'Transition Rocks and Grauwacké' — The Silurian and Cambrian Systems through 150 Years

by Michael Bassett

The terms Silurian and Cambrian were first published in a geological sense in 1835. This article reviews the historical background to the concept and early application of these stratigraphical divisions, and their international status after 150 years of development.

Introduction

Dublin, Ireland, was the setting for the fifth annual meeting of the British Association for the Advancement of Science in August 1835. On Friday, August 14th, the Reverend Professor Adam Sedgwick and Mr. Roderick Impey Murchison (Figs. 1 and 2) read a communication to the final session of the Geology and Geography Section entitled "On the Silurian and Cambrian Systems, exhibiting the order in which the older Sedimentary Strata succeed each other in England and Wales." Sedgwick read the details of the Cambrian rocks as established by his research, whilst Murchison discussed the basis for his Silurian stratigraphy; this presentation, by the seemingly unlikely combination of a Cambridge University professor/clergyman and an ex-soldier turned amateur geologist, was the first announcement at a formal scientific meeting of the terminology and relationships of the major stratigraphical units that were to become accepted universally as the lower and upper divisions of System rank within the Lower Palaeozoic rocks.

The official proceedings of the Dublin meeting were not published until 1836, but two separate reports appeared in 1835, the first being privately printed in Dublin in September (Hardy, 1835; see also Morrell and Thackray, 1981, p. 185), and the second distributed to a wider scientific audience in the December issue of *The London and Edinburgh Philosophical Magazine and Journal of Science* (Sedgwick and Murchison, 1835). Although the former account is relatively poorly known, it constitutes the first formally published record (on page 107) of the term Cambrian as presented by Sedgwick.

In the case of the Silurian System, however, Murchison had pre-empted the announcement at the Dublin meeting by publishing a paper in July 1835 entitled "On the Silurian System of Rocks" (Murchison, 1835). Throughout their scientific careers Murchison wrote up and promoted his results much more rapidly and in greater volume than Sedgwick, and although in 1835 the two were close friends and collaborators, this early publication by Murchison of "his System" was symptomatic of what was later to become the well-known, bitter controversy between the two men (e.g. see Thackray 1976).

Formative Studies

Sedgwick and Murchison first met in the winter of 1824-25, when the latter joined the Geological Society of London, being admitted to membership on January 7th, 1825. Sedgwick had been a member since 1818 and had rapidly become a leading figure in the Society, which by then was one of the main forums for the discussion of science and philosophy in Britain. As an authoritative teacher, Sedgwick soon exercised a profound influence on the younger man, who was both ambitious and determined to make his mark on the exciting geological developments of the early 19th Century. After initial instruction from Dean William Buckland of Oxford University, much of Murchison's detailed appreciation of field observation and interpretation was with Sedgwick, following the first of their geological excursions together in July 1827.

By the late 1820's, the succession of fossiliferous "Secondary" and "Tertiary" rocks of England (essentially Upper Palaeozoic and younger) was reasonably well established, based on the principles of mapping and faunal superposition demonstrated first by William Smith. To the north and west, however, lay large tracts of older, supposedly poorly fossiliferous "arenaceous and slaty rocks" whose succession and relationships remained not well understood. These older rocks were com-

Figure 1: Adam Sedgwick (1785-1873) aged 47.

Figure 2: Roderick Murchison (1792-1871) probably aged 55.

monly referred to as "Transition Rocks" or "Transition Series," implying that they had formed in a period transitional between the earliest chemical or molten phases of earth history and a time when more recognizably modern faunas and floras developed worldwide. The old German rock name "Grauwacké" (both with and without the Continental accent) was also used as an approximate synonym of these "Transition Rocks," since this general lithological type was a substantial component.

In his lecture syllabus at Cambridge as early as 1821, Sedgwick had certainly begun to consider some of the problems associated with the classification of the older stratified rocks (Clark and Hughes, 1890, pp. 288-290, 533); he had been aware of them in his native north-west England from boyhood and began to study them seriously there in 1822. It is not difficult to assume that he discussed these studies many

Figure 3: Ludlow and its Norman castle - part of Murchison's type Silurian region in the Welsh Borderland. Upper Ludlow rocks in the foreground pass up into Devonian Old Red Sandstone facies of the Cleve Hills in the distance.

times with Murchison, and by 1831 the two had determined to unravel the succession in Wales and the adjacent Welsh Borderland where the "grauwacké" and associated slaty rocks are particularly well exposed below the Old Red Sandstone.

At a time when the stimulating scientific climate encouraged the extension of geological principles into relatively unknown territory, it is equally important that the two men must have acted as catalysts to one another. The problems were considerable, but John Phillips, a leading contemporary geologist, was later to emphasize the qualities of the investigators for such work "Practically, before the summer of 1831 the whole field of the ancient rocks and fossils of Wales was unexplored; but then arose two men - *par nobile*, of all men fitted for the purpose - Sedgwick and Murchison - and simultaneously set to work to cultivate what had been left a desert" (Geikie, 1875, p. 179). Another contemporary, W.D. Conybeare, pointed out the practical necessity for these studies in commenting on the "... need of a term less barbarous than grauwacké-slate, which would conveniently denominate the characteristic rock of this era" (Geikie, 1875, p. 177).

In the late spring-early summer of 1831, Sedgwick was detained on various business in Cambridge, so that Murchison set out for his first field season in Wales without his colleague. He traversed rapidly through south-central Wales and the Welsh Borderland, and within just a few weeks of his first encounter with the "Transition Rocks" (early in June) he identified abundant fossils below the Old Red Sandstone that he was able to trace along strike to the Ludlow district (Fig. 3) and which gave him an immediate key to the struc-

ture and succession of the region. "For a first survey, I (i.e. Murchison) had got the upper grauwacke, so called, into my hands, for I had seen it in several situations far from each other all along the South Welsh frontier, and in Shropshire and Herefordshire, rising out conformably from beneath the lowest member of the old red sandstone. Moreover, I had ascertained that its different beds were characterized by peculiar fossils." (Geikie, 1875, pp. 183, 184).

Thus, in one remarkable first summer, Murchison established the lithological and faunal control for most of his later work. Such was the scope of his coverage, that in September 1831, at the inaugural meeting of the British Association for the Advancement of Science held in York, he demonstrated coloured maps of the "Transition Rocks" that he considered to be "a good broad announcement of a new step in British geology" (Geikie, 1875, p. 184).

Figure 4: The Rhinog Mountains in the Harlech Dome of north-west Wales - the heart of Sedgwick's Cambrian System; the rocks are mostly coarse arenites of early Cambrian age.

Meanwhile, Sedgwick finally left Cambridge at the beginning of August and proceeded to North Wales, where he arrived on August 5th, 1831. For a few weeks he was accompanied and helped by the young Charles Darwin, to whom he taught the rudiments of geological mapping in a series of traverses (Clark and Hughes, 1890, p. 380). In the Caernarvon district of north-west Wales, where Sedgwick concentrated his early field work, he considered that the "structure is on the whole regular, and the strike longitudinal," but it was certainly more complex than that encountered by Murchison, and the area was only sparsely fossiliferous. Although Sedgwick reported good progress in his first summer, he felt obliged to stay in North Wales rather than attend the British Association meeting at York, but it was eventually necessary for him to leave the field in October before completing his planned programme (Clark and Hughes, 1890, pp. 377-382).

It was twelve months before Sedgwick gave the first formal report of his findings (following his second season's field work) at the second meeting of the British Association in Oxford (Sedgwick, 1833). Like Murchison, Sedgwick demonstrated the "mineralogical structure" of his rugged area (Figs. 4 and 5) with the aid of maps and sections, and it is clear that he too had solved many of the essential problems of structure and succession in his early investigations.

Surprisingly, the two colleagues made no attempt to marry their findings at this first formative stage, and from then on they continued their field studies independently; the differences in faunas, lithological succession and structural complexity were presumably too much even for them to

relate initially, and within a few years they were each to become more deeply involved in their own detailed problems. The 1835 announcement at Dublin was to be their only joint contribution on Cambrian-Silurian geology.

Refinements and Developments

From 1831 onwards Murchison published a regular series of reports and papers in which the nature, relationships and detailed subdivision of the "upper Grauwacke Series" were set out. In 1833 he first used the terms "Ludlow Rock" and "Wenlock Limestone," and in 1834 introduced the "Horderley and May Hill Rocks" and "Builth and Llandeilo Flags." These were the four great divisions of his Silurian System presented in 1835, the first two grouped together as "Upper Silurian," with the others (now renamed as the "Caradoc" and "Llandeilo" formations) combined in the "Lower Silurian."

Figure 5: Arennig Fawr in North Wales - part of Sedgwick's original Cambrian System (see also Fig. 9). The rocks are mostly tuffs and agglomerates now classified within the lower part of the Ordovician System.

Almost from the outset of his studies, the extent of Murchison's ambition and purpose were abundantly clear. In a letter of December 12th, 1833, to Henry Thomas De la Beche, who was later to become the first Director of the Geological Survey, he emphasized that "It is not merely the Upper Grauwacke the relations of which I am desirous of illustrating, but the whole mass of strata from the Mountain Limestone downwards which part of the Series has in my conscience no development in any part of the world equal to that seen in my regions (National Museum of Wales archive)." Murchison devoted almost all of his energy to this work, each summer extending the limits of his mapping, and recording his field observations with detailed notes and sketches; even just after the Dublin meeting he pushed his boundaries into new areas (Figs. 6 and 7), and by 1837 his field work was essentially complete. Through this period the scope of his Silurian System became well defined (Fig. 8).

By late 1835, Murchison had obviously formulated plans to incorporate all his results in a single large book (Geikie, 1875, pp. 231-232), which appeared in January 1839. This volume, *The Silurian System* (Murchison, 1839), is a magnificent compilation and is the keystone on which all subsequent studies of Silurian rocks have been built (Thackray, 1978b). Most importantly, it contained abundant descriptions and beautiful illustrations of faunas, which immediately provided the basis for recognition and correlation of Silurian strata in other regions.

Murchison himself played no small part in tracing his System more widely. After his monograph appeared, he was invited to Russia in 1840, and returned again in 1841 and 1844. These visits resulted in the joint authorship of an equally impressive monograph (in 1845) on the *Geology of Russia in Europe* (Thackray, 1978a). He also visited Scandinavia in 1844 and published a series of papers on the Silurian geology of the Oslo Region in Norway and of different areas of southern Sweden. At home he "popularized" and advertised his work by producing it as a simplified, inexpensive version of his book entitled *Siluria*, published in four editions between 1854 and 1872 (Thackray, 1981).

Figure 6: A page from Murchison's 1835 field note book depicting the geology of Marloes Sands in south-west Wales (notebook N74, Geological Society of London archive).

Figure 7: "The Three Chimneys" - almost vertical sandstone beds of early Silurian (Llandovery) age at Marloes Sands in south-west Wales; these beds are shown clearly in the centre of Murchison's sketch of the section (Fig. 6).

Silurian System

On the right hand the old Red Sandstone appears in the Ludlow Rocks.

a. Old Red

b. Aymestry Limestone

c. Lower Ludlow

d. Wenlock Limestone

e. Wenlock Shale

f. Caradoc Sandstones

g. Caradoc Sandstones

h. Caradoc Sandstones

i. Caradoc Sandstones

j. Caradoc Sandstones

k. Caradoc Sandstones

l. Caradoc Sandstones

Llandeilo Formation. Caradoc Formation. Wenlock Formation. Ludlow Formation.

Figure 8: An early sketch (above) by Murchison, probably about 1835-36, depicting the subdivision and relationships of units in his Silurian System (Geological Society of London archive LDGSL859); this sketch was clearly the basis for the published version (below) that appeared in his 1839 book (p. 196).

Meanwhile, Sedgwick was certainly not idle and continued to attack the older "Grauwacke" in North Wales, after 1831. His correspondence indicates that he rapidly refined his views on the structure of his region (Fig. 9), but little of the detailed succession was published. Unlike Murchison, Sedgwick was obliged to attend to his academic and ecclesiastical duties, and he was also still very occupied with publishing the results of his work in north-west England. At the 1835 Dublin meeting, therefore, the Cambrian System was divided only generally into Lower, Middle and Upper groups.

It was not until the 1850's that Sedgwick eventually began to expand his views of Cambrian geology and classification (e.g. Sedgwick, 1852). The basis for wider correlation was not published until 1855, when Sedgwick's faunas were described monographically by Frederick M'Coy (Sedgwick and M'Coy, 1855), and by this time, of course, Murchison's Silurian System was widely recognized and accepted internationally. The problems of the clear overlap between the original Cambrian and Silurian Systems were not to be resolved until Charles Lapworth erected the Ordovician System in 1879 (Bassett, 1979).

An Internationally Agreed Silurian System

150 years after the birth of the System, Silurian rocks are now known from every continent except Antarctica. Almost exactly 125 years after the announcement at the Dublin meeting, the term "Silurian" itself was finally approved internationally, when the 21st Session of the International Geological Congress in Copenhagen ruled (23 August 1960) that it should be used for the upper System of the Lower Palaeozoic, taking precedence of the term "Gothlandian," which had been employed widely in continental Europe following its introduction (also by Murchison, in 1845) for correlative strata in Scandinavia.

The subsequent 25 years have witnessed substantial increases in international cooperation. One session of the Copenhagen Congress focussed on Silurian (and Ordovician) stratigraphy and correlations. In the same year in the U.S.A., W.B.N. Berry and A.J. Boucot began to compile data for the production of Silurian correlation charts for all known areas of outcrop in the world; the first of these charts was published in 1970 by the Geological Society of America, and the series is still continuing. Without doubt, the scope and scale of these charts was a major factor in encouraging a new global look at the Silurian System. In September 1971, a first international symposium devoted to Silurian geology was held in Brest, France (although again in conjunction with Ordovician specialists).

Since 1974, the coordination of international effort has become the increasing responsibility of the International Commission on Stratigraphy (ICS) within the International Union of Geological Sciences (IUGS). In that year a Subcommittee on Silurian Stratigraphy formed in Birmingham, England and began to

tackle the problem of defining major, globally applicable subdivisions of Series and Stage rank within the Silurian System, and the boundaries between them. By 1984 that work was completed and was presented to ICS in August at the International Congress in Moscow. Following ratification by IUGS, the results were published formally last June (Bassett, 1985; Holland, 1985). It is appropriate that almost exactly 150 years after Murchison first used the term Silurian, his "Transition Rocks" should become the first stratigraphical System for which international agreement has been reached on both the upper and lower boundary levels, and on a full set of Series and Stage divisions between those limits.

The chronostratigraphical framework for future studies is thus now firmly established. In 1986 a book will be published that will describe in further detail the global standards and the basis for this correlation, and in 1989 the Silurian Subcommittee will sponsor a second international symposium (in Keele, England) as a means of reviewing progress over the

Figure 9: Sedgwick's early view of the structure across part of North Wales as depicted in sections drawn in a letter to Murchison dated July 23, 1832; the lower section (with Arennig Fawr at left - see Fig. 5) overlaps with the right hand edge of the upper section (from Clark and Hughes, 1890).

next few years. The occasion should prove to be a fitting celebration of the 150 years since the publication of Murchison's classic volume on the *Silurian System*.

Continuing International Initiatives on the Cambrian System

Cambrian rocks crop out on every continent. Just as the System name was launched in 1835 together with the Silurian, so the two were again linked in international recognition when the 23 August meeting in Copenhagen of the 1960 International Geological Congress confirmed the term "Cambrian" for the lowest System of the Lower Palaeozoic.

Modern studies of Cambrian geology can be regarded as beginning with a symposium on "The Cambrian System, its Palaeogeography and the Problem of its Base" held at the 20th Session of the International Geological Congress in Mexico City in 1956; sponsorship was by ICS and the International Palaeontological Union. At the 1960 Congress there was a sectional meeting on Cambrian (and late Precambrian) stratigraphy, and the idea was first mooted of forming a Subcommittee on Cambrian Stratigraphy within ICS. Further steps were taken at an informal meeting connected with the next International Congress in New Delhi in 1964, and later that year the Cambrian Subcommittee was "born."

As with the Silurian, the coordination of studies directed towards the establishment of global standards for the Cambrian has now become the major responsibility of the Subcommittee. Problems of definition of the base and top of the Cambrian System, and of globally applicable internal subdivisions, continue to be major topics of debate within the Subcommittee. In 1981 a second international symposium on the Cambrian was held in Golden, Colorado, U.S.A., under the auspices of the U.S. Geological Survey as part of the Subcommittee programme.

Although by 1985 there has been no international agreement on standard Cambrian chronostratigraphical subdivisions and boundaries, intensive studies are under way throughout the world to resolve correlations across different facies and biogeographical realms. Beginning in 1983, the Subcommittee instigated a series of correlation charts (published by IUGS) aimed at covering all known outcrop areas, and their production holds great promise for international agreement on standards in the near future. As the bicentenary year of Sedgwick's birth, and 150 years after the introduction of his System, he would surely be well pleased with the continued expansion of Cambrian investigations made through 1985.

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