University Collection of Air Photographs, BM 8: copyright reserved.)

abouts, are the type localities for the trilobite *Neseuretus murchisoni* (Salter), the bivalve *Redonia anglica* Salter and the rostroconch *Riberia complanata* Salter. A short distance to the north-east, just west of Eastridge (3828 0226), is one of the few points at which beds transitional to the underlying Stiperstones Quartzite can be seen; flags with a preponderance of quartzitic rocks are exposed here (Whittard, 1979, locality 858). West of Lordshill Farm a small dry valley (3782 0210) (Whittard, 1979, locality 157) exposes resistant gritty flags belonging presumably to horizons seen along the steep northern side of Mytton Dingle. The resistant sandstone bodies present around Mytton and Crowsnest dingles do not appear to be developed around Snailbeach.

At Old Perkins level (380 023), above the reservoir in the valley east of Snailbeach, *Neseuretus* and *Monobolina plumbea* are reported from a horizon probably slightly younger than most of the fossiliferous horizons described above. However, a small quarry NNE of the reservoir (3790 0242) exposes blocky siltstones cut by a small dolerite intrusion immediately to the south. Whittard (1955–1967) estimated these siltstones to lie 610 m above the Stiperstone Quartzite, and they have afforded a diverse fauna of trinucleid trilobites; it is the type locality for Whittard's species *Anebolithus simplicior*, *Bergamia matura*, *B. inquilinum* and *Lordshillia confinalis*, as well as for the non-trinucleid trilobite *Thymurus incertus*. Other trilobites reported from this locality are *Merlinia major*, *Neseuretus murchisoni* and *Macrogrammus scylfensis* Whittard, and it is also the type locality for the brachiopod *Astraborthis uniplicata* Williams. An exposure near the top of the Mytton Flags in Snailbeach Coppice (375 026) (Whittard locality 894) does not resemble the 'Tankerville Flags' lithology seen at Bergam Quarry (see site report), indicating either that those flags are laterally impersistent or that they are not exposed at Snailbeach.

Lastly, a little beyond the northern extremity of the site, exposures in the old adit in Maddox's Coppice (3815 0300) is worthy of mention as the type locality for the trilobites *Myttonia multiplex* and *Macrogrammus sclyfensis*, occurring here with *Merlinia major* and species of the brachiopods *Euorthisina*, *Orthis* and *Monobolina* (Williams, 1974). This fauna contains species common to the locality north-east of Snailbeach Reservoir and to lower horizons exposed between Perkins Beach and Lord's Hill and may therefore fall within the intervening stratigraphical interval.

Interpretation

The bulk of the Mytton Flags Formation is assigned on faunal grounds to the Moridunian and Whitlandian stages of the Arenig. Most of the fauna is peculiar to the Mytton Flags, which makes correlation with other areas difficult, but *Neseuretus murchisoni* is common to parts of the Ogof Hên Formation in South Wales and *N. parvifrons* to the Henllan Ash in North Wales, both Moridunian, and *Cyclopyge grandis* is known from rocks of Whitlandian age in both North and South Wales. Because the succession can only be pieced together from isolated outcrops, the precise relationships of the succession here with the 'Tankerville Flags' (see site report for Bergam Quarry) and the 'Shelve Church Beds' (see site report) is uncertain, though their faunas show that those two divisions are Fennian and lie near the top of the succession.

Although detailed sedimentology and facies analysis remain to be done, it is likely that much of the Mytton succession was deposited in shallow subtidal conditions, similar to those of the higher part of the Habberley Formation beneath the Stiperstones Quartzite (see Granham's Moor site report, Chapter 7). In contrast to the Arenig of South Wales, the Mytton Flags show a persistence of the shallow-water *Neseuretus* biofacies throughout most of the succession. Slightly deeper-water conditions are likely for the 'Shelve Church Beds' and 'Tankerville Flags' facies at the top of the sequence, probably heralding the generally deep-water offshore regime of the succeeding Hope Shales Formation.

The trinucleid trilobites from the Mytton Flags are some of the oldest known from anywhere in the world, and specimens from this site (and several other localities in the Shelve area whose names have been bestowed on trinucleid genera), contribute significantly to our understanding of the early evolutionary history of the group (Hughes *et al.*, 1975). In *Lordshillia* they include probable ancestors to the genus *Trinucleus* itself.

Conclusions

The present site is important regionally and nationally. Exposures of the Mytton Flags show the development of the Arenig at the edge of the Welsh Basin, where shelly faunas continued to develop in a shallower-water setting than obtained in South Wales. The trinucleid trilobites from the Mytton Flags Formation uniquely represent the early evolutionary radiation of this stratigraphically important group.

BERGAM QUARRY (SO 3564 9974)

Introduction

This disused quarry (locality '8' in Figure 10.1) affords the best section in the 'Tankerville Flags' of Lapworth (1916) and has yielded a fauna of late Arenig age, including trilobite species common to the overlying Hope Shales. Apart from those in the 'Shelve Church Beds', this is the only locality in the Shelve area to have yielded a late Arenig fauna.

The 'Tankerville Flags' have been distinguished as the youngest Arenig division in the Shelve area (e.g. Whittard, 1931, p. 326) and are considered to correlate with the *hirundo* Zone. Whittard (1955–1967) used the term in his trilobite monograph, although in the penultimate part (1966, p. 303) he suggested that, despite its distinctive lithology and fauna, especially of trilobites, it could be applied only to a restricted part of the outcrop of the Mytton Flags. Later, Whittard (1979, p. 8) no longer regarded the 'Tankerville Flags' as a separately mappable unit and included them within the Mytton Formation. Although Whittard (1960, p. 260) gave the type area for the 'Tankerville Flags' lithology, rather imprecisely, as 'Tankerville Mine', Bergam Quarry is effectively the type locality.

Description

Bergam Quarry is adjacent to a sharp bend on a minor road, 305 m NNE of Tankerville Mine and 900 m south-west of the Stiperstones Inn. Bluish-grey micaceous flaggy shales and silt-stones dip at 84° to the NNW and are cut by a dolerite intrusion 4.3 m wide, to the north of which the shales are pale-grey and altered through a thickness of 3.4 m; shales on the south side are not visibly altered. The base of the Hope Shale Formation is mapped a short distance to the north-west (Whittard, 1979, fig. 7, p. 13), although the junction is not exposed there, nor elsewhere in the Shelve area.

Strachan (1986) recognized the graptolites *Expansograptus* cf. *nitidus* (Hall), *E.* cf. *praenuntius* (Törnquist), *E.* cf. *suecicus* (Tullberg) and stipes of *E.* cf. *hirundo* (Salter). No biserial graptolites have been reported. Bergam Quarry is the type locality for the dendroid graptolites *Callograptus extensus* Bulman and *C. tenuis* Bulman. The trilobites, described by Whittard (1955–1967) and revised by Fortey and Owens (1987), include *Placoparia cambriensis* Hicks and *Pricyclopyge binodosa* (Salter), in common with the Hope Formation, and also *Segmentagnostus scoltonensis* (Whittard), which is reported from the Pontyfenni Formation (Fennian) and the Llanvirn part of the Llanfallteg Formation in South Wales. *Asaphellus whittardi* (Bates) occurs both at Bergam and in the early Fennian Cwmfelin Boeth Formation in South Wales, whereas the trinucleid *Bergamia rhodesi* Whittard, for which Bergam is the type locality, has not been found elsewhere. Other fauna includes hyolithids and orthoconic nautiloids.

Interpretation

Collectively, the trilobite and graptolite faunas place the 'Tankerville Flags' high in the Arenig, and a level within the *hirundo* graptolite zone has been suggested. However, the extensiform graptolites are not positively identified with species known elsewhere and indicate only a Fennian age, and even if the presence of *E. hirundo* were confirmed it would not prove the the presence of the uppermost Arenig, for that species is long-ranging (Fortey *et al.*, 1990). The trilobite fauna, too, has long-ranging species that are found in both the late Arenig and the early Llanvirn, with elements from the earlier late Arenig (early Fennian); combined with the lack of biserial graptolites, this suggests that Bergam Quarry lies in the earlier rather than the later Fennian (Figure 10.2) and that the fauna is older than that at Shelve Church (see site report).

The presence of cylcopygid trilobites, graptolites and altheloptic trilobites suggests that the 'Tankerville Flags' were deposited in fairly deep, offshore waters.

Conclusions

Bergam Quarry exemplifies the 'Tankerville Flags' facies of the Mytton Flags Formation and yields a trilobite fauna of Fennian age, including species known from localities in South Wales, that is quite distinct from the fauna of the bulk of the Mytton Flags.

SHELVE CHURCH (SO 3365 9901)

Introduction

Small exposures in the vicinity of All Saints Church, Shelve (locality '7' in Figure 10.1), represent the typical development of the 'Shelve Church Beds', now known to be of late Arenig age. They contain an abundant fauna of dendroid graptolites that, together with the rest of the fauna, is one of the most diverse in the Arenig of the Shelve area. It is the type locality for several graptolite and brachiopod species.

The 'Shelve Church Beds' of Lapworth (1916, p. 37) were for many years regarded as a discrete division of the Shelve Arenig (e.g. Whittard, 1931, 1955–1967). They are 'blue-black shaly flags interleaved with silver-grey weathering, rusty-coated, blue-hearted shales' (Whittard, 1979, p. 24), characterized by a high percentage of volcanic dust. The term 'Shelve Church Beds' has now been abandoned, following Whittard (1955–1967, p. 303; Whittard, 1979, pp. 16, 24), since it was claimed to represent a local facies at more than one horizon within the Mytton Flags Formation, rather than a discrete mappable unit. Beds of this lithology crop out in the central Shelve Anticline in the Shelve area, especially in the vicinity of Shelve Church, but also around Wood House and Gravels to the north. Long regarded as belonging to the *extensus* Zone, the

'Shelve Church Beds', with their fauna of biserial graptolites and trilobites such as *Placoparia cambriensis* Hicks and *Selenopeltis buchi macrophthalma* (Klouček), are now seen as of latest Arenig age, and their fauna is presumably the youngest in the Mytton Formation, that of the 'Tankerville Flags' appearing to be slightly older (see Bergam Quarry site report). No upward passage from the 'Shelve Church Beds' into overlying strata is exposed.

Whatever the stratigraphical status of the 'Shelve Church Beds', their fauna is significant both in its diversity and in demonstrating the presence in the Shelve area of the latest Arenig.

Description

The roadside section adjacent to All Saints Church, which afforded so many of the fossils in the past, is currently grassed over, but a small exposure remains accessible in a nearby field. In the short distance between Shelve Church and the faulted boundary against the Hope Shale Formation, unfossiliferous rocks of 'Shelve Church Beds' and Mytton Flags lithologies have been reported (Whittard, 1979, p. 24) at Whittard's localities 682 and 681 respectively.

This locality was mentioned briefly by Lapworth and Watts (1894, p. 316) as a source of graptolites noted by Hopkinson and Lapworth (1875, p. 636). Elements of the fauna have since been described by, for example, Bulman (1927–1963) and Strachan (1986) (graptolites), Whittard (1955–1967) and Fortey and Owens (1987) (trilobites), Williams (1974) (brachiopods) and Yochelson (1964) (the gastropod *Modestospira*). Other fossils include ostracods and cystoid plates, sometimes crowded on bedding planes in association with gastropods, small brachiopods and cyclopygid trilobites (Whittard, 1955–1967, p. 176). The fauna is dominated by dendroid graptolites that include *Aspidograptus implicatus* (Hopkinson), *Callograptus salteri* Hall, *C. radiatus* Hopkinson, *Dictyonema cobboldi* Bulman (type locality), *D. fragile* Bulman (type locality) and *D. shelvense* Bulman (type locality). Graptoloid graptolites include biserial taxa (see below), with '*Corymbograptus*' *deflexus* (Elles and Wood), *Expansograptus* cf. *nitidus* (Hall) and *E. sparsus* (Hopkinson). Trilobites are less frequent and, besides *Selenopeltis buchi macrophthalma,* include *Placoparia cambriensis* Hicks, *Ectillaenus bergaminus* Whittard and *Pricyclopyge*. This is also the type locality for *Protoskenidioides revelatus* Williams and *Dalmanella elementaria* Williams, among the brachiopods.

Interpretation

Whittard (1955–1967, p. 4) placed the 'Shelve Church Beds' near the top of the *extensus* Zone, on account of the presence of *E. nitidus* and the absence of *D. hirundo*. However, these extensiform graptolites are less reliable than the biserial graptolites present: *Undulograptus shelvensis* (Bulman; see Mitchell, 1992) (type locality) and *U. austrodentatus* (Harris). These, together with *Expansograptus sparsus* and the trilobite *S. buchi macrophthalma* place the beds firmly within the upper Arenig (Fortey and Owens, 1990b, p. 607), equivalent to the *hirundo* Zone of Fortey *et al.*, (1990) (Figure 10.2) and within the *Undulograptus austrodentatus* Zone of Mitchell and Maletz (1995), which has been recognized world-wide.

Several of the dendroid graptolites are common to the mid-Arenig (Whitlandian) of Pwlluog (see site report), but the associated graptoloids and trilobites there are different taxa. Evidently the dendroids are long-ranging, but a similar palaeoenvironment may be represented at both localities. Apart from the pelagic cyclopygids, the trilobites are small-eyed or blind, a typical atheloptic association. A fairly offshore environment is probably represented within the cyclopygid biofacies (Fortey and Owens, 1987, p. 105), although probably not as far offshore or as deep as at Pontyfenni (see site report), which lacks abundant dendroid graptolites and articulate brachiopods.

Conclusions

The Shelve Church site is of considerable importance on account of the rich fauna in the 'Shelve Church Beds', which demonstrates the presence of the late Arenig *hirundo* and *austrodentatus* graptolite zones in the Mytton Formation.

HOPE VALLEY (SJ 3390 0128–SJ 3550 0209)

Introduction

This is the type area for the 'Hope Shale Formation', a term introduced by Lapworth and Watts (1894, p. 316) as the 'Hope Shales' or

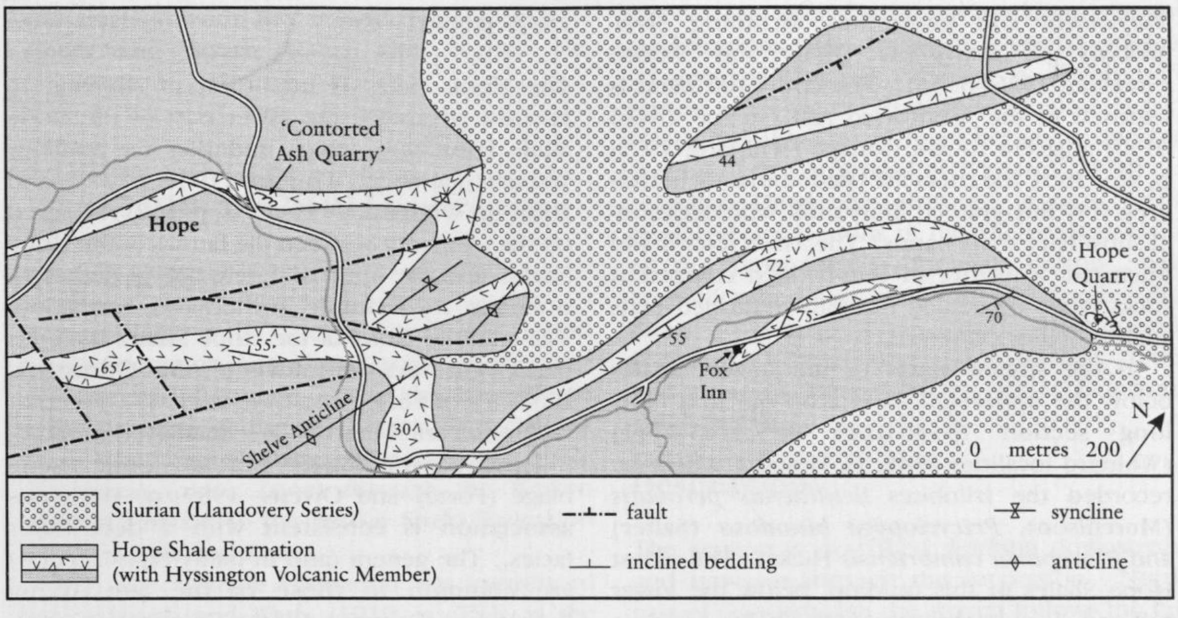

Figure 10.5 Geological map of the type area of the Hope Shale Formation in the Hope Valley, from the British Geological Survey (1991).

'Hope Shale Group'. Strictly speaking, the term 'Hope Shale Formation' related to the mudstone formation lying below the Stapeley Volcanic rocks, but in current usage (British Geological Survey, 1991) it encompasses both the Stapeley Volcanic rocks (as a 'Member') and the overlying Stapeley Shales, the type localities for which are respectively Stapeley Hill, west of Shelve, and Holywell Brook, near Rorrington.

The Hope Shale Formation as developed in the Hope Valley (Figure 10.4) is referred to the *Didymograptus artus* Zone, in the lower part of the Abereiddian Stage of the Llanvirn Series. The site is on the western flank of the Shelve Anticline. Although they have the largest area of outcrop of any of the Ordovician formations in the Shelve area, the shales tend to be poorly exposed because they weather regressively. Old quarries and discontinuous stream sections along 1.8 km of the Hope Valley afford exposures of significant parts of the sequence and yield representatives of the mixed trilobite–graptolite fauna that have been described respectively by Whittard (1955–1967) and Strachan (1986). Williams (1974) described the brachiopods and Jenkins (1967) the chitinozoans. The stratigraphy was revised and updated by Whittard (1979), who gave a large-scale map of the site (fig. 15). Modifications to Whittard's map were given on the British Geological Survey (1991) 1:25 000 Shelve sheet and refinements to the nomenclature, adopted here, on that sheet and on the 1:50 000 Montgomery Sheet (British Geological Survey, 1994b).

Description

The Hope Shales below the Stapeley Volcanic Member are, on Whittard's (1931, p. 327) estimate, nearly 245 m thick and consists of a monotonous sequence of blue-black, rusty-weathering shales. It includes beds of acid vitroclastic tuffs, the so-called 'Chinastone Ash' of earlier publications, now referred to as the 'Hyssington Volcanic Member' (Figure 10.5), and, away from the Hope Valley (e.g. around the Llan Syncline, on the south-east flank of the Shelve anticline), also includes volcaniclastic sandstones and wackes. Formerly the tuff bands were used to subdivide the Hope Shales, but they are now known to be laterally impersistent.

There are two major tuff bands in the vicinity of Hope hamlet, around the NE-plunging nose of the Shelve Anticline. Some of the youngest Hope Shales locally, above the upper tuff band, are exposed in the stream (3390 0128–3399 0135) (Whittard's localities 834L, M and N) and have yielded occasional trilobites including

Barrandia and graptolites including *Acrograptus* cf. *acutidens* (Elles and Wood) (Strachan 1986, p. 55). The upper tuff band is exposed in the 'Contorted Ash Quarry' (3425 0147) adjacent to Ash Cottage (Whittard, 1979, p. 26). Here the rocks are predominantly bluish-grey, very fine-grained flinty tuffs, with occasional subsidiary shale bands. The ash is folded and fractured, a feature of thin-bedded competent rocks when contained in easily deformed beds such as shales (Whittard, 1979, p. 27).

In the stream south of the quarry, shales below the upper tuff band crop out in a fairly long section (3426 0143 to 3443 0141) (Whittard localities 834E, G, H and I, where he recorded the trilobites *Ectillaenus perovalis* (Murchison), *Pricyclopyge binodosa* (Salter) and *Placoparia cambriensis* Hicks). The oldest Hope Shales in this outcrop, below the lower tuff and close to the axis of the Shelve Anticline (3438 0143), are exposed in the stream behind Hope Cottage (Whittard locality 142). These have yielded a rich trilobite fauna, including *E. perovalis, P. binodosa, Barrandia homfrayi* Hicks, *Microparia* cf. *princeps* (Barrande), *Gastropolus obtusicaudatus* (Hicks) and *'Neseuretus' bullatus* Whittard (type locality), together with the brachiopod *Paterula* cf. *bohemica* Barrande and pendent didymograptids. Jenkins (1967) reported chitinozoans including *Sphaerochitina vulgaris* Jenkins, *Siphonochitina robusta* Jenkins, *S. tenuicollis* Jenkins, *Rhabdochitina usitata* Jenkins, *R. turgida* Jenkins, *Cyathochitina campanulaeformis* (Eisenack), *C. calix* (Eisenack) and *Conochitina chydaea* Jenkins; this is the type locality for all of Jenkins' species.

Shales above the upper tuff, at a similar horizon to those seen at Whittard's localities 834 L–N at Hope (see above), are exposed in Hope Brook (3494 0104); this well-known collecting locality has yielded *Ectillaenus perovalis* and other trilobites, hyolithids and a specimen of the starfish *Palaeura* (Whittard, 1931b, p. 340). Similar shales are exposed a short distance downstream, near Fox Inn, where they have yielded the trilobite *Ellipsotaphrus monophthalmus* (Klouček).

Hope Quarry, at the northern end of the site (3550 0209), is renowned for the unconformity between the Hope Shales and overlying Silurian sandstones of the Venusbank Formation (Llandovery, Aeronian Stage), seen in the lower part of the quarry.

Interpretation

The Hope Valley is important in showing to greatest advantage the lower part of the Hope Shale Formation, which underlies the Stapeley Volcanic Member. Whittard (1931, p. 323) and Dean (in Whittard, 1955–1967, p. 312) remarked on the similarity between the faunas of the Hope Shales and the approximately coeval faunas of Bohemia, for example in the Šárka Formation. The trilobite fauna of the Hope Shales includes cyclopygid taxa indicative of the Cylcopygid Biofacies of Fortey and Owens (1987), together with other trilobites that are small-eyed or blind, together constituting a typical atheloptic assemblage (Fortey and Owens, 1987, p. 105); this association is consistent with a deep-water facies. The genera (and in many cases species) are common to those of the late Arenig Pontyfenni Formation (see Pontyfenni site), which was deposited under very similar conditions, but the difference in age is reflected in different subspecies of *Pricyclopyge binodosa* and in particular in the graptolite fauna, which includes abundant pendent didymograptids; these indicate the presence of the *artus* Zone of the Abereiddian Stage. Coeval strata in south-west Wales (e.g. at Llanfallteg and Abereiddi – see site reports) have similar faunas but were probably deposited in slightly shallower conditions, having fewer cyclopygid trilobites. This contrast implies major subsidence on the Linley–Pontesford Fault at the margin of the Welsh Basin (cf. Prigmore *et al.*, 1997).

Many of the chitinozoans have long ranges extending up to the Llandeilian or into the Caradoc (see Jenkins, 1967, table 1), but some species, for example *Cyathochitina calix* (Eisenack), appear to be shorter-ranging and are common to the approximately coeval *expansus* Limestone of Sweden and 'Glaukonitkalk' of Estonia.

Conclusions

The Hope Shales Formation exposed at this site represents typical background deep-water deposition of the early Llanvirn and contains a particularly varied and well-preserved trilobite fauna associated with graptolites of zonal significance. This is valuable nationally and internationally because it contributes to the correlation of the graptolitic successions in west Wales and northern England with the trilobitic succession in North and South Wales and abroad (in Bohemia).

BETTON DINGLE (SJ 317 019–SJ 320 011)

Introduction

Betton Dingle is the type locality for the Betton Shale Formation and shows some of the best exposures in the upper part of the Abereiddian Stage as developed in the Shelve area, ranging from the higher part of the Hope Shale Formation (*artus* Zone) through the Weston Flags Formation to the Betton Shale Formation (both *murchisoni* Zone).

The Betton Shale Formation was introduced by Lapworth and Watts (1910, p. 752) as the 'Betton' or '*Didymograptus murchisoni* Shales'. Although the Weston Flags Formation, introduced by Lapworth (1887, p. 662) as the 'Weston Group', has its type locality to the south, at Priestweston (Whittard, 1960, p. 281), its most fossiliferous development is to be found in Betton Dingle. The stratigraphical nomenclature in the Shelve area has undergone many modifications since Lapworth's (1887) original scheme (see Whittard, 1979, fig. 3). The nomenclature used by the British Geological Survey (1991, 1994b) is used here, being an updated version of that proposed by Whittard (1979).

Betton Dingle has featured in most stratigraphical descriptions of the Shelve succession, as the type locality for the Betton Shale Formation and also as a source of fossils: trilobites (Whittard, 1955–1967), brachiopods (Williams, 1974), graptolites (Strachan, 1986) and crinoids (Ramsbottom, 1961; Donovan, 1986–1995).

Description

The section is described working downstream and upwards through the succession. North-east of Ganderbeach the stream follows the line of a fault, which controls its course along the western flanks of Bromlow Callow (Figure 10.6). Along this stretch (3204 0114) there are exposures of andesitic lavas and tuffs of the Stapeley Volcanic Member of the Hope Shale Formation, dipping WNW at 35°. Immediately north of the footpath (3201 0119), soft shales of the highest

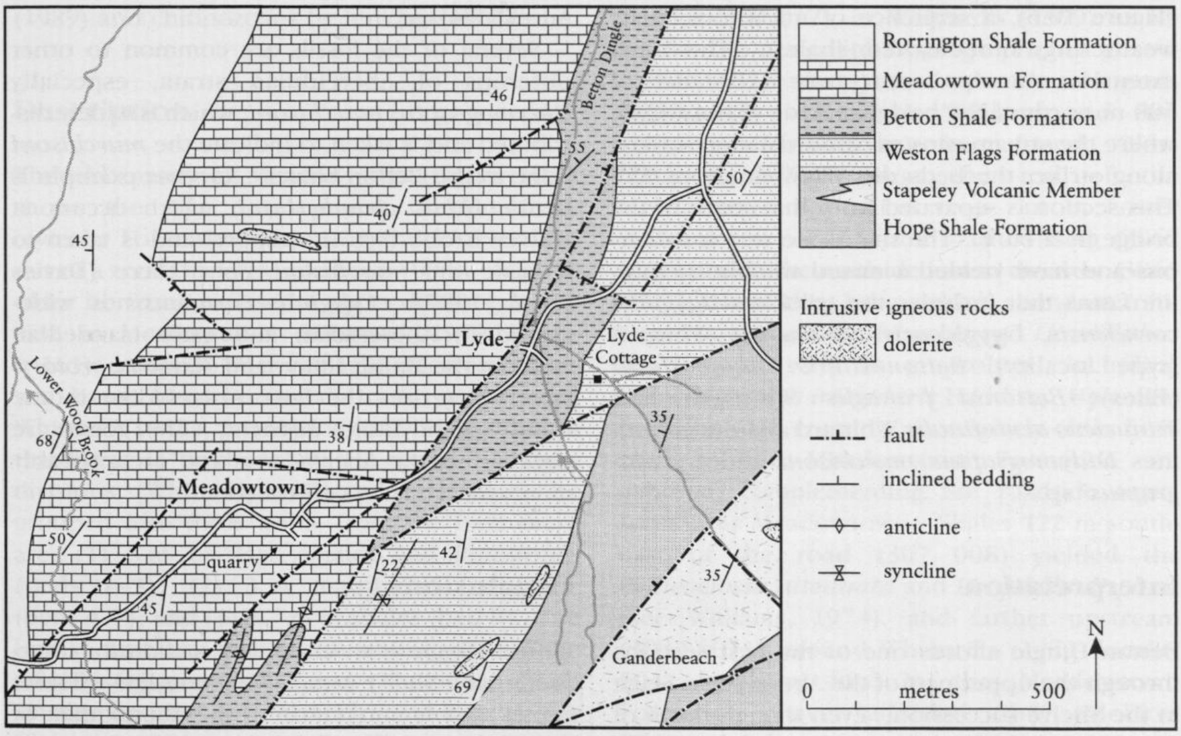

Figure 10.6 Geological map of the area of Betton Dingle and Meadowtown, from the British Geological Survey (1991).

part of the Hope Shales (formerly termed the Stapeley Shales) crop out in the stream and yield trilobites including *Ogygiocaris seavilli* Whittard, *Protolloydolithus neintianus* Whittard and *Platycalymene tasgarensis* Shirley and the graptolites *Didymograptus artus* Elles and Wood and *Acrograptus acutidens* (Elles and Wood). This outcrop of Hope Shales is in faulted contact with the Stapeley Volcanic Member to the south-east and is locally faulted against the Weston Flags Formation to the north-west. The latter comprises massive flagstones and siltstones with subordinate shale horizons, one of which is exposed in the angle between two streams to the east of Lyde Cottage (3180 0147) and has yielded the richest fauna known from the Weston Flags: the trilobites *Ogyginus corndensis* (Murchison) and *Platycoryphe vulcani* (Murchison), the brachiopods *Pseudolingula granulata* (Phillips) (= *spatula* Williams) and *Tissintia prototypa* (Williams), the graptolite *Didymograptus murchisoni* (Beck) and the crinoid *Iocrinus shelvensis* Ramsbottom (type locality), together with cephalopods and numerous bivalves.

Some 120 m south-east of the road bridge at Lyde, the Weston Flags Formation passes upwards into the Betton Shale Formation (Figure 10.6), a sequence of micaceous, rusty weathering, blue-hearted shales. The most extensive outcrops occur over a distance of 400 m north of the bridge at Lyde (3164 0159), where the stream runs northwards, more-or-less along strike; the beds dip WNW at about 55°. This section is separated from that south of the bridge by a fault. The shales are very fossiliferous and have yielded a mixed trilobite–graptolite fauna that includes the trilobites *Ogyginus corndensis*, *Ogygiocaris bettonensis* Whittard (type locality), *Bettonolithus chamberlaini* (Elles) (=*Bettonia frontalis* Whittard) and *Trinucleus acutofinalis* Whittard and the graptolites *Didymograptus murchisoni* and *Gymnograptus?* sp..

Interpretation

Betton Dingle affords one of the best sections through the upper part of the Abereiddian Stage in the Shelve succession. Even though much of it is drift-covered and exposure is discontinuous, there are sufficient exposures to demonstrate the typical lithologies and faunas of the upper part of the Hope Shale, Weston Flags and Betton Shale formations.

Faunally there are changes from the atheloptic *Ampyx–Protolloydolithus–Stapeleyella* faunas of the higher Hope Shales to the *Platycoryphe–Ogyginus–Tissintia*–bivalve fauna of the Weston Flags, which is akin to the *Neseuretus* biofacies, and the *Bettonolithus–Trinucleus–Ogygiocaris–Didymograptus* fauna of the Betton Shales, which is of intermediate character. The whole sequence is a markedly shallower-water facies than that of the lower Hope Shales (see Hope Valley site report), which is in a cyclopygid biofacies. The Weston Flags Formation in particular has been interpreted as being extremely shallow-water, even estuarine, in origin (Whittard, 1979, p. 38), with fossiliferous horizons containing rich, bivalve-dominated faunas; the presence of brachiopods, trilobites and crinoids attests to fully marine conditions prevailing, at least during deposition of the shale horizons. The mixed, more 'normal' trilobite–graptolite faunas in the silty shales of the Betton Shale Formation suggest a return to slightly deeper, more offshore conditions and seem to herald a general deepening in the succeeding Meadowtown Formation and Rorrington Shale Formation of Llandeilian–Aurelucian age.

Several of the fossils are common to other outcrops of Abereiddian strata, especially *Didymograptus murchisoni,* which is widely distributed and is taken to indicate the *murchisoni* Zone in the Betton Shales. Another example is *Bettonolithus chamberlaini,* which occurs at Howey Brook (see site report) and is taken to indicate the *murchisoni* Zone there (Davies *et al*., 1997). *Ogyginus corndensis* is widespread in Abereiddian and early Llandeilian rocks in the Builth Inlier, and *Tissintia prototypa* characterizes the later Abereiddian in the Llandeilo and Builth districts. Other forms are peculiar to the Shelve area and are probably more closely facies-controlled.

Conclusions

Betton Dingle is an important section for interpreting the Shelve area. The graptolite–trilobite faunas enable correlation of the Abereiddian of the Shelve sequence with areas elsewhere and allow an interpretation of the changing environments of deposition.

MEADOWTOWN QUARRY (SJ 3111 0116)

Introduction

This quarry is the type locality for the Meadowtown Formation, a varied succession of flags, mudstones and calcareous beds that equates with the Llandeilian Stage in the Shelve area. It was known to Murchison (1839), as 'Meadow Town' and is the type locality of his graptolite *Diplograptus foliaceus* (Murchison). The formational name was proposed by Lapworth and Watts (1910, p. 752) as the 'Meadowtown Calcareous Beds' or 'Stage', a restricted use of Lapworth's (1887, p. 662) term 'Meadowtown Series', which encompassed a much broader group of strata, ranging from the Weston Flags Formation up to and including the Rorrington Shale Formation of present usage.

Meadowtown Quarry is a well-known source of fossils and, together with localities along the road to Rorrington and in Lower Wood Brook, shows a discontinuous succession through much of the *teretiusculus* Zone as it is developed in the Shelve area. Trilobites were described by Whittard (1955–1967), brachiopods by Williams (1974), graptolites by Hughes (1989) and chitinozoans by Jenkins (1967).

Description

The old quarry in Meadowtown (Figure 10.6) shows the type development of the Meadowtown Formation, exposing the lowest third out of a total thickness of about 400 m. Slightly older horizons exposed a short distance to the east, in Meadowtown (Whittard, 1979, locality 161), comprise 20 m of flaggy calcareous beds with bands of ashy material. In the quarry itself, Whittard (1952a, p. 160) logged 9.75 m of strata that dip at 45° to the WNW. He recognized eight divisions (Whittard, 1979, p. 44), which he grouped into three units; from the base these are: (1) 3 m of flags, shales and limestones (beds 1–3); (2) 3 m mainly of limestone (beds 4–7); and (3) 3.7 m of shales (bed 8). The lowest unit has yielded an abundance of the trilobite *Ogyginus corndensis* (Murchison), with smaller numbers of *Flexicalymene cambrensis* (Salter) and rare *Basilicus tyrannus* (Murchison), *Metopolichas patriarchus* (Wyatt-Edgell) and *Marrolithus craticulatus* Whittard. Bed 3 yielded the holotype of *Ogyginus corndensis novenarius* Whittard, and 'Meadowtown Quarry' is the type locality for *Whittardolithus superstes* (Whittard). Williams (1974, p. 110) reported the brachiopod *Tissintia immatura* (Williams) from 'bed B' here. At the west side of the quarry the highest beds exposed are probably the source of the holotype of *Diplograptus foliaceus* (Murchison) (see Whittard, 1952a, p. 150), although graptolites are uncommon there (Hughes, 1989, p. 51).

Correlative beds, currently well exposed in Quinton's Quarry, 200 m NNE of Meadowtown, are the source of the types of *Eumorphocystis coxi* Paul and Fone (in Paul, 1973–1997, p. 157).

Higher horizons in the Meadowtown Formation are exposed along the road to Rorrington, west of Meadowtown (Whittard, 1979, localities 164–166). The trilobite *Whittardolithus inopinatus* (Whittard) is reported 18 m west of the quarry (3109 0118), and 73 m west (311 013) is the type locality for the brachiopods *Lingulella displosa* Williams and *Schizotreta transversa* Williams; *Palaeoglossa attenuata* (Sowerby) and the trilobites *Lloydolithus lloydii* (Murchison) and *Ogygiocarella debuchii* (Brongniart) also occur here. Around 200 m west of Meadowtown Chapel (309 012), at Whittard's (1979) locality 164, the graptolite *Cryptograptus* ex gr. *tricornis* (Carruthers) and the brachiopods *Dalmanella salopiensis* Williams and *Palaeoglossa attenuata* have been found. Blue-black mudstones near the top of the Meadowtown Formation crop out in Lower Wood Brook north of the road crossing (3062 0107) and in the roadside just to the west (3065 0093), where they have yielded abundant trilobites (*Ogygiocarella debuchii* and *Lloydolithus lloydii*), as well as graptolites, including *Dicranograptus irregularis* Hadding. Upstream from the road crossing, successively older horizons in the Meadowtown Formation are exposed, complementing the roadside exposures near Meadowtown. Shales 122 m south-east of the road (307 008) yielded the *Palaeoglossa attenuata* and *Lingulella displosa* (see Williams, 1974), and farther upstream (3082 0073), around Whittard's (1979) locality 504, horizons low in the Meadowtown Formation have afforded the trilobites *Whittardolithus intertextus* (Whittard), *Marrolithus inflatus* Williams and *Atractopyge williamsi* McGregor. According to Whittard

(1979, fig. 28), the adjacent locality 505 falls within the underlying Betton Shale Formation, but Hughes (1989, text-fig. 13) noted *teretiusculus* Zone graptolites there, and the British Geological Survey (1991) 1:25 000 geological map places the formational boundary farther upstream.

Interpretation

Meadowtown Quarry and nearby localities together provide a composite section through the Llandeilian Stage at Shelve and have yielded an abundant fauna dominated by trilobites, brachiopods and graptolites. From the point of view of correlation, all the graptolites are long-ranging taxa, except *Dicranograptus irregularis*, which ranges through most of the *teretiusculus* Zone and the basal part only of the *gracilis* Zone (Hughes, 1989). Of the trilobites, *Lloydolithus lloydii* and *Marrolithus inflatus* are restricted to the lower Llandeilo Flags at Llandeilo, whilst *Flexicalymene cambrensis* extends up to the basal upper Llandeilo Flags (see Wilcox and Lockley, 1981); R. Bettley (pers. comm., March 1998) has recorded *F. cambrensis* and *B. tyrannus* up to the equivalent of the top of the Llandeilo Flags in the Narberth Group around Llan-Mill. On balance, the Meadowtown Formation appears to equate to the lower half of the Llandeilo Flags sequence in South Wales, although facies control in the vertical distribution of these species cannot be ruled out.

Applying the Wilcox and Lockley (1981) biofacies model to the Shelve succession gives a generally upwardly deepening sequence, from the more onshore, lower, beds in Meadowtown Quarry, with *Basilicus tyrannus* and *Flexicalymene cambrensis,* to distal, dysaerobic mudstones characterized by *Schizocrania transversa* and *Ogygiocarella debuchii* in higher beds exposed along the Rorrington road and near its crossing over Lower Wood Brook (see also Williams *et al.*, 1981).

Conclusions

The variety of facies present in the Meadowtown Formation leads to a diverse brachiopod–trilobite fauna that represents the Llandeilian Stage in the Shelve succession, and the presence of such species as the trilobite *Lloydolithus lloydii* enables correlation with the type succession near Llandeilo. The site is the type locality for several fossil species, including the venerable species *Diplograptus foliaceus*.

SPYWOOD AND ALDRESS DINGLES (SO 276 957–SO 281 966 AND SO 284 961)

Introduction

Spywood and Aldress dingles expose an almost continuous succession, in fossiliferous strata and without structural complications, through the lower Caradoc Series from the base of the Aurelucian well into the Burrellian Stage of

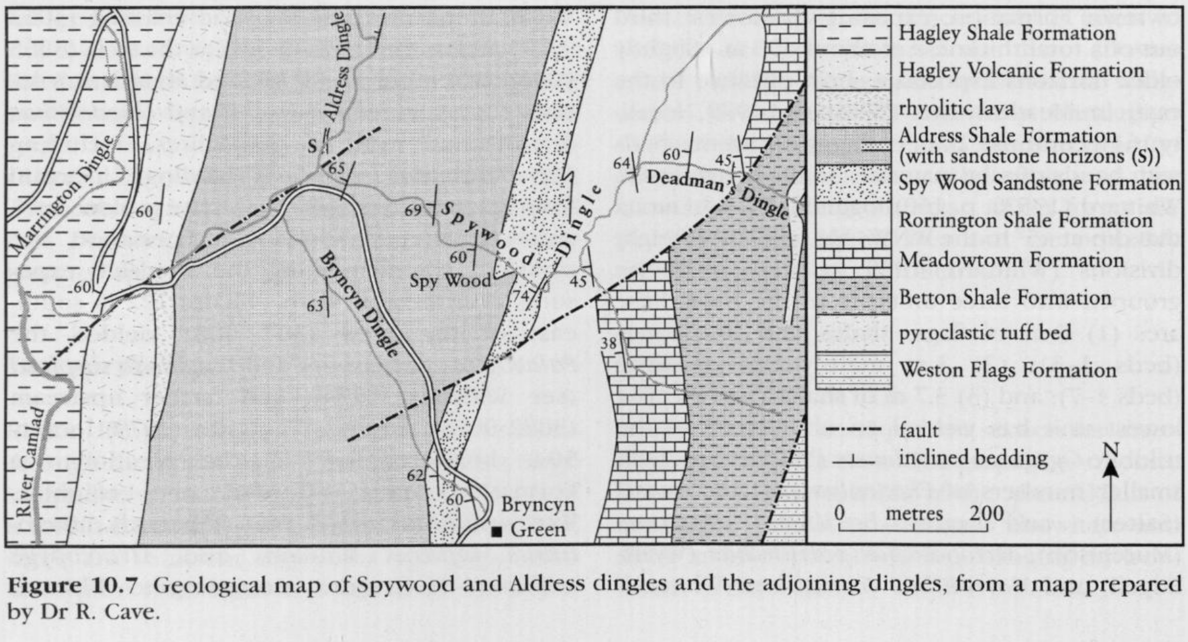

Figure 10.7 Geological map of Spywood and Aldress dingles and the adjoining dingles, from a map prepared by Dr R. Cave.

Fortey *et al.* (1995) (the Llandeilo to Caradoc of earlier writers, e.g. Williams *et al.*, 1972). The sequence exposes much of the Rorrington Formation, the whole thickness of the Spy Wood and Aldress formations, and the base of the Hagley Volcanic Formation. It is a prime reference section for the Caradoc rocks and the faunal succession of the Shelve area and of particular importance in regional correlations between the historical type Caradoc area and the contemporaneous basinal graptolitic succession.

The stratigraphy has been summarized in several papers (listed by Whittard, 1931), and details of the section appear in Whittard (1979, pp. 48–51, figs 30, 32), who gave brief descriptions and sketch maps. The present account draws on a synthesis by Cave and Hains (in press) describing the geology of the Shelve and Montgomery areas (British Geological Survey, 1991, 1994b).

Description

Spywood Dingle extends obliquely across the strike of the Rorrington Formation (Figures 10.7 and 10.8), from close to its contact with the Meadowtown Formation (at 285 962) to the base of the Spy Wood Formation (2819 9581). It then extends WNW across the Spy Wood Formation and most of the Aldress Formation, to join Aldress Dingle at 279 960. Aldress Dingle exposes a section, mainly along strike, in the upper part of the Aldress Formation and exposes the Hagley Volcanic Formation near its junction with Marrington Dingle.

The Rorrington Formation consists of dark-grey mudstones dipping steeply (about 60°) west. Outcrop is discontinuous, and the middle parts are less readily examined (Dr R. Bettley, pers. comm., March 1998). Towards the base the mudstones are blocky, soft and very dark-grey, with a brown streak. Above the middle of the formation the rock is less dark, slightly silty, finely micaceous and locally faintly colour-banded, and higher in the formation black mudstones again dominate the succession. Bioturbation is generally absent.

The fauna includes shelly fossils, mainly brachiopods, trilobites, ostracods, orthoconic cephalopods and numerous graptolites. The brachiopod fauna is dominated by lingulate forms, articulate genera being represented by scarce juvenile valves. Whittard (1955–1967) described 14 species of trilobite from the

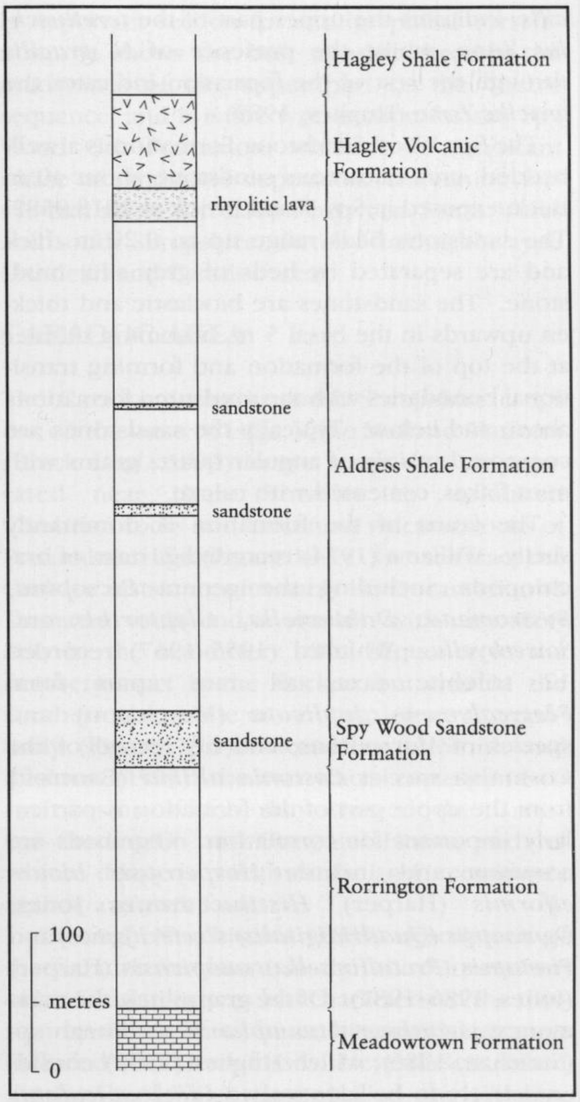

Figure 10.8 Vertical section exposed in the Spy Wood and Aldress areas, prepared by Dr R. Cave.

Rorrington Formation, of which *Spirantyx calvarina* and *Primaspis whitei* are from Spywood Dingle. Jones (1987) recorded three new ostracod species from the Rorrington Formation in Spywood Dingle: *Bullaeferum llandeiloense*, *Laterophores elevatus* and *Pariconchoprimitia oscillata*. Hughes (1989, fig. 12a) recorded several graptolites, including *Dicellograptus geniculatus* Bulman, *D. salopiensis* Elles and Wood, *Hustedograptus* [*Glyptograptus*] cf. *teretiusculus* (Hisinger), *Leptograptus validus* Elles and Wood, *Nemagraptus gracilis* (Hall), and *Pseudoclimacograptus modestus* (Ruedemann). *Dicellograptus geniculatus*, which occurs low in the succession below the range of the *N. gra-*

cilis, indicates the upper part of the *teretiusculus* Zone, whilst the presence of *N. gracilis* through the rest of the formation indicates the *gracilis* Zone (Hughes, 1989).

The Spy Wood Sandstone Formation is a well-bedded, grey calcareous sandstone about 40 m thick, exposed in Spy Wood Brook at 2818 9582. The sandstone beds range up to 0.20 m thick and are separated by beds of grey silty mudstone. The sandstones are bioclastic and thicken upwards in the basal 5 m, becoming thinner at the top of the formation and forming transitional boundaries with the mudstone formations above and below. Typically the sandstones are composed mainly of angular quartz grains with mica flakes, cemented with calcite.

The fauna of the formation is dominantly shelly. Williams (1974) recorded 21 taxa of brachiopods, including the genera *Bicuspina, Bystromena, Dalmanella, Glyptorthis* and *Sowerbyella*. Whittard (1955–1967) recorded 12 trilobite taxa, all rare apart from *Platycalymene duplicata* (Murchison) and species of *Marrolithus*, and his record of the Costonian species *Costonia ultima* (Bancroft) from the upper part of the formation is particularly important for correlation. Ostracods are common and include *Harperopsis bicuneiformis* (Harper), *Histina xanios* Jones, *Ogmoopsis (Quadridigitalis) siveteri* Jones, and *Piretopsis (Protallinnella) salopiensis* (Harper) (Jones, 1986–1987). Of the graptolites, the commonest is *Orthograptus uplandicus* Wiman sp. (Strachan, 1986), which Hughes (1989) considered likely to be identical to *O.* cf. *apiculatus* Elles and Wood. The discovery of *Nemagraptus gracilis* near the middle of the formation (Cave and Hains, in press) is valuable for correlation. Fragmentary bryozoa and crinoids are abundant and plates of the machaeridian *Lepidocoleus* occur.

The Aldress Shale Formation is about 300 m thick and consists mainly of finely micaceous shaly mudstone, usually grey or olive grey-green in colour. There are sporadic interbeds of fine-grained, usually feldspathic, non-laminated volcanogenic sandstone (Figure 10.8). A massive fine-grained feldspathic sandstone several metres thick is exposed in Aldress Dingle (2810 9645).

The faunas from Spy Wood Dingle and Aldress Dingle contain numerous graptolites, including *Amplexograptus leptotheca* (Bulman) (= *A. fallax* Bulman, according to Hughes, 1989, but not Strachan, 1986), *Climacograptus* cf. *antiquus* Lapworth, *Dicranograptus* cf. *furcatus minimus* Lapworth, *D. spinifer* Elles and Wood, *Diplograptus foliaceus* (Murchison), *Lasiograptus costatus* Lapworth and *Orthograptus* cf. *amplexicaulis* (Hall), together with the dendroid *Dictyonema fluitans* Bulman. Shelly fossils include lingulate brachiopods, various bivalves and other mollusca, and the trilobite *Dionide euglypta quadrata* Whittard. At Ox Wood Dingle, north of the present site, volcanogenic sandstones in the upper part of the formation have yielded dalmanellid brachiopods and *Sowerbyella* cf. *sericea permixta* (Williams, 1974), together with the trilobites *Salterolithus caractaci* (Murchison) and *Broeggerolithus broeggeri* (Bancroft), which give an early Soudleyan age.

The Hagley Volcanic Formation is composed of feldspathic sandstones, volcanic conglomerates and breccias, with thinner cross-bedded sandstones and minor rhyolitic tuffs. The base rests on the Aldress Formation in Aldress Dingle, 200 m east of the junction with the River Camlad (2770 9587). A roadside section (2760 9580) shows more than 25 m of massive greenish-grey sandstones, with sedimentary breccia horizons containing siltstone clasts up to 100 mm long. Sole markings are common and some beds are clearly load-cast into the underlying sediments. No fossils are recorded from the Hagley Volcanic Formation at this locality, but *Broeggerolithus broeggeri* and *Salterolithus caractaci*, recorded elsewhere in the formation by Whittard (1955–1967, p. 306), indicate an early Soudleyan age. Graptolites from the formation include *Climacograptus antiquus*, *C. bicornis* (Hall), *Diplograptus foliaceus* and *Pseudoclimacograptus scharenbergi* (Lapworth) and are referable to the *multidens* Zone.

Interpretation

The dark-coloured laminated mudstones of the Rorrington Formation, generally lacking bioturbation and with a limited benthic fauna but with a rich graptolitic fauna, are considered to have accumulated in a basinal setting with poorly oxygenated waters at the sea floor. These conditions obtained during the later part of the *teretiusculus* Zone and the greater part of the *gracilis* Zone, which was a time of marine transgression (Brenchley, in Bevins *et al.*, 1992).

The Spy Wood Sandstone represents a phase of high-energy influxes of sand and bioclasts from a shallow, well-oxygenated sea, transported by frequent storm events into an existing low-energy muddy environment. It is likely that the marginal sea was formed by rapid marine inundation of the existing basin-margin in the neighbourhood of the Long Mynd, for the Caradoc area to the east was inundated at exactly this time: the Hoar Edge Grits and Coston Beds, which rest unconfomably on Cambrian and Precambrian rocks, are identical with the Spy Wood Sandstone in yielding respectively *Nemagraptus gracilis* and *Costonia ultima*, allowing their close correlation (Whittard, 1966, p. 283). The ostracods and articulate brachiopods of the Spy Wood Sandstone also permit correlation with Costonian strata in parts of Wales, e.g. at Bryn-banc Quarry, Lampeter Velfrey (Jones, 1986–1987; see site report for Bryn-banc).

The Aldress Shale Formation represents a return to deposition of graptolitic mud but differs from the Rorrington Formation in lacking fine lamination and in being pervasively bioturbated. Although the formation accumulated in a slightly more oxic environment, the articulate brachiopods are not in the mudstones but are confined to the volcanogenic sandstone beds (Williams, 1974, p. 21) and seem to have been transported into the basin. The trilobites from the higher beds indicate an early Soudleyan age, but there is no evidence of a stratigraphical break above the Spy Wood Sandstone, and the lower part of the formation presumably belongs to the Harnagian Substage.

The Hagley Volcanic Formation represents the reworked remains of an explosive volcanic centre. Some lines of evidence – the lack of sorting of many of the conglomerates, the range of maturity in the clast shapes and the fact that in some beds the clasts are mud-matrix supported – suggest that much of the detritus was transported in high-density turbidity flows and mass-flows. Allochthonous brachiopod debris in the sandstones indicates a shallow marine source. The thinner and finer interbedded sandstones may be low-density turbidites formed during the waning of high-energy activity. Cross-bedding, flute casts and groove casts indicate turbidity flow from the NNE.

Conclusions

The Spy Wood and Aldress section is a nationally important section for stratigraphical correlation. It shows the best transect through the mudstones of the upper part of the Shelve sequence, and it is the type section for the Spy Wood Grit Formation, which is a significant phase of sandstone deposition, containing fossils that allow correlation between South Wales and south Shropshire, thereby linking the type Llandeilo and Caradoc areas.

CARADOC AREA

The Caradoc Series in south Shropshire crops out on the western edge of the Midland Platform (Bluck *et al.*, 1992) in two tracts that are separated near Hope Bowdler by upfaulted Cambrian rocks and Uriconian volcanic rocks of Precambrian age (Figure 10.1). In each tract the Caradoc rests unconformably on Precambrian to Tremadoc rocks and is overlain with unconformity by the Llandovery. The sequence in the northern tract is the thicker, but that in the southern tract is the more complete stratigraphically (Figure 10.9). According to Smith and Rushton (1993), the two tracts correspond to two basins, which they termed the Cressage–Cardington and Onny sub-basins, each of which deepens southwards and terminates against a growth fault.

Although Murchison's (1839) description of the Caradoc Sandstone as the 'third formation' of his Silurian System had characterized the division by means of its fauna, his original account included Llandovery fossils. Nevertheless, when the fossils of Wales were studied, the Caradoc became widely recognized in the Principality, including parts that Sedgwick had ascribed to his Cambrian System. The ensuing conflict between Sedgwick and Murchison over the limits of the Silurian (Secord, 1986) was exacerbated by Murchison's 'blunder' in conflating Caradoc and Llandovery (Sedgwick, 1852), though the unconformity between the two in the Caradoc area was admittedly difficult to discern (Salter and Aveline, 1854; cf. Figure 10.19).

Lapworth effected a division of the 'Caradoc Sandstone' into constituent formations, and these were adopted by the Geological Survey (Pocock *et al.*, 1938; Greig *et al.*, 1968). That scheme is applied to the northern area, though Dean (1958, 1964) proposed a different subdivision for the lower units in the southern area (Figures 10.9 and 10.10).

The succession contains shelly faunas

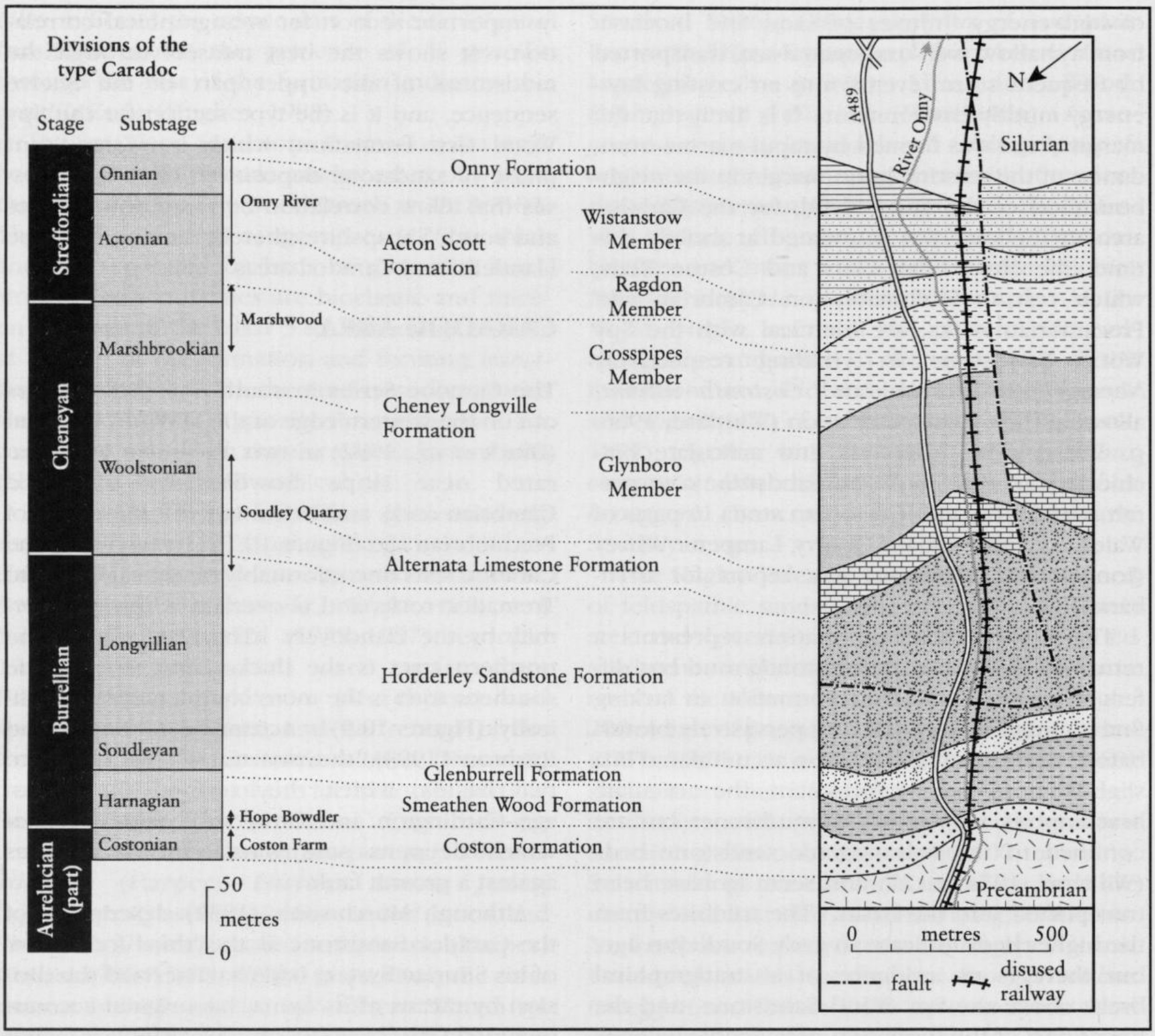

Figure 10.9 Geological map of the Onny Valley showing the Caradoc succession in the southern Caradoc area, based on Savage and Bassett (1985, fig. 3), with stratigraphical amendments proposed by Owen and Ingham (1988) and Fortey *et al.* (1995).

throughout, and Bancroft's (1933, 1945) detailed study of these allowed him to characterize seven stages (and many local zones, based mainly on brachiopods) within the type Caradoc Series. Dean (1958) gave a review of Bancroft's stages and found them of value in northern England (Dean, 1959a), though they are more difficult to apply in Wales and appear too detailed for use in wider correlation. In their review of Ordovician chronostratigraphy, Fortey *et al.* (1995) reduced the Bancroft stages to substages and grouped them into four larger units of wider utility (see Figures 6.2 and 10.9). Hurst (1979a) reviewed the ecological setting of the shelly faunas and recognized several upper Caradoc benthic associations (see also Lockley, 1983). The type Caradoc contains a succession of trinucleid trilobites (Dean, 1960; Owen and Ingham, 1988) that has proved of particular value in correlation, both in Wales and northern England.

The localities are shown in Figure 10.1 (numbers 11–16). The transgressive base of the succession, with its shallow-water faunas, is shown at Coston Farm. The Burrellian Stage is seen resting on Precambrian rocks at Hope Bowdler, and, in the only site in the northern Caradoc area, a deeper-water, partly graptolitic facies of the Costonian and Burrellian rests on Tremadoc shales at Coundmoor Brook, Harnage (Figure

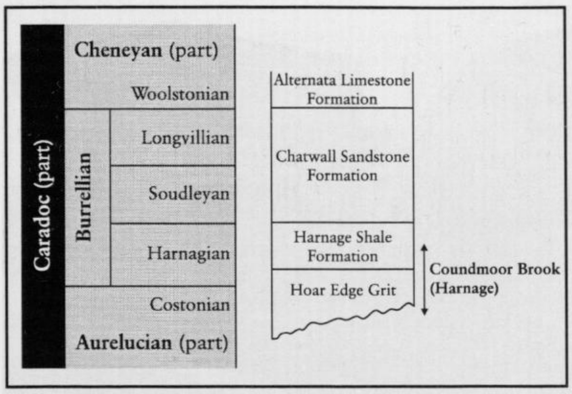

Figure 10.10 Stratigraphical succession for part of the northern Caradoc area, showing the stratigraphical range of the Coundmoor Brook site near Harnage.

10.13). Soudley Quarry shows strata at the junction of the Burrellian and Cheneyan stages, and Marshwood has the stratotype base of the Streffordian Stage. The Onny River site is the type locality for the Actonian and Onnian substages of the Streffordian and includes the historically elusive unconformity between the Caradoc and Llandovery.

COSTON FARM (AROUND SO 39 80)

Introduction

This is the eponymous area for the Costonian Substage of the Aurelucian Stage and probably includes the lowest Caradoc strata in the historical type Caradoc area. It is also the type locality for the trilobite *Costonia ultima* (Bancroft) and for four species of brachiopod.

Bancroft (1929a) originally named the lowest stage of the Caradoc the Girvanian, based partly on the succession at Girvan, but subsequently replaced the name with Costonian, without comment and without further reference to Girvan (Bancroft, 1933). He subsequently noted (1945, p. 182) that the stage was 'typified by the grits of Horderley, Hoar Edge and Coston' but did not designate a type locality. Costonian beds rest unconformably, and probably diachronously, on Tremadoc or Precambrian units in the type Caradoc area, a situation that is clearly unsatisfactory for the base of an international standard (see Whittington *et al.*, 1984; Fortey *et al.*, 1991, 1995). To remedy this, Fortey *et al.* (1995, p. 20) redefined the base of the Caradoc at a level much lower than is recognized in recent usage, at the base of the *Nemagraptus gracilis* Zone. In also defining a new set of stages and reducing Bancroft's divisions to substages, Fortey *et al.* made the Costonian the upper substage of their newly proposed Aurelucian Stage and suggested Bryn-banc Quarry (see site report), near Lampeter Velfrey, as its possible basal stratotype section. Coston Farm remains one of the principal sites for the Costonian Substage in the type Caradoc area.

The lithostratigraphical terminology for the beds of Costonian age in south Shropshire was summarized by Dean (1958) and Greig *et al.* (1968). Whereas the Geological Survey (Greig *et al.*, 1968) applied the term 'Hoar Edge Grits' over the whole area, subsequent authors (e.g. Lockley, 1983; Savage and Bassett, 1985; Bassett *et* al., 1992) have reverted to the usage of Dean (1958) in restricting that term to the northern inlier and using 'Coston Formation' for the southern inlier, though the use of two terms for the same transgressive basal unit seems unduly divisive. As Fortey *et al.* (1995, p. 21) have stressed, the uppermost parts of the Hoar Edge Formation extend up into the Burrellian Stage (Harnagian Substage) in many sections (see the Coundmoor Brook site report).

Dean (in Whittington *et al.*, 1984, p. 25) summarized the geological setting of the Coston area, noting that neither the base of the Costonian nor younger Ordovician rocks are exposed. There is an unconformable relationship with the Llandovery to the east, and the Church Stretton Fault brings the Costonian into juxtaposition with upper Ludlow strata in the west.

Description

The isolated outcrops in the Coston area (Figure 10.11) reveal the threefold division of the SE-dipping 'Coston Beds' described by Dean (1958, 1964, p. 272; Greig *et al.*, 1968, p. 107). The lowest unit comprises over 14 m of conglomerates with white and grey quartz clasts and rarer pebbles of fine-grained pink volcanic rock, thought to be derived from the Uriconian Volcanic Group. These conglomerates are exposed in quarries near The Hollies (387 807), Quarry House (391 804) and south of Upper Coston Farm (386 802). They pass upwards into the *Harknesella* Beds: at least 7.5 m of brown-grey coarse sandstones with rare quartz pebbles, lenticular shell bands and a few thin quartz conglomerate horizons. This unit is well exposed in

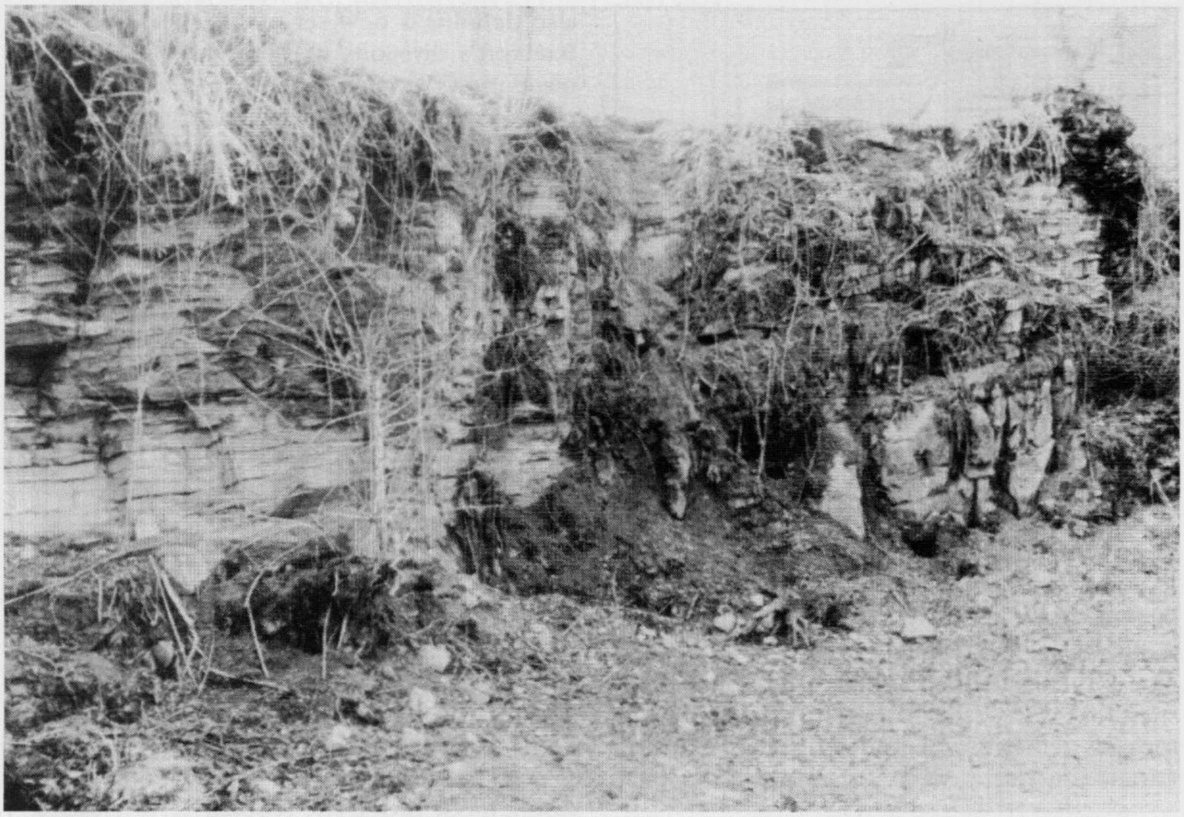

Figure 10.11 Coston Farm. The Coston Formation (the local equivalent of the Hoar Edge Grit Formation) in the old quarry north of Coston Manor. (Photo: J. K. Ingham.)

the southern quarry near the Hollies (387 806) and in the track section east of Upper Coston Farm (387 803). The overlying *Costonia ultima* Beds comprise over 10.5 m of medium- and coarse-grained sandstones with rare quartz pebbles and are exposed in and around the quarry south of Upper Coston Farm.

Interpretation

The basal conglomerates seen in the Coston area are unfossiliferous and are not seen elsewhere (see the Coundmoor Brook site report). The lower Caradoc beds in other localities are correlated with levels above the conglomerates at Coston, suggesting that the latter may be the oldest strata above the sub-Caradoc unconformity (Dean, 1958, p. 198). The fossil lenticles in the *Harknessella* Beds contain *Harknessella verpertilio* (J. de C. Sowerby), for which this is the type locality (Figure 10.12a, b). Fossils are more evenly distributed through the *Costonia ultima* Beds; *Dinorthis flabellulum* (J. de C. Sowerby) is typical (Figure 10.12c, d), and this is also the type locality for the trinucleid trilobite *C. ultima*, also known from the upper part of the Spy Wood Formation in the Shelve area (see the Spywood Dingle site report), which likewise contains the graptolite *Nemagraptus gracilis*, indicating the top of the *gracilis* graptolite zone. As the *Nemagraptus gracilis* Zone has also been recorded from the *Harknessella* Beds in the northern part of the Caradoc area, it seems that the *gracilis–multidens* zonal boundary lies near the top of the Costonian Substage (see the Coundmoor Brook site report).

In addition to *Harknessella vespertilio*, three other species of brachiopod have their type locality in the Coston area; Dean (1960, 1963a, b) described trilobites here, Greig *et al.* (1968) listed the whole fauna from the exposures by Coston Farm, and Jones (1986–1987) described the ostracods. The faunas of the Hoar Edge Formation (*sensu lato*) were assigned to the *Dinorthis* association by Williams (1973),

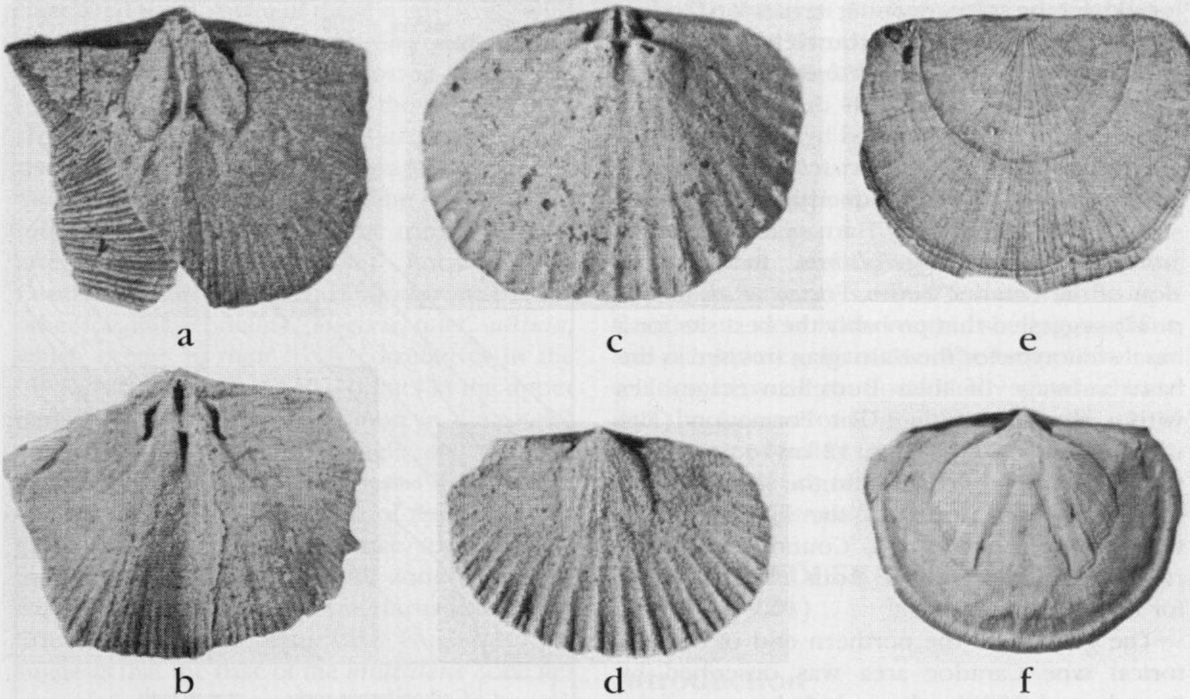

Figure 10.12 Brachiopods from the type Caradoc area. (a, b) *Harknessella vespertilio* (J. de C. Sowerby), ×2, Coston. (c, d) *Dinorthis flabellulum* (J. de C. Sowerby), ×2, Coston. (e, f) *Heterorthis alternata* (J. de C. Sowerby), ×1.5, Soudley.

and Lockley (1983, fig. 8) also indicated, without giving details, the presence of the *Heterorthis* association. Both these associations are regarded as typical of inshore facies with coarse-grained sediments (Lockley, 1983, fig. 12).

Conclusions

The Coston Farm area lends it name to the Costonian, formerly the lowest division of the historical type Caradoc Series. It exposes the oldest beds in the type Caradoc area, but their base is an unconformity and the base of the Caradoc has been proposed at a lower level in South Wales. The beds at Coston yield fossils that enable correlation with the Shelve area and thus indirect correlation with the graptolitic zonal scheme.

COUNDMOOR BROOK, HARNAGE (SJ 558 037)

Introduction

Coundmoor Brook (once known as Cound Brook) is the historical type locality for the Harnagian Substage of the Burrellian Stage. It is one of the few sites in the type Caradoc area to yield sufficiently diagnostic graptolites to allow correlation between the graptolite and shelly zonal schemes. It is also the type locality for the stratigraphically important trilobite species '*Broeggerolithus*' *harnagensis* (Bancroft).

In their detailed subdivision of Murchison's (1839) 'Caradoc Sandstone', Salter and Aveline (1854) termed the lowest units the 'Shales of Harnage and Shineton', here overlain by the Hoar Edge Grits. Callaway (1877) separated the Shineton Shales of Tremadoc age from the Harnage Shales and placed the latter in their correct position above the Hoar Edge Grits (see the Sheinton Brook and Coundmoor Brook, Evenwood site reports in Chapter 7).

Bancroft (1929a) introduced the stage term 'Harnagian', which he subdivided into trilobite biozones, citing Coundmoor Brook as containing the typical representatives for the lower zones. Subsequently (1933) he refined the trilobite zonation and in 1945 (p. 182) gave the Harnage Shales in Coundmoor Brook as the type locality for the stage, defining its base on the first appearance of the trinucleid trilobites *Reuscholithus* and *Salterolithus*. Dean (1958, p. 201) subtly amended this definition to state that the boundary is 'marked by the appearance of the trilobite genera *Reuscholithus* and/or *Salterolithus*'. He subsequently (1960) reassigned some of the early Harnagian material of *Salterolithus* to *Broeggerolithus*. In their revision of the Caradoc Series, Fortey *et al.* (1995, p. 22) suggested that probably the best site for a basal stratotype for the Harnagian (revised as the basal substage of their Burrellian Stage) lies within the Hoar Edge Grit Formation (Figure 10.10) in Cwms Brook, 12 km to the south-west of Coundmoor Brook, at the southern end of the northern inlier of the historical type Caradoc. None the less, Coundmoor Brook remains an important site, both historically and for its fossil content.

The geology of the northern end of the historical type Caradoc area was described by Pocock *et al.*(1938), who included a map of the Harnage–Coundmoor Fault Complex (Pocock *et al.*, 1938, fig. 28). Within this, the Uriconian Volcanic Group, Tremadoc Shineton Shales, Hoar Edge Formation and Harnage Shales are extensively faulted and locally folded and lie in faulted western contact with Upper Carboniferous and Triassic red beds (Figure 10.13). Dean (1958) outlined the historical development of terminology applied to the Caradoc stratigraphy, which he revised, and in so doing rebutted the assertion of Pocock *et al.* (1938) that there was a considerable break between the Hoar Edge and Harnage formations. He subsequently included material from Coundmoor Brook in his descriptions of the Caradoc trilobites (Dean, 1960, 1961b, 1963a, b).

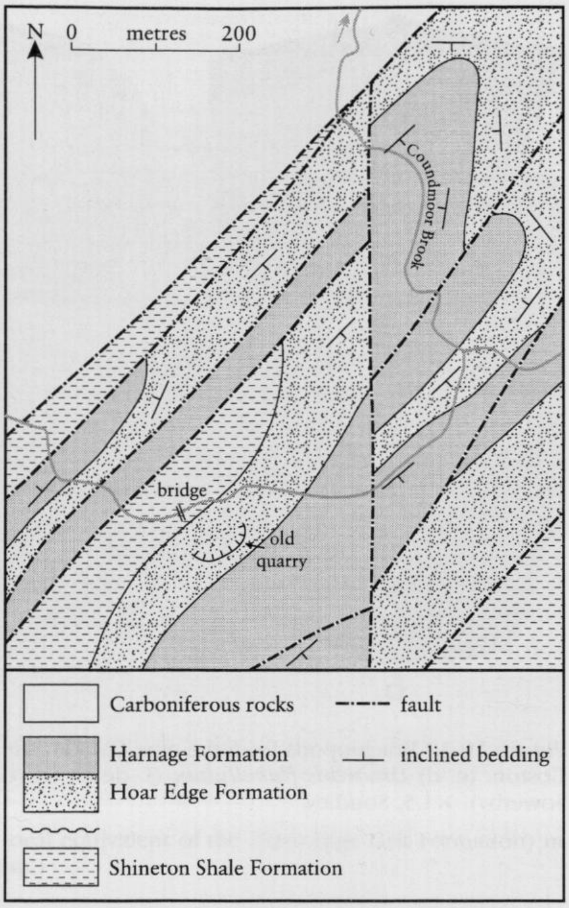

Figure 10.13 Geological map of the area around Coundmoor Brook, south-west of Harnage, after Pocock *et al.* (1938, fig. 28). For location, see Figure 7.10.

Description

Although the contact is not seen, the uppermost part of the Shineton Shales, the Arenaceous Beds, at the western end of the site, are overlain unconformably by the SE-dipping Hoar Edge Formation (Figure 10.13). Coarse sandstones, shales and impure limestones of the latter formation also crop out in the old quarry on the south bank of the brook. The Hoar Edge Formation is repeated by faulting some 250 m along the brook. Pocock *et al.* (1938, fig. 28) also show the formation, along with a sliver of Shineton Shale, at the very northern-most end of the site just south of the faulted contact with the Upper Carboniferous Keele Formation. The remainder of the outcrops in the section are of the micaceous grey silty mudstones, shales and rare thin sandstones of the Harnage Shale Formation. In the northern part of the section, these beds are folded into a SW-plunging syncline that is repeated by a fault sub-parallel to its axial plane.

Interpretation

The Hoar Edge Formation in the northern inlier of the type Caradoc was divided by Dean (1958, essentially following Bancroft, 1928b, 1929a, 1933) into the following: (1) sandy shales and limestones with *Harknessella subplicata*, overlain by (2) sandy limestones with *H. subquadrata,* followed by (3) Rhynchonella Grits. Dean correlated the first two of these respectively with the *Harknessella* Beds and *Costonia ultima* Beds at Coston (see the Coston Farm site report), at the southern end of the type Caradoc area. Dean (in Whittington *et al.*, 1984, p. 25) also summarized records of graptolites of the *Nemagraptus gracilis* Zone in the *Harknessella subplicata* Beds. Although the trinucleid trilobite *Costonia* is not yet known from Coundmoor Brook, the *H. subquadrata* Beds at other localities contain *C. elegans*, not *C. ultima,* which occurs in their likely correlatives in the Coston area. *C. ultima* also occurs in the upper part of the Spy Wood Formation in the Shelve area (see the Spywood Dingle site report), immediately above the highest *Nemagraptus gracilis* and close to the base of the *multidens* graptolite zone. This occurrence, together with that of graptolites of the latter zone (including *Diplograptus foliaceus*) in the Harnage Shales at Coundmoor Brook (Dean, 1958; Hughes, 1989), suggests that the base of the *multidens* Zone lies very close to the Costonian–Harnagian boundary. Moreover, the occurrence in the Rhynchonella Grits at nearby Stevenshill of trilobites ascribed to *Salterolithus* (Dean, 1958, p. 198) indicates that they are Harnagian in age and that the Hoar Edge Formation thus extends, at least locally, up into the Harnagian.

The lowest part of the Harnage Shales in Coundmoor Brook has yielded abundant specimens of '*Broeggerolithus*' *harnagensis,* including the type material; this very variable species occurs in abundance, and a detailed statistical analysis being undertaken by Ms A. Bowdler-Hicks of Glasgow University promises to form a starting point for understanding the subsequent evolution of the stratigraphically important British Caradoc cryptolithines. The range of growth stages of *Reuscholithus reuschi* known from Coundmoor Brook enabled Bancroft (1929a) and Dean (1960) to describe aspects of its ontogenetic history. With the exception of ostracods, described by Jones (1986–1987), and the type specimen of *Platanaster ordovicus* Spencer, redescribed by Blake (1994), other elements of the diverse lower Harnagian fauna (Pocock *et al.*, 1938, appendix 4) are in need of modern description. Geographical variation in composition of the trilobite fauna of the Harnage Shales and the laterally equivalent Smeathen Wood Formation in the southern Caradoc area suggests that subtle but significant ecological controls affected the distribution of species in the area. The same also applies to the underlying Costonian faunas (Dean, in Whittington *et al.*, 1984, p. 26).

Conclusions

Coundmoor Brook is the historical type locality for the division of the Caradoc Series now termed the 'Harnagian Substage' of the Burrellian Stage. It is one of few sites in the type Caradoc to yield both benthic shelly organisms and planktonic graptolites. The latter allow correlation between the local shelly zonal scheme and the international graptolitic scheme. It is also the type locality for the stratigraphically and evolutionarily significant Harnagian trilobite species '*Broeggerolithus*' *harnagensis*.

HOPE BOWDLER ROAD SECTION (SO 474 924)

Introduction

This site shows the unconformable relationship between the base of the Harnage Shale Formation and the underlying Uriconian Volcanic Group of Precambrian age. The basal Caradoc rocks here are younger than elsewhere in the type Caradoc area and the locality is thus important in demonstrating the marked diachronism of the base of the series in south Shropshire.

The Caradoc Harnage Shale Formation in the Hope Bowdler Road Section has a conglomeratic base and unconformably overlies Precambrian rocks. In the context of other outcrops in the area (see Greig *et al.*, 1968, p. 123), the irregular nature of this unconformity surface, with fissures up to 15 cm wide, can be deduced.

Description

This small roadside cutting, about 200 m west of the church at Hope Bowdler ('12' in Figure 10.1), exposes 30 cm of pebbly conglomerate overlying tuffs of the Precambrian Uriconian Volcanic Complex (Figure 10.14). The conglomerate is overlain by shales of the Harnage Shale Formation that contain a rich shelly fauna indicative of the lower part of the Harnagian Substage of the Burrellian Stage. At Upper House (475 926), some 60 cm of conglomerate overlie the Uriconian rocks (Greig *et al.*, 1968, pl. 7C), and in the quarry on Hazler Hill (463 925) neptunian

Figure 10.14 Roadside section at Hope Bowdler, showing the pebbly lower part of the Harnage Shale Formation resting unconformably on an irregular surface of the Uriconian complex (Precambrian). The hammer head lies at the unconformity. (Photo: J. K. Ingham.)

dykes of sandy Harnage Shale in the Uriconian Group also contain a Harnagian fauna (Strachan *et al.*, 1948).

Interpretation

The shelly fauna from the Harnage Shale in the road section and elsewhere indicates that the basal Caradoc rocks in the Hope Bowdler area are Harnagian, and therefore younger than the Costonian basal rocks elsewhere in the type Caradoc area of Shropshire (see the site report for Coston Farm). Thus the basal Caradoc transgression was demonstrably diachronous over an irregular surface of Precambrian, Cambrian and lower Ordovician (Tremadoc) rocks.

Conclusions

This site shows evidence of the transgression of the sea during the early Caradoc over the eroded surface of much older rocks. Fossils from the beds above the unconformity indicate that this drowning took place at a later date than elsewhere in south Shropshire.

SOUDLEY QUARRY (SO 477 918)

Introduction

Soudley Quarry contains the basal stratotype for the Glynboro Member of the Cheney Longville Formation, beneath which is the thinnest development of the Alternata Limestone Formation, the basal unit of the type upper Caradoc. Sedimentological and palaeoecological information from the quarry have played a key role in understanding the history of the margin of the Welsh Basin.

The disused sandstone quarries at Soudley, 600 m south-east of Hope Bowdler, were described by Murchison (1839). The section comprises two sandstone–siltstone units, separated by a thin limestone. The historical development of the stratigraphical terminology applied to the south Shropshire Ordovician, outlined by Dean (1958, 1964), Greig *et al.* (1968) and Hurst (1979b), shows that the lower unit exposed in Soudley Quarry has been variously termed the 'Horderley Flags' (introduced by Salter and Aveline, 1854), the 'Chatwall Sandstone' (or 'Flags') (Callaway (1877), the 'Horderley Sandstone' (La Touche, 1884) and the 'Soudley Sandstone' (Cobbold, 1901). Bassett *et al.* (1992, fig. 4.15) summarized current usage, as applied by Hurst (1979b), using the terms 'Horderley Sandstone Formation' for the southern Caradoc area (which includes Soudley) and 'Chatwall Sandstone' in the northern area.

The limestone was termed the Alternata Limestone by Cobbold (1901) and has been variously grouped with the underlying unit (Cobbold, 1901; Lapworth, 1916) or the overlying unit (Bancroft, 1933; Greig *et al.*, 1968). Dean (1958, 1964) made no such grouping and Hurst (1979b) explicitly applied formation status to it, defining the base of the Woolstonian (formerly Upper Longvillian), and hence the upper Caradoc, at its base in the Onny River section (418 856) (Hurst, 1979b, p. 210, fig. 12) (Figure 10.9 herein). Soudley Quarry is the only locality where the base of the Cheney Longville Formation (introduced by La Touche (1884) as Cheney Longville Flags) can be seen. Hurst (1979b, p. 191) stated that this was not an ideal locality for a formational boundary stratotype but nevertheless used it as the stratotype for the basal Glynboro Member.

The sedimentology, palaeoecology and stratigraphy of the units in Soudley Quarry were described by Hurst (1979a, b, c) in his assessments of the Alternata Limestone and contiguous units and the type Upper Caradoc. Figure 10.15 is based on his measured sections.

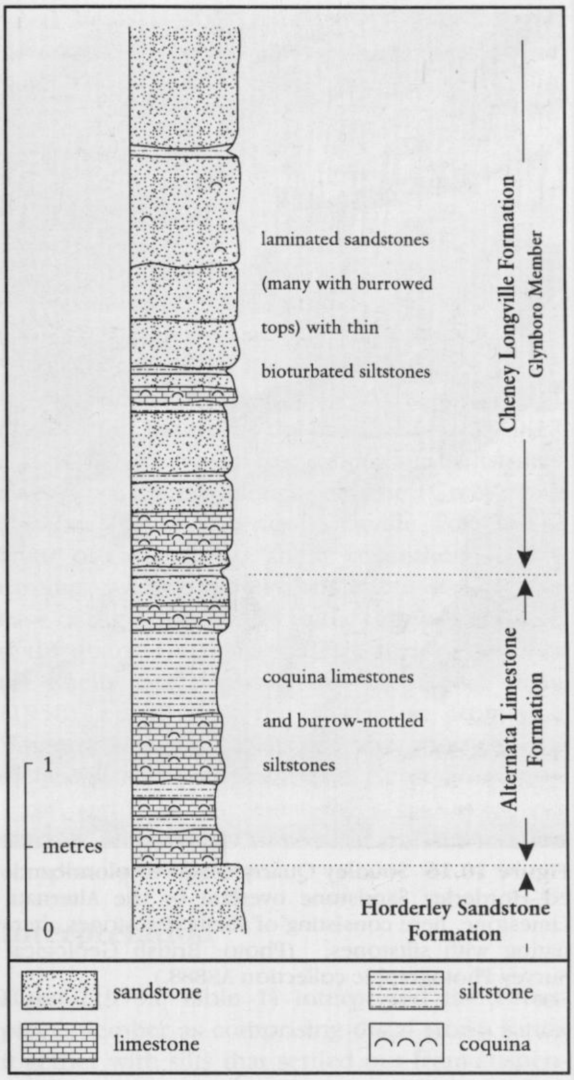

Figure 10.15 Sedimentary log of the Alternata Limestone Formation and the lower part of the Cheney Longville Formation at Soudley Quarry, based on Hurst (1979b, fig. 4).

Description

Although this quarry is overgrown, the three units present are all exposed (Figure 10.15). The parallel-laminated purple and green sandstones of the Horderley Sandstone Formation give way abruptly to the silty muds, sandy silts and coquina limestones of the Alternata Limestone, here 2 m thick (Figure 10.16). The coquinas and shell lags are dominated by bryozoans and the brachiopods *Sowerbyella sericea* (Sowerby), *Kjaerina bipartita* Bancroft, *Bancroftina typa* (Bancroft – formerly *B. robusta*) and *Heterorthis alternata* (Sowerby), the eponym for the unit (Figure 10.12e, f). The base of the Alternata Limestone is marked by a 20 cm limestone unit; phosphatized pebbles and shells occur within its lower half. The top is gradational to the planar and cross-bedded sandstones and thin bioturbated siltstones of the Glynboro Member of the Cheney Longville Formation. A few limestone coquinas, dominated by *Kjaerina bipartita,* are present in the lowest part of the formation, and the gradational nature of the change is exemplified by Hurst's drawing of the boundary at slightly different levels in his 1979b and 1979c papers. The lower part (but not the base) of the Glynboro Member

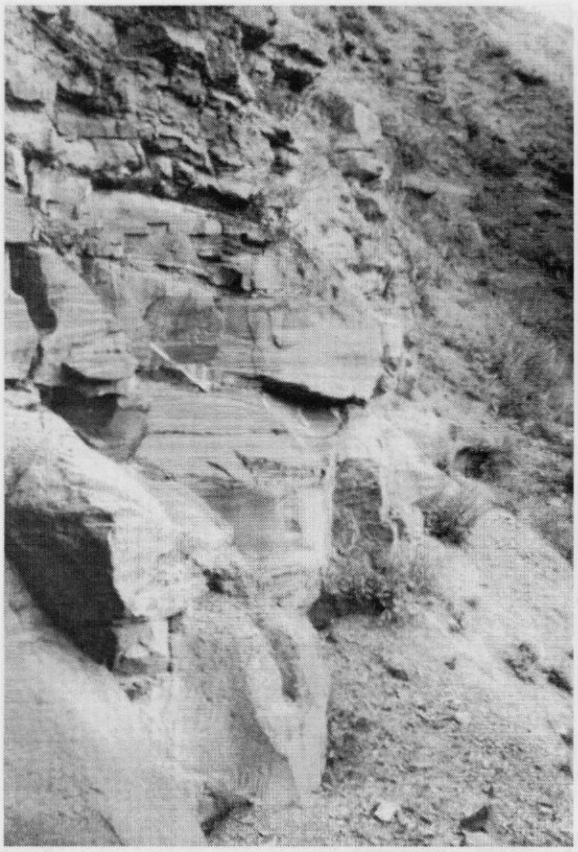

Figure 10.16 Soudley Quarry. Massive colour-banded Horderley Sandstone overlain by the Alternata Limestone, here consisting of shelly limestones alternating with siltstones. (Photo: British Geological Survey Photographic collection A8888.)

is also well exposed in the stream section to the south-west of Soudley Quarry (478 916), and a measured section from there was given by Hurst (1979c, fig. 9B). Coquinas in the stream section contain fewer bryozoans than the Alternata Limestone but have similarly dominant brachiopod species, with the exception of *H. alternata* (Hurst, 1979c, table 3).

Interpretation

Bancroft (1929b, p. 40) argued that the Alternata Limestone rests on upper Soudleyan strata at Soudley, the Longvillian (his Lower Longvillian) being absent. This view was upheld by Dean (1958, 1964) and Hurst (1979b, p. 214, fig. 15). Bassett *et al.* (1992, p. 102) suggested that reported breaks in the Horderley–Chatwall sandstones in Shropshire 'may be a result partly of erosive scour and ecological gaps rather than original non-deposition'. However, Bassett *et al.* (1992) also recognized that the phosphatic nodules in the lower part of the Alternata Limestone (such as at Soudley) may reflect transgression over a previously non-depositional surface and thus may indicate, at least locally, emergence during the Longvillian. Hurst (1979b, p. 191) suggested that the presence of phosphatic nodules and phosphatized fossils and the very reduced thickness of the Alternata Limestone at Soudley Quarry point towards a condensed sequence here – the formation is up to 30 m thick elsewhere.

All of the units present in Soudley Quarry are fossiliferous. Greig *et al.* (1968, appendix 1) listed species from various levels through the section, and Hurst (1979c, table 3) presented the quantitative results of bulk sampling from the Alternata Limestone and Glynboro Member. Brachiopods (Hurst, 1979b), trilobites (Dean, 1960, 1961b, 1963a, b) and ostracods (Jones, 1986) have been described from the quarry. Savage and Bassett (1985) recorded conodonts from the Alternata Limestone and Glynboro Member there, although zonally diagnostic forms were not present in their samples.

Hurst (1979a, c) assigned the faunas from both the more complete development of the Horderley Sandstone (not present at Soudley) and the Cheney Longville Formation to what he termed the '*Bancroftina robusta* association' (which Lockley (1983, p. 120) corrected to *B. typa* association). Hurst (1979a, c) considered the faunas of the Alternata Limestone to consist of transported shelly faunas of such variable composition that no obviously recurring faunal associations could be recognized. He interpreted this mixing of faunas as reflecting a rather varied environment, possibly associated with marine bars. He considered the Alternata Limestone of the Soudley–Cheney Longville area to have been deposited in a more distal environment than the equivalent limestone in the northern inlier (Hurst, 1979c, p. 29), which he subsequently termed the 'Chatwall Limestone' (Hurst, 1979b, p. 199).

Conclusions

Soudley Quarry shows a significant succession of two fossiliferous sandstone–siltstone formations separated by the Alternata Limestone, which is widespread in south Shropshire but at it thinnest (2 m) here and may be condensed. The

Longvillian Substage is missing beneath the limestone, possibly indicating an episode of erosion. The quarry is the type locality for the base of the Glynboro Member of the Cheney Longville Formation, and sedimentological and palaeoecological information there have played an important role in the understanding of the changing environments near the edge of the Welsh Basin during the mid-Caradoc.

MARSHWOOD (SO 444 891)

Introduction

Marshwood is the historical type section for the Marshbrookian Substage of the Cheneyan Stage and is nationally important in containing the basal stratotype for the Actonian Substage of the overlying Streffordian Stage. The faunal change at the base of the Actonian is one of the most striking in the type upper Caradoc and permits correlation with Scandinavia and potentially with sequences deposited around Gondwana. Marshwood is also the type locality for several trilobite and brachiopod species.

Bancroft (1929b) introduced the term 'Marshbrookian' for a stage of the Caradoc and subsequently (1945) designated his Upper Longville Flags in the lane through Marshwood as the type section. The Marshbrookian is now considered a substage of the Cheneyan Stage (Fortey *et al.*, 1995). Bancroft (1929b) divided the Marshbrookian into three brachiopod zones, in ascending order the zones of *Wattsella wattsi*, *W. unguis* and *Kjaerulfina polycyma*. The last of these was subsequently renamed the *Onniella reuschi* Zone (Bancroft, 1933). Hurst (1979b) redefined Bancroft's Upper Longville Flags as the Crosspipes Member of the Cheney Longville Formation. He designated its basal stratotype and that of the Marshbrookian at Cheney Longville, south of the Onny River, but illustrated a reference section for the lower part of the member in the river section at the northern end of Marshwood (442 891) (Hurst, 1979b, fig. 6B), and considered the exposures in Marshwood to be the best section of the Marshbrookian. Hurst also recognized Bancroft's three zonal faunas as successive faunal associations (Hurst, 1979a, b) within the Crosspipes Member, and he redefined the base of the Actonian (now the Actonian Substage of the Streffordian Stage, following Fortey *et al.* (1995)) at the incoming of the third of them. The section in Marshwood was designated the basal stratotype for the revised base of the Actonian (Hurst, 1979b, p. 211, fig. 14). The Marshwood section has also been described in varying detail by Bancroft (1945, p. 195), Dean (1958, p. 209) and Greig *et al.* (1968, p. 133).

Description

At the time of writing (1996) the Marshwood section is extensively overgrown, but Greig *et al.* (1968) estimated a succession of a little over 30 m was present in the quarry and track to the south. The measured section provided by Hurst (1979b, fig. 14) forms the basis of Figure 10.17 and shows the typical fine sandstones, siltstones and bioturbated shales of the Crosspipes Member of the Cheney Longville Formation. Some of the beds are shelly and otherwise calcareous, weathering to form rottenstones. The base of the Actonian lies to the immediate south of the quarry and is marked by a major change in the shelly fauna within this member. Dean (1958) noted that the transition from the 'Cheney Longville Flags' to the mottled siltstones of the overlying Acton Scott Formation (now within the Actonian Substage) could be seen in the track to the south, but this is now completely overgrown.

Interpretation

Hurst (1979a, table 1) interpreted the Crosspipes Member as comprising distal storm sands together with silts that settled out from suspension (cf. Brenchley and Newall, 1982). It represents a deepening from the Woolstonian Glynboro Member of the Cheney Longville Formation. The Marshwood section is richly fossiliferous. Faunal lists were given by Greig *et al.* (1968, appendix 1) and incorporated by Hurst (1979a, b) in the quantitative and semiquantitative lists of the faunal associations present in the member. Trilobites (Dean, 1960, 1961b, 1963a, b), brachiopods (Hurst, 1979b) and chitinozoans (Jenkins, 1967) have been described from the site, which is the type locality for several species, including the zonally important Marshbrookian trilobite *Broeggerolithus transiens*.

Hurst (1979a; see also Lockley, 1983) termed the three faunal assemblages present in the Crosspipes Member, in ascending order, the *Dalmanella multiplicata–Sowerbyella sericea* Association, the *D. unguis* Association and the

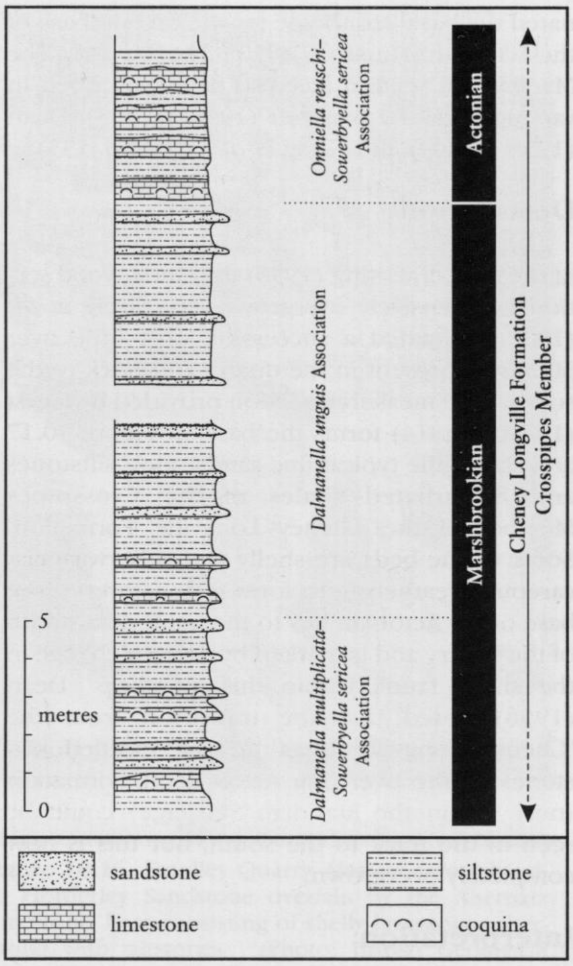

Figure 10.17 Sedimentary log through the Crosspipes Member of the Cheney Longville Formation in Marshwood, based on Hurst (1979b, fig. 14), showing the base of the Actonian Substage and the three faunal associations recognized by Hurst (1979a; see also Lockley, 1983).

Onniella reuschi–Sowerbyella sericea Association. The base of the Actonian was defined at the base of the last of these, at a level that Hurst (1979b, p. 211) considered to be one of the most prominent faunal turnovers in the type upper Caradoc, possibly representing a wider than local ecological event. He gave a quantitative breakdown of the highest Marshbrookian and lowest Actonian faunas in the Marshwood section, showing the sudden introduction and dominance of the brachiopod *Onniella reuschi*. The Streffordian Stage, of which the Actonian is the lower substage, can be recognized in Scandinavia on the basis of its trilobite faunas (Fortey *et al.*, 1995, p. 23), and the appearance of the trilobite *Onnia* in the upper part of the stage holds the promise of close correlation with Gondwanan successions.

Conclusions

Marshwood is a nationally significant site, being the type section for the Marshbrookian Substage of the Cheneyan Stage of the type Caradoc Series and for the base of the succeeding Actonian Substage of the Streffordian Stage. It is thus important for correlation of the Caradoc, both within the Anglo-Welsh area and internationally. The site is the type locality for species of trilobite and brachiopod, and the shelly faunas have played a significant role in assessing the changes in Ordovician benthic communities in this part of the Welsh Basin.

ONNY RIVER (SO 422 854–SO 426 852)

Introduction

This is the type locality for the Actonian and Onnian substages of the Streffordian Stage, for the Acton Scott and Onny formations, and for some 17 taxa of trilobites and brachiopods. The section also contains a mid-Actonian bentonite for which fission-track ages have been obtained. The top of the section shows the historic unconformity between the upper Caradoc and the upper Llandovery, the recognition of which was an important factor leading to the establishment of the Ordovician System.

Bancroft (1945) designated the Onny River as the type section of his Actonian and Onnian stages of the type Caradoc Series (Bancroft, 1929a, 1933), and these now form substages of the Streffordian Stage (Fortey *et al.*, 1995). The base of the Actonian, and hence the Streffordian, is not exposed here and its basal stratotype is at Marshwood Quarry (see site report), 4 km to the north-east (Hurst, 1979b). In addition to its national and international importance to chronostratigraphy, the Onny River was the first Ordovician stratotype section to yield a chronometric age: this was obtained from a bentonite in the Actonian part of the section (Ross *et al.*, 1976, 1982) and is thus a global reference point on the chronometric time-scale. The type Onnian rocks are overlain with very slight angular unconformity by the upper Llandovery Hughley Shale Formation. Murchison (1839) overlooked this unconformity when describing

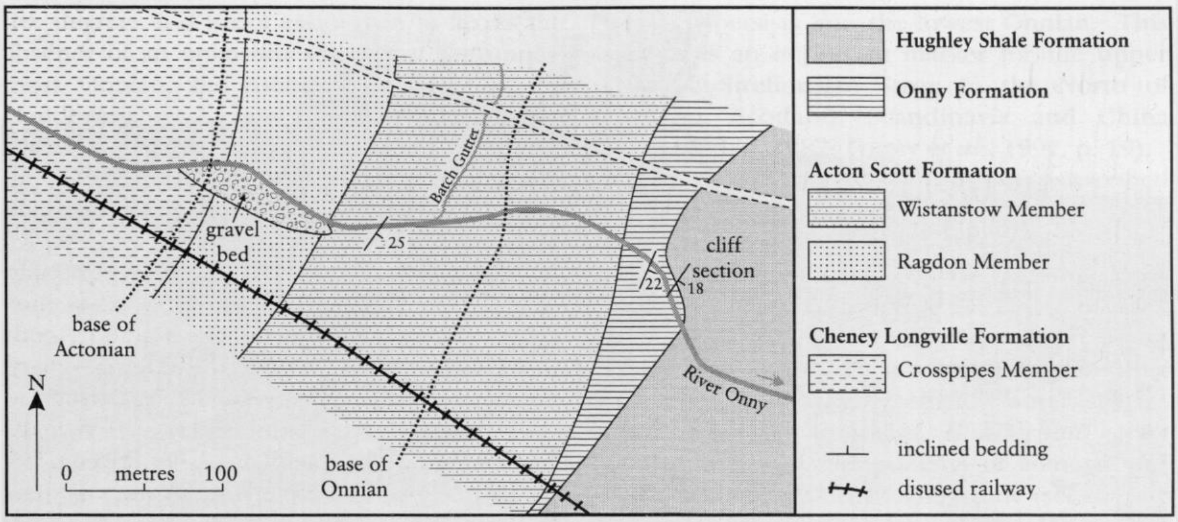

Figure 10.18 Geological map of the eastern part of the Onny River section showing the bases of the Actonian and Onnian substages and their relationship to the upper Caradoc formational boundaries, after Hurst (1979b, fig. 8), and Toghill (1992, fig. 4), with the amendment to the Onnian lithostratigraphy proposed by Owen and Ingham (1988).

his 'Caradoc Formation', but it was subsequently described by Salter and Aveline (1854). The recognition of this unconformity between Murchison's lower and upper Silurian played a fundamental part in Lapworth's (1879a) establishment of the Ordovician System for the lower succession.

The lithostratigraphical terminology applied to the Actonian and Onnian strata in Shropshire was summarized by Hurst (1979b) and further refined by Owen and Ingham (1988). Hurst assigned all but the lowest part of the Actonian strata to the Acton Scott Formation, with the basal stratotypes for its Ragdon and Wistanstow members defined in the section near Oakwood, south of Ragleth Hill (SO 451 908 – SO 451 906). Hurst placed the overlying Onnian rocks in the Onny Shale Formation, but Owen and Ingham (1988) reverted to the usage of Bancroft (1929a, 1933), who restricted what he termed the 'Trinucleus' or 'Onnia Shales' to the uppermost part of the Onnian Stage. Owen and Ingham advocated the use of the term 'Onny Formation' for this unit and reassigned the underlying Onnian strata to the Wistanstow Member of the Acton Scott Formation.

The type Actonian and Onnian are locally richly fossiliferous, especially with brachiopods (Hurst, 1979a, b) and trilobites (Dean, 1960, 1961b, 1963a, b; Owen and Ingham, 1988), 17 species or subspecies having their type locality here. Other taxa include ostracods (Jones, 1986–1987), conodonts (Savage and Bassett, 1985), acritarchs (Turner, 1982, 1984), chitinozoans (Jenkins, 1967), annelids, bivalves, gastropods, monoplacophorans, cephalopods, bryozoans and fragmentary graptolites. Hurst (1979a) undertook palaeoecological analysis of the faunas, and Lockley (1983) further analysed them in the context of Llanvirn and Caradoc palaeoecology of the whole Welsh Basin. Descriptions of the Actonian and Onnian of the Onny River section are given by Greig *et al.* (1968) and by Toghill (1992). Savage and Bassett (1985, fig. 3) gave a geological map of the Onny Valley that puts the section in its immediate stratigraphical context (Figure 10.18 herein).

Description

The Actonian and Onnian rocks in the Onny section dip south-east at 22–25° and are exposed discontinuously in the banks and bed of the river (Figure 10.18). It is clear from the literature that erosion, changing vegetation cover and shifting patterns of river sediment have influenced the parts of the section available to workers over the years. The lowest part of the Actonian currently (1997) exposed comprises bioturbated siltstones of the Ragdon Member, though most of this unit is not exposed.

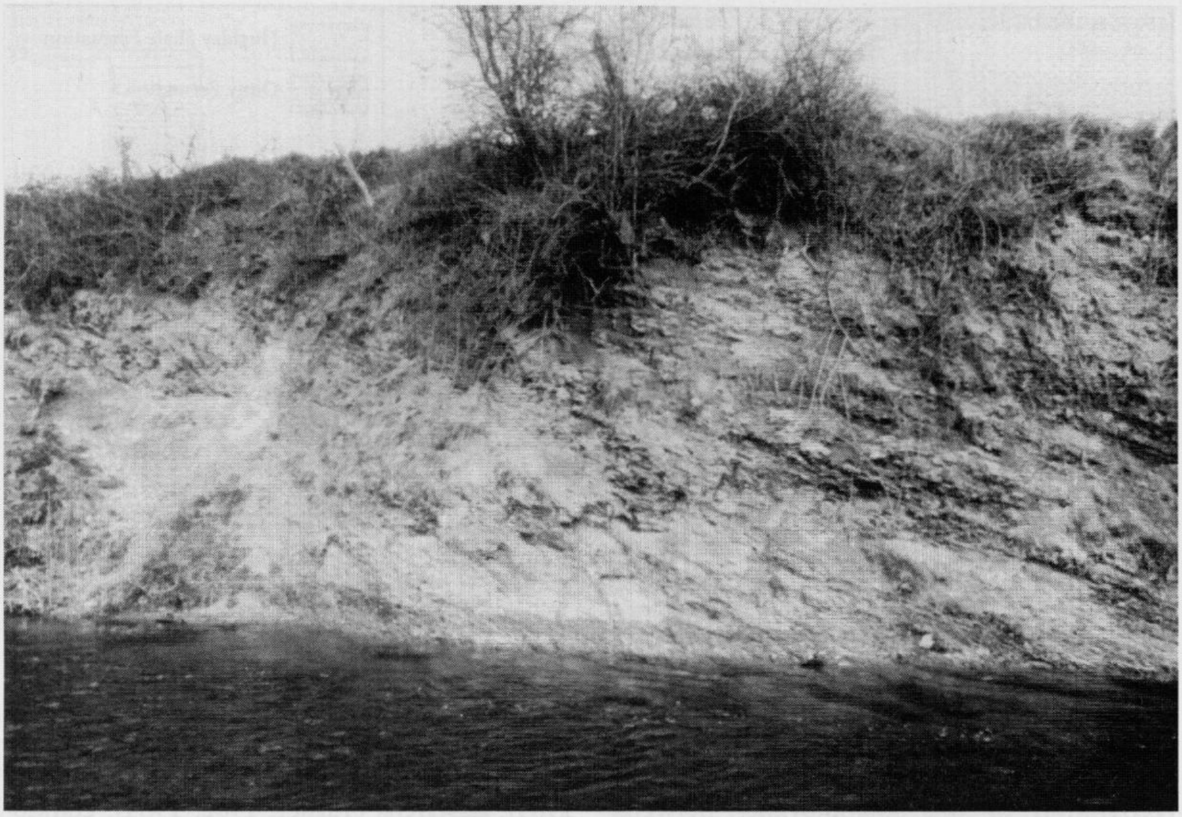

Figure 10.19 The cliff section at the eastern end of the Onny River section, showing how difficult it is to see the slight angular unconformity of the Lower Silurian (upper Llandovery) Hughley Shale Formation above the shales of the uppermost Caradoc Onny Formation (Caradoc, Streffordian, Onnian Substage). (Photo: J. K. Ingham.)

Immediately east of where the river turns almost due east, this member is overlain by blocky grey bioturbated siltstones, some of which are calcareous and contain limestone nodules. These belong to the Wistanstow Member, 70 m thick, and are best seen on the south bank of the river in a cliff 50 m west of Batch Gutter. About 2.5 m of the Wistanstow Member crops out in this cliff, including two orange-weathering bentonites 8 cm and 5 cm thick separated by 12 cm of silty mudstone. The higher and thicker of these bentonites, known as Jack Slither (Bancroft, 1949), has yielded a zircon fission-track age of 468 ± 12 Ma and an apatite fission-track age of 464 ± 21 Ma, giving an average value of 466 ± 15 Ma (Ross *et al.*, 1982).

The Wistanstow Member continues downstream and extends well into the Onnian, where the dark, rubbly calcareous siltstones bear a stronger similarity to the underlying upper Actonian strata than to the shales and blocky mudstones of the upper 15 m of the Onnian (Owen and Ingham, 1988). The base of the Onnian is defined on the first occurrence of the trinucleid trilobite *Onnia superba cobboldi* (Bancroft) in the northern bank, about 30 m to the east of Batch Gutter (Dean, 1963b, p. 8; Owen and Ingham, 1988, fig. 1). The Wistanstow Member continues downstream for some 70 m (about 31 m stratigraphical thickness), and at about 7 m from its summit, a layer of phosphatic nodules may represent an episode of reduced sedimentation rate. The base of the lower part of the overlying Onny Formation is marked by about 5 m of laminated blue-grey mudstone and is overlain by 10 m of blocky blue-grey mudstones that weather orange. The upper 3 m of the Onny Formation exposed in the famous cliff section on the north bank of the river (Figure 10.19) are overlain by purple shales and fine sandstones of the Hughley Shale Formation of Upper Llandovery age. This unconformity shows an eastward overstep, and although the angular discordance is of only a few degrees and is not easily seen, it marks the absence of an unknown amount of the uppermost Onnian, the Ashgill and much of the Llandovery.

Interpretation

The faunas of the Actonian strata in the Onny River section are dominated by brachiopods, especially *Onniella*. Hurst (1979a) replaced earlier biozonations (Bancroft, 1929a, 1933; Dean, 1958) by a twofold faunal division based on the whole fauna and conforming to the Ragdon and Wistanstow members, with a lower *Onniella reuschi–Chonetoidea radiatula* Association succeeded by an upper *Onniella depressa* Association. About 6 km to the north-east, around Acton Scott, hard calcareous sandstones of the Henley Member (Hurst, 1979b) are developed in the upper part of the Acton Scott Formation and contain a fauna termed the '*Dalmanella unguis*' Association by Hurst (1979a). This marks a return of a faunal association that typifies the middle part of the Marshbrookian Crosspipes Member of the Cheney Longville Formation.

Hurst (1979b) noted that the upper Actonian marked a significant species turnover and an increase in trilobite diversity. Of particular importance is the occurrence of *Tretaspis ceriodes* (Angelin) (*T. ceriodes favus* Dean), which first appears at the very top of the Actonian in the Onny River section (Dean, 1963b, p. 8), where it persists into the lowest Onnian. This species is an important marker for the upper Caradoc Streffordian Stage in the North of England, Scotland, Scandinavia and China (Owen, 1980, 1987; Fortey *et al.*, 1991, p. 19).

The overall fauna of the Onnian was ascribed to the *Onniella broeggeri–Sericoidea homolensis* Association by Hurst (1979a). A thin, shelly lens, rich in the brachiopod *Heterorthis alternata,* was described from near the top of the section by Harper (1978) and was interpreted by Hurst (1979b, p. 205) as representing a distal storm deposit bringing shallow-water species into a deeper environment. *H. alternata* is one of the dominant components of some of the coquinas in the Alternata Limestone (see the site report for Soudley Quarry), but both Harper and Hurst noted that it cannot be considered an index fossil for the Woolstonian.

The Onnian was divided into three zones by Bancroft (1929a, 1933, 1949); in ascending order: the zones of the trilobites *Onnia cobboldi*, *O. gracilis* and *O. superba*. Closely spaced sampling by Owen and Ingham (1988) enabled a more detailed analysis of populations and a taxonomic revision of *Onnia* in the type Onnian. This resulted in a four-fold division, in ascending order: *Onnia superba cobboldi* Local Range Zone (LRZ), *O. superba creta* LRZ, *O. gracilis* Acme Zone and *O. superba superba* LRZ. This analysis has become an important case study in patterns of evolutionary or environmentally controlled change through time (Fortey and Owens, 1990a; Skelton, 1992). The base of the Onny

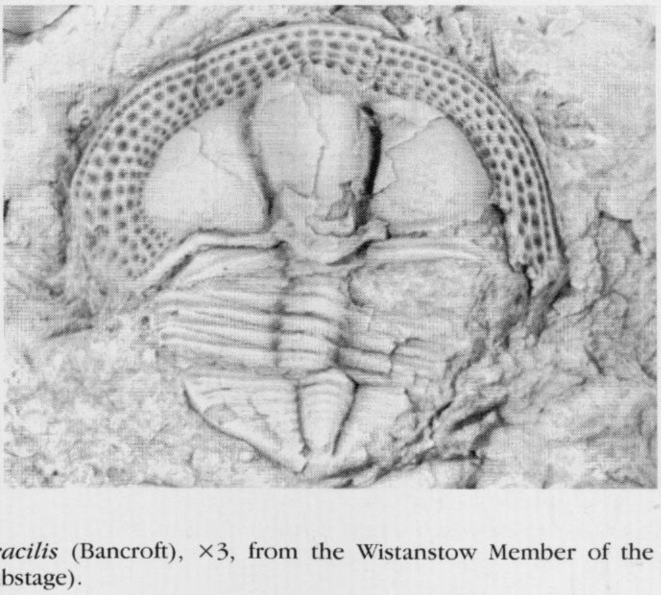

Figure 10.20 *Onnia gracilis* (Bancroft), ×3, from the Wistanstow Member of the Acton Scott Formation (Streffordian, Onnian Substage).

Formation lies some 9 m above the base of the *O. superba superba* LRZ and marks a distinct shift in variance in some features of the zonal subspecies. Although *O. gracilis* (Figure 10.20) occurs as a rare component of the late Actonian fauna near Cardington in south Shropshire, its occurrence at Welshpool (see the Gwern-y-brain site report) and in the Cross Fell and Cautley inliers of the north of England (see the Pus Gill and Sally Beck site reports) may well be at levels equivalent to its Acme Zone in the Onny River section. In the north of England it is succeeded by *O. pusgillensis* Dean, which may have been its descendant or a derivative of *O. superba*; the precise correlation of the sections there with the upper part of the type Onnian is not clear-cut. However, in the north of England the succession continues into the Ashgill, the base of which is marked by (*inter alia*) the disappearance of *Onnia* from Britain and the replacement of *Tretaspis ceriodes* with members of the *T. seticornis* group (see Chapter 11).

Conclusions

The Onny River GCR site is internationally and historically important. It is the type locality for the Actonian and Onnian substages of the upper Caradoc, as well as for the Acton Scott and Onny formations and some 17 taxa of trilobites and brachiopods. The middle Actonian part of the section contains a bentonite that has been dated radiometrically at about 466 ± 15 Ma before present and is an important marker internationally in the dating of the Ordovician. The cliff at the top of the section shows a classic unconformity between the upper Caradoc and the upper Llandovery, giving evidence for the absence of the uppermost Caradoc, Ashgill and much of the lower part of the Silurian. The recognition of this unconformity between Murchison's Lower and Upper Silurian (overlooked by Murchison) was a factor leading to Lapworth's establishment of the Ordovician System.