g-327E

Cambria versus Siluria: A Dispute over the Emerging Geology of Wales

Colin Humphrey

GEOLOGICAL HISTORY AND THE ORIGINS OF A DISPUTE

One of the great scientific disputes of the mid-nineteenth century concerned the partitioning of a large part of Wales into younger and older rocks. It started in the 1830s with the work of two very different men, and the most important British geologists of the time. They began as close friends but eventually were bitterly estranged. Their failure to collaborate resulted in a big overlap between their scientific claims. Neither would concede. They argued over terminology, and priority - the right to name the hitherto un-described rocks. This right was a treasured intellectual property, more so then than it is now. There was more interest in geology then because the age of steam had begun, the industrial revolution was well under way, and the realisation was dawning that geology pointed the way to coal.[1] Over a period of nearly forty years their differences first simmered and finally erupted; many others took sides, and even after the protagonists died the dispute rumbled on.

Voluminous biographies of both men are well over one hundred years old. Their mutual correspondence amounts to nearly six hundred letters, and there are many relevant old technical papers about the subject. A splendid book by James Secord, *Controversy in Victorian Geology*, is a detailed account, widely and meticulously sourced.[2] Though twenty five years old, nobody can now work on this subject without Secord's book to hand. He describes the matter as one of the great set pieces of the golden age of science, and examines the two men and their work at length and with perception. But this is a complex subject and it is still possible to add further opinion about the origin and development of an antagonism which at times transfixed the geological community, and to give further consideration to some of the geology, especially in and around Montgomeryshire.

William Boyd Dawkins, later Sir William, a famous son of Montgomeryshire, wrote about the controversy in 1875 after the deaths of the protagonists. Born in Buttington, near Welshpool, he became the first professor of geology at Manchester, and at one time completely rearranged the Powysland Museum, well before its collection of local geological specimens was removed to the National Museum of Wales. He described the controversy as a story about a 'man of genius who was . . . outstripped in the race by the practical man of method'. The Revd Professor Adam Sedgwick was the man of genius, and R.I. Murchison, later Sir Roderick, was nothing if not the practical man of method.[3] During their lifetimes Murchison eclipsed Sedgwick though, as Dawkins wrote, 'Murchison was not the greatest, but the most successful'.[4] After their deaths Sedgwick's standing gradually recovered and today he is generally regarded as having been unfairly treated by Murchison. The present review comes to a different conclusion: the early mistakes were due more to Sedgwick's preconceptions, uncooperative attitude, and lack of application and method, than they were to Murchison's failings, but both men's intransigence, and Sedgwick's resentment, ensured that a lifelong dispute ensued.

Regional geology and what the old geologists knew

More than 500 million years ago, in the Cambrian period, Mid Wales was an ancient sea, known rather unimaginatively by geologists as the Welsh Basin, a sea which probably extended north into another basin around the Lake District. The Welsh Basin (Figure 1) lay near the edge of a supercontinent called Gondwana, situated near to where Australia is now.

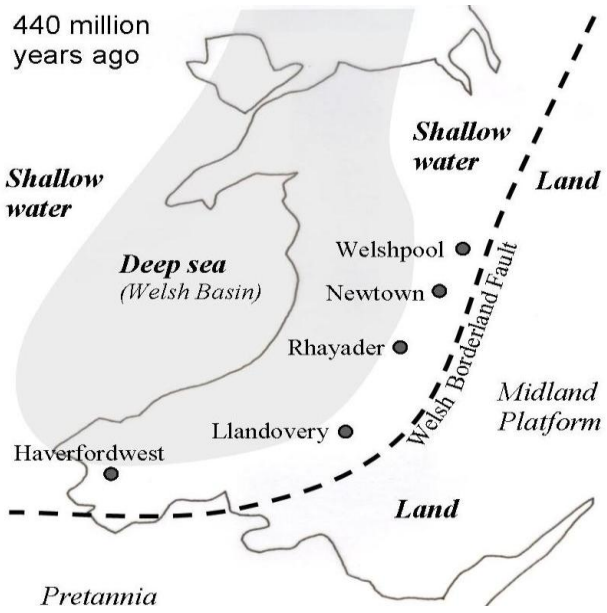

Figure 1 – The Welsh Basin 440 million years ago.

Sediment flowed to the sea from a mountainous English Midlands, called the Midland Platform, and from a *southern* land mass across the Bristol Channel called Pretannia. Around 490 million years ago the micro-continent of Avalonia detached from the north-west edge of the Gondwanan supercontinent and began to journey north. The Iapetus Ocean lay between Avalonia on one side and Laurentia on the other. As the Iapetus Ocean closed, Avalonia moved towards Laurentia, and after nearly one hundred million years they collided, uniting England & Wales with Scotland along the Solway Firth. Throughout all this time the subsiding Welsh Basin received sediment

from the surrounding mountains and coastal alluvial plains. At the end of the Silurian period sedimentation ceased and, in the early Devonian, folding squeezed Wales, uplifted the Basin, and formed the Cambrian Mountains. The long life of the Welsh Basin was over and the elevated land began to erode.

The nature of the Welsh Basin was first explained by Owen Thomas Jones, born in 1878 in Cardiganshire, and known irreverently as 'OT' by generations of students at Aberystwyth, Manchester and finally Cambridge, where he succeeded to Sedgwick's old chair. He was described in 1958 as a world figure in science and the greatest geologist Wales ever produced.[5] His meticulous work on fossils, especially graptolites, tiny floating colonial creatures like a piece of fretsaw blade, in the rocks around Ponterwyd on the flanks of Plynlimon, won him recognition, a DSc and an invitation to become, in 1910, the first professor of geology at Aberystwyth. By 1912 he had explained the overall structure of the Welsh Basin and he developed this in detail in a famous 1938 paper.[6] On the award of the Wollaston medal in 1945 he was hailed as field marshal of the Silurian rocks, an allusion to Murchison's earlier 'crowning' as king of Siluria. But even 'OT' did not know then about the forces moving the continental plates; this understanding is more recent still.

The eastern and southern edge of the Welsh Basin ran south through Montgomeryshire more or less along the Welsh border, then curving past Builth to Llandovery and round to Haverfordwest. This is the Welsh Borderland Fault System, a band of deep cracks in the Earth's crust even older than the geological story told above. This boundary buffered the effects of the continental collision by sliding rather than folding, so that folding only occurred in the muddy Basin sediments. A shallow shelf formed around the Basin, on which there was little folding; and beyond the Basin there was no folding at all. Sediments deposited in the deeper water of the Basin and then folded by the pressure of continental collision were muddy. Microscopic, soft, platy clay particles in the mud recrystallised and realigned under pressure and the heat of deep burial to create the slaty texture called cleavage, which dominates the rocks to the west. The rocks of the shelf were less muddy, less deeply buried, and thus less heated, and less folded, exhibiting little or no cleavage, or slatiness. Sedgwick in the late 1820s was the first to recognise cleavage, and distinguish it from bedding and jointing. His paper of 1835 dealt with the phenomenon and included examples in Wales,[7] but unfortunately his ideas about the cause were very wide of the mark.

Again and again our two geologists, knowing nothing of the Welsh Basin, were deceived into thinking that the metamorphosed slaty rocks were older, and Sedgwick especially had to deal with the difficulty that sediments deposited in the deeper Basin, during a hundred million years, all looked very similar. Fossils have always been an important way to distinguish rocks from one another; they abound in rocks formed as the shallows of the Welsh Basin shelf and made life easier for Murchison's studies, but are almost absent from the deeps in Sedgwick's territories to the west. When global sea-level rises and falls it has little effect on the deeper sea, but when the marine shelf becomes land the shallow water fauna perishes and new species emerge later. Rocks of the same age from deeper water look very different to those of the shelf and the shallows, but the fact that the deeper sediments show a slaty cleavage and have hardly any fossils does not necessarily make them older. Eastern Montgomeryshire was much affected by sea-level changes 400 to 500 million years ago, as we shall see.

One more vital diagnostic tool we have today in the old Welsh Basin district is the ability to read directly from the rocks the way the sediments flowed into the Basin. Earthquake-disturbed multi-million tonne packages of sediment and water, called turbidites, plunged down submarine canyons and rolled many miles out into the Basin, with the muddiest sediments carrying furthest. The directions of these movements and how often they occurred is now well known, but nearly all this understanding of geological processes has come within the last fifty years. Today we can only marvel at the way the old geologists learned as much as they did.

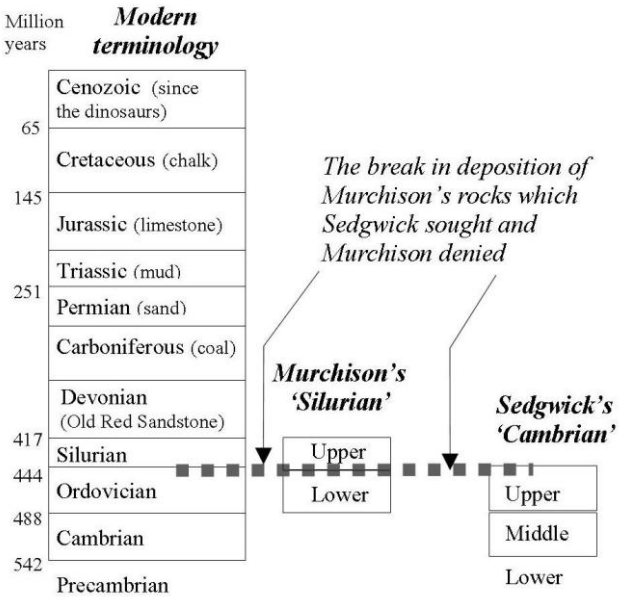

Figure 2 – The division of the rocks, then and now.

In this story our geologists rather arbitrarily divided the older rocks into two (Figure 2). Above lay a Lower and Upper Silurian; below was an Upper and Lower Cambrian. Mistakes and failure to collaborate meant the Upper Cambrian in North Wales turned out to be the same age as the Lower Silurian in Mid and South Wales. So Murchison then claimed the Upper Cambrian as Silurian, and Sedgwick claimed the Lower Silurian as Cambrian. Sedgwick also insisted there was a break between Lower and Upper Silurian and the term Silurian could not be used below the break. Murchison insisted there was no break.

Eventually Sedgwick proved his case, but by this time Murchison had called everything Silurian, including

Sedgwick's Cambrian. A missing interval in the geological succession, where rock has been removed by erosion, is called an unconformity. It signals that an important change in conditions took place at the time. There is an unconformity between what Murchison called his Lower and Upper Silurian. In retrospect this story is about the search for it. After both men were dead another great geologist proved that the disputed overlap did not belong to either Silurian or Cambrian. It was different to both, and he called it Ordovician. But in the years before that happened a storm raged.

When Sedgwick and Murchison began their work in Wales almost nothing was known about these rocks except that they were older than most of the rocks in England. The Old Red Sandstone of the Brecon Beacons, formed in the Devonian period, and the coal measures and associated grits and limestones of South and North-East Wales, formed more recently in the Carboniferous period, had already been mapped, and formed an eastern boundary for the older rocks. To the west, over most of Wales, lay a tract of mostly unfossiliferous and often slaty rocks described at greywacke. William Smith's famous 1815 map, and Greenough's more detailed 1820 map, contained almost no detail of this greywacke, but it was thought to be many miles deep. The understanding was that these rocks inclined steeply to face roughly east, and so became progressively older to the west.[8]

In the early nineteenth century most geologists were still diluvianists, believing that the upper rocks had been laid down in the biblical deluge. Sedgwick, one of the leading teachers of his day, did not fully abandon this idea until the 1820s.[9] Fossils were common in younger rocks but during his work in the mid 1820s he thought the older rocks 'below the region of animal life' and did not even look for fossils.[10] When the two men entered Wales there was no concept of the movement and collision of continents, and no understanding of the frequent rise and fall of sea-level. They thought simply that volcanism uplifted rocks, and thermal relaxation allowed subsidence.[11]

There was an established view that the Creator's plan for faunal development would show as progressive change, though Murchison was also aware of the phenomenon of mass extinction: he observed correctly in 1838 that 'as the globe passed from one condition to another, whole races of animals perished and were succeeded by others'.[12] Sedgwick however persisted with the view that 'in the great section of North Wales there is no positive zoological distinction in the successive descending groups, however vast in thickness or distinct in mineral structure. It is not by the addition of new species, but by the gradual disappearance of species, that the successive groups are zoologically characterised'.[13] This mistaken adherence to a progressive theory of speciation, as opposed to recognition of intermittent mass extinction was, for years, a limitation on Sedgwick's ability to recognise breaks in the older geological succession.

Unlike Murchison, Sedgwick was untroubled by the extent to which the fossils of his Upper Cambrian were identical to those of Murchison's Lower Silurian. At first neither Sedgwick nor Murchison thought there might be unconformities in the rock succession. Remarks in Sedgwick's 1841 paper confirm his early view: 'there is a continuous and apparently uninterrupted sequence of deposits from the lower beds of the new red sandstone formation [Permian] to the lowest known strata of England' [which of course included his Lake District rocks, subsequently correlated with the Welsh rocks]. Specifically in Wales he asserted that 'from the . . . new red sandstone down to the Llandeilo Flagstone [bottom of Murchison's Lower Silurian] there is one continuous unbroken sequence'. Sedgwick's misguided certainty on this matter must have encouraged Murchison during the 1830s, as Sedgwick was then recognised as the leading authority on the oldest rocks.

Sedgwick and Murchison, and a friendship

Adam Sedgwick was born in 1885 in the Yorkshire Dales; he went to Trinity College, Cambridge and it was his home for nearly seventy years. He began as a mathematician, becoming senior tutor in mathematics and winning a fellowship in 1810. Under the college statutes all but two of the fellows had to be in holy orders within seven years. It was characteristic of the man that he left it until the last moment before taking up the priesthood.[14] In 1818 he was elected Woodwardian professor of geology. At the age of 32, after what he regarded as a life of dull uniformity at Cambridge, at last he had a purpose. He said later 'hitherto I had never turned a stone, henceforth I never left a stone unturned', though his claim to have had no previous interest in geology was not correct.[15] A condition of the Woodwardian chair was that the incumbent remained unmarried 'in order to avoid the distractions of matrimony'.[16] For much of Sedgwick's career his income was a restriction on his activities, for which reason in 1834 he became a canon at Norwich cathedral, a commitment which took him to Norwich, and almost completely away from geology, for two months each year and sometimes for longer.[17]

Sedgwick was a hypochondriac[18] but he did also suffer prolonged bouts of ill health which frequently deprived him of working time. One of the attractions of the Woodwardian chair for Sedgwick was its opportunity for months spent in the fresh air and away from other commitments. He was a spellbinding speaker, capable of 'eloquence of astonishing beauty and grandeur', with men from William Smith to Sir John Herschel testifying that his words were the most impressive and remarkable they had ever heard, all doubtless an important factor in his reputation for brilliance. Murchison's biographer describes Sedgwick's words 'now embalmed in printed publications' as bearing to those who heard them 'as much resemblance as dried leaves do to the plant which once tossed its blossoms in the mountain wind'.[19] He was much involved in the politics of the University, where he eventually became vice master of Trinity College, and in Whig politics, as well as many reforming causes. This was a man thoughtful and kind, but

also 'highly explosive'.[20] Unquestionably brilliant, recognised as one of the important thinkers at the interface of science, religion and philosophy, he was, as Dawkins suggested, touched by genius. There is much more to the man than can be discussed here, not least the high regard in which he was held by Albert, Prince Consort, and Queen Victoria, and his role in establishing what became one of the great geological museums, the Sedgwick Museum in Cambridge.

Murchison was a very different man. Eight years younger than Sedgwick, he was born in 1792 of Scottish descent, schooled in Durham and then the military school at Great Marlow. At fifteen he became an army ensign and at eighteen aide-de-camp to his uncle, General Mackenzie. He saw action in the Peninsular War in Portugal but his military career ended as a captain on half pay, with the peace which followed the battle of Waterloo in 1815. That year he married the accomplished daughter of a general, retired from the army and spent two years travelling in Europe, before returning to a life of fox hunting in the north of England. Such a life was eventually beyond his means and he moved to London in 1824, where his wife encouraged him to attend lectures at the Royal Institution, and he quickly found an interest at the Geological Society.[21]

Like Sedgwick, and at a similar age, Murchison had discovered his vocation in his early thirties. Unlike Sedgwick he had the time and the money to indulge his geological interests without restraint. He rose to international geological fame, was knighted in 1846 and became a baronet in 1866, twenty five years after writing to the prime minister soliciting a baronetcy![22] In 1855 he became Director General of the Geological Survey, in which post he remained until his death in 1871, a year and a half before the death of Sedgwick. Not only was Murchison famed as a geologist, he was powerfully influential in the Royal Geographical Society, from its inception in 1830 until just before his death, and he was its president for sixteen years. Fourteen places around the world carry the name Murchison. He came to exercise enormous influence in geological circles, but in later life he became a haughty man, determined not to recognise his mistakes and wrongly to insist on the unbroken integrity of his Silurian system.

The two men met at the Geological Society in 1825 or 1826.[23] Murchison took to Sedgwick at once,[24] and soon was joshed by his friends for idolising Sedgwick[25], but a lot of people did. They first geologised together in the summer of 1827 when, on Murchison's initiative, they spent more than two months in Scotland.[26] Their joint papers on the subject were favourably received by the Geological Society the following year but Sedgwick was the cause of delay to the second, a matter of concealed annoyance to Murchison.[27] It was during this trip that Sedgwick first noticed cleavage in rocks, the phenomenon which so misled the two geologists in Wales several years later.[28] In 1829 they spent 3½ months together on the continent.[29] As an early example of Sedgwick's perpetual unpreparedness, all the arrangements had to be made by Murchison.[30] Two papers on the Salzburg and Bavarian Alps were read to the Geological Society in November and December 1829, with Sedgwick playing his part, but the preparation of a paper for publication necessitated Murchison's return to the Alps in the summer of 1830, with Sedgwick unable to accompany him. Murchison prepared a short paper on his return but the wider paper fell to Sedgwick and so was not published for some years, until 1835.[31]

Thus, even before work in Wales began, Sedgwick's dilatory nature, and the frustration this caused Murchison were clear, and Sedgwick's explosive temperament was revealed. In 1830 he wrote to Murchison about the latter's carelessness: speaking of 'serious blunders' he said 'you cannot conceive how much these papers have enraged me this morning'.[32] Nevertheless, during their friendship they exchanged hundreds of letters, practically all of which have survived. Murchison's biographer wrote that Murchison regarded Sedgwick as his greatest friend and mentor during those early years. This respect, admiration and affection never left Murchison, even as Sedgwick's bitterness grew.

Conflicting ambitions

Sedgwick's intention to write a great book is well known, but the possible conflict with Murchison in this matter deserves further attention. Sedgwick first became interested in writing a book on the older rocks as early as 1824/5 but it was not until 1828 that he took action[33], by offering to undertake the preparation of Volume 2 of *Outlines of the Geology of England and Wales.*[34] The first volume, dealing with the younger rocks, had been published by Conybeare and Phillips in 1822. Phillips having died and Conybeare being busy, the second volume, dealing with the older rocks was delayed. Sedgwick's offer was taken up with enthusiasm. In Conybeare's reply[35] he suggested that Sedgwick, who had already been working in the English north-west, took on 'a large half of the work', and especially the work in South Wales[36]. Work in Scotland and the Alps with Murchison distracted Sedgwick for three years. Bad weather precluded a start in 1830 but he entered Wales in 1831.[37]

Although Sedgwick expected North Wales to be the key to understanding the principality, he must have expected in due course to tackle the older rocks of the southern part of Wales, as agreed. Murchison was well aware of Sedgwick's intentions, as their correspondence shows,[38,39] and Murchison also knew Conybeare.[40] We may imagine what Sedgwick thought when he first learned of Murchison's claim to have discovered the base of the older rocks in Mid Wales[41] and of his intention to write a book. Some tart words came later from Sedgwick on this subject. It grieved him never to have produced his great book, but it was always to be so: Charles Lyell wrote in his diary in 1834 'He has not the application necessary to make his splendid abilities tell in a work. Besides, every one leads him astray. A man should have some severity of character, and be able to refuse invitations'.[42] Poor Sedgwick did have distractions, but he was also quite unable to devote himself single-mindedly to the task of writing a book and, a fault he recognised in himself, he found sedentary work disagreeable.[43] His friends came to know him well: twenty

years later when he offered to 'dash off' a memoir on Scotland they said 'he will never write it but we shall perchance have it well spoken'.[44]

Throughout their work together Murchison depended on Sedgwick's geological experience, but repeatedly Sedgwick was the cause of delay. He was unable to translate his remarkable verbal fluency into detailed written papers. Often he felt that more work was needed before publication could be justified. This caution contrasted strongly with Murchison's impetuosity and relentless determination to press matters to a speedy conclusion, often in order to secure scientific priority. Sedgwick's personal problems and talent are no better illustrated than by his 1831 sermon on the anniversary of the commemoration of the benefactors of Trinity College. Important though it was, he did not begin to write it until four days before he spoke it; and then its eloquence was such that a petition was prepared calling for its publication. Yet he felt compelled to spend much more time on the justification of his words and so *The Discourse* took a year to appear in print.

His illnesses certainly laid him low and enforced bouts of inactivity, sometimes for weeks or even months at a time. He believed himself 'constitutionally incapable of much sedentary exertion', and regarded this characteristic as an 'organic peculiarity'. In a letter to a clerical friend he wrote 'Some of my friends expect more from me than I can do. Because on some occasions I speak fluently, it by no means follows that I write readily.[45] Experience tells me the very contrary. I write with pain to myself in every sense of the word, for a very few hours writing will bring on a fit of indigestion and a swimming in the head. I was, ever since my childhood, incapable of doing more than one thing at a time to any purpose'.[46] This shortcoming, together with a self-confessed tendency to procrastinate,[47] and a singular failure to devote enough time to his Welsh field studies, plagued him for decades. Meanwhile Murchison, determined to distinguish himself, worked single-mindedly towards his objectives.

1831-33: Work starts in Wales

Both Murchison and Sedgwick entered Wales for the first time in 1831, one in the south, the other in the north. Murchison was determined to examine the greywacke and began work in June. He invited Sedgwick to join him but the latter was out of sorts and behind with the preparation of their joint paper on the Alps,[48] a problem which he partly attributed to Murchison.[49] Sedgwick evidently had no intention of embarking on a joint venture in Wales. He declined again in 1832, and was otherwise committed in 1833. Finally he was persuaded to make a joint visit in 1834, and then, as we shall see, only briefly. They had already collaborated on studies of Scotland and the Alps and were soon to collaborate on work in the West Country. Had they begun their Welsh surveying together, their great dispute would never have arisen, a point made by Murchison some years later.

Murchison found the downward passage from the Old Red Sandstone into the underlying greywacke on the banks of the Wye near Trericket Mill, south of Erwood. He later wrote the often quoted piece: 'Travelling from Brecon to Builth by the Herefordshire road, the gorge in which the Wye flows first developed what I had not till then seen. Low terrace-shaped ridges of grey rock dipping slightly to the south-east appeared on the opposite bank of the Wye, and seemed to rise out quite conformably from beneath the Old Red [Sandstone] of Herefordshire. Boating across the river at Cavansham Ferry,[50] I rushed up to these ridges, and to my inexpressible joy found them replete with Transition [older rock] fossils, afterwards identified with those found at Ludlow. Here then was a key, and if I could only follow this out on the strike of the beds to the north-east the case would be good'.[51] It was an early example of Murchison's habit of omitting to give credit where credit was due. A few years later Sedgwick reproved Murchison sternly, knowing that he had been advised where to look.

Sedgwick ventured into Wales for the first time in 1831 in the company of the newly graduated Charles Darwin who was then thinking of visiting the volcanic rocks of Tenerife and wanted to learn a little geology.[52] They were probably together for no more than a week[53] but Darwin regarded the time as a vital and formative experience. Sedgwick stayed with the family at The Mount, Shrewsbury, overnight on 4 August 1831. On the 5th he left in his gig with Darwin for Llangollen. His visit to The Mount caused a stir. It was the first time Darwin had brought home an eminent person for supper. Darwin's elder sister, Susan was bowled over by the attractive and fascinating Sedgwick. Darwin's biographer writes that her brother teased her about whether there was to be an announcement about a forthcoming Mrs Sedgwick.[54] Sedgwick later visited Darwin's father several times. Murchison wrote to William Whewell of visits to the Mount in 1834, immediately after the joint tour: 'whether he fell in love with some of the Salopian lasses or not is in his own breast; but I can assure you that a whole houseful of them are deeply smitten with him. When we parted at Ludlow it was found that he had left that beautiful brown coat of his in the very house where all these sirens were, so I left him posting back to recover the old garment, and perhaps to leave his heart'.[55]

Not only did Sedgwick exert an important influence on the young Darwin, helping to shape him into the 'powerful geological thinker' he became,[56] he may also have been responsible for a very long delay in the publication of *Origin of Species*. A celebrated book on the natural history of creation, published anonymously in 1844 was the subject of a ferocious attack by Sedgwick in the Edinburgh Review.[57] Darwin read Sedgwick's diatribe 'with fear and trembling',[58] knowing what was coming eventually to his own book. Fifteen years passed before he was compelled to publish *Origin of Species*; and he was hurt by the fury it then provoked from the pen of Sedgwick.[59] The two men however, remained friends. Sedgwick's journey with Darwin concentrated on the search for the western boundary of the known, younger rocks, and hence the beginning of the older, unknown greywacke rocks. One month earlier in Mid Wales Murchison had set himself the same task and, with good luck, prior help and much easier

conditions, had succeeded. For Sedgwick in North Wales, under far more difficult circumstances, the search was unsuccessful. A band of Carboniferous limestone ranges from Colwyn Bay in the north to past Oswestry in the south. To the west of it Sedgwick thought he would find the Old Red Sandstone and then the greywacke emerging from beneath the sandstone.[60] But there is no Old Red Sandstone there. The younger rocks were deposited unconformably onto the much older Carboniferous rocks. There had been erosion, so he could not know whether or not any part of the older rocks was missing.

He had to get his bearings by finding a marker horizon, from which he could trace the geological succession either side into younger and older rock. After leaving Darwin he worked another seven weeks in and around Snowdonia until, in early October, bad weather halted his efforts. Much of Sedgwick's reputation in later stages of the controversy derives from the universal acknowledgement of the great difficulty of his mostly solitary early North Wales fieldwork, compared to Murchison's more amenable task further south. He wrote to a close friend 'the Welsh are a kind hearted but a rather dull set of people; just made to be beaten by the Saxons. It is, however, wrong to judge people whose language one does not speak. I like to talk to country people but from this I am shut out from these children of Caractacus . . . it makes my solitude doubly solitary'.[61]

Sedgwick wrote to Murchison on his return to Cambridge, planning to start the following year, 1832, at the beginning of May, spending five months in the field, and largely completing his work in Wales. Even a man of his brilliance hardly had grounds for such optimism. In the event he began in 1832 in late May and spent only two months in his North Wales territory. Again Murchison tried to persuade Sedgwick to look at their joint boundary together. Again Sedgwick declined[62], but he wrote to Murchison about his progress. A letter from Barmouth indicates his speedy understanding of the complexities of North Wales.[63] Beginning as it does with the news that, in June, Sedgwick had stood at Rodney's Pillar, Breidden Hill, and seen Murchison on Moel y Golfa, Sedgwick relayed news of his progress from Llanymynech to the Berwyn, down to Bala, and thence to Bangor. He sent to Murchison cross-section sketches from Caernarfon to Meifod, and from Harlech to Arran Fawddwy, demonstrating in only two short field seasons an astonishing grasp of the stratigraphy across more than fifty miles of very difficult terrain. He realized that the rocks of North Wales repeated in folds and were 'not one tenth part the thickness one might at first imagine', yet somehow it did not shake his conviction that there was still an enormous depth of much older rock exposed in the west.

Sedgwick was president of the Geological Society for 1829-31 and Murchison for 1832-33. For his presidential anniversary address in early 1833 Murchison sought from Sedgwick a statement linking his older rocks to those younger ones of Murchison. A letter from Sedgwick to Murchison in February 1833 discloses Sedgwick's inability to do this. As both men would fully realise after another ten years, there was no relationship to describe, Sedgwick's upper set was the same as Murchison's lower set. But for years Murchison believed Sedgwick would be able to show a relationship. Given that Murchison initially set out to describe only his Silurian rocks, but that Sedgwick wished to describe the whole stratigraphy of the older rocks, it was for Sedgwick to describe the relationships. Sedgwick replied: his upper [Cambrian] system is 'as plain as daylight and entirely under your set but . . . I hardly know what to say regarding the dovetailing of our work, and I am not so confident as to commit myself in any formal précis'.[64] At first Murchison waited confidently for a clarification, later he just hoped, and then he realized: Sedgwick was in a quandary about the relationships.

Gout and other work stopped Sedgwick entering Wales in 1833. Instead he attacked older rocks in Charnwood Forest. In August Murchison's wife, Charlotte, made a late attempt to persuade him, with a further invitation to join their party. She held out the attractions of a lady who was with them. Sedgwick evidently knew of her. He replied 'she is a most formidable and cruel tyrant, who has slain tens of thousands without pity. I should not like to be . . . a burnt offering . . . besides, what have I to do with love . . . I am wedded to the rocks'.[65] Murchison meanwhile spent the summers from 1831 to 1837 making the most detailed survey of eastern Wales and the borders, with many descriptions of places in Montgomeryshire, all carried later into his great work *Silurian System*. Murchison, for his part, knew where the top of his Silurian system was to be seen, but he still wanted Sedgwick's help to prove where the bottom was. At last Sedgwick agreed to a joint tour in 1834.

The 1834 tour: a hasty journey

On Thursday 12 June 1834 Sedgwick left Cambridge for London and travelled by the mail coach to Worcester, and then seven miles further to meet Murchison at Malvern. The intention was that Murchison would act as guide over the southern part of the boundary between the older and younger rocks and Sedgwick would do the same for the northern part. Despite their apparent friendliness, we gain an insight into the difficulties from Murchison's biographer. They met, he says, 'to arrange if possible an amicable arrangement of boundaries'.[66] It has been suggested that they believed 'they were removing the last vestiges of overlap and confusion; neither suspected that any major structural revisions would be required and by the end of the tour all remaining difficulties had been swept away.[67] If that was the intention it certainly was not the outcome. On Friday 13 June they went round Murchison's rocks on the north end of the Malvern chain, and then to Little Malvern in the south. On Sunday 15 June as was his custom during fieldwork, Sedgwick would have gone to church, and in the afternoon he looked at Murchison's Ludlow shales near Ledbury.[68] From there they worked their way west through red rocks which Murchison reasonably believed were at the bottom of the Old Red Sandstone [but which much later geologists assigned to the top of his Silurian]. On Tuesday 17 June they were at Bredwardine on the Wye, and on Wednesday 18 June they crossed into Wales at Hay-on-Wye and travelled via

Felinfach to Brecon and Llandovery. Here they began to examine the boundary. Their joint work on the boundary, which could usefully have lasted for months, lasted less than two weeks.

On Thursday 19 June they journeyed south-west to Llandeilo and on the 20th to nearby Golden Grove. The boundary with the younger rocks is clear along this line but Murchison thought his Silurian rocks occupied a band only a few miles wide. To the west Murchison wrongly considered the rocks to be older. We now know these rocks to the west as Ordovician, or what Murchison then called his Lower Silurian. Yet at the time he did not claim them as Lower Silurian, but ceded them to Sedgwick as even lower Cambrian rocks. Sedgwick must have accepted that. They are in fact slightly older, but only for a few miles, because, as O.T. Jones showed a hundred years later, along the edge of the Welsh Basin from Carmarthen to north of Rhayader there is a great upfold, which after erosion exposes the older rock in the core of the fold. Not realising this, and being unable to define a boundary, Murchison was later obliged on his maps to place the letter 'P', signifying a 'Passage' from younger to older rocks.

They moved fast, as their respective notebooks show. From the Sugarloaf on Monday 23 June, along the present A483, they travelled via Llanwrtyd Wells, Builth Wells, Llandrindod Wells, Llanbadarn Fynydd and Newtown, and then to Llanfair Caereinion. On Friday 27 June they were still in Murchison's territory, examining the fossils at Gallt-yr-ancr, near Meifod. From their arrival at Murchison's 'boundary' it had taken only nine days to reach Meifod. Murchison later drew the dividing line south of the Berwyn. Sedgwick drew the line to the north.[69] They spent Saturday 28th on the Berwyn Hills, Sunday 30th in the Hirnant Valley (presumably Sedgwick also went to church), and on Monday 1 July they travelled along the north of the Berwyn to Llangollen and south to Chirk. On Tuesday 2 July they drove via Oswestry and Llanymynech to Powis Castle. They had travelled through Sedgwick's territory in just three days and were back in what they agreed then, and has remained ever since, Murchison's Silurian rocks. It is clear that Murchison was anxious to discuss his rocks with Sedgwick, but not clear that Sedgwick had the same desire to explore his North Wales Rocks with Murchison. On Wednesday 3 July they crossed back into England, travelled again to Llanymynech, and to Welshpool, and some sites in Shropshire, and on 10 July they parted company in Ludlow.

Curiously, Murchison's field notes mention Sedgwick, but Sedgwick's notes make no mention of Murchison, though they do sometimes mention other people. It seems likely that even on this one and only short joint trip in Wales he was not all the time with Murchison. For example, on 20th he 'returned to Llandovery with Mr Lloyd', and on 22nd he 'went to church in the morning and spent the afternoon with Dr Williams and travelled back to Llandovery'.[70] Sedgwick recalled years later that occasionally he spent days collecting fossils while Murchison worked out minute details.[71] There was not the collaborative working which characterised their earlier work in Scotland and in the Alps, and their later work in Devon and Cornwall.

Sedgwick returned to North Wales for another two months. Murchison thought he had achieved his objective and wrote to their mutual friend William Whewell 'The Professor and I . . . parted company on the most friendly terms'.[72] Surely nobody writes in such a way about a trusted friend, and the phrase is pregnant with tension. Even more telling is the friendly letter which William Whewell had written to Murchison's wife during the tour: 'I hope you fall in with them in time to prevent their turning their fratricidal hammers on one another . . . which I feared would be the result if they could not agree about the dovetailing'.[73] Eighteen years later, when both men had taken deeply entrenched positions, Murchison wrote to Sedgwick 'if we had united to describe the whole principality and the bordering counties of England, the lamentable position in which we now stand could never have occurred'.[74] There seems no doubt that Murchison really had wanted to collaborate in the early 1830s. We will now look at some of the places on or close to the important geological boundary which the two men sought but often failed to find.

THE GEOLOGY OF THE BOUNDARY

Llandovery

The first section to be examined jointly lay between Llandeilo and Llandovery. Noeth Grüg, four miles north-east of Llandovery, and just south of the Sugarloaf was studied in detail by Murchison.[75] At this point it is only about four miles from the [then known] red rocks of Mynydd Eppynt, across Murchison's Upper Silurian and into his Lower Silurian. This transition from land to old Welsh Basin deep water is very narrow here. Murchison describes Noeth Grüg as the most interesting tract in Camarthenshire, exhibiting a passage to the east into Upper Silurian rocks, and a passage to the west into Upper Cambrian rocks.[76] Now thickly forested, Noeth Grüg was once a bare hill, revealing abundant Upper Silurian rock.[77] One mile north-west is the steep slope of Cefngarreg on which Lower Silurian fossils were found. To the west of that Murchison noticed the fossils disappeared and the rocks became more slaty. Here was the Welsh Basin confusion. West of Cefngarreg the old Basin deepened. The rocks became more slaty but no clear line of demarcation could be seen, and there were no changes in mineral structure. This rock, Murchison observed, extended over two-thirds of Camarthenshire. He had made traverses from St Clears to Newcastle Emlyn and from Llandovery to Lampeter and found no striking variety of mineral structure. He even correctly described the area as undulating, which might have suggested folding to him. It was not getting older, but he wrote 'a detailed examination of this area was not within the objects of my work'.[78] He said the rock was Cambrian, and ceded it to Sedgwick, who seems to have agreed.

The eminent Welsh geologist, O.T. Jones, reviewing the controversy in 1921, before he had fully explained the

Welsh Basin, said it is clear that neither Murchison nor Sedgwick examined these rocks [to the north-west of Llandeilo] in detail. He describes Sedgwick's consideration of their relation with the rocks he was familiar with in North Wales as cursory.[79] Sadly for both protagonists, that word, which means performed with haste and scant attention to detail, is an appropriate description of the 1834 joint tour. O.T. Jones knew by 1921 that tiny differences in fossil graptolites were useful indicators. Sedgwick and Murchison had not realised this, nor did they for many years. Much later, in 1845 Sedgwick sent the brilliant palaeontologist Salter to collect fossils from Builth to Aberystwyth. Salter reported that he had found hardly any fossils, and so Sedgwick was still quite unable to separate this series.[80] Fossils are much more difficult to find in slaty rocks because the fossils lie on the bedding and slaty rocks do not split on the bedding; they split on the cleavage.

Powis Castle

Murchison was well known to Lord Clive, later earl of Powis, and made many visits[81] to Powis Castle while researching his book *Silurian System*. Indeed Lord Clive advised Murchison to write his Silurian book, even contributing a list of some eighty subscribers.[82] A view of the gardens, with Moel y Golfa, the Breiddens and Long Mountain in the distance, appears in *Silurian System*, drawn by Murchison's wife, Charlotte (Figure 3). Murchison was certainly there in 1832 and 1833, and again with Sedgwick in 1834, towards the end of the tour.[83]

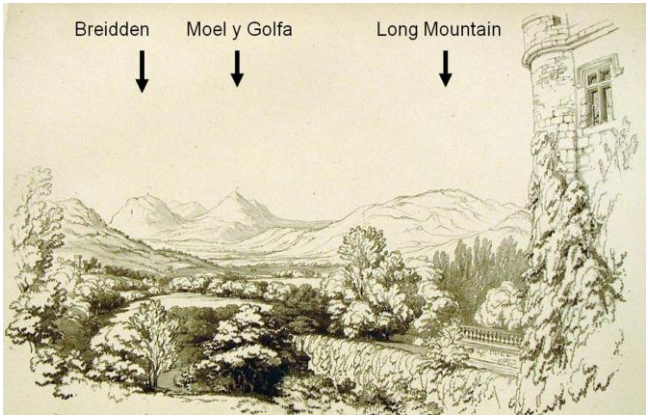

Figure 3 – View from Powis Castle drawn by Charlotte Murchison in the 1830s. (In Silurian System. i, 218).

The stratigraphy is presented in *Silurian System*, and could not have been examined in such detail without walking all around the grounds. Sedgwick's notebook mentions a specimen collected in Powis Castle Park in 1834. Murchison considered the red rocks to be the upper part of his Caradoc[84] [the upper part of his Lower Silurian], whereas now we know that locally it is the lowest part of his Upper Silurian. The unconformity lies between these red rocks and the grey mudstones beneath, some fifteen million years separating the two rocks. The base of the Powis Castle Conglomerate is exposed in the bank of a park drive through the wooded eastern ridge (Figures 4 and 5). The underlying Ordovician rock is a few metres away on the other side of this narrow ridge.[85] In the 1830s much more of the ridge and its surrounding rocks would have been exposed but neither geologist noticed the difference in lithology or faunal assemblage between these [Silurian and Ordovician] rocks, or its significance.

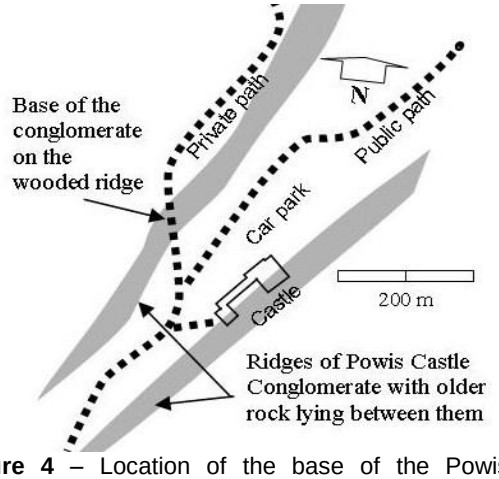

Figure 4 – Location of the base of the Powis Castle Conglomerate on the park drive.

Figure 5 – The base of the Powis castle Conglomerate on the park drive.

Of course the two men did not know that, towards the end of Murchison's Lower Silurian, and before the start of his Upper Silurian, there was a dramatic fall in global sea-level. Welshpool was again dry land and was eroding.[86] At the beginning of the Upper Silurian [modern Silurian, Llandovery] global sea-level rose and again covered Welshpool. In the meantime the rocks had been slightly tilted and eroded flat so the red conglomerate was deposited with a slight angular unconformity as a beach sediment on the edge of the shallow sea, full of small marine creatures (Figure 6). Subsequently folded by the collision of England & Wales with Scotland, after erosion the underlying grey rock was exposed in places. The characteristic small, blind trilobite *Salterolithus caractaci* is found in this rock, the very last stratum in which this creature lived before the loss of shallow water habitats around the world caused its extinction. The vital division in the rocks was to be seen at

Powis Castle all the time, but Murchison was not looking for it and Sedgwick never went back there.

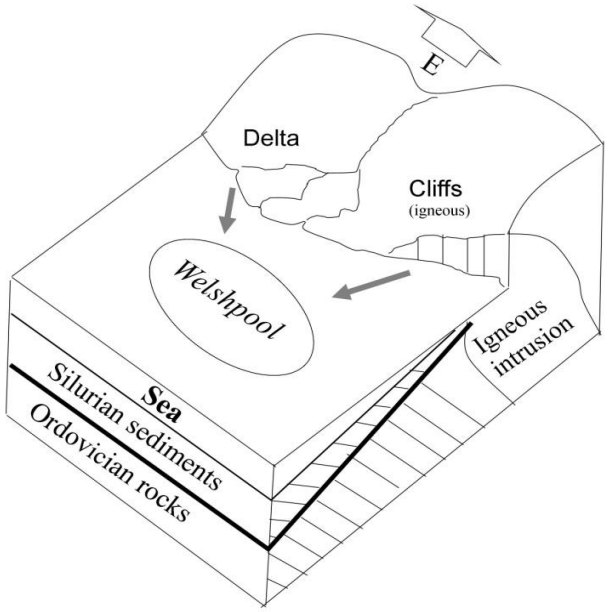

Figure 6 – Welshpool at the beginning of the Silurian period. (From a sketch by Dr R. Cave).

It was a young Welshpool man, Joseph Bickerton Morgan, who was the first to realise, around 1890, that the red conglomerate on which Powis Castle stands is actually the base of Murchison's Upper Silurian [modern Silurian] and not the top of the Lower Silurian [later re-named Ordovician]. Morgan had been advised to study the basal Silurian rocks in the Welshpool district by Charles Lapworth, the leading British geologist of the time, and the man who erected the Ordovician system. As an honorary assistant curator at the Powysland Museum, J.B. Morgan arranged a fine collection of local fossils at the museum, contributing from his own collection, all since removed to the National Museum of Wales. He then won a scholarship to the Royal College of Science, and died tragically at the age of only thirty-four, before he was able to complete a re-mapping of Welshpool. His demise is mentioned in the 1895 anniversary address of the President of the Geological Society.[87]

Onny Valley

The separation in the rocks was also there to be seen, more clearly, in the banks of the river Onny, nearly twenty miles to the south-east, beside the A489 near Wistantow, shortly before turning right to Craven Arms.[88] The whole of the upper part of Murchison's Lower Silurian, his Caradoc sequence, is exposed periodically over a distance of around 1½ miles (now with public access). Murchison noted that these rocks emerged from beneath the lower part of his Upper Silurian but he believed they did so conformably. He observes in *Silurian System* 'We here lose all traces of the trilobites common to the Upper Silurian rocks and in place of them we meet with other forms . . . never observed in the Upper yet abounding in the Lower Silurian'.[89] Despite such explicit recognition of a change of faunal assembly, and his recognition elsewhere in the book that this is caused by 'the globe passing from one condition to another' he never considered a major split in his Silurian.

This is now a famous spot, not just because of the change in fossils, but because the angular unconformity is clearly evident here (Figure 7). Both men missed it, as did many others. Sedgwick collected fossils along the Onny Valley in 1834.[90] The same uplift which had slightly tilted the underlying grey Caradoc rock at Powis Castle uplifted and tilted the same rocks in the Onny Valley. They eroded during exposure, and then the overlying Upper Silurian sediments were deposited flat above them. Around twenty-five million years later all the rock was tilted again by further continental collision. The angular unconformity in the bedding between the Lower and Upper Silurian rocks proves conclusively there was a substantial break in the succession, but it was not seen until 1853, when Sedgwick finally, and rather gleefully, proved the break and forced Murchison into other tactics to hold the Silurian together.[91]

Figure 7 – Bedding on the bank of the river Onny shows an angular unconformity between top Ordovician (lower arrow) and bottom Silurian (upper arrow); not noticed until 1853.

Meifod

Both Murchison and Sedgwick had visited Meifod before 1834.[92] They examined the fossils at Gallt-yr-ancr (Welsh: hill of the anchorite) near the top of the south-west end of the Meifod ridge. Numerous small quarries were once used for building stone, and are rich in fossils. Murchison noted the chief fossils in his notebook.[93] Sedgwick noted only the structure, an interesting example of their different approaches. Murchison recognised at once that the muddy sandstones above Meifod were the same as the Caradoc sandstone in Shropshire [the upper part of his Lower Silurian]. This was also a locality from which Sedgwick collected many fossils, now in the Sedgwick Museum at Cambridge, and thus many fossils in Salter's famous *Catalogue* come from this district.[94]

These thick, hard sandstone beds of the upper Caradoc produce the characteristic steep-sided hills of northern Montgomeryshire between the Breiddens and the Berwyn because where they surface as sharp upfolds they stand out,

and the overlying softer rocks in the downfolds erode into valleys. The two men were deliberately making a traverse north-west, across the grain of the rock, believing they would find the rocks getting older as they progressed towards the Berwyn Hills. Unfortunately they made a big mistake when they got to the Berwyn, but before we go there let us first consider another aspect of Meifod which they missed. South-west for five miles from Meifod the A495 runs very close to the important boundary between Murchison's Upper and Lower Silurian rocks [modern Silurian and Ordovician] and the break can be seen in the rocks and the fossils. Surprisingly, after McCoy and then Salter had studied the many fossils collected there, and Salter's *Catalogue* had been published in 1873, little further interest was shown in the district for more than fifty years.[95]

The story of geological change is revealed with remarkable clarity in some small roadside quarries at Graig-wen, on the A495, 4½ miles south-west of Meifod.[96] Our two geologists may even have passed that way from Llanfair Caereinion. Neither man mentions the site in his 1834 notebook but Sedgwick certainly saw it in 1843. The full geological story was only told in 2006.[97] The small quarries next to Graig-wen farm (Welsh: white rock; probably alluding to the pale limestone seen in the sandstone there) record a dramatic fall in sea-level at the end of the Caradoc [top of Murchison's Lower Silurian]. The ice sheets which formed on the supercontinent of Gondwana, which included Africa, then at the South Pole, caused global sea-level to fall by as much as one hundred metres. This is known as The Late Ordovician Ice Age, and it led to the first of the five great mass extinctions in the geological record. As the sea receded north-west from Meifod the river drainage gradually cut a 350 metre wide estuarial channel, over twenty metres deep. A brief and partial return of the sea allowed limestone beds up to fifteen metres thick to form in the channel. Then a final retreat of the sea left these limestones completely exposed. They eroded deeply, leaving numerous prominent pillars of limestone.

When the sea finally returned, these limestone pillars (Figure 8) and the trenches around them were submerged under a thick bed of sand. The later continental collision folded the rock almost vertically and, over four hundred million years later, the 17th and 18th century road makers quarried the sandstone. This has left pillars and domes of fossiliferous limestone protruding from the vertical face of a small quarry so that they are seen, as it were, from above (Figure 9). The limestone pillars are surrounded by sandstone and, because they were near the side of the channel, it is even possible to see the shale on which the limestone beds began to form. When Sedgwick remarked on it in 1843 he thought the limestones were boulders in a conglomerate, an easy mistake, and one which persisted until the 1990s. Eventually Sedgwick realised there is a major break in the rock sequence nearby, and hence a break in Murchison's series.

Three-quarters of a mile up the road from Graig-wen towards Meifod, on the south-western flank of Ffridd Mathrafal, is a cutting, now a geological SSSI on a forestry road. Together, Sedgwick and the palaeontologist Salter, collected many fossils there, though they did not at first realise the significance. Like the park at Powis Castle, the road south-west from Meifod, Ffridd Mathrafal and Gallt-yr-ancr are situated along the flank of an ancient fold where subsequent erosion has left modern Silurian [Murchison's Upper Silurian] adjoining the Ordovician [Murchison's Lower Silurian, and Sedgwick's Upper Cambrian]. Work by J.T. Temple at Ffridd Mathrafal in 1970 identified fifty three species of brachiopod and trilobite, very different from the fossils of the Caradoc.

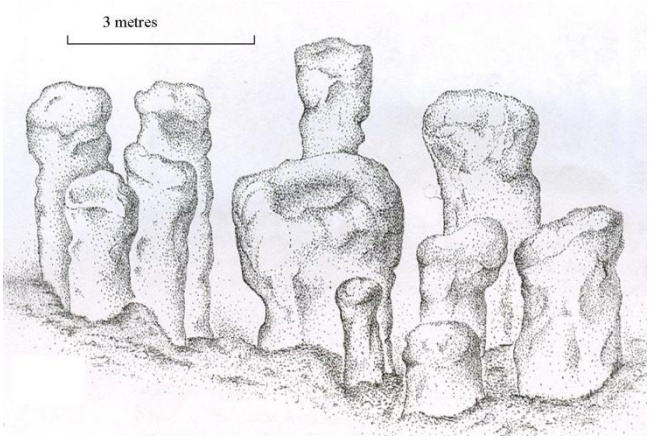

Figure 8 – Artist's impression of limestone pillars at Graig-wen before inundation. (From a sketch in Brenchley et. al. (2006); see footnote 97).

Figure 9 – The top of a limestone pillar now protruding from the quarry face at Graig-wen.

The Berwyn

Now firmly in Sedgwick's territory, the pair passed through Llanfyllin and on to Llanrhaeadr-ym-Mochnant where, 1¾ miles north of the town, on the east flank of the Berwyn, in the extreme north of Montgomeryshire, they visited one of Sedgwick's sites and made a mistake which, even then, more time and careful surveying might have avoided. They found fossils of the Llandeilo Flags [lower part of Murchison's Lower Silurian]. This discovery placed the

rock below the Caradoc rocks which lay around Meifod, so the two men were sure the rocks were getting older and all was well.[98] Murchison explained their find in *Silurian System*, 'To determine the boundary line between the Cambrian and Silurian Systems [Professor Sedgwick] led me to the flanks of the of the Berwyn, and on the banks of the Iurch, a tributary of the Taunat, we observed that the rocky gorge called Craig-y-glyn and the ridge of Mynydd Mawr were of Lower Silurian rocks. These strata dip to the south-east beneath the Caradoc Sandstone, and repose upon the more ancient rocks of the Berwyn chain. The most interesting fossil is the *Asaphus Buchii* [a trilobite]. It has been stated that this crustacean characterises the Llandeilo Flags, a formation well defined by its mineral and zoological characters. The clear evidence of the relative antiquity of these beds was therefore a subject of great satisfaction'.[99]

Sedgwick also stressed the presence of this characteristic fossil. In his field notebook he wrote 'go to the gorge west of Llanarmon Fach (Voel Vawr) and find fine calcareous slate with bands of L.S. [limestone] . . . various fossils, among 'em the *Asaphus Buchii*'.[100] So here was a fossil normally found at the bottom of Murchison's Lower Silurian.[101] But there was a problem: the fossil does indeed appear on the Berwyn, but in rocks exposed only in a very small area, around 1km square, bounded by faults and squeezed up from below around 400 million years ago during the Caledonian Orogeny, when England and Wales collided with Scotland.[102] The age difference between these up-thrust rocks, and those younger ones making up the rest of the Berwyn hills for some miles in each direction is unclear, but quite possibly it is millions of years.[103] In fact the rocks were not getting older as the two friends walked across the Berwyn. This mistake was mainly Sedgwick's, though in 1852 he claimed that it was Murchison who pronounced the Llanrhaeadr slate to be the lower part of the Lower Silurian, and he, Sedgwick, had accepted this reluctantly.[104] Now, as they travelled further north-west, they believed the rocks were getting older still. This mistake continues to puzzle in the present day because, as described below, in 1832 Sedgwick had conjectured correctly that Meifod and rocks even west of the Berwyn were of a similar age. Murchison's reliance on Sedgwick's authority regarding the Berwyn in the 1830s can be seen in a note on the map accompanying Murchison's 1839 book. Over the Berwyn the map reads 'Silurian rocks' and then in small print 'described by Sedgwick'.

The Berwyn Hills, which straddle the northern Montgomeryshire border, were the cause of a further misunderstanding. This spectacular landscape feature, rising to 827 metres at Cadair Berwyn, is not a mountain chain as Sedgwick appeared to think;[105] it was uplifted into a pericline or dome. When such a structure is flattened by erosion and viewed from above, the rock strata appear to run around the outside of the structure. Hence on the north Berwyn the strata run approximately east-west, and on the west of the Berwyn the strata run north-south, with beds showing an outward dip or decline, reflecting the original dome structure before erosion. Sedgwick adhered strongly to a theory propounded at the time by the Frenchman Élie de Beaumont, and sometimes called parallelism.[106] This teaches that when rocks are uplifted at the same time they display a similar strike (fold alignment), with folds lying roughly parallel to each other. And where the strike is different this indicates a different episode of uplift. The theory has its uses, but it does not work on the Berwyn, where the different dip directions of the bedding result from erosion following a single episode of uplift into a pericline. In 1832 Sedgwick noted the westward dip of the west flank[107] but in 1834 on his way back to Bala he passed along the [A5] road through Corwen off the northern edge of the Berwyn, and noted that the rocks on the north of the Berwyn had a very different strike and dip to the western flank.[108] He described them as upper system [Murchison's rocks], whereas he was satisfied that the west flank was his older rocks. The remark appears in his field notebook in 1834 but does not appear in his publications until 1845.

Bala

On 29 June they spent the evening at Bala,[109] having visited Gelli-grin farm just over one mile north-east of the northernmost part of the lake. The farm exposes Sedgwick's Bala Limestone, which he found in 1831, and in 1832 traced from Glyn Diffwys, five miles west of Corwen [on the A5], south to Dinas Mawddwy, a considerable feat given its very intermittent exposure.[110] They were now sure they were deep into Sedgwick's older system of rocks. Murchison's field notebook mentions Sedgwick's confirmation that the limestone is the same as that of Coniston Water Head in the Lake District. Murchison noted 'two fossils equal to those on top of the Berwyn', suggesting the rock is probably the same age. He also noted that it contained one or two fossils the same as at sites in Shropshire. Yet he allowed himself to be swayed by Sedgwick's structural assurances and instinct that this was all older rock. Sedgwick as usual was not troubled by the similarity of fossils, but he should have been.

Murchison's sketch at the time incorrectly adopted Sedgwick's interpretation of the Bala Limestone to the east of the lake, showing it passing on a downfold beneath the Berwyn.[111] Now we know the Berwyn is an upfolded structure. In 1842 Murchison sent to Sedgwick a draft of an address he was shortly to make when again president of the Geological Society. It contained the words 'we were both aware that the Bala Limestone fossils agreed with the Lower Silurian; but depending on Professor Sedgwick's conviction that there were other and inferior masses, also fossiliferous, we both clung to the hope that such strata, when thoroughly explored, would offer a sufficiency of new forms to characterise an inferior system'.[112] Sedgwick did not demur when he received those words but much later, in a letter to the poet Wordsworth he wrote: 'I smiled when I read this strange passage; but I did not think it worth while formally to contradict it; in omission and commission it is a virtual mis-statement of the facts'. Murchison trusted Sedgwick's judgement regarding the age of the Bala rocks, despite the contrary evidence of the fossils, but he was at least prepared later to recognise it as a joint error.

Sedgwick, in retrospect, simply dissociated himself from the error and, later on, from all the other errors as well. He protested that 'my friend left me . . . with a most express declaration that the Bala groups could not be brought within his [Silurian] limits'.[113]

Even more remarkable is the sketch, mentioned earlier, which Sedgwick sent to Murchison in a long letter in 1832 just after visiting Bala.[114] This conjectures that the upfold emerging on the east of the Berwyn continues east, turning into a downfold which arrives at Meifod, making the two places more or less the same age. The assumption of a single great fold was not correct, although that is not vital.[115] The conjectured correlation of the Bala Limestone with Meifod was, however, correct and hugely important. Sedgwick wrote 'the shell limestone east of Bala Lake reappears, if I mistake not, near Meifod in Montgomeryshire'. Structurally and palaeontologically the evidence of an overlap in their respective systems was staring them in the face. But to even entertain the possibility that this limestone was the same age from west of Bala, across the Berwyn, on to Meifod, and then into Shropshire, would at a stroke have threatened their concept of two systems. There and then, either Sedgwick's older rocks or the lower part of Murchison's younger rocks would have had to disappear. Murchison's doubts quickly emerged and can be seen in *Silurian System*, which was in print a few years later. Sedgwick obstinately stuck to his view for much longer.

The unconformity within the Bala Limestone was only ever going to be found with the most meticulous study of the fossils, and with a readiness to hypothesize that it existed even if it had not yet been proved. The district is severely deformed and in places heavily faulted; it was also heavily glaciated, and glaciation was not recognised in the 1830s. These confusions gave rise until recently to various interpretations of the geological succession. The Bala Group of rocks is about 1½ miles thick, with nearly all the rocks apparently unfossiliferous, and with only a few widely separated and often highly localised fossiliferous horizons to assist in correlating the rocks with other places.[116]

In 1842 Sedgwick, with Salter's help on fossils, correctly recognised three different limestones.[117] His famous Bala Limestone just east of Bala Lake,[118] was roughly paralleled by the younger, Hirnant limestone to the east, and the Rhiwlas Limestone to the west of the lake. The Bala Fault, along which the lake runs, is downthrown to the north-west so the Rhiwlas Limestone which appears to the west of the lake is not older, as Sedgwick at first thought, but merely a repetition by downfaulting of the band of limestone appearing on the east side of the lake. The intermittent nature of three distinct limestone bands caused confusion for many years, with some workers mistakenly believing that even a single band was split into three. The unconformity actually occurs within Sedgwick's original Bala Limestone, found in 1832 and described in 1843 by him as a 'complex group about 100 feet thick containing two bands of impure limestone'. The existence of a break in the geological succession was first recognised in 1928,[119] but not until 1966 was there recognition of the size of the hiatus (the erosion before further deposition).[120]

The Bala Limestone is described by Dr Douglas Bassett in an important and detailed paper in 1966.[121] Born a miner's son near Llanelli, he was a great enthusiast for the history of geology in Wales, becoming Keeper of Geology at the National Museum of Wales in 1959, and later an 'inspirational' director of the museum. He died in 2009. He mapped the Bala district and concluded in 1966 that Sedgwick's two bands must be the Rhiwlas Limestone and the very impersistent Cymerig Limestone, located near the top of the underlying Gelli-grin Calcareous [volcanic] ashes. His paper lists the species of brachiopod and trilobite found in these rocks.[122] Eighty eight species were identified by different workers, equally divided between trilobites and brachiopods.[123] Of the forty five species found in the Gelli-grin Ashes, none were found in the Rhiwlas Limestone; and of the forty three species found in the Rhiwlas Limestone, none were found in the Gelli-grin Calcareous Ashes. This complete exclusivity between the two faunal assemblies, points to a huge extinction of fauna. Here is the unconformity and a mass extinction.

Fossils in Cambrian rocks

Before we leave the regional geology we must visit Pembrokeshire. It was the apparent absence of a distinct fauna in Sedgwick's rocks that finally dashed his early hopes. Had he found fossils different to those of the Lower Silurian he would at once have shared an equal place with Murchison. But only someone with a mind open to fossil evidence, and a readiness to persevere looking for fossils in the Cambrian, could have achieved such a breakthrough; and Sedgwick was neither of these. The two main areas of (modern) Cambrian rocks in Wales are around Harlech in the north-west, and a smaller area near St David's in the south-west. Murchison did not know Harlech well but was familiar with St David's. As Sedgwick's Cambrian gradually disappeared, Murchison assured him that some of the Pembrokeshire rocks were older than any of the Lower Silurian.[124] Sedgwick nevertheless spent little time in Pembrokeshire, and did not look seriously for fossils in the older rocks, presumably not expecting to find any. He even wrote to Murchison from Carmarthen in 1846 and mentioned Pembrokeshire, about which he said 'I speak nothing and know little or nothing'.[125] Around Harlech the rocks were deposited in the deeper water of a subsiding basin, making fossils few and difficult to find.[126] Further south, near St David's, the Cambrian rocks were deposited in shallower water and some parts of the succession, especially the Menevian Group of rocks, were much later found to contain a diverse trilobite and brachiopod fauna,[127] of which the most dramatic find came in Sedgwick's lifetime.

In 1862 Salter, sometimes an assistant to Sedgwick, but then a palaeontologist with the Geological Survey, was holidaying while comparing the Cambrian of Pembrokeshire with that of North Wales. Viewing the coast from a boat just west of St David's, he landed by chance at

Porth-y-rhaw inlet. There he discovered by accident in the (modern) Middle Cambrian one of the largest trilobites ever found. *Paradoxides davidis*,[128] is over 50 cm long, a magnificent creature larger than any of Murchison's Silurian fossils.[129] He wrote to Sedgwick in January 1863 'Dear Professor, I send you one of my best specimens, [its] place has been truly determined . . . [it] will rival the great [Paradoxides] specimen from Massachusetts'.[130] By then however, nothing would change Murchison's mind. He had decided that all older rocks with fossils were part of his Silurian system. It must have been very hard for Sedgwick, yet in some ways he had only himself to blame.

RESENTMENT, ESTRANGEMENT AND BITTERNESS

The late 1830s: Sedgwick's missed opportunity

The 1834 joint tour clearly did not agree a lower boundary for the Silurian, though Murchison seemed to think at the time that it had. Writing to William Whewell immediately after the tour Murchison said he 'was very nervous until he had such a backer'. It showed just how anxious he had been about the boundary.[131] Neither could Sedgwick have been unconcerned about the boundary, because he spent some further weeks surveying it in North Wales; but if he had concerns, evidently he did not convey them to Murchison. For eight years Sedgwick failed to return to North Wales, and failed to find distinctive Upper Cambrian fossils, or to demonstrate conclusively that structurally his Upper Cambrian was separate and below the Silurian. As time passed Murchison began to wonder. Several years later in *Silurian System* he wrote 'it would seem that as yet no defined line of zoological division can be drawn between the Lower Silurian and Upper Cambrian groups and as our knowledge extends, we may probably fix the lowest limit of the Silurian system beneath the line of demarcation which has for the present been assumed'.[132] When Sedgwick read that he must have been cross. Meanwhile both he and Murchison had missed the vital unconformity between Upper and Lower Silurian, Murchison because he had mixed fossils from both sides of the gap, and Sedgwick because he had not even examined his own fossils.

In 1835 Murchison named the Silurian system after the tribe which had once occupied south-east Wales and fiercely resisted Roman occupation. He said he did so when advised that geologists in Europe might seek to name it themselves.[133] He then urged Sedgwick to name the Cambrian rocks, even proposing Snowdonian, which Sedgwick abruptly rejected as 'a beastly modern word of the Saxon tourists', preferring instead the name Cambrian, the classical name for Wales, though he seemed in no hurry to do so. Sedgwick was always less concerned with carefully mapping the Cambrian rocks than he was in dealing with the older succession as a whole.

In the years following the joint tour Murchison spent many months in Wales and the borders. Sedgwick did not return until 1842,[134] first devoting time to a joint study with Murchison of the rocks of Devon, which he began by believing were Cambrian, and must have been disappointed eventually to find were not. The two men produced six joint papers on the Devonian rocks. Sedgwick's characteristic slowness in producing written papers again showed itself, and Murchison chafed at the delays. In 1837 Murchison was to read a paper about their joint work on the Devonian rocks.[135] For months Sedgwick had known that information from him was necessary. A week before the meeting he still promised to do his best. Murchison wrote to him 'I was in great hopes to have your despatches before now, but I wait patiently like a lamb for the sacrifice, and sacrificed I most assuredly shall be without your aid. However, I will drink the best part of a bottle of sherry to screw me up to face [the forces] which are to be brought against us'. Only a brief note came from Sedgwick and the event had to be cancelled. Two days later Murchison wrote again 'The part of Hamlet omitted the play was not performed . . . I am mortified that the memoir did not come . . . did you really imagine that I was to dramatise the whole thing without a sermon before me'. Sedgwick's lack of contrition in his reply to Murchison, and his self-excusatory letter to the Geological Society president (Lyell), do him no credit. He had flu and was 'wretchedly out of sorts' but, as usual he had not delivered, and he felt that more work was needed.[136]

The president of the Geological Society, Whewell, said in his 1838 address that he hoped Professor Sedgwick would not 'withhold from the world much longer the views of his sagacious and philosophical mind [about the older rocks]'.[137] Very shortly afterwards Sedgwick presented a memoir entitled 'a Synopsis of the English series of stratified rocks inferior to the old red sandstone – with an attempt to determine the successive natural groups and formations'. This was brief and based on earlier field work. Only a small part of the paper deals with Wales, and the whole is only eleven pages long although it must have been accompanied at the reading by drawn sections.[138] With Murchison's book about to be published, this was evidently an effort to maintain Sedgwick's position as an authority on the older rocks as a whole. He dealt with the similarity of fossils between his Upper Cambrian and Murchison's Lower Silurian by asserting that the 'so-called laws' respecting fossil distribution are mere general results, and cannot upset conclusions from clear and unambiguous evidence of sections,[139] asserting that in many parts of England the Silurian system does not present a succession of natural groups [*i.e.* fossils].

The 1838 paper emphasises the importance of strike [the alignment of fold axes] in distinguishing between different episodes of deformation, correctly noting the north-east strike of the Cambrian system, but incorrectly noting a north-west strike for the Silurian System.[140] The paper summarises very briefly the succession of the older rocks, from the oldest in west of Scotland, to the youngest rocks of Murchison. In Caernarfonshire Sedgwick correctly recognised some very old rock – what today we call the Harlech Dome – and he placed this below his Cambrian system, describing it as Protozoic. Today it is the main area in Wales which retains the name Cambrian. Sedgwick's

Lower Cambrian lay west of his Bala Limestone which ran from Bala to Dinas Mawddwy. To the east of the Bala Limestone was the upper part of the Berwyn, and this he classified as Upper Cambrian, although the following year Murchison described it as Silurian, clearly thinking this was Sedgwick's advice. Sedgwick did not present a map. There is of course no single boundary. The structure of Wales exposes older rocks in the core of folds in various places. An attempt to draw a single continuous boundary was always doomed to failure, even if they had collaborated.

In 1838 Sedgwick firmly believed that his Cambrian system was substantial and widespread, though without mention of the (modern) Cambrian rocks of Pembrokeshire, which Murchison had accepted from the beginning were older than any of his Silurian rocks. Unlike Murchison, Sedgwick also still wrongly believed that in Devon there was some Cambrian rock.[141] In 1841 an equally short supplement to the 1838 paper repeated some of the earlier information; there was nothing new apart from some fossil identification work, undertaken by Salter,[142] which led Sedgwick to accept that 'no positive zoological distinction' was possible of the rocks below [Murchison's] Caradoc, and all fossil changes were progressive and gradual. Both men had now arrived at this conclusion and both were wrong.

As Murchison's great work developed he began to send draft material to Sedgwick, who displayed moments of considerable resentment. In mid January 1836 he told Murchison how busy he was, and he took offence at Murchison's remark that if Sedgwick was unable to look over his drafts then he 'must pocket the affront'. Sedgwick replied 'if I am to see this or any other manuscript on such conditions, I must formally and positively decline the task'. Ten days later, after looking over the papers, he wrote again; regarding Murchison's claim to have 'discovered' the Silurian on the Wye, he wrote 'you assume a prescience I don't believe real, and you set down as little better than a pack of asses everyone who had preceded you'. He seems to have taken exception to Murchison's claim to have been the first to discover the nature of rocks below the Old Red Sandstone: 'I gave the succession correctly in a paper read at the Geological Society before you ever struck your hammer against Siluria. 'It was a part of geology you had never studied – nor do I believe you [then] had the most distant idea of interpolating . . . so as to fill up a great gap'.[143] Clearly Sedgwick thought he had the right to continue the work and to assume the priority.

Sedgwick was upset that he was now seen as claiming an interest in only the oldest of the older rocks; he went on, 'I never limited my enquiries to any particular field, and only gave up the Silurians because you had made them your own in a particular part of the region'. When Sedgwick began in North Wales he evidently intended to cover the same ground as Murchison: 'I started in the same year you did and attempted to begin with the upper system' but I was defeated [because] the upper system is unconformable with the [rock to the east]'.[144] He also stated an interest in South Wales, pointing out that in 1832 he made 'detailed sections' of three traverses from the Old Red Sandstone [Brecon Beacons] to Cardigan Bay. Elsewhere he described the dips along these journeys as confusing. But nowhere did he question the erroneous assumption that the rock was tilted (rather than folded), and thus grew progressively older to the west.[145]

Sedgwick reviewed the introduction to *Silurian System*, but only three pages of the main work, and that, he grumbled to Murchison, took him three hours.[146] Shortly before publication his annoyance exploded as he saw *Silurian System* 'beginning to encroach on his [own] work'.[147] He wrote about 'a very painful misunderstanding, which left on his mind a feeling not of anger but of sorrow mingled with a most wretched and miserable condition of surprise, uncertainty and suspicion . . . I persist most positively and unequivocally in refusing to look over any single page of your book until it is before the public'.[148] Nevertheless, at the time of publication he wrote a friendly letter to Murchison, thanking him for the gift of the book, but declining Murchison's request to write a review for *The Times* newspaper. He said he had no time to review it, had not yet read it, and there were others who could write such a review.[149] Several weeks later he wrote again to say he delighted in the drawn sections, but evidently he still had not read the book.[150]

Despite the geological complexity of Wales, north and south, Murchison claimed he had to bring out his book speedily, or within a year or two the Americans would have pre-empted him.[151] At the end of 1838, following eight years of prodigious effort, the great book was complete.[152] *Silurian System* has been described as 'probably the greatest work ever to be published embodying the results of a single piece of original research by one man'.[153] Soon Murchison was world famous, and within seven years was knighted. Today a copy with its maps would cost several thousand pounds. The dedication reads: 'To you my dear Sedgwick, a large portion of whose life has been dedicated to the arduous study of the older British rocks, I dedicate this work. Having explored with you many a tract, both at home and abroad, I beg you to accept this offering as a memorial of friendship, and of the high sense I entertain of the value of your labours'. It deals with the stratigraphy of eastern Wales and the borders, a territory which Murchison claimed as his Silurian rocks, though a much larger area in the west he ceded to Sedgwick's Cambrian (Figure 10). The line between the Silurian and Cambrian was drawn by Murchison south from the Berwyn, and by Sedgwick north from there. South from Builth Wells Murchison marked the western side of the boundary with a 'P', signifying Passage Beds, because he could not confidently distinguish a boundary.

In February 1839, just after the book appeared, Murchison told Sedgwick that many believed the appearance of *Silurian System* 'should be accompanied by a powerful general review of the older rocks, and that no man alive is so fitted to this as yourself'. Naturally, Murchison still wanted Sedgwick to describe the overall stratigraphical context for the Silurian rocks but evidently he also believed

his friend could easily do it. 'Do not', he wrote, 'refuse or get into a rage because I say you can do this thing . . . you would thoroughly write it in fifteen days. The whole of the matter is completely in your head . . . if this occasion be not seized then such another may not occur within our lives'.[154] A few days later he wrote again urging Sedgwick to 'make more than ordinary efforts to complete the extra work, without which', he said, 'your labours are incomplete'.[155]

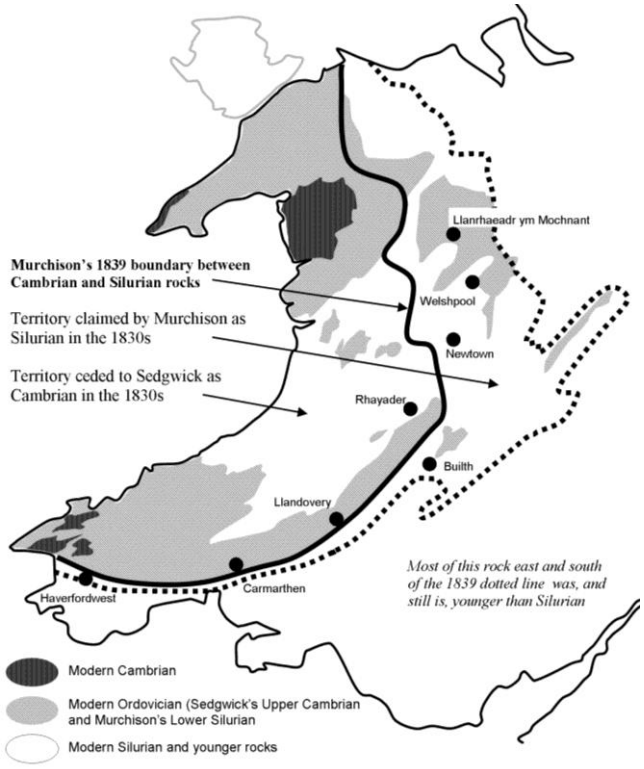

Figure 10 – Murchison's geological boundaries in the 1830s, and some modern boundaries.

Sedgwick must surely have known that, apart from the fact that writing indisposed him, he did not have the knowledge to do what was asked. Nor could it have been possible after the limited time he had spent in Wales. It was not just Murchison who believed implicitly in Sedgwick. Nearly everybody believed in 1841 that he would soon publish the overview of the older rocks. Fitton in 1841 wrote of his 'earnest hope and expectation that Professor Sedgwick will soon . . . publish the details of his valuable labours on the most ancient groups'. The geological fraternity must have felt it necessary to accelerate work on the older rocks because Fitton also took the unusual step of advocating an 'invasion' of the Cambrian territory, by other geologists, adding the reassurance that 'whenever [Sedgwick] publishes he can have no rival to fear'.[156]

The 1840s – Sedgwick gets going again

For more than twenty years Sedgwick had no space to set out his fossils, but in 1841 the university provided space to start a geology museum. With Salter's assistance the crates could at last be unpacked and cataloguing could start, a long, slow process. For Sedgwick this was the beginning of a five year period of catch-up, during which he returned to Wales, and finally completed some detailed papers on the overall succession of the older rocks. Murchison was now fully aware that the Silurian–Cambrian boundary in the *Silurian System* map was provisional but he still thought, largely due to Sedgwick's apparent confidence, that to the west there was rock still to be revealed as lower than Lower Silurian. He may privately have begun to wonder whether the Lower Silurian and the Upper Cambrian were the same but he was not the first to say so publicly. Bowman in 1840 and 1841 proposed that part of the Upper Cambrian was Lower Silurian.[157] Then in early 1842 the Geological Survey began work in Pembrokeshire and Carmarthenshire with extraordinary thoroughness, and they soon informed Murchison that his Silurian rocks repeated in folds all the way to Cardigan Bay, and his Silurian boundary was sure to be extended.

After years of inaction in North Wales Sedgwick, realising he was being overtaken by others, returned there in 1842 for some weeks with Salter.[158] He failed to find any distinctive fossils different from the Lower Silurian ones, and told Murchison so.[159] He now began to doubt his certainty that his rocks were older than those of Murchison. Secord describes how Sedgwick contacted Phillips at the end of November that year to enquire whether he believed that the rocks, from the Bala Limestone west to Cadair Idris, were really only undulations, in which case Sedgwick's Bala Limestone was no older than Murchison's Caradoc. Phillips replied in the affirmative.[160] The Geological Survey had already said this was the case further south. Sedgwick's Cambrian was fast disappearing in Wales, as it had disappeared in Devon.

By early 1842 Murchison was able to inform the Geological Society in his presidential address that Sedgwick's Cambrian had no fossils different to the Lower Silurian, and that 'all researches . . . have led to the belief that the Lower Silurian fossils were the earliest created forms'.[161] Ten years later this turned out to be wrong, but now it would only be a short step to claiming that all the older rock was Silurian. This he did in 1843 on a small map published by the Society for the Diffusion of Useful Knowledge. The same colour was applied to all Silurian and previously Cambrian rock in Wales. Sedgwick said there had been no consultation; he was very cross.[162] Murchison's presidential address also contained a long insistence that the terms Upper and Lower Silurian had acquired international significance and must not be altered. Up to this point Murchison had been prepared to share the rights to naming of the older rocks. From then on he quickly became entrenched in the opinion that the Silurian system embodied all the older rocks in which fossils are to be found, and no division within the Silurian system could justify a change in nomenclature.

In the summer of 1842 Sharpe concluded that that the Bala Limestone appeared to be no more than a band of calcareous rocks within the Caradoc (as then defined). His paper of 1843 called for a re-mapping of the country west of a line from Llangollen to Welshpool with most of the Upper Cambrian to be reclassified as Lower Silurian, and a small part of Upper Cambrian to become the bottom of

Upper Silurian, with the term Cambrian to be retained only for central bosses of much older rocks.[163] The 1838 line between Silurian and Cambrian now had no validity. In October 1842 Murchison was anxious to complete his book on Russia, where he had spent much time, and was also preparing for his Geological Society address in February 1843. He had to make a statement about the Silurian - Cambrian relations. He wrote to Sedgwick expressing concern that on the continent and in Asia work on the geological succession was continuing but 'at home has been silent . . . I was rejoiced that you had been again to Wales and . . . taken young Salter with you, because you could then make up your own mind'. By that he meant, make up your own mind that there are no different fossils in the Upper Cambrian. Of course there are not, because the Upper Cambrian was the same as the Lower Silurian, but he wanted Sedgwick 'to speak in his own place', and even suggested a form of words in which Sedgwick himself declared that to be the case.[164] Sedgwick did not take up the offer then or in his next paper eight months later, but neither did he dispute what Murchison wrote. In fact he wrote back 'I did look over the peroration. It is very good'.[165] It is as if Sedgwick was aware of the mistake but not prepared to admit it. We shall see the same trait in Murchison soon.

Sedgwick determined to return to Wales in 1843, but just before he did so, in June he read a paper to the Geological Society updating earlier work on the basis of the 1842 field work, and dealing with the counties of Denbigh, Caernarfon, Merioneth and Montgomery. With Salter's help in fossil identification, he now concluded that the most important separation in the Palaeozoic rocks of Wales existed between Murchison's Upper Silurian, and what he called the Great Protozoic Group below it, abandoning for the moment the term Cambrian. He claimed the separation was demonstrable by near exclusivity of fossils as well as by physical differences; and that in large districts the two divisions were unconformable, and hence there were two separate systems. It took another ten years to prove the break but at last he was groping towards it.[166]

The work of summer 1843 was reported to the Geological Society in November (though not published until 1845).[167] It shows numerous cross-sections, and lists copious fossils identified by Salter and Sowerby. At last, Sedgwick was making systematic use of fossils as a critical tool in the correlation of strata. He agreed that Meifod and Bala should be placed on the same horizon. But now, for the first time in his published technical papers there are remarks critical of Murchison. He refers to errors in the location of the Bala Limestone in Murchison's maps, clearly implying they were Murchison's fault; and he states that the neighbourhood of Mallwyd, and Montgomeryshire to the south of the Berwyn, were territories he 'never examined or professed to have examined until 1843'. This was of course mostly territory described by Murchison in 1838 as Sedgwick's older Cambrian rocks, and part of the boundary which Murchison had relied on Sedgwick to delineate, and which Sedgwick seemed happy to do in 1834. In March 1845 Sedgwick published a short paper bringing the Cumbrian mountains (Cumberland and Westmorland) into comparison with what he described as the primary divisions of the Welsh series: Carboniferous, Devonian, Upper Silurian and Protozoic, the latter being all the 'roofing slate and greywacke of great thickness' below Murchison's Upper Silurian. This was of course a serious bid to divide Murchison's Silurian, but without using the term Cambrian.

Sedgwick's next two papers to the Geological Society were read in January and December 1846. These formed a pair, the first dealing in detail with the slate rocks of Westmorland, Cumberland and Lancashire and the second with North Wales. Together they make up an overview of all the older rocks. Both are substantial and detailed papers. The second paper, on Wales, reclaims 'all the rocks in the uncoloured portions of Sir RI Murchison's map' [i.e. the Cambrian of 1839], and describes as 'the Cambrian group' all the rocks below Murchison's Upper Silurian, again striking out the Lower Silurian, but this time replacing it with the term Cambrian. The paper contains a full six page diatribe against the term Silurian. Sedgwick asserts that the Silurian cannot be a system, and is not representative of Cumbria, or of north and south Wales. He pleads that, although he entered no protest against it when it was introduced, he never supported it. He says he never attempted to meet the difficulty of drawing a well defined boundary until after the publication of *Silurian System* and that five summers had been taken up dealing with the Devonian. Dissociating himself from the joint work in this way, and attacking the Silurian nomenclature so publicly was bound to infuriate Murchison. It did; he wrote to Sedgwick 'nothing has annoyed me so much in recent years as having yet again to defend [the Silurian]. If we had fully cooperated in Wales as we did in Scotland and the Alps, when we found, as soon we must have done, that you had no fossil base essentially differing from Lower Silurian, we could have merged it into the term Cambrian'.[168] From the beginning Murchison had sought a collaborative venture with his then mentor but now it was far too late.

The split in the Silurian became more obvious to Sedgwick in 1846 with his finding, aided by Salter, that in the Silurian of Westmoreland, a total 103 fossils were divided between the Upper and Lower Silurian with only three fossils common to both. Murchison had begun correctly by recognizing the importance of faunal extinction but now he was prepared to insist very firmly that there was no break in his Silurian. The growing threat to the Silurian nomenclature prompted Murchison in 1847 to read a paper which sought to show the whole Cambrian System was nothing other than the Lower Silurian, and that the former term should be abandoned in favour of the latter.[169] He asked rhetorically whether geologists will be able to use two names for one succession of animal life. Regarding the critical region of Bala he informed listeners that he was only ever in Bala for one day and that with Sedgwick, intimating that he did not feel able to survey in a territory Sedgwick had made his own. He suggested from what he knew that Bala might be the lower part of Lower Silurian [i.e. Llandeilo Flags]. In fact we now know it is the upper part of Lower Silurian - the Caradoc.

The 1850s: bitterness

In 1851 the Geological Society awarded Sedgwick its highest honour - the Wollaston Medal, and he spoke at length wishing the Society well. Two years later he had fallen out with the Society, of which he had once been president, so much so that he cut himself off from it forever, declaring they had treated him 'scurvily'.[170] On 25 February 1852 He read a particularly vituperative paper, reviewing at length the mistakes made during the joint tour of 1834 and the North Wales errors in *Silurian System*, and placing the entire blame on Murchison. It is surprising that the Geological Society decided to publish it. Many were shocked. Some even questioned Sedgwick's sanity. Charles Lyell thought the argument was bringing geology into such disrepute that scriptural geologists would regain the ascendancy. Having issued the shocking paper to the printers, the council of the Geological Society lost their heads[171] and appeared foolish by trying unsuccessfully to cancel the journal in which it appeared, leaving Sedgwick with the feeling they had tried to stifle him.[172]

Murchison stood at the meeting and replied forcefully. Two days later he wrote to Sedgwick to say the accusation of acting unfairly had made him 'speak more vehemently than I intended'. There followed a reasonable explanation of events, and Murchison 'entreated' Sedgwick 'not to allow anything to appear in print which can lead the world to suppose we can wrangle about a name'. He added 'I have been grievously pained to be set in antagonism to you'. The letter does however conclude by re-stating his assurance that the Silurian system, Upper and Lower, is an unbroken single series.[173]

Murchison was then given an opportunity to reply, and did so in June 1852. The Society's council, fearful of a repeat of the previous debacle, did not arrange for a reading and discussion, but the paper was soon published. The chronology and the claims he made for himself were correct save in one critical respect. He still insisted that his Silurian, Upper and Lower, was one natural history system, and he hoped that Professor Sedgwick would see that 'had two names been applied to that which is ascertained to be one natural system, great disservice would have been done to geological science'. Well, Professor Sedgwick did not see it that way, and that very summer he proved Murchison wrong.[174] Murchison ended with the assurance that 'the controversy which has prevailed between the eloquent Woodwardian Professor and myself has not for a moment interrupted our strong personal friendship. I am indeed confident we shall slide down the hill of life with the same mutual regard which animated us formerly when climbing many a mountain both at home and abroad'.[175]

In the 1830s Murchison had muddled his fossils across the boundary, thus uniting the Upper and Lower Silurian. Neither he nor his assistants discovered the error. Sedgwick's own specimens would have revealed it had sufficient attention had been given to them early enough, but they remained packed. In 1850-51 Frederick McCoy, a young assistant to Sedgwick, was cataloguing specimens in Sedgwick's museum, and began to notice two distinct groups of fossils within the epoch called Caradoc. Sedgwick, long suspecting that such a division would one day be found, decided to return in the summer of 1852 to some of the localities already known to him.[176] In his usual fashion it was late September before he went. He and McCoy spent only five days in the field, of which Sedgwick spent three days in his room indisposed by the wet weather, and anxious about an outbreak of cholera. At May Hill in Gloucestershire, and on the west side of the Malverns, it was clear that the fossils had incorrectly been classified by Murchison as Caradoc. They were different and younger than those in the true Caradoc rocks elsewhere. McCoy actually went to the Onny river section (shown in Figure 7) but the river was too swollen to prove the point there.[177] In November 1852 Sedgwick triumphantly read to the Geological Society his paper 'On the proposed separation of the so-called Caradoc Sandstone into two distinct groups; the May Hill Sandstone and the Caradoc Sandstone'. Two years later he submitted a short paper extending the split in the Caradoc along the boundary from Llandovery in the south to Glyn Ceiriog in the north.[178]

The Geological Survey, realising that their maps probably showed the boundaries of the Caradoc incorrectly, promptly returned to the field to check. They saw on the banks of the Onny what none had seen before, an angular unconformity.[179] Sedgwick then complained of a 'needless insult' in delaying the printing of his 1854 paper until after two papers expressing similar views by the Survey had been published, and in deleting from his own paper his criticism of the Survey for its mapping error.[180] The initial mistake of mixing fossils and failing to spot a division in the Caradoc was Murchison's, with the Survey following his lead, but Sedgwick was not free from error in this respect. He admitted in a letter to Murchison that seven or eight years earlier he had confused two bridges on the Onny river and thus assumed that the Caradoc rocks extended further down river than they actually did, falsely overlapping the younger Silurian rock.[181] He admitted that both McCoy and Salter had told him years earlier that he had blundered, but that he had obstinately stuck to his notebook; and he said McCoy had long insisted the fossils were in two separate groups. Although Murchison never explicitly admitted that his Silurian had been split, he knew it: two months after Sedgwick's paper was read, Murchison wrote a kind letter to McCoy about an unrelated matter but added 'it has been whispered to me that you were the prime agent in pulling down the Silurian mansion I had built for myself'.[182]

Murchison's friendship with Sedgwick was already ruined and now what he most wanted, preservation of the unity of his Silurian, was undone. Despite the increasingly fractious nature of the relationship, the two men still wrote to each other occasionally, sometimes at length, most often initiated by Murchison. Even in late 1853 Sedgwick was able to sign off with a veneer of friendship 'ever (whether in war or peace) your affectionate old friend',[183] but he kept up his protests for another twenty years. With the publication of Murchison's 1852 paper, the Geological Society decided to carry no more disputatious papers on the subject. Denied

the forum of the Journal of the Geological Society for protest, Sedgwick published in the Literary Review, and Murchison followed him there.

Sedgwick's disappointment must have been amplified when, in 1854, a book was published by Murchison dealing with all the older rocks: *Siluria, a History of the Oldest Rocks of the British Isles and Other Countries*. This reinforced Murchison's claims to his extended Silurian empire, as well as demonstrating his other geological achievements. It was perhaps the sort of book that Sedgwick wished that he could have produced, but now knew he never would. Although it mentioned Sedgwick, it did not do so as a co-worker and, to the latter's growing bitterness, it firmly laid claim to nearly all the rock which fifteen years earlier Murchison had called Cambrian, but by then everyone was calling Lower Silurian. Yet only two years earlier Sedgwick had conclusively proved that the Lower Silurian was a different series of rocks from the Upper Silurian. Later editions of the book even described as 'Primordial Silurian' all the fossils which had by then been found in rocks much older than Murchison's Lower Silurian, and which today we do call Cambrian, including the huge trilobite *P. davidis*.[184]

After the Geological Survey officially recognized that the Upper and Lower Silurian rocks were divided by an unconformity and a sudden change in faunal assembly, Sedgwick might have hoped for a change in the nomenclature, but it was not to be. He complained at the British Association at Liverpool in 1854 'we have no example in English geology of two great formations which are . . . unconformable in their position, yet at the same time belong to a common series and pass under a common name'.[185] In 1855 any chance of a change in nomenclature vanished. Murchison, at the age of 63, was appointed Director General of the Geological Survey, and occupied the post until his death sixteen years later. He was so determined to insist on maintaining a unified Silurian on the Survey's maps that his most senior staff had to urge him quietly for the good of the organisation to desist. Sedgwick lent his support to Murchison's appointment, though he could hardly have not done so. Murchison wrote to thank him saying 'I would rather have had your name than that of a thousand others'.[186] There were still some light-hearted moments. In 1855 at the British Association meeting in Glasgow, Murchison was making a contribution when Sedgwick rose, struggling to divest himself of his heavy greatcoat. Noticing the nervous mirth of the audience he announced merrily, and to general applause 'Oh! I'm not going to fight him'.[187]

The 1860s and the end

Murchison continued to hope for a reconciliation with Sedgwick until around 1860, but he still fought to the last for the integrity of his Silurian. The final revision of *Siluria* was published in 1872, just after his death. Even though it was by then widely agreed that there was a break in the Silurian, he still refused publicly to accept it. The Tarannon Shales he said, ran through Radnor and Montgomery and were clearly exhibited [at locations] between Llanbrynmair and Llanidloes. He classified them as 'intermediate', and therefore connecting the Lower and Upper Silurian rocks.[188] The Tarannon Shales were eventually accepted as Upper Silurian, Llandovery epoch, but Murchison died refusing publicly to acknowledge the break in his Silurian.

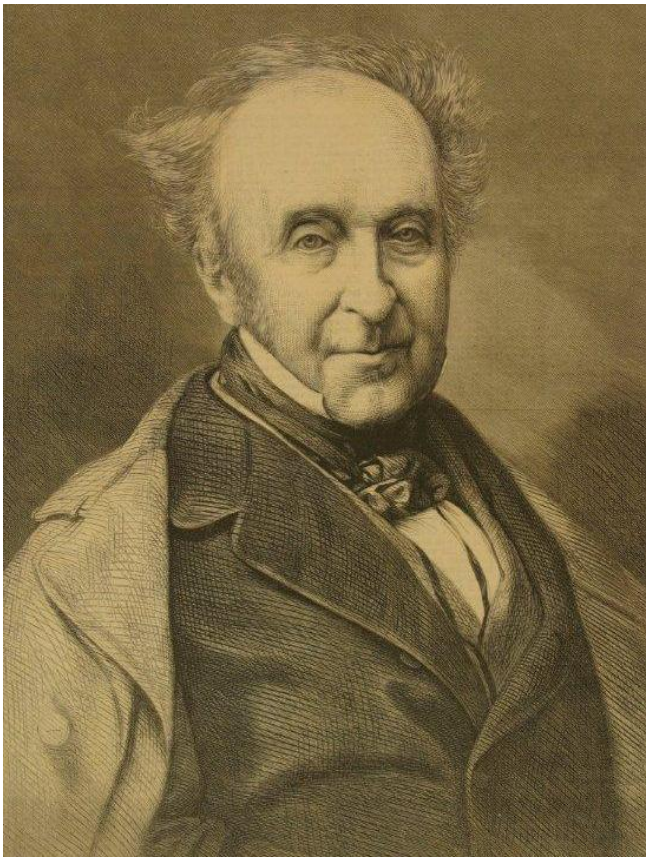

Figure 11 – Sir Roderick Murchison in the late 1860s. (Reproduced courtesy of the Geological Society of London. GSL/POR/56).

In 1861 Sedgwick pointedly absented himself from British Association meetings in Manchester, attending the geography discussions, not the geology ones chaired by Murchison; and he was absent from Cambridge when an honorary degree was bestowed on Murchison. On both occasions Murchison had hoped to propitiate his old friend. In Cambridge he confided in his diary that the snub had made him unwell.[189] Yet he still wrote to Sedgwick that night 'I consider this and all worldly distinction that might be bestowed on me as nothing in my estimation compared with one kind letter from yourself (in your old manner)'.[190] Five years before his death Murchison penned a long note to his executor: 'I have only one deep source of regret . . . that I shall probably pass out of this world without being able to induce my old and valued friend Sedgwick to relent his hostility towards me'.[191] Sedgwick, though irascible in later years remained a kind man. Only Murchison had to bear his bitterness.

On 2 January 1869 Sedgwick wrote a harsh letter to Murchison blaming him for spreading Silurian colours across the map without informing Sedgwick, and of

claiming that he had been misled by Sedgwick. It was a letter so very unkind that Murchison instructed his executors not to reprint it unless further untruths were written, and it does not appear to have been reprinted until 1982.[192] Deeply hurt, he drafted, but never sent, a letter saying 'the rupture of our former friendship has always been felt by me to be one of the greatest misfortunes which ever befell me'.[193] The following day he actually sent a letter saying 'it would give me the sincerest satisfaction if there is any explanation which I can possibly give [which] would be accepted by you, and put an end to the estrangement which for more than twenty years I have never ceased to lament'.[194] Sedgwick's reply was brutal, 'your nomenclature . . . is false . . . your original and typical section is false . . . My order of superposition was not false in any essential part . . . you have acted contemptuously, unjustly and falsely towards me. I cannot smooth over the matter by the shallow gloss of vulgar courtesy'.[195]

A month later Murchison's beloved wife died. Sedgwick had known her well as a fond friend, but when he received in the post a copy of the obituary he set it aside, not realising it had been sent by Murchison himself. Only when he took it out some days later did he see the initials RIM, and write a letter of condolence. Addressed to 'Dear Sir Roderick Murchison', and signed 'in all Christian sympathy and goodwill, faithfully yours, A Sedgwick',[196] it is too formal to be regarded as reconciliation. They were never in contact again, although Sedgwick, through a mutual friend, passed to Murchison a Christmas greeting in 1870 – 'if he be well enough to receive it'.[197] Murchison died in 1871. Though paralysed by a stroke, he attended to his many duties to the end.[198] The prime minister Mr Gladstone walked bareheaded behind his bier.[199] Sedgwick died eighteen months later, in January 1873, and was buried beneath a simple stone in a quiet ceremony one frosty morning at Trinity College. Four months before his death Sedgwick had completed his preface to Salter's mighty *Catalogue of the Cambrian and Silurian fossils contained in the Geological Museum of the University of Cambridge*. The *Catalogue* was published just after Sedgwick's death, with the preface containing a long, intemperate rant about his treatment at the hands of Murchison, in which he accused Murchison of 'conduct unworthy of a gentleman'.[200] Even after his death Sedgwick's fury reverberated.

The two men cast such long shadows that for years after their deaths nobody attempted a scientific resolution of the dispute. The claims of both men continued to be argued by their supporters. In the 1870s a brilliant young geologist, Charles Lapworth, discovered that tiny fossil graptolites existed in many hundreds of species throughout the older rocks. Each species survived for only a million years or less, making it possible to separate the older rocks into many different bands and correlate them across great areas. This was later to form the basis of much of the stratigraphy of the Welsh Basin, together with brachiopods, shelly creatures with stems fixed to the bottom, which vary in species with water depth. In 1879 Lapworth published a balanced and reasoned paper summarising the claims made for the Cambrian and Silurian systems, and the need to recognise, in the disputed overlap, a third system. He said it should be called Ordovician, 'after the old British tribe belonging to the counties of Montgomery, Merioneth, Caernarvon, Denbigh and Flint'.

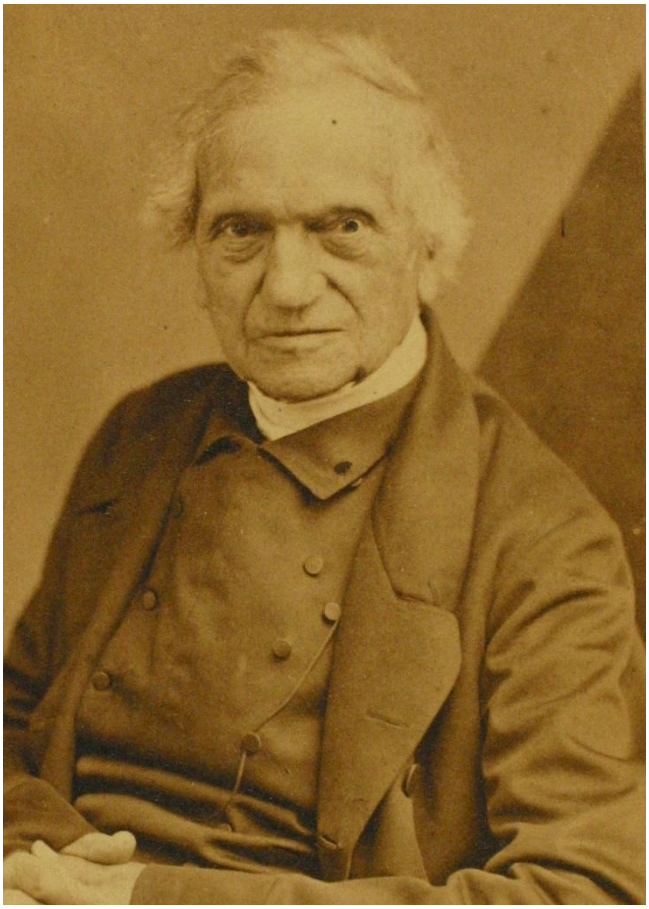

Figure 11 – Adam Sedgwick in the late 1860s. (Reproduced courtesy of the Geological Society of London. GSL/POR/56)

Many people for years refused to accept the Ordovician, including Thomas McKenny Hughes, the Aberystwyth man who succeeded Sedgwick in the Woodwardian chair, and was his co-biographer; also Archibald Geikie, Murchison's biographer; and the Geological Survey, which persisted with Murchison's nomenclature for thirty years after his death. But the term Ordovician stuck and, like Silurian and Cambrian, has since covered the world. Today the Silurian [largely Murchison's Upper Silurian] accounts for 26 million years of geological history. By interpolating the Ordovician between the modern Silurian and modern Cambrian, Lapworth separated the two not by the thickness of a few beds, but by over fifty million years. The Cambrian and Ordovician together account for over 100 million years of history. As one reviewer has written, Sir Roderick would have been deeply offended, but Adam

Sedgwick, if a little hurt, would have felt quietly vindicated.[201]

More than twenty years before Sedgwick's death he stated the rights he thought he had been denied. In his shocking 1852 paper he said 'I claim the right of naming the Cambrian groups because I flinched not from their difficulties, made out their general structure, collected their fossils, and first comprehended their respective relations to the groups above and below them . . . in the complicated sections of North Wales'.[202] It was true, but sadly, as Dawkins said, despite his genius he had been outstripped in the race by the practical man of method. Dawkins also wrote in 1875, speaking of these great men, and comparing them to his own generation, 'we are only scientific specialists; they were philosophers'.[203] Few would argue with that.

Acknowledgements
The author is grateful to Wendy Cawthorne and her colleagues at the Geological Society library, London, and to Sarah Finney and her colleagues at the Sedgwick Museum, Cambridge, for help with source documents.

Adapted, with modifications from a paper in *Montgomeryshire Collections*, vol. 100 (2012), published by the Powysland Club.

The author is at: pantmaenog@aol.com

References and Footnotes

[1]R.I. Murchison, (1839), *Silurian System*, John Murray, London. This book, central to the controversy, carries in the long title the words 'with descriptions of the coalfields'.
[2]J.A. Secord, (1986), *Controversy in Victorian Geology: the Cambrian-Silurian dispute*, Princeton University Press, New Jersey.
[3] W.B. Dawkins (1875), Review of Geikie's 'Life of Murchison', *Edinburgh Review*, part 142, p.190.
[4] *Ibid*. 174.
[5]Dr Alan Wood, presenting O.T. Jones for an honorary doctorate at Aberystwyth in 1958. O.T. Jones (1878-1967) elected FRS in 1926, twice president of the Geological Society.
[6]O.T. Jones, (1938), On the evolution of a geosyncline, *Quarterly Journal Geological Society*, vol. xciv. Anniversary address of the president.
[7]Sedgwick, (1835), Remarks on the structure of large mineral masses, *Trans. Geol. Soc*., ser. 2, vol. 3: 461-486. Sandra Herbert, (2005), in *Charles Darwin Geologist*, 372, f.n. 196, quotes Oldroyd as crediting a Lakeland guide with showing Sedgwick the distinction between bedding and cleavage. Sedgwick acknowledged the debt.
[8]For example, the inset cross-section on Wm. Smith's famous 1815 map shows steeply dipping rocks in Wales, facing east.
[9]J.W. Clark and T.M. Hughes, (1875). *Life and Letters of Sedgwick*, Cambridge University Press, two vols, i:251, f.n. describes his adherence, in 1819, to the 'nonsense' of Werner, who taught the idea. Secord (1986), 64, argues that Sedgwick was never strictly a Wernerian.
[10]*Ibid*., i:251, Sedgwick to Harkness in 1856.
[11]*Op. cit*., (note 1, *Silurian System*). Various remarks, *e.g*., 568-576.
[12]*Ibid*., ii:579.
[13]Sedgwick, (1841), Supplement to a synopsis, *Proc. Geol. Soc*., 3, 550.
[14]*Op. cit*., (note 9) i:151.
[15]He was formally introduced to the Geological Society of London in 1816 without seeking fellowship.
[16]Sedgwick's predecessor resigned the chair in order to marry. In 1832 Sedgwick declined the possibility of matrimony by refusing the Lord Chancellor's offer of a prosperous living at a country parish in Kent, in order to pursue geology, especially the writing of a book. His friend, Charles Lyell, recalls Sedgwick's dejection after refusing the living, and his intention within a few years to retire and marry. Much later, wistful remarks in his letters suggest that he would have liked to marry. His biographer believed he should have accepted the living, that he would have been happier in marriage, and the life of a parish clergyman would not have been inconsistent with pursuit of geological interests (*Life and Letters of Sedgwick*, i:386). After Sedgwick's tenure the bachelor condition was waived; his successor in the chair was married.
[17]*Op. cit*., (note 9, Clark and Hughes) i:468. During winter 1836/7 he spent 3 months in residence at Norwich. Ten years later he was sometimes engaged in summer residences.
[18]Dr Darwin, Charles Darwin's father, believed Sedgwick to be a hypochondriac from their first meeting.
[19]A. Geikie, (1875). *The Life of Sir Roderick Murchison*, John Murray, London, 2 vols, i:195.
[20]*Op. cit*., (note 2, Secord), 40, cites Crosse (1892).
[21]*Op. cit*., (note 19, Geikie), i:123. He took his seat January 1825. He was also encouraged into science by Sir Humphry Davy.
[22]J.L. Morton, (2004), *King of Siluria*, Brocken Spectre Publishing, p.141. Letters in the British Library reveal that Murchison wrote to Sir Robert Peel in 1845 asking for a baronetcy, citing his Russian honours, his achievements in geology, his active support for the Tory cause in Durham in 1818, and the fact that he was heir to his uncle, but not to his uncle's baronetcy, which would die with him. Peel replied that honours had already been too lavishly dispensed by the previous government.
[23]*Op. cit*., (note 19, Geikie), i:124, suggests that only a year elapsed before he and Sedgwick, in 1827, first geologised together.
[24]*Op. cit*., (note 19), 'Sedgwick at once won my heart'.
[25]*Op. cit*., (note 9), i:301, refers to a letter by Charles Lyell in *Life of sir Charles Lyell*.
[26]*Op. cit*., (note 9), i:300.
[27]*Op. cit*., (note 9), i:321.
[28]*Op. cit*., (note 9), i:306.
[29]Sedgwick left England 24 July 1829 and returned 6 November (Clark and Hughes, i:349 and 358). See also Geikie, i:157-162.
[30]Geological Society of London, GSL 838, S11, 32. Sedgwick to Murchison 15 June 1829, 'Good God, you will have to do everything for me . . . pray look out some papers for me to read'. Sedgwick was preoccupied with the election of an MP for the University.
[31]*Op. cit*., (note 9), i:361.
[32]Sedgwick to Murchison, 15 July 1830. GSL 838, S11, 41.
[33]We may assume this from o*p. cit*., (note 9), i:385. In 1832 Sedgwick wrote to his to his lifelong friend, Ainger, 'on my return [from fieldwork in Wales] I shall begin to write a book with which I have been pregnant for seven or eight years'.
[34]W.D. Conybeare and W. Phillips, (1822), *Outlines of Geology of England and Wales*, London. Murchison regarded this book as his scientific bible, *op. cit*., (note 19), i:126.
[35]*Op. cit*., note 19, Geikie), i:325. Conybeare to Sedgwick 24 April 1828. Conybeare, rector of Sully in S Wales, and later dean of Llandaff, said only such an offer allowed him to hold out the prospect of producing a second volume.
[36]*Ibid. C*onybeare proposed that Sedgwick and De la Beche did South Wales.
[37]*Op. cit*., (note 9), i:365.
[38]Sedgwick to Murchison, 25 June 1828. GSL 838, S11, 23. 'On my return from Cornwall I shall cross to S. Wales and visit Conybeare (I think I told you we were going to scribble in company)'.
[39]Murchison to Sedgwick 18 Aug 1828. *op. cit*., (note 9), i:340. Four months after the letter from Conybeare, Murchison wrote to Sedgwick from Nice urging him to look at continental geology 'even before you bring forth that long-expected second volume on the geology of England and Wales'.
[40]GSL 839, Murchison Notebook 57:75. In July 1831 he passed through Sully, the rector's home town, spending 6 July, or at least part of it, with him.
[41]Trericket Mill, near Erwood.
[42]*Op. cit*., (note 9), i:386.
[43]*Ibid*. i:499.
[44]*Op. cit*., note 19), ii:109.
[45]*Op. cit*., (note 9, Clarke and Hughes), i:498. In 1837.
[46]*Op. cit*., (note 9), i:496, in 1837 to Canon Wodehouse, replying to a friendly letter saying his sermons needed more preparation; and i:466, in 1836 to his close friend, Ainger: 'the moment I try to employ my pen the inner man gets out of order and my brain might just as well be filled with brick dust'.
[47]*Op. cit*., (note 9), ii:251 'I know that I am a great procrastinator, partly from temperament'.

[48]*Op. cit*., (note 9), i:376.
[49]Sedgwick to Murchison 13 September 1831, from Llanllyfni, near Caernarvon. GSL 838, S11, 51. Sedgwick complains the fossils were not his responsibility, should have been arranged sooner, and had caused much delay.
[50]The site of Cavansham Ferry is identified (O.S. ref. 111 429) in Hawley (1997), *Proc. Geologists' Association,* vol. 108.
[51]*Op. cit*., (note 19, Geikie), i:182. The date was 11 July 1831. According to Geikie, Phillips said that Murchison began to dream of Siluria in that year.
[52]Darwin's Beagle opportunity was waiting for him on his return home from North Wales.
[53]There is controversy about the time Sedgwick and Darwin were together. Some authors, including Sedgwick's biographer, say several weeks. I believe a comparison of Sedgwick's field notebook and Darwin's notes, and a biography by Janet Browne, confirms one week. Sedgwick's notebook and letters did not mention Darwin at the time. Roberts, in *Endeavour*, vol. 25(1), 2001, suggests that Darwin may have extended their time together by accompanying Sedgwick to Dublin and Anglesey, citing a comparison of sandstones which Darwin later made on the Beagle, between Quail Island and Anglesey.
[54]J. Browne, (2003), *Charles Darwin*, Pimlico, i:140.
[55]*Op. cit*., (note 19), i:223.
[56]J. Browne, (1995), *Charles Darwin*, i:142. Pimlico.
[57]*Op. cit*., (note 9, Clarke and Hughes), ii:81-88. Sedgwick seems to have been beside himself with annoyance and his biographer describes the work as 'dogmatical, ponderous and dull'.
[58]Charles Darwin also feared it was a 'grand piece of argument against the mutability of species', *ibid*., i:88.
[59]Spectator, 24 March 1860, and much else.
[60]Sedgwick was using Greenough's unreliable 1820 map.
[61]*Op. cit*., (note 9), i:395. Sedgwick to Ainger, from Oswestry, August 1832.
[62]Sedgwick to Murchison, from Machynlleth, 15 June 1829. GSL 838, S11, 66. 'You must see at once it is impossible we should meet'. Also o*p. cit*., (note 9), i:394.
[63]Sedgwick to Murchison, 25 June 1828. GSL 838, S11, 65. Also o*p. cit*., (note 9), i:391.
[64]Sedgwick to Murchison, 4 February 1833. GSL 838, S11, 73. In Clark and Hughes, Geikie, and Secord, p.80.
[65]*Op. cit*., (note 9), i:409.
[66]*Op. cit*., (note 19, Geikie), i:222.
[67]*Op. cit*., (note 2, Secord), 80.
[68]Sedgwick Museum, Sedgwick notebook 27 (1834), 10. The entry does not mention church on the 15th.
[69]It has been suggested by authors that Sedgwick drew the line north of Meifod, but Murchison states in *Silurian System*, page xxix, 'Professor Sedgwick determined the outline between the Silurian and Cambrian rocks from the Berwyn Mountain northwards'.
[70]Sedgwick travelled 'back over Noeth Grüg' and saw Castell Graig Gwyddon.
[71]*Op. cit*., (note 19), i:224.
[72]*Op. cit*., (note 19), i:222.
[73]Quoted by Secord (*op. cit*., note 2), 90.
[74]Murchison to Sedgwick, 27 February 1852. *op. cit*., (note 9), ii:219.
[75]Murchison had been to Noeth Grüg before, and again a third time in 1835 (*Silurian System*, p.353). In *Silurian System*, p.352 he describes Noeth Grüg as a passage between Upper Cambrian to the west and Upper Silurian to the east, suggesting it is Caradoc, Lower Silurian. In his 1834 notebook (GSL, MN 57, p.45) Noeth Grüg appears between Lower and Upper Silurian.
[76]*Op. cit*., (note 1, Murchison), 352-3.
[77]*Ibid*., 353, the hill had 'only a slight covering of soil'. The name is probably mutated from Noeth Crüg (bare hill).
[78]*Ibid*., 359.
[79]O.T. Jones, (1921), The Valentian Series. *QJGS*, 77, p.146.
[80]Sedgwick (1846), *QJGS*, 2, 125-127.
[81]A. Wade, (1911), The Llandovery and associated rocks of north-eastern Montgomeryshire. *QJGS*, 67, 415-469.
[82]*Op. cit*., (note 19, Geikie), i:218.
[83]Murchison's notebook, GSL, MN 61 (1832), p55, 'details corrected 1833'. He was at Powis Castle during 11-13 July 1832. Sedgwick's notebook (Sedgwick Museum, notebook 22, number 1 (1831), 10-14) mentions Welshpool, but not specifically the Castle, between Dudley on 3 August 1831 and Shrewsbury on night of 4 August. Both men's notebooks record a visit on July 2nd or 3rd 1834, (Sedgwick notebook 27, p.22; Murchison notebook 69, p.95). Sedgwick's specimen from Powis Castle Park was despatched on 12 July according to his notebook.
[84]*Op. cit*., (note 1, Murchison), 303. *Op. cit*., (note 81), 431.
[85]R. Cave and R.J. Dixon. The Ordovician and Silurian of the Welshpool area, p.61-62. In *Geological Excursions in Powys*, N.H. Woodcock and M.G. Bassett, (eds.), (1993), University of Wales Press, National Museum of Wales. The appearance of Ordovician rock at this place, and the age difference, proved by faunal assemblages, was noted by Dr Richard Cave (drafts for a geological walk around Welshpool, 1992). Dr Cave also suggests an alternative to Murchison's explanation for the repetition of the red conglomerate ridge.
[86]*Ibid*., 55.
[87]*QJGS*, (1895), 51, xiii. Obituaries also appear in *Geological Magazine* (1894) p.240; and in *Montgomeryshire County Times*, 17 March 1894.
[88]Car parking is at O.S. SO 430 844, about 300 metres from the river.
[89]*Op. cit*., (note 1, Murchison), 217.
[90]Among the fossils despatched on 12 July 1834 (Sedgwick's notebook, Sedgwick Museum, notebook 20).
[91]The angular unconformity is at O.S. SO 4264 8525, and first described in J.W. Salter and W.T. Aveline, (1854), On the Caradoc sandstone of Shropshire. *QJGS*, 10, p.70.
[92]W.B.R. King (1928), The geology of the district around Meifod, *QJGS*, 84, p.671, 'The Meifod district was visited by Sedgwick on various occasions in 1832 and again in 1842 and 1843, in the latter year with Salter'. Of course Sedgwick also visited in 1834.
[93]Murchison notebook, GSL 839, MN69 (1834), 77. Five fossils are mentioned, and Murchison classified the area as Caradoc [Lower Silurian]. He included 'coral of May Hill', which is modern Silurian, i.e., Murchison's Upper Silurian.
[94]*Op. cit.*, (note 92, King), p.676 attributes the collection to Sedgwick, but many were probably collected by Salter.
[95]King (*op.* cit., (note 92) and Temple (1970) made detailed studies of the fossils. J.T. Temple (1970), The Lower Llandovery brachiopods and trilobites from Ffridd Mathrafal, near Meifod. *Palaeontographical Society*, London.
[96]P.J. Brenchley, *et. al*., (2006), A late Ordovician karstic surface in a submarine channel, recording glacio-eustatic sea level changes: Meifod, central Wales. *Geological Journal* 41, 1-22.
[97]*Op. cit.*, (note 2, Secord), 81.
[98]P.J. Brenchley. The Ordovician of the South Berwyn hills, 48-50. In *op. cit.*, (note 85, Woodcock and Bassett).
[99]*Op. cit.*, (note 1, Murchison), 307.
[100]Sedgwick Museum, Sedgwick notebook 27 (1834), 15. 28 June. For Voel Vawr read Foel Fawr [Welsh = big bare hill].
[101]Personal communication from Dr Joe Botting, Leeds Museum. The *A. buchii* of Murchison and Sedgwick may have included other similar asaphids by default, some of which are hard to differentiate. *A. buchii* is now called *Ogygiocarella debuchii*, but the many names given to it in the past have caused confusion even to modern palaeontologists. It ranges from mid to Upper Ordovician, specifically from the Llanvirn stage, to the basal Caradoc. *Ogygiocarella* is replaced in some parts of central Wales (*e.g.*, Builth) by *A. angustissima*. Some asaphids are very hard to differentiate, and species probably ranged further than *Ogygiocarella*.
[102]British Geological Survey sheet 137, Oswestry. The fault bounded area is at SH 121 288. The source of the detail is described as a 1990 PhD thesis, although the area is fault bounded on the 1957 'Ten Mile Map'.
[103]Llanvirn age. The latest map says 'unknown thickness faulted out'.
[104]Sedgwick, (1852), On the classification and nomenclature of the Lower Palaeozoic rocks of England and Wales, *QJGS*, 8, 152.
[105]Sedgwick, (1845), read November 1843, On the older Palaeozoic rocks of North Wales, *QJGS*, 1, 12.
[106]Secord (*op. cit.*, note 2), p.65 discusses Sedgwick's enthusiasm for Élie de Beaumont.
[107]Sedgwick Museum, Sedgwick notebook 23 (1832), 34.
[108]*Op. cit.*, (note 105, Sedgwick).
[109]Murchison notebook, GSL MN 69 (1834), 86. Sedgwick notebook 27 (1834), 18.
[110]The distance is twenty miles, not thirty as stated by Sedgwick and repeated by authors.
[111]Murchison notebook, GSL MN 69 (1834), 84.
[112]*Op. cit.*, (note 19, Geikie), i:381. In 1842.
[113]*Op. cit.*, (note 104), i:154. In 1852.
[114]Sedgwick to Murchison, 23 July 1832. GSL 838, S11, 65. The sketch also appears in Clark and Hughes, i:394. Sedgwick adds that he had not yet seen the dark calcareous beds at Meifod and that he was arguing on an

imperfect case. Yet at some point in 1832 he collected limestone specimens at Meifod.
[115]The Berwyn is a dome, so the assumption that the Bala Limestone passes under the Berwyn is incorrect; it passes over the Berwyn, and there are multiple folds between the Berwyn and Meifod.
[116]D.A. Bassett, *et. al*., (1966), The stratigraphy of the Bala district, *QJGS*, 122, p.256.
[117]Sedgwick (1845). *op. cit.*, (note 105), 8-10.
[118]*Ibid*. (1845). It is not clear if the map accompanied the 1843 reading.
[119]Bassett (1966) cites B.B. Bancroft (1928), On the unconformity at the base of the Ashgillian in the Bala district. *Geological Magazine*, 65, 484-493. Bancroft was killed during the invasion of Normandy, 1944.
[120]*Op.* cit., (note 116, Bassett), 226. The unconformity resulted in the loss of the upper four Caradoc stages, plus the lowest Ashgill.
[121]The unconformity lies between the Rhiwlas Limestone, itself at the base of the Moelfryn Mudstones, and the underlying Gelli-grin Calacareous Ashes, which contain the very impersistent Cymerig Limestone. The two bands must have included part of the Gelli-grin Calcareous Ashes, and possibly the local equivalents of the Rhiwlas Limestone which appears on the west side of the lake as a result of faulting.
[122]Bassett (1966), 263-266. The Gelli-grin Calcareous Ashes are exposed at fourteen isolated localities. The Rhiwlas Limestone, only 5-8 ft thick (p.227), appears in a similar number of places; trilobites were studied from eleven locations.
[123]Although the brachiopod fauna is restricted, the trilobite fauna was the most diverse discovered in the Ordovician at that time, Bassett (1966), 262.
[124]*Op. cit*., (note 19, Geikie), 378), quotes Murchison to Sedgwick, 16 October 1842, 'I am certain there are inferior slaty greywackes in St David's which are much older than my fossiliferous Silurian, like those of the Longmynd'.
[125]Sedgwick to Murchison, 7 August 1846, GSL 838, S11, 235. From Carmarthen. Reprinted in Clarke and Hughes, ii:104.
[126]P.J. Brenchley and P.F Rawson, (eds.) (2006), Geology of England and Wales, p.34.
[127]*Ibid*., p.37.
[128]Not named after St David's, but after Salter's geologist friend, David Homfray.
[129]J.W. Salter, (1863), On the discovery of Paradoxides in Britain, *Quarterly Journal of the Geological Society*, 19, (1-2) 224-277. Porth-y-rhaw is 'one mile south of Whitchurch on the St David's road'. Salter says he was actually looking for Solva harbour.
[130]Letter from Salter, IIFF 1, 12 January 1863. Cambridge University Library.
[131]Secord (*op. cit*., note 2), 90, quotes Murchison to Whewell 18 July 1834. Dawkins (*op. cit*., note 4), 189, believes that Murchison 'was by no means satisfied as to the definite boundary between Cambrian and Silurian'.
[132]*Op. cit*., (note 1, Murchison), 308, is only one of several such references. Murchison also considers it 'obviously impracticable to draw a precise boundary line' in the Berwyn region (p.256), clearly regarding Sedgwick's authority as overriding any fossil overlap.
[133]*Op. cit*., (note 2, Secord), 98-100, discusses the naming. Murchison recalled that the Cambrian was named by Sedgwick in 1836, at Murchison's suggestion, see G.Y. Craig, (1971), Letters concerning the Cambrian-Silurian controversy of 1852, *QJGS*, 127, 496). Murchison touches on the subject in his address from the chair in 1842 (*Proc. Geol. Soc*., 3, pt2, 86, p.641).
[134]Apart from a spell in north Pembrokeshire while working on the Devonian issue.
[135]Sedgwick was at his annual residence as a canon at Norwich cathedral, and bound to remain in the city during this time.
[136]*Op. cit*., (note 9, Clark and Hughes), 474-480, including letters from Murchison to Sedgwick, 30 January and 2 February 1837, and Sedgwick to Lyell, 4 Feb 1837. See also (note 19, Geikie), ii:23). The paper was finally read 31 May and 14 June 1837: On the physical structure of Devonshire and on the subdivisions and geological relations of its older stratified deposits.
[137]W. Whewell, (February 1834), *Proc. Geol. Soc*., 2, 634.
[138]Sedgwick, (1838), Synopsis of the English series of stratified rocks inferior to the old red sandstone, *Proc. Geol. Soc*., 2, 679.
[139]*Ibid*., p.675
[140]*Ibid*., p.679 states the strikes. In North Wales some younger rocks exhibit a north-east strike but this is not generally true. In any case there was only one orogeny and it led to the north-east Caledonian trend, resulting from continental collision from the north-west.
[141]J.L. Morton, (2004), *King of Siluria*, Brocken Spectre Publishing, 79.
[142]Sedgwick, (1841), Supplement to a synopsis on the English series of stratified rocks inferior to the old red sandstone, *Proc. Geol. Soc*., 3, 541-554. Page 549 refers to an examination of fossils *of* the author, not *by* the author. Salter was then in Sedgwick's employ.
[143]Sedgwick to Murchison, 24 January 1836, GSL 838, S 11, 96. Secord (*op.* cit., note 2), 56, observes these remarks are touched by more than a shade of jealousy.
[144]A band of Mountain Limestone (Carboniferous limestone) is exposed roughly from Prestatyn, south to Oswestry. The older rock lying to the west of it had eroded before deposition of the limestone, leaving a confusing break in the succession.
[145]Henry de la Beche wrote to Murchison in 1843, describing the folding as a great roly poly extending Murchison's Silurian rocks to Cardigan Bay.
[146]Sedgwick to Murchison, November 1837, GSL 838, S 11, 138. Sedgwick's biographer states that although Murchison's note on Sedgwick's letter says that Sedgwick only reviewed these three pages, in fact he also reviewed the introduction, making changes of which Murchison approved (i:501 f.n.). The introduction to *Silurian System* is complimentary to Sedgwick, respects his authority and contains nothing that might have dismayed him.
[147]*Op.* cit., (note 9, Clark and Hughes), ii:531.
[148]*Ibid.* f.n.3, Sedgwick to Murchison, 27 & 29 March 1838. These letters are not held in the Geological Society library with other Sedgwick letters to Murchison.
[149]Sedgwick to Murchison, 10 January 1839, GSL 838, S11, 149. Sedgwick's biographer, however, says Sedgwick's admiration of the book was sincere to the end of his life (*op. cit*., (note 9), i:522).
[150]Sedgwick to Murchison, 4 Feb 1839, GSL 838, S 11, 150.
[151]*Op. cit*., (note 9), ii:219. Murchison said Logan and others had told him this.
[152]Murchison, ever determined to establish his priority, says on p.27 of a later book, *Siluria*, that *Silurian System* was issued in 1838 and quoted by another author in that year, although the year 1839 appears on the title page.
[153]J. Challinor, (1971), *The history of British geology*, David & Charles, Newton Abbot. Challinor was a senior lecturer at Aberystwyth University.
[154]Murchison to Sedgwick, Feb 1839. Add. 7652, iiiD.20. Cambridge Univ. Lib.
[155]Murchison to Sedgwick, 7 Feb 1839. Add. 7652, iiiD.21. Cambridge Univ. Lib.
[156]W.H. Fitton, (1841), Review of *Silurian System*. In *Edinburgh Review*, 73, 38-41. Fitton was president of the Geological Society 1827-1829.
[157]Report of the British Association, 1840, pt ii:100-102.
[158]*Op. cit*., (note 9, Clark and Hughes), ii:47-8. From mid-July to late-September when he returned for his residence at Norwich.
[159]*Op. cit*., (note 19, Geikie), i:381-2, f.n. Geikie quotes Sedgwick's autumn letters to Murchison.
[160]Secord, *op. cit.*, (note 2), 152-3, quotes from the correspondence.
[161]Murchison (1842), *Proc. Geol. Soc*, 3, pt. 2, number 86, 641. presidential address. He also cited work in Germany, Belgium and Russia to prove the point.
[162]*Op.* cit., (note 105), 12. Sedgwick (1845), read 1843, records his annoyance. But Geikie (note 19), ii:1, states that Murchison sent a draft of part of the map to Sedgwick (letter dated 24 February 1843) asking him to insert some features on it.
[163]D. Sharpe, (1843), On the Bala Limestone, *Proc. Geol. Soc*., 4, 14.
[164]Murchison to Sedgwick, 16 October 1842. Camb. Univ. Lib. Add. 7652, Notebook iiiD (letters 19-37), 37. For discussion see Geikie, *op. cit.*, (note 19), i:376-384.
[165]*Op. cit*., (note 19, Geikie), i:380.
[166]Sedgwick (1843), Outline of the geological structure of North Wales, *Proc. Geol. Soc*., 4, 212-224. The final paragraph is critical.
[167]Sedgwick reported that it brought to a happy end the revisions begun the previous year.
[168]*Op.* cit., (note 19, Geikie), ii:61, f.n.
[169]Murchison (1847), On the meaning originally attached to the term 'Cambrian Systerm' and on the evidences of its being geologically synonymous with the previously established term 'Lower Silurian'. *QJGS*, 3, 175.
[170]Sedgwick to Murchison, 18 October 1853, GSL 838, S 11, 281. This long letter is dealt with in note 9 (Clark and Hughes), ii:250-256. The word 'scurvily' appears on p.256.
[171]*Op. cit.*, (note 9, Clarke and Hughes), ii:216.
[172]Sedgwick (1852). Read 25 February. On the classification and nomenclature of the Lower Palaeozoic rocks of England and Wales. *QJGS*, 8, 136-168. See p.152 *et. seq.*, for remarks about Murchison, and about the

Society's president, Warburton. Sedgwick also discusses Warburton's role in Sedgwick to Murchison, 18 October 1853. GSL 838, S11.281. See also Clark and Hughes, ii:251.
[173]Murchison to Sedgwick, 27 February 1852. *op. cit.*, (note 9), ii:218-9.
[174]Sedgwick (1853). Read November 1852. On a proposed separation of the so-called Caradoc Sandstone into two distinct groups, *QJGS*., 9, 215-230.
[175]*Op. cit.*, (note 173).
[176]*Op. cit.*, (note 174), 218.
[177]*Ibid*.
[178]Sedgwick (1854), On the May Hill Sandstone, and the Palaeozoic System of the British Isles, *QJGS*, 10, 366. Abstract only.
[179]*Op. cit.*, (note 91, Salter and Aveline).
[180]Sedgwick to Murchison, 18 October 1853, *op. cit.*, (note 170). See Clark and Hughes, ii:255.
[181]*Ibid.* Sedgwick mistook the upper bridge for the lower (the bridge to Cheney Longville, a few hundred metres downstream of the unconformity). Knowing that the Caradoc rocks extended well downstream of the upper bridge, he then mistakenly mapped the Caradoc as extending well downstream from Cheney Longville Bridge, thus overlapping the Pentamerus beds. Thus, he rightly included the (modern Caradoc) *Orthis alternata* brachiopods, but wrongly included the (modern Silurian) *Pentamerus* brachiopods in the Caradoc sequence.
[182]*Op cit.*, (note 2, Secord), 271. Murchison to McCoy, 10 January 1853.
[183]*Op. cit.*, (note 170), ii:256.
[184]R. I. Murchison, (1872), *Siluria*, John Murray, London. Annex A, vertical range of the Silurian fossils in Britain. Republished as facsimile (2005), by Elibron Classics.
[185]Clark and Hughes, *op. cit*., (note 9), ii:277. A note prefixed to his paper read at the British Association, Liverpool, September, 1854.
[186]Murchison to Sedgwick, 30 April 1855. Camb. Univ. Lib. Add. 7652, notebook iiiD, 71.
[187]Geikie, *op. cit*., (note 19), ii:206. Also Clarke and Hughes, ii:304.
[188]*Op. cit.*, (note 184, Siluria),103.
[189]*Op. cit*., (note 19, Geikie), ii:312-14.
[190]Murchison to Sedgwick, 22 May 1861. Camb. Univ. Lib. Add. 7652, Notebook iii D, 84.
[191]G. Y. Craig (1971), Letters concerning the Cambrian-Silurian controversy of 1852. *Journal. Geol. Soc*, 27, p.498.
[192]Sedgwick to Murchison, 2 January 1869. Quoted in Speakman, (1982), *Adam Sedgwick, Geologist and Dalesman*, published jointly by Broad Oak Press, Geol. Soc. and Trinity College, Cambridge. p.83.
[193]Murchison to Sedgwick, 6 January 1869, but not sent. Speakman (*ibid.*) sources it in the Camb. Univ. Lib.
[194]Murchison to Sedgwick, 7 January 1869. Quoted in Clark and Hughes, *op. cit.*, (note 9), ii:441.
[195]Sedgwick to Murchison, 20 January 1869. Quoted in Speakman, (1982). *op.cit*., (note 192), 84.
[196]Sedgwick to Murchison, 21 February 1869. Quoted in Clark and Hughes, *op. cit.*, (note 9), ii:441-2.
[197]*Op. cit.*, (note 9), ii:459.
[198]Trenham Reeks of the Geological Society came in daily to help him with his post
[199]*Op. cit*., (note 19, Geikie), ii:344.
[200]J.W. Salter (1873), *A catalogue of the collection of Cambrian and Silurian fossils in the University of Cambridge*. Sedgwick's preface is dated 17 September 1872. His introduction to McCoy's work earlier also contained a rant.
[201]Speakman, see *op. cit.*, (note 192), 85.
[202]Sedgwick (1852), On the meaning of the term 'Silurian System' as adopted by geologists in various countries during the last ten years. *QJGS*, 8, 168.
[203]Dawkins, *op. cit.*, (note 3), 201.