Chapter 5 The Ludlow Series

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Introduction

The Ludlow Series takes its name from the historic market town in the Marches county of Shropshire. The various basal boundary and body stratotypes of the stratigraphical units of the Ludlow Series are located in its type area, the Ludlow Anticline. This district was identified by Murchison (1839; see also 1833, 1834 and 1835) as the reference area for his 'Ludlow rocks' (see (Figure 5.2)), which formed part of his 'Upper Grauwacke Series' of his Silurian System below the Old Red Sandstone. Holland *et al.* (1959, 1963) are acknowledged to have undertaken the seminal modern study of the type Ludlow rocks and, as a result, rekindled much academic study of British Silurian geology in general. This research was undoubtedly also spurred on through the informal network of friends of the Silurian, the 'Ludlow Research Group' (itself largely fostered by Holland, Lawson and Walmsley) and by the Silurian Subcommission of the International Commission on Stratigraphy, which, in the 1970s and 1980s (with Holland as Chairman 1976–1984), established the global standards for Silurian stratigraphy.

Holland *et al.* (1963) gave a detailed account of the history of study of the (type) Ludlow Series. Holland and Bassett (1989 and references therein) documented the work, deliberations and internationally agreed decisions of the Subcommission on Silurian Stratigraphy regarding the stratigraphical framework and internal divisions of the Ludlow and other series of the Silurian System.

There are two stages in the Ludlow Series: the Ludfordian, the base of which is defined at the GCR site called Sunnyhill, and the Gorstian. The base of the Gorstian is coincident with the base of the Ludlow Series and is defined at the GCR site at Pitch Coppice. Stratigraphically, the latter level approximates to the lower boundary of Murchison's (1834) 'Lower Ludlow rock', which he recognized as overlying the 'Wenlock and Dudley limestones'. In contrast, the exact position of the upper limit to the Ludlow Series (base of the overlying 'Downtonian' unit) and hence the position of the 'Silurian–Old Red Sandstone boundary' (White, 1950) has been a matter of greater contention for more than 150 years (see Holland *et al.,* 1963 for discussion; also Bassett *et al.,* 1982; Holland and Bassett, 1989; and Miller, 1995). Notwithstanding that local debate, historically and with reference to key sections in the Welsh Basin, the top of the Ludlow Series was generally accepted internationally to be the top of the Silurian System itself. However, at the time (1960) of the 'Bonn–Brussels Symposium' on Silurian and Devonian stratigraphy it was beginning to be more widely realized, on the basis of a labyrinth of trans-European correlation, that there was a top series 'missing' from the Silurian System. This fact was formally endorsed when the Silurian Subcommisson established the P■ídolí as the fourth and youngest series of the Silurian. By a happy twist of fate, correlation of the base of the P■ídolí, the basal boundary stratotype of which is located in the Czech Republic (see Holland and Bassett, 1989), lies at or close to the base of the Downton Group of the Welsh Basin. In other words, there is no measurable time (biozonal) gap represented in the basal Downton Group Ludlow Bone Bed Member of the Welsh Basin (see Bassett *et al.,* 1982; Siveter, 1989; Hansch and Siveter, 1994; Miller, 1995 and references therein); however, some authors (Miller *et al.,* 1997, Viira and Aldridge, 1998) suggest that the latest Ludlow may possibly be missing from the shelf sections of the Welsh Borderland.

Occurrence

The Ludlow Series occurs in Wales, the English Midlands, the Lake District and in southern Scotland (see Cocks *et al.,* 1992). Some of the Silurian that occurs subsurface below eastern England is also of Ludlow age (Woodcock and Pharaoh, 1993).

The Ludlow is mostly or entirely complete in many of the Silurian sequences in the Welsh Basin, such as those in the English Midlands, the Welsh Borderland and much of southern Wales. The Ludlow is absent in the Meritlips Inlier and the Haverfordwest area (in both, Upper Palaeozoic rocks rest on Wenlock strata) and does not crop out in western Wales (Cardigan Bay) and many parts of central Wales (Rhayader–Abby–Cwmhir). In northern Wales (Llangollen and

Denbigh–Conway areas) approximately the upper part of the Ludlow is absent. Much or all of the Ludlow is also missing from most of the Silurian sequences in the Lake District Basin, such as in the western Lake District (Coniston to Ashgill), the Howgill Fells, Cross Fell and at Horton-in-Ribblesdale; however, the central Lake District (Windermere area) has a full Ludlow succession.

The Ludlow Series is, at best, poorly represented in Scotland. In the Southern Uplands and nearby Girvan and Craighead areas the Ludlow is missing and post-Silurian Old Red Sandstone rests on deposits of Llandovery (Craighead) and Wenlock age. The various Midland Valley Silurian inliers (Lesmahagow, Hagshaw Hills, Carmichael, Pentland Hills), just to the north of the Southern Uplands Fault, have proven lower Silurian sequences but it is problematic whether or not younger (lower Ludlow) Silurian rocks are present. Equally, the existence of Ludlow in the Stonehaven Group, which crops out immediately south of the Highland Boundary Fault, is debatable: its fish and arthropod-bearing strata are, traditionally, supposed correlatives of the Downton Group (P■ídolí) of the Welsh Borderland, but palynological evidence suggests that at least part of the sequence is of late Wenlock to early Ludlow age (Marshall, 1991; Wellman, 1993).

Palaeoenvironmental setting

The Ludlow sediments of Wales and the English Midlands were deposited in the Welsh Basin, situated mostly to the west of the Midland Platform microcraton that today underlies much of central England (see Siveter *et* al., 1989; Bassett *et al.,* 1992; and Chapter 1 and (Figure 5.1), this volume, for palaeogeography of the Ludlow of Britain). Coeval strata in the Lake District accumulated in another, slightly more outboard sedimentary basin, which can be traced south-westwards into parts of Ireland. The early Palaeozoic Anglian Basin, detected subsurface below parts of southeast England, the East Midlands and East Anglia, was also a depositional basin during Ludlow times. The Ludlow was, overall, a time of shallowing seas in the Welsh arid Lake District basins, both of which gradually silted up during that period.

The Ludlow of these areas represents mostly marine deposition across a wide range of palaeoenvironmental conditions and bathymetries, from platform to basin margin and true basinal settings. For example, in the Welsh Basin the Ludlow Series includes shell-rich shelf elastics and coral-bearing carbonate banks, submarine channel and slope apron deposits, deeper-water turbidites and associated graptolitic hemipelagites, deltaic sediments and even terrestrial red beds. Many of the major lateral lithofacies changes reflect shelf to basin transitions, and are typically associated with substantial changes in biota and thickness of sediments. Evidence of igneous activity in the Ludlow of Britain is particularly scarce, being confined to tell-tale degraded volcanic ash bands (bentonites).

Overall, the late Ludlow to early P■ídolí interval witnessed the transition from marine to quasi-marine and ultimately to terrestrial conditions (Old Red Sandstone facies) in the Welsh and Lake District depositional basins. This change, charted in lithofacies and faunas and floras, marks the demise of the Iapetus Ocean. It is dramatically signalled in the occurrence, in the late Silurian of the Welsh Basin, of the earliest global stratigraphical record of land animals which, moreover, are associated with early vascular land plants. However, this important palaeoenvironmental shift was not coeval throughout Britain. For example, the transition occurred much earlier (variously, Wenlock to early Ludlow) in sequences in the Midland Valley of Scotland and even in parts of the Welsh Basin (south-western Wales).

Biostratigraphy

In its marine facies the Ludlow Series is highly fossiliferous in many areas of its occurrence in Britain, particularly in sediments that reflect relatively shallow-water settings. Virtually all forms of Silurian macro- and microbiota are represented.

In its type area the Ludlow Series is subdivided and correlated largely on the basis of a succession of brachiopod dominated, shelly-rich assemblages (Holland *et* al., 1963). Acritarchs, conodonts, chitinozoans, ostracods and, most notably, graptolites also facilitate various formal and informal, and low to high resolution biostratigraphical schemes for the Ludlow, a summary of which was given by Lawson and White (1989 and references therein). Locally, relatively minor groups such as spores and even fish are very useful in biostratigaphy. All of these groups offer, though to varying extents, value and potential for international correlation of the Ludlow; in particular, the full correlative worth of various

microfossil groups has yet to be realized. The base of the Ludlow in the type area lies at or close to the base of the *Neodiversograptus nilssoni* Biozone and the last true graptolites in the British stratigraphical sequence occur in the Ludfordian of the Welsh Basin, where they form the *Bohemograptus* proliferation Biozone.

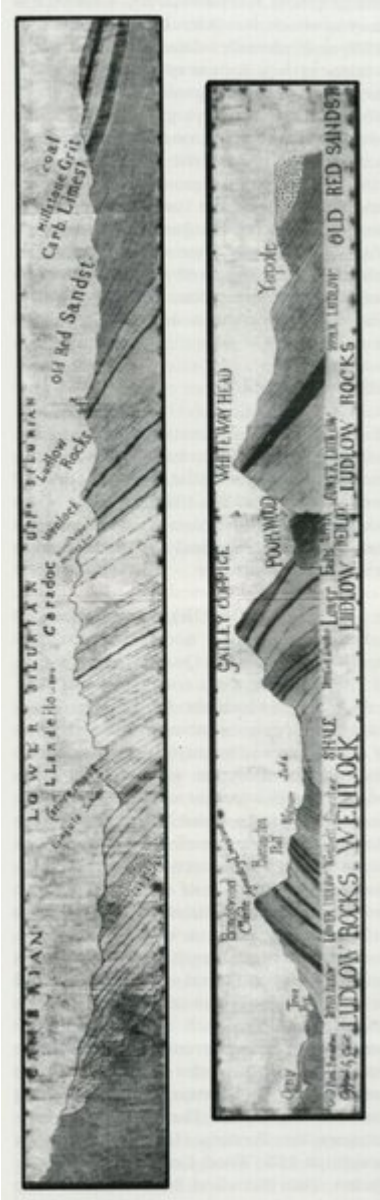
Site selection

The Geological Conservation Review network of sites for the Ludlow Series has been built up by the selection of individual sites by many workers over several decades. Sites (Figure 5.1) have been selected on the basis of several types of criteria: their international and/or national stratigraphical importance — for example, Pitch Coppice; their historical or palaeontological (e.g. Beacon Hill) or sedimentological and/or palaeoenvironmental and palaeogeographical significance (e.g. Hills Quarry); or, as in the case of The Whitcliffe, on a combination of such criteria. The sites have also been selected in order to embrace representative localities of the basins of deposition and major facies of the Ludlow of Britain. Inevitably the sites selected acknowledge — though arguably to a numerically disproportionate degree — the historical and nomenclatural importance proffered to localities in the Welsh Basin. Moreover, in part as a consequence of the nature of the type Ludlow sediments, the vast majority of selected Ludlow sites reflect relatively shallow water shelf settings.

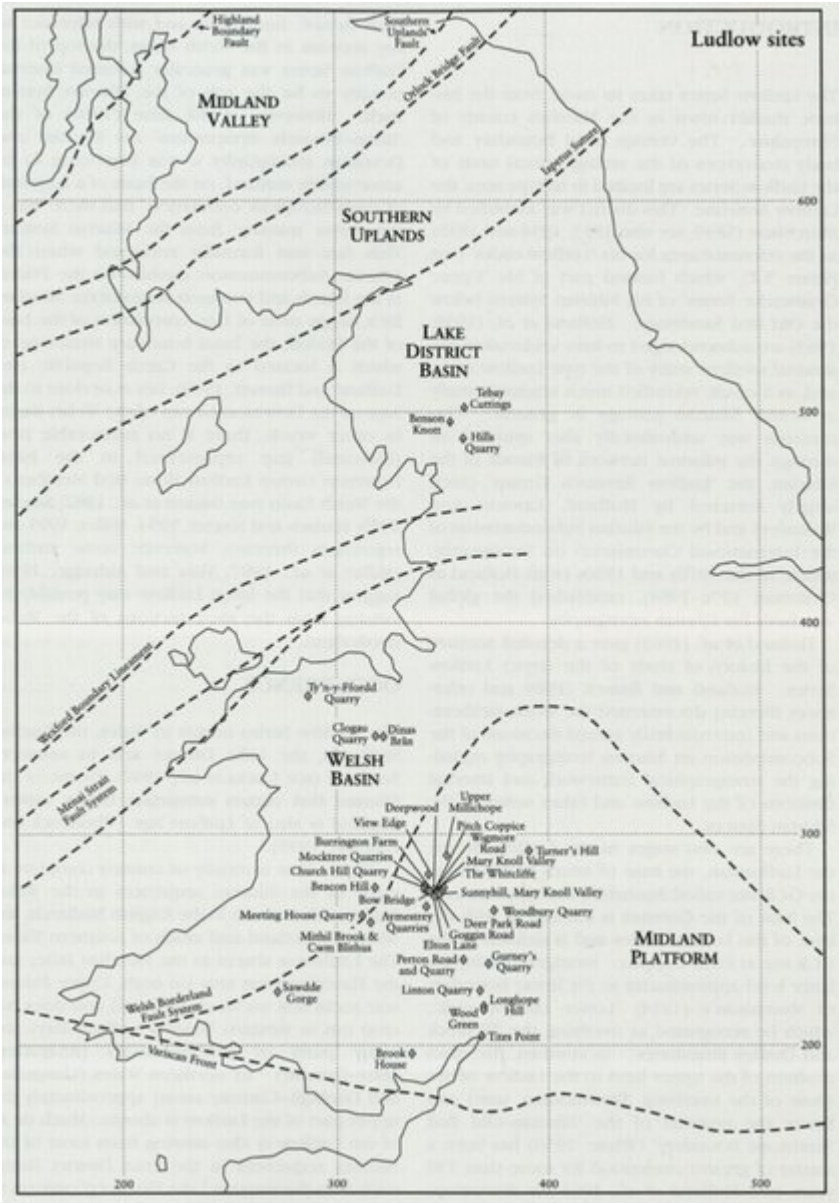
As a result of the way the site boundaries were originally drawn, several of the sites treated here as Ludlow sites also contain small thicknesses of P■ídolí strata. In such cases deposits of the younger series are described together with the Ludlow deposits in order to provide a complete coverage and to maintain scientific integrity for the sites in question. The sites that fall into this category are Turner's Hill, Woodbury Quarry, Longhope Hill, Wood Green, Perton Road and Quarry, Tites Point and Brook House; the basal P■ídolí at such sites includes the local equivalent of the famous Ludlow Bone Bed Member. The main scientific interest of the classic locality of Ludford Lane and Ludford Corner in Ludlow, Shropshire and of Brewin's Canal in central England, clearly focuses on P■ídolí deposits (rather than the also present Ludlow rocks) and, therefore, these sites are treated alongside the other sites of the fourth series.

In addition to those occurring at the GCR sites detailed in this chapter, Ludlow strata are also present within the geographical boundaries of certain Wenlock (Rumney River, River Irfon, Ty Mawr, Trewern Brook, Wren's Nest and Marloes) and P■ídolí (Capel Horeb Quarry, Lower Wallop Quarry, Albion Sands and Gateholm Island) sites. The Silurian section at Sawdde Gorge in southern Wales contains mostly Wenlock and Ludlow strata but also includes deposits of late Llandovery and basal P■ídolí age; in this particular case the locality is treated as two sites, one of which appears together with Wenlock sites and the other with the Ludlow sites. The Linton Quarry site, in the southern Welsh Borderland, exposes Wenlock through to basal P■ídolí and is described in both the Wenlock and Ludlow parts of this volume.

References



(Figure 5.2) Geological cross-sections drawn by Sir Roderick Murchison for a lecture given in 1852 to the Ludlow Natural History Society and now housed in Ludlow Museum. The upper section runs from east to west, from the Cambrian of Wales, through Murchison's 'Lower Silurian' (now Ordovician) of the Stiperstones area of Shropshire and beyond to Ludlow Castle, to the Old Red Sandstone and, ultimately, the Carboniferous of the Clee Hills to the north-east of Ludlow. The lower section runs north–south, from Bromfield just north of Ludlow, across the Ludlow Anticline and into Herefordshire.



(Figure 5.1) Distribution of the Geological Conservation Review sites for the Ludlow Series, set against the palaeogeographical elements of Silurian Britain.