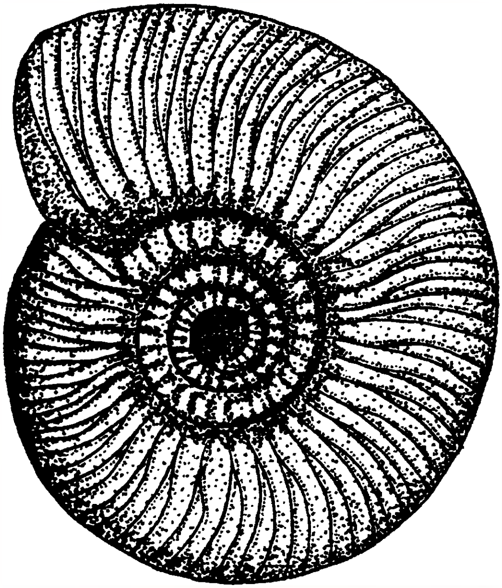
THE CUMBERLAND GEOLOGICAL SOCIETY



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EDITOR'S NOTES

I would like to thank all those who have contributed articles, provided lecture and excursion notes and assisted in the preparation of the Proceedings.

The Proceedings is a biennial publication that caters for contributions on all aspects of geology and geomorphology of northern England. Contributions are welcome and should be submitted to the Editor.

Chris Thompson, Editor.

Published by the Cumberland Geological Society, March 2000

General Secretary: Dr R. A. Smith,
[redacted]

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Introduction

GEOLOGICAL PIONEERS IN THE LAKE DISTRICT

At a meeting of the Council of the Society in 1999 the posed the question was raised of undertaking some special activities or events to mark the Millennium.

Although there was general agreement that it would be appropriate to mark the event in some way it was agreed that it should be in keeping with the prime purpose of the Society.

Following discussions it was agreed that a suitable way of marking the Millennium would be for this volume of the Proceedings to review the work and contributions of some of the geological pioneers in the Lake District. At the outset it was agreed that no living workers would be included. It was also recognised that there were likely to be difficulties in obtaining information for some workers, and this is reflected in the varying lengths and level of detail in the articles.

This is the first time that a thematic volume has been produced by the Society. This volume is also notable for the number of contributors, all members or friends of the Society, who have given significant time and effort to produce the articles.

The papers are generally arranged in chronological order, and it is readily apparent how much of the work of individual pioneers has built on the work of their predecessors and the co-operation that so often occurred. Also of note, in view of the make-up of the membership of the Cumberland Geological Society, is the impact that 'amateurs' have had on furthering geological knowledge in the area.

To complement the theme of the Proceedings, the year 2000 field excursions will focus on some of the pioneers described in these Proceedings.

Thanks are due to Dick Clark and Mervyn Dodd for their valuable assistance in the editorial process.

Chris Thompson
Editor
March 2000

JONATHAN OTLEY (1766-1856)

FATHER OF LAKELAND GEOLOGY

Dr. Alan Smith

Outside Cumbria the name of Jonathan Otley is not well known and in national geological circles his contribution to Cumbrian geology is scarcely noted. In any review of the 'Geological Greats ' of the district, however, he rightfully must come first. His pioneering work in the district was acknowledged by Adam Sedgwick in the 1830's and J.E. Marr in 1916 gave him the title of 'Father of Lakeland Geology'.

Otley was the true pioneer; the local man who walked the ground and came to know it like the back of his own hand. He had the eye not only for the local detail but the amazing ability, so early in the nineteenth century, to see the broader picture of this structurally complex region. Otley unselfishly fed this local knowledge to Sedgwick and others, and has remained the unsung hero. Otley led Sedgwick on a number of excursions around the district, starting in the summer of 1823. This was the start of a long association between the two men. Fortunately much of their correspondence remains and provides a great insight into the early geological work in the district. Otley also corresponded with many other eminent scientists of the time, including John Dalton, (another Cumbrian); G.B. Airey, the then Astronomer Royal, and the geologist Professor John Phillips, the Museum Curator at York. He also met William Smith and accompanied him in his field work although their meeting was apparently not totally amicable.

Jonathan Otley was born in October 1766 at Loughrigg, near Grasmere in south Lakeland. Although he was a child from a humble family he was encouraged to study and attended schools in both Langdale and Ambleside. Up to the age of 25 he worked with his father making baskets, but he also developed the skills of watch and clock repairing. In 1791 he moved north to Keswick, where, within a short time, he had established himself in a small town centre cottage and workshop to be known locally as 'Jonathan Otley's up t'steps'. From there his business as clock and watch repairer flourished, but, more importantly, this was the base throughout his long life for the exploration of the Lake District, and for his interests in map making, geology, meteorological observations and natural history. Fittingly the building still stands and his life and work are commemorated in a plaque alongside the old steps to his cottage door. From this humble cottage workshop he produced his writings and, most particularly, in 1818, his now famous map of the Lake District and in 1823 the accompanying guide book - *A concise description of the English Lakes and adjacent mountains*. It eventually ran to 8 editions in the period up to 1849, selling over 8000 copies - all now collectors' items. Within this guide book his essay *The Geology of the Lake District* originally written in 1820, was the first published account of the rocks of the district and was undoubtedly a seminal work.

Otley was a quiet, reserved, modest man who never married. It is clear from his correspondence and from contemporary accounts that he was renowned as a listener rather than a talker, a thinker who offered an opinion only when he had thought through and grasped the whole matter. He also had the habit of very careful field observation and a love for accuracy of detail. He was not a particularly prolific writer but what he did produce was done with great care and was plainly to the point. His earliest work was a paper on the Black Lead Mine (plumbago) in Borrowdale, read before the Manchester Philosophical Society on December 27th 1816. It was a comprehensive account of what was then known about this unique deposit. In 1819 the same Society published his paper on *The Floating Island in Derwentwater* - the first systematic account of this feature compiled from his very detailed field observations, done over many seasons. He was able to describe how the island occasionally rises from the bottom of the lake to the surface, and how it is related to periods of dry summer conditions between June and September. He saw it was related to decaying vegetation liberating gas, which gave buoyancy to the mat of vegetation. In a letter to John Dalton in September 1815 he refers to samples of the gas which Dalton had analysed for him, and of samples of the vegetative matter which he had systematically sampled from the surface, from varying depths within the island and from the water beneath. This was typical of the thoroughness of his observational work in the field. There was a second paper of further observations of the island in the same journal in 1831, illustrating his perseverance in continuously observing natural phenomena.

It is in his guide books, however, that Otley made his great contribution to Lakeland geology. This was the medium where all his talents and interests came together and found full expression. He was a local guide, a map maker and engraver, a person who knew the mountain routes and the topographic detail. His geological, meteorological and natural history observations gave the books real substance.

He actually published his essay on the geological structure of the Lake District in the Philosophical Magazine in 1820 and also in the first volume of a short-lived local journal, *The Lonsdale Magazine*, in the same year. However, it was in the guide books that the material was most read and progressively developed in the various editions up to the middle of the century. In the first paragraph of the 1830 edition of the Guide he remarks ..."at the time this essay was first published in 1820 the structure of the mountainous district of Cumberland, Westmorland and Lancashire was but little understood; scientific travellers had contented themselves with procuring specimens of the different rocks, without taking time to become acquainted with their relative position". He goes on to point out that... "the greater part of the central region of the Lake mountains is occupied by three distinct groups of stratified rocks of a slaty texture". These he called the Clayslate, Greenstone and the Greywacke - remarkably perceptive descriptions of the three familiar group of rocks which we now know make up the Lower Palaeozoic inlier of the Lake District and we now term the Skiddaw Group, the Borrowdale Volcanic Group and the Windermere Supergroup. Otley had clearly worked this out long before 1820. In September 1823 he introduced Sedgwick to the rocks of the Skiddaw area in the first of their field excursions. It was not until 1831 that Sedgwick first went into print with his ideas on the structure of the district. In his address to the Geological Society of London in that year he acknowledged that it was Otley who first recognised the three distinct groups of stratified rocks in the district. Later, in 1836, Sedgwick in a paper to the Geological Society entitled *Introduction to the General Structure of the Cumbrian Mountains* after describing the various subdivisions of the altered slate around the Skiddaw Granite (the location of the pair's first excursion in 1823) goes on to say "we owe our first accurate knowledge of these subdivisions to Mr Jonathan Otley of Keswick, who not merely described them in general terms but gave their geographical distribution with a very near approach to accuracy".

An examination of Otley's descriptions of the three great rock groups of the Lake District reveals not only his intimate knowledge and observations of the area but, more importantly, his insight into what these rocks were telling him of their history. The 'Clayslate' (Skiddaw Group) he recognised as the oldest group and commented on its great structural complexity. He remarks on its lithological variability, its weaknesses as a useful building material, its intrusion by complex dyke systems and its rich mineralogical associations. Equally his descriptions of the 'Greenstones' (the volcanics) were remarkably accurate. Not only was he able to describe what he saw, he also seemed able to perceive which features did not quite fit into the general pattern of things and perhaps had special circumstances surrounding them. He clearly drew the distinctions between the porphyritic lavas and what we now know are the pyroclastic materials with a strong slaty structure. But, even more intuitively, his observations of the volcanics on Binsey and of the northern Caldbeck Fells were telling him there was something rather different here. Only relatively recently has it been demonstrated that they are in fact a chemically distinct group and the product of a separate early phase of the mid-Ordovician island arc volcanic sequences (the Eycott Group). He knew of the red haematite breccias at the base of the Lower Borrowdale Volcanic Group in the Keswick area and carefully described the presence of garnets in certain volcanic horizons - a problem that was later to fill a great deal of space in the geological literature on the district.

'The Greywacke' (Windermere Supergroup) of the southern Lakes he observed with equal insight. In his guide we read ... "The Third Division - forming only inferior elevations - commences with a bed of dark blue or blackish transition limestone, containing here and there a few shells and madrepores, and alternating with a slaty rock of the same colour; the different layers of each being in some places several feet and in others only a few inches in thickness. This limestone crosses the River Duddon near Broughton; passing Broughton Mills it runs in a N.E. direction through Torver, by the foot of the Old Man mountain, and appears near Low Yewdale. Here it makes a considerable slip to the eastward, after which it ranges past the Tarns upon the hills above Borwick Ground, and after stretching through Skelwith, it traverses the vales of Troutbeck, Kentmere and Longsleddale;....". To have produced such an accurate description of what has since been known as the faulted outcrop of the Coniston Limestone not only illustrates pioneeringly perceptive geological mapping but immense physical effort tramping on foot over terrain which even today is not highly accessible nor hospitable. Bearing in mind this was a time long before the existence of accurate Ordnance Survey maps his achievements are all the more remarkable.

Perhaps Otley's greatest geological achievement was his exposition of the relationship between bedding, cleavage and jointing in the Lake District rocks. Even today the fundamental differences between these properties and their structural implications are not always easy to grasp, and in many field situations in Lakeland they have to be established before the geological story can be revealed. His early observations were later refined by John Phillips and others, but Otley was the instigator.

Many other examples of his field observations and early understanding of Lakeland rocks and landscapes exist. He clearly understood the zonation in the metamorphic aureole surrounding the Skiddaw Granite and introduced Sedgwick and others to that area. He delineated the Shap and Eskdale Granite intrusions and described the Armboth Fell Dyke. Interestingly he did not differentiate between the Eskdale Granite and the Ennerdale Granophyre and says little about the Carrock Fell Complex. Surprisingly he seems to have had little interest in palaeontology, referring only fleetingly to fossil finds. He appears to have been rather unsure how to explain the existence of 'erratic' boulders. His knowledge of the pattern of outcrops and of the topography was telling him that these stray boulders needed explaining. He describes and locates many examples and saw they had been carried, often across the topography, by some powerful erosive agent. Some, like the Bowder Stone in Borrowdale, he rightly saw as a products of rock fall. What he described as "rounded and smoothed surfaces ... some striped and scored in a remarkable manner" in Borrowdale and Langdale also illustrates his uncertainty about geomorphlogical processes. His conclusion however that "some, who have become converts to a recently promulgated theory will attribute those appearances to the agency of GLACIERS; but the action of WATER seems more intelligible to the mere English Geologist".... leaves no doubt where he stood on this debate.

There is doubt whether Otley ever produced a geological map of the Lake District. None was ever published. It is hard to believe that someone with Otley's talents for map making and his knowledge of the regional geological pattern did not at least produce some drafts of sketches of a geological map. Otley and Sedgwick clearly exchanged topographical sketch maps. A letter from Otley to Sedgwick of January 30th 1828 refers to some errors Sedgwick had incorporated in a map of the Skiddaw area. More interestingly, Sedgwick in a letter to Otley dated February 14th 1847 writes ... "Do you wish to publish a geological map of your country, on a scale of your Lake map? If so, I would most willingly help you to the best of my power; and you might use my name in any way you thought fit. I think such a map, with a short explanatory sheet, might have a sale". Sedgwick clearly seems to suggest Otley should commit his knowledge of the region on to a map, but nothing remains to suggest he ever completed it.

Jonathan Otley undoubtedly laid the foundations of Lakeland Geology. He set up the framework for others to elaborate. Because he was an amateur and a Cumbrian who appears to have rarely ventured much beyond the County, he has received less recognition than he deserves. His friendship with Sedgwick was lifelong. There are records of field excursions together in 1823 and 1824 and correspondence between the two men for almost 30 years between 1827 and 1855. Sedgwick came to see Otley on his deathbed, speechless and paralysed, days before he died aged 91 on December 7th 1856. It is arguable that without Otley's pioneering work in the district Sedgwick and others would not have been able to make such early progress in deciphering the region.

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Dr. R. A. Smith
[redacted]

ADAM SEDGWICK (1785-1873) AND LAKELAND GEOLOGY (1822-24)

THE FIRST PROFESSIONAL LAKE DISTRICT GEOLOGIST

Prof. David Oldroyd

One of the great founders of British geology was the Cambridge professor, Adam Sedgwick (1785-1873). Aspects of his work have been intensively studied by Rudwick and Secord, regarding his role in the establishment of the Devonian and Cambrian Systems respectively. Earlier, Sedgwick was the subject of a two-volume Victorian 'Life and Letters' by Clark and Hughes, and there is a short non-technical biography by Speakman.

Sedgwick's studies in the Lake District, which provided the conceptual and methodological foundation for much of his subsequent work, have not been closely studied. In fact, despite Sedgwick's importance in the history of geology, there has been little detailed examination of just how he worked as a young man. I have therefore examined how Sedgwick carried out his investigations with the help of a study of his field notebooks for his work in the Lake District for 1822, 1823, and 1824. From these notes, we can learn something about how early nineteenth-century geologists went about their work; and how one such as Sedgwick began to study the geology of a complex region where little systematic fieldwork had been undertaken previously.

Sedgwick came from Dent in the Yorkshire Dales, to the south-east of the Lake District. His father was the local parson, and the family seems to have been reasonably well off. Adam was the third of seven children. He went to a nearby school of some reputation, Sedbergh, and on to Trinity College, Cambridge. There he studied mathematics and theology with great diligence, and in 1808 he was fifth in the University for mathematics (5th Wrangler). This led to a fellowship (by further examination) at Trinity in 1810, and then to the geology chair in 1818. The present geology department at Cambridge has its museum named in Sedgwick's honour, and his private notebooks and some manuscript maps are held there.

The story of Sedgwick's appointment has often been told. According to a statement that Sedgwick himself originated, there were two applicants, and although Sedgwick knew no geology he got the position since what the other candidate knew was wrong! This story cannot be entirely true. Sedgwick's fragmentary autobiography, preserved among his papers at Cambridge University Library, tells us that as a lad he became intrigued by the rocks and fossils that could be seen near Dent and he realised how the structure of the strata along the sides of the valley could be understood. Sedgwick suffered a breakdown in his health in 1813 and it is surely relevant to the present enquiry that he recuperated by taking a walking holiday in the Lake District. He was actively geologizing on the Continent in 1816, and was 'introduced' at the Geological Society that year. He was elected Fellow of the Society in 1818 and FRS in 1821, with Sir John Herschel heading the list of twelve who nominated him. No doubt the Cambridge chair smoothed the path to the Fellowship.

Immediately after being elected professor, Sedgwick began fieldwork in a serious way. He went to Derbyshire, Somerset, and Cornwall in 1818-19. He went to Wiltshire, Somerset, and Dorset in 1820, to the Yorkshire coast and Teesdale in County Durham in 1821; and in 1822 he worked his way north through Nottinghamshire and Lancashire, and into Cumberland, thus initiating his Lakeland work proper. In 1823, he went again to Yorkshire and to Cumberland; and in 1824 he spent the whole season in the Lake District. He returned in 1833, 1835, 1845, 1851, and 1857, but his major survey work in the region was done in the years 1822-24 and his later efforts will not be examined here.

Lakeland geology is difficult, compared with that of southern Britain. The terrain is tough, and the rocks are very confused, in most places quite different from the nicely layered fossiliferous strata of the Yorkshire Dales where Sedgwick had grown up. So how did Sedgwick go about his task?

First let me say something about Sedgwick's financial situation, as background to his work. His income in 1822 from his chair and his College fellowship was £407 6s 8d, but, depending as it did on Trinity's financial well being, it declined in the following two years to £283 1s 0d and £232 15s 8d, but he probably had additional income from private pupils. I have no evidence that Sedgwick obtained financial support for his fieldwork, but being unmarried he would, I think, have had sufficient money to be self-financing. He was in the field from about the beginning of June until mid-October each year.

Sedgwick travelled by carriage, on horseback, or on foot. His obituarist John Phillips stated that Sedgwick travelled chiefly on horseback when in the field, but this cannot have been the case for many of the localities that he visited in the Lakes. Sedgwick had a portable writing desk, a leather specimen bag, and an assortment of hammers, which are now on display in the Sedgwick Museum. He also used a portable laboratory, though his notes say little or nothing about the results obtained with it. No doubt he had an acid bottle though.

For accommodation, Sedgwick stayed with friends or at local inns. There is no record of his having made arrangements in advance of his arrival. So I cannot say whether he just 'turned up', or made elaborate prior 'bookings'. But one is struck with the way everything slotted into place so far as accommodation was concerned, despite the fact that he seemed to leave little time to organise his domestic arrangements, being out in the field all day and every day, except for Sundays, when he attended church. Often he was in the field for fourteen hours or more. There is a record that when Sedgwick was visited by his colleague William Whewell in 1824, both were in 'breathless haste'.

Just as Sedgwick's accommodation arrangements worked smoothly, so too did his transport. There always seemed to be a carriage waiting at an appropriate spot, or a horse. Again, I do not know whether he planned everything carefully beforehand, or altered arrangements from day to day according to the weather and the exigencies of fieldwork. I suspect the latter. However, one thing is certain: he used local people as guides at virtually all stages of his fieldwork, and John Phillips recorded that when he met with Sedgwick by chance in the field in Teesdale in 1822 he had a miner's boy with him as a guide.

Sedgwick seemed to be remarkably little bothered by the weather. There were occasional days when he did not attempt to go out because of rain, but he never mentions problems due to cloud, and he was rarely driven home by rain, despite the Lake District's high rainfall. It may be noted, however, that in 1824, which was the year that Sedgwick made his greatest effort in the field, the Lakes had an exceptionally dry summer.

The question of maps available to and used by Sedgwick is important. There was a map of the Lakeland region by Thomas Donald (2nd edn, 1810, but originally surveyed in 1771), and we know that Sedgwick possessed a copy, for it still exists in the Sedgwick Museum. But at two miles to the inch Donald's map lacked detail and Sedgwick mentions numerous places and topographic features in his notebooks that do not appear on Donald's map, or any other published map available at that time. It may be noted that Sedgwick complained in his notes on several occasions about the inaccuracy of 'the map' and once he mentions Donald by name. One can see, by comparing Donald's work with modern survey maps, how inaccurate his map was.

Significantly improved topographic maps for the Lakeland counties, Cumberland and Westmorland, were published in 1823 and 1824 by C. and J. Greenwood, having been surveyed in 1821-22 and 1822-23 respectively. But even these did not give all the detail that Sedgwick mentions in his notebooks. Therefore, much of Sedgwick's information about local topography must have been supplied by guides.

Sedgwick's geological map of the Lakes was only published as late as 1835, the paper in which it appeared having been read to the Geological Society in 1831. Sedgwick's manuscript geological map of Cumberland (only), entered on an edition of Donald (1802), is preserved at the Sedgwick Museum, it is interesting to consider how and when this was coloured in.

On his days off in the field, due to rain or the Sabbath, Sedgwick frequently mentions writing up his journal ('journalise', he wrote), but he says little about maps. He probably synthesised his Lakeland work some time in the years 1825 to 1830, and the manuscript Cumberland map probably dates from that period. Interestingly, an annotation in the hand of George Greenough to a published map of Westmorland by John Cary (1811), held at the Geological Society, states that 'a map of Westmorland on a large scale was published by Hodgson at Lancaster in 1828 coloured geologically by Prof. Sedgwick'. I have not located Sedgwick's Westmorland map, but the annotation may give a clue to the approximate date of the colouration of his surviving Cumberland map.

Sedgwick's journals for 1822-24, name no fewer than fifty-one persons in the Lakes with whom he journeyed, stayed, dined, or conversed, or who acted as his guides. These included farmers, miners, the Lakeland poets Robert Southey and William Wordsworth, and local naturalists. His most important scientific contacts were two Keswick residents: the engineer and surveyor, Joseph Fryer; and the local guide, naturalist, meteorologist, cartographer, and clock repairer, Jonathan Otley (1766-1856).

Otley was a man of many parts. Interested in meteorology and an authority on local topography, he knew the Lakes like the back of his hand. In connection with his business as a guide, he published a topographic map of the region in 1818. In 1823, he extended this into a full guidebook, which incorporated the map, and also contained information about the local mineralogy and geology. This contained a stratigraphic subdivision of the Lakeland rocks, which Otley had already published in a local journal.

Thus, Sedgwick undoubtedly learned much from Otley, besides how to find his way around in the mountains. Most importantly, there was Otley's division of the Lakeland strata into three main categories. First, there were the dark rocks of the northern Lakes, now called the Skiddaw Group, forming mountains such as Skiddaw, near Keswick, with generally rounded profiles. South of this unit, there was a more varied group, with slates of blue or green colour, forming the knobbly hills of central Lakeland. These are now called the Borrowdale Volcanic Group, but Otley called them the 'Greenstone division'. Third, there was a group forming the gentler region of the southern Lake District. The lowest member of this third unit was a quite narrow band of fossiliferous limestone associated with slaty rock; while other members of the unit (now collectively called the Windermere Supergroup) were true slates. The limestone, which Otley suggested, in Wernerian terminology, might be a 'Transition Limestone', ran right across the Lake District, roughly from west to east. Subsequently, it came to be known as the Coniston Limestone.

Otley further noted that the slates of the northern part of the middle division appeared to be generally inclined to the north and those of the southern part inclined south. It was, he said, 'as though the mountain ridge, dividing the counties of Cumberland and Westmorland, had acted as a wedge in separating them'. So virtually the first scientific paper on Lakeland geology laid down a broad stratigraphic classification that has lasted until the present. Moreover, an important suggestion about general structure was proposed. Additionally, Otley distinguished between bedding, jointing, and cleavage-features that may easily be confused in the Lakes. Sedgwick himself said that he did not at first understand the difference properly; and it was Otley who taught him.

In his published description of Lakeland geology, based on his fieldwork of 1822-24, Sedgwick described the outcrop of Otley's 'Transition Limestone' (a term that Sedgwick himself deployed in his notebooks) as if he had traced it in the field from west to east. He described how the outcrop would continue steadily for a while, and then be displaced to the north or south for perhaps up to three miles. Sometimes a large lake or valley could be found associated with the line of displacement.

On the basis of his published paper, it would appear that Sedgwick followed the outcrop of limestone, using it as a marker band. But in practice this was not what he did, as his notebooks reveal. Rather, he would stay in one spot for three or four days and range out from there in several directions. In fact, Sedgwick's 'journals' provide enough information to enable one to trace his movements approximately on modern 1:25,000 maps. When this is done, one can see how he ranged over the country so that after three years' work he had covered, albeit hastily, most of the Lakeland terrain. And when his observations were transferred to his map, perhaps back in Cambridge, the outcrop of the 'Transition Limestone', and other important features such as the granites near Eskdale and Skiddaw, or Otley's three types of slates, would have emerged as the various areas of the map were coloured in. In fact, not all the Limestone's outcrop was covered even in the same year. It is true that for some days Sedgwick would become particularly interested in the Limestone and he was evidently following its course; but he did not do so consistently. Actually, he very likely knew what to expect, for even in his short paper of 1820 Otley had indicated in words the general outcrop of the 'Transition Limestone'.

Sedgwick's notebooks contain much information about different rock types, the lines of their outcrop and the boundaries between them, and, most particularly, information about dips and strikes ('ranges' as he called them); also the bearings of principal topographic features. His interest was evidently lithological and structural, and in his early Lakeland work he gave little attention to fossils.

There is so much numerical information about dips and strikes in Sedgwick's journals that one wonders how he remembered it all. Were rough notes made during a day's excursion, and then entered up in the journal in the evenings, or did he just have a phenomenal memory? I have no means of answering this for certain, but I believe that there must have been rough notes used to compile the surviving notebooks. So we have several stages of knowledge filtration and construction:

1. Observations in the field;
2. Writing of rough notes;
3. Composition of the 'Journal' and the destruction of the original notes;
4. Preparation of geological maps from the 'Journal';
5. Composition of a paper for public presentation and evaluation, perhaps in the light of higher geological theory or some ongoing theoretical controversy;
6. Defence of the paper at the meeting of some learned society (usually the Geological Society);
7. Revision of the paper, and its refereeing;
8. Further revision and eventual publication.

Sedgwick's journal/notes contain few sketches and those there are are unimpressive. His procedure seems to have been to cover as much ground as possible in a fairly theoretically neutral or positivistic way, and fill in a map. His categories for this were very simple, but that was doubtless to his advantage in dealing with such a difficult area in pioneering fashion. By contrast with the impoverished petrographic categories, there was a wealth of detail regarding dips and strikes of beds and of cleavage. Little immediate attempt was made to draw sections (in contrast to the notebooks of his later friend, and eventual enemy, Roderick Murchison).

As said, Sedgwick's petrographic vocabulary was impoverished. He often referred in his journal to a rock type by its locality or approximate appearance. Thus we have the 'Wallow Crag' type; the 'Barrow rock'; 'the concretionary'; 'the porphyry'; or even 'the blue'. Interestingly, some of these terms appear in Otley's writings, so Sedgwick probably got them from him, but he did not use them in his published work.

Back at Cambridge, Sedgwick's positivism dropped away to some extent as he developed grander, theoretical pictures. For example, when his map was finished it was obvious from its outcrop that the 'Transition Limestone' had been affected by massive faults that cut across the outcrop, wrenching it into a number of severed fragments; from which it appeared that the whole region of the Lakes had been upheaved and fractured. Then the great valleys, such as those of Windermere or Coniston, had subsequently been carved out along the lines of weakness produced by the faults. Later, when he published his work, Sedgwick suggested that the movements were caused by the intrusion of the great masses of igneous rock, such as the granites near Eskdale or under Skiddaw.

Since Sedgwick made no effort to squeeze the history of the district into a Biblical time-scale, there was no problem about the erosion of the lines of fracture taking an indefinitely large time. But the fractures, he thought, were produced by what were called at the time (by William Whewell) 'catastrophic' earth movements, acting for a relatively short time, before the subsequent unconformable deposition of the New Red Sandstone round the margins of the Lake District. Thus the arguments of Reijer Hooykaas, that catastrophism could be scientific and empirically based are well supported by Sedgwick's example. His catastrophism was not just a form of physico-theology. It was grounded in, and warranted by, an enormous effort of fieldwork.

Over and above Sedgwick's catastrophism, he sought to account for what he had seen in the Lakes with the help of the overarching theory of Élie de Beaumont, though with some caveats. In agreement with the Frenchman's doctrines, Sedgwick asserted that the main lines of mountain chains in the Southern Uplands of Scotland, the Lakes, Wales, the Isle of Man, and Cornwall, were approximately parallel, and were thus generated during the same epoch. The elevation of the Pennines, running N-S, could be attributed to a different (later) epoch. Said Sedgwick in his Presidential Address to the Geological Society in 1831: 'The investigation of the faults and dislocations interrupting the continuity of our secondary deposits is becoming, daily, a subject of increasing importance; and we are now called upon, not to regard them as solitary phenomena, but to trace them through whole regions, and to examine their relations to each other'. Further, the uplift and fracture of central Lakeland might, Sedgwick suggested, be an exemplification of the theory of 'craters of elevation' of Alexander von Humboldt and Leopold von Buch. Thus, what started off with observations about the obscure outcrops of calcareous rocks in southern Lakeland, which rocks fizzed with acid and which did not, could, with the help of the maps constructed on the basis of his fieldwork, turn into grand speculations about the history of the globe. Thus it was that the endless notes about dips, strikes ('ranges'), and cleavage were used to underpin grand theoretical models. Ultimately, it seems, this was the point of Sedgwick's preoccupation in the field with all the structural details of the Lakeland rocks.

If we compare Sedgwick's work with that of Otley and other amateurs, we can recognise significant differences. Otley was born and lived in the Lakes, and knew them intimately. Besides discovering the outcrops and showing them to Sedgwick in a number of important cases, he produced two significant theoretical advances, and moreover taught them to Sedgwick, namely the tripartite division of the Lakeland rocks, and the distinction between stratification and cleavage, the understanding of which was essential to the success of Sedgwick's work, otherwise his 'structural' observations would have been hopelessly confused and in error. But while he knew many of the exposures, Otley did not ascend to any higher theory. Indeed, by virtue of his profession as a part-time guide, he was, I believe, more interested in topography and meteorology than geology. He sometimes sent Sedgwick topographic information or beautifully drawn topographic maps (there are examples preserved at the Sedgwick Museum), but I have no evidence that Otley sent geological information in the form of maps, though he did produce some.

Other amateurs were also at work. There was Sedgwick's friend Joseph Fryer of Keswick, who is thought to have been the anonymous author of the very first geological paper on the Lakes. There was the cobbler from Kendal, John Ruthven. He was employed by Sedgwick as a fossil collector in some of his later Lakeland work, and published his own geological map of the Lakes in 1855. Ruthven had, I am sure, covered the ground over a period of years, though he would not have had time or money to spend months at a time in the field like Sedgwick. Perhaps like another remarkable amateur, John Bolton of Furness in southern Lakeland, he would have had to sleep out on the fells to do his work.

There lay the difference. Sedgwick could approach the task in a professional, full-time manner; and with the advantages of education, connections, and libraries, he could ascend to higher levels of geological synthesis. His structural information was put at the disposal of a grand theoretical model, that of Élie de Beaumont. This theory was soon shown to be unsatisfactory; but such efforts towards higher levels of synthesis were what were required of the geological élite. And the élite players had to be unremitting in their efforts towards reading the literature, and constructing and defending their views against all comers. They had to have money or position; and preferably both. By contrast, the 'peripheral' amateurs, whose work was usually confined to a restricted region, had perforce to remain as collectors, and helpers of the 'central' players. If, as sometimes happened, they published grand schemes in local journals, no one took much notice.

Of the English geologists of the day, it was only William Smith who achieved immortality from a position of weakness. And he was given a hard time. But given different circumstances, I dare say Jonathan Otley might have been just as distinguished a professor as Adam Sedgwick. Certainly, he taught him a good deal, and Sedgwick surely appreciated the value of his humble friend, visiting him in Keswick not long before he died at the age of ninety, and being reduced to tears at the sight of his dying former companion in the field. I know of no similar case in the history of geology.

Acknowledgements

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[redacted]

(Editor's note. Adam Sedgwick authored a large number of papers relating to the Lake District, too numerous to be listed here as a bibliography. A comprehensive list is contained in:

SMITH, R.A., 1974, A bibliography of the Geology and Geomorphology of Cumbria, Cumb. Geol. Soc. 32pp)

JOHN BOLTON (1790–1873)

PIONEER GEOLOGIST IN THE FURNESS AREA

David Kelly

In the villages of Low Furness it is common for garden walls to have an ornamental capping of blocks of Urswick Limestone. However in the case of the former Post Office in Swarthmoor, a variety of rocks is displayed - Borrowdale Volcanics, Brockram, coral limestone and others. The name of the house, *Sedgwick Cottage*, is also evidence of the interest of a former inhabitant; this was John Bolton, born at Mountbarrow Farm in 1790 and educated at Urswick Free School. Bolton left the area when a young man and earned his living as a journeyman weaver. He possessed powers of enterprise and intellect, adapting his loom to work on the Jacquard principle and in 1870, his *Personal Narrative of a Twenty-four Year Residence in the Borough of Barnsley* was published.

Bolton's geological interest had been fired as a boy in Urswick by finding fossils in the Carboniferous Limestone of buildings and walls and in the discarded rock from a well sunk behind his school in Urswick. He returned to Furness in 1851 and took up residence in the house in Swarthmoor which he was to name *Sedgwick Cottage*. At the time only A. Sedgwick and E. W. Binney had published research into the geology of Furness and the pioneering work of J. D. Kendall was not published until after Bolton's death. The primary survey of the Furness peninsula was carried out in 1865 -70 by W. T. Aveline and A. C. G. Cameron. Back on home territory Bolton began his geological investigations in earnest and like others who lacked formal scientific or geological education, he compensated by acquiring a detailed knowledge of field localities. He became a friend and correspondent of many of the leading geological figures of the day, including, of course, Adam Sedgwick. This was the time of the Furness iron mining boom and Barrow-in-Furness briefly had more blast furnaces than any other town in the world. However Bolton's geological interests remained firmly focussed on the academic rather than commercial aspects of the subject.

Bolton made a major contribution to our understanding of the geology of Furness through meticulous site investigations and diligent fossil recording. Of particular note are fossil specimens, now housed in national collections, which he discovered in parts of the Windermere Supergroup that today would not considered to be particularly fossiliferous. Although Bolton's contribution to the understanding of the geology of the Furness peninsula is nothing like as great as that of Kendall and others who followed him, he is an interesting character. His published literary output was limited to just two papers: *On a deposit with insect, leaves, etc., near Ulverston* (1862) and *Explorations of a cavern at Stainton, Low Furness* (1871). He is best known for his book, published when he was aged 78, *Geological Fragments collected principally from Rambles among the rocks of Furness and Cartmel*, re-published under a similar title by Michael Moon in 1979. This fascinating book provides an insight into the state of geological knowledge and the social and economic history of the time.

Many of Bolton's studies were of the Upper Ordovician and Silurian rocks of south Cumbria now referred to as the Windermere Supergroup but which Bolton called the 'Clay-Slate'. The stratigraphy of these rocks in Furness has continued to prove problematic in more recent times. The lithostratigraphic units identified in the main part of the outcrop in the Windermere area have not been found easy to apply further south west. Norman in an unpublished PhD thesis in 1961 proposed different units for the Blawith area and Rose and Dunham (1977) proposed another set of units for the Furness peninsula. The recently published Ulverston 1:50,000 sheet 48 uses modern nomenclature. In *Geological Fragments* Bolton described in detail the extent of the outcrop and discussed an apparently upward succession from north west to south east of Coniston Limestone, Coniston Flags, Coniston Grit, Lower Ireleth Slate, Ireleth Limestone and Lower Ludlow Rock. Although he described the outcrop of these units, matching them in detail to modern stratigraphy is not always easy. Bolton examined the fossil content of the Ireleth Limestone in the Mere Beck area and concluded correctly that it was the same age as the Coniston Limestone although he notes that the strike of the two units is different. We now know that these are in fact the same unit - the Dent Group - and the outcrop is displaced laterally some 5km by the Kirkby Fault. Bolton rarely referred to the effects of faulting, even when considering the haematite ore deposits of the district.

Mystery surrounds Bolton's description of finding three or four "characteristic Coniston limestone fossil" species on Todhillbank (now Tottlebank) Fell. This area is now considered to be underlain by the Yewbank and Bannisdale Formations and too high in the succession to be part of the Dent Group. However the limestone outcrop itself (also described by Sedgwick) has also proved elusive. The late Harry Kellett, a noted amateur geologist of a more recent times, failed to find limestone exposures here despite repeated searches.

Bolton spent considerable time searching for 'organic remains' in the relatively unfossiliferous parts of the Silurian. At Knottallow Quarry (SD 270 803) he collected a slab bearing numerous specimens of the crinoid *Scyphocrinites pulcher* (McCoy) and at Rosside (SD 271 788) he collected large, distorted specimens of the bivalve *Cardiola interrupta* (J. de C. Sowerby). Bolton described how, as a seventy year old, he spent two hundred days at the latter locality excavating the crest of a hill on the road in search of fossils, much to the consternation of passers-by.

Bolton's writing on the Carboniferous or 'Mountain limestone' is somewhat disappointing. Although he described the outcrop and fossil localities, detailed studies of the stratigraphy had to wait for Aveline and Kendall and a detailed study of the palaeontology was not carried out until the work of Garwood. Bolton's understanding of the Carboniferous basal unconformity is interesting but at odds with a modern interpretation. The faulted boundary with the Silurian at Castle Head is described as being conformable. In Furness, Bolton noted that the Carboniferous and Silurian are "indented into each other". He imagined an upland, coastal landscape of Silurian rocks with bays into which the Carboniferous carbonate sediments were deposited. The landscape was, however, almost certainly a lowland one and the 'bays' are where the boundary is displaced by north west - south east faulting. Many of these faults carry the commercial haematite deposits yet they are not referred to. In the Lindal Moor - Marton area there are examples of ore bodies occupying faults with Carboniferous rocks on the hanging wall and Silurian rocks on the foot wall. Bolton surmised that this may be a simple sedimentary sequence and, contrary to modern interpretation, used this as evidence against the epigenetic nature of the ore deposits.

Bolton described the 'Magnesian Limestone' in a quarry in the Stank area, quoting the thickness as no more than 20 feet. The rock is not exposed today but is visible in buildings in the area. Bolton commented on its excellent properties as a building stone and considered the decision of the Commission appointed by the Government to choose the Magnesian Limestone from Yorkshire to build the Palace of Westminster a great mistake. The palace built in the 1840's was already weathering badly by the 1860's and Bolton asserted that this would not have happened had what he considered to be the superior 'Magnesian Limestone' of Furness been chosen!

In 1862 Bolton documented what may be an interglacial lake deposit beneath 30m of boulder clay near Lindal. This was found in shafts, including those sunk in the construction of a drainage adit from the Lindal Cote mines to Urswick Tarn. Diatoms, insects, seeds and leaves were identified from a clay or peat which appears to cover an area at least 400m across. In the 1970s the Geological Survey sank a borehole which failed to find this deposit, possibly because it hit a higher area of Carboniferous Limestone within the hollow.

Typical of Bolton's enterprising nature is the investigation he carried out on Urswick Tarn in the icy winter of 1852-3. Having set up fixed survey stations on the shore, using specially made equipment he drilled 16 holes at regular spacing into the surface of the frozen tarn to take soundings, noting the water depth and the nature of the sediment on the bed. He then measured the discharge and sediment load of the feeder streams and calculated the time required to completely fill the lake basin with sediment. He noted that much of the sediment being deposited at the time was haematite-rich mud from the Lindal mining area and concluded that the rate of sedimentation was much higher than in the past.

Bolton provided a contemporary account of the Rampside earthquake of 1865 and attempted to produce an isoseismal map of the effects. These include fallen chimneys, more than 300 points in the ground from which groundwater rose to the surface of the sands between Concle and Westfield Point and a major crack in the Concle railway embankment. By interviewing people in the area he deduced that the earthquake travelled from south east to north west. He attributes the limited lateral extent of the effects to the shallow depth of the focus.

Geological Fragments contains a contemporary account of haematite mining of interest to the historian. Much of the book is written almost as a "field guide" as a series of localities are described along different routes. In the style of Wordsworth and Coleridge he also indulged in longer distance treks, often sleeping outdoors, and accounts of these journeys are included, written in the literary style of the day. Although by modern standards much of the book could not be considered a scientific work, it is a fascinating account of interest to the geologist and is a fitting memorial to an extraordinary character.

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JOHN RUTHVEN (1793-1868)

GEOLOGICAL MAP MAKER AND FOSSIL COLLECTOR

Dr. Alan Smith.

The inclusion of John Ruthven in these accounts of the early geologists is warranted on two grounds. First, he illustrates very well the part the local amateur could play in the early history of geological exploration, and secondly his Geological Map of the Lake District, published in 1855 was one of the earliest to be compiled.

According to Cornelius Nicholson, John Ruthven was a "local geologist who, like Hugh Miller, proves how a man may overcome the want of education, and render important services to science, by the bent of natural genius". He was born in Kirkby Stephen in 1793, eight years after Adam Sedgwick had been born in the village of Dent not far away. Ruthven moved to Kendal, where he took up the trade of cobbler, but his real interests came to the fore when he made the acquaintance of three local naturalists and amateur geologists: Cornelius Nicholson, business man and local historian, later Mayor of Kendal; Thomas Gough, surgeon, son of John Gough, blind mathematician and botanist - said to have been the 'blind philosopher' of Wordsworth's poem *The Excursionist*; and Francis Danby, Curate of St. Thomas's Church, Kendal. These three tutored Ruthven in local geology and he became a keen collector of rocks and fossils, soon becoming so proficient that he was able to sell his specimens at good prices. As well as supplying Gough and Danby he also collected for Sedgwick and slightly later sent a complete collection of Silurian fossils to Sir Roderick Murchison in London. Eventually he began dealing directly with London dealers and established a sound reputation as a person with a detailed knowledge of South Lakeland geology in particular. In 1844 he reported to Sedgwick that he had plotted the course of the Coniston Limestone outcrop across the southern Lake District from Longsleddale to Broughton Fell.

In 1835 Nicholson and Gough founded the Kendal Natural History and Scientific Society. Over the succeeding years it attracted many eminent scientists of the day. In 1838 Sedgwick agreed to become its President, a position he held for thirty-two years. The records of the Society show he frequently lectured to the group on local geology, at which he was assisted by John Ruthven. Sedgwick thought highly of Ruthven, taking him on excursions into Wales in 1846 and 1851, and to Scotland in 1848. In 1845 he described him as a "famous fossil collector, once a cobbler..... now a geologist whose fame will last longer than the stoutest shoe that ever came of his ancient last" ; in 1845 he called him "my old heart-of-oak friend" who, "has Westmorland at his fingertips". Two years later Sedgwick wrote to Harkness, ' I advise you to go to

Kendal and call on John Ruthven, the well known collector of northern fossils (Palaeozoic); he knows the country well and as far as I know is the only person to have found fossils in the Skiddaw Slates'. This claim had already been made a year earlier, in an appendix on Geology contributed by an unknown author to Harriet Martineau's, *Complete Guide to the English Lakes* (published by John Garnett of Windermere, 1861). It has been suggested that Ruthven himself wrote this account in the Martineau Guide, but it seems unlikely as Ruthven was largely uneducated and was most likely incapable of writing scholarly prose.

John Ruthven's *Geological Map of the Lake District* was published in 1855 by John Garnett of Windermere. The topographical base map was engraved by W. Banks of Edinburgh. The geological boundaries were drawn in by Ruthven and the strata hand coloured. The scale was approximately three and a half miles to the inch. It was linen mounted and folded into a smart folder made for the pocket. There are geological sections drawn to the same scale as the map along all four of the margin edges.

Given the date of the map, the outcrop patterns shown are surprisingly good. The Skiddaw Slates in the north are accurately delimited, although the Ullswater and Haweswater inliers and the Black Coombe outcrop are less precise. Sedgwick's term ' Green slates and Porphyries ' is used for the volcanics for which the map contains no details. Southern Lakeland contains significantly more divisions, although the Coniston Limestone is somewhat diagrammatic in its presentation. Perhaps least accurate of all are the intrusives. Surprisingly he shows Kendal, his home town, on an outlier of Old Red Sandstone, with a further exposure to the north of the town. The key, which is detailed, reflects thinking at the time on the classification of strata into systems. An upper sequence, below the New Red Sandstone and down to and including the Old Red, is assigned to the Carboniferous System. Below that, in the Silurian, come Kirkbymoor Flags, Ireleth Slates and Coniston Grits. Below these, the Coniston or Brathay Flags, Coniston Limestone and Green Slates and Porphyry, classified as Cambrian, with the Skiddaw Slates beneath being unclassified, by implication Pre-Cambrian.

Little further remains by way of a record of Ruthven's life. Like Jonathan Otley, his local knowledge and expertise was clearly used by Sedgwick and other professional geologists. His map is the only tangible document to his work. He died in London at his son's house in 1868.

Acknowledgements

(The original work on John Ruthven was done by the late Toby Butler of the Westmorland Geological Society. The preceding account has been re-drafted from material compiled by Toby and recorded in the Westmorland Geological Society Proceedings No 26 1998. I am indebted to the WGS for the loan of the Ruthven map which is now in their Library collection by kind permission of Toby's widow).

Dr. R. A. Smith
[redacted]

ROBERT HARKNESS (1816-1878)

A GEOLOGICAL PIONEER IN NORTHERN ENGLAND AND SOUTHERN SCOTLAND

Margaret Fox

If Robert Harkness had cared more about immediate glory and less about his future quality of life and the wellbeing of his sister, he might have made less of an impact on Cumbrian geology. For in 1854, five years after Harkness' first visit to Cumbria, Sir Henry de La Beche offered Harkness the appointment of Professor of Geology at the Engineering College of Roorkee, Northern India.

In writing to reluctantly decline this appointment, Harkness expressed concerns about the lack of opportunities to discuss ideas with others; the fact that he could not imagine life without his sister, for whom India would not be a suitable environment; and his fears that, on returning, his health and the social effects of his long absence would mean that he would find little pleasure in life.

Harkness must indeed have been reluctant to turn this offer down, for it would have given him an unrivalled opportunity to extend his knowledge in an area about which little, if anything, had previously been written; but he does not appear to have expressed regret in later life. Instead he used his considerable energies in working out problems in a number of different fields, ready to travel widely in the British Isles in search of clues to illuminate aspects of a problem or to link areas together in geological terms.

Robert Harkness' interest in geology seems to have been aroused during his years at Edinburgh University, where he attended lectures by the Wernerian geologist, Professor Jamieson and also those of Professor J D Forbes.

Born in Ormskirk in 1816 and educated initially in Ormskirk and later in Dumfries before going to Edinburgh, it was to Ormskirk that he returned when first leaving university. With the prospect of employment in a firm of India Merchants having fallen through, Harkness occupied much of his time in a study of the local rocks. Having read all he could find on the geology of this area he began to use his knowledge on unsolved problems.

This preliminary literature survey was characteristic of Harkness' approach throughout his life. Each time he tackled a new area or a new problem, he first made himself acquainted with any published work and also talked or corresponded with others who had worked in the area. Nor were these discussions one-way. He was always equally willing to make the results of his researches available to others.

In 1843 at the age of 26, Harkness read his first paper, on The Climate of the Coal Epoch, to the Geological Society of Manchester. This was printed the same year in Annals of Philosophy. In it he suggested that from the first dawn of animal life to the first terrestrial beings the climate was warmer and more equable than today, due to the greater presence of carbonic acid gas in the atmosphere. This led to absorption of heat when the sun's rays were oblique and prevented dissipation when the rays were vertical, resulting in a more uniform temperature across the earth and supporting luxuriant vegetation. Over 20 years later, similar views were reiterated by Professor T Sterry.

Later that same year Harkness communicated another paper on climate to the Geological Society of London, this time proposing temperature change as a mechanism for the relative variation of sea level in relation to the land.

In 1848, the Harkness family moved to Dumfries. From then on, Harkness spent much of his time studying occurrences of red rocks, first encountered around Ormskirk, and also the crushed and contorted lower Palaeozoic rocks. Sedgwick had begun a few traverses and collected fossils in the Moffat area, but few other geologists had turned their attention in this direction.

By the time of the British Association (BA) meeting in Edinburgh in 1850, Harkness had a general idea of the structure and characteristics of the area and had collected a range of new graptolites from the anthracitic schists around Moffat. Sedgwick's account at the meeting of his own finds stimulated Harkness into further work. He sent his specimens to the palaeontologist J. W. Salter to be named and shortly afterwards produced the first of his many memoirs on a subject in which he remained enthusiastic throughout his life.

Harkness had been struck by the resemblance between the red rocks of Lancashire and those north of the Solway and had read a paper at the BA on the *Position of the Footsteps in the Bunter Sandstone of Dumfriesshire*. Sedgwick had been writing about the New Red in Cumberland and Westmorland, with the result that a friendship began between the two men that lasted until Sedgwick's death in 1873.

In 1849, Robert Harkness made his first visit to Cumberland and from then on his name came to be associated with the interpretation of the geology of the north of England. His first paper on the Silurian rocks of the Solway Basin appeared in the Quarterly Journal of the Geological Society (QJGS) in 1851. Several other articles on the New Red quickly followed, leading to communications with some of the foremost men of science of his day.

A common interest in graptolites led to a two-way exchange of specimens with Joachim Barrande, who had made a major contribution to knowledge of the older Palaeozoic rocks. Barrande's graptolites of Bohemia form part of the Harkness collection in Carlisle Museum, along with material Harkness collected himself.

All this activity did not go unrecognised. When in 1853 Harkness applied for the Chair of Geology at Queen's College, Cork, his application was supported by a list of eminent geologists, among them Professor James Nicol, whom he succeeded, J Beete Jukes and Sir Roderick Murchison. The last named corresponded with and supported Harkness over many years, but relations later cooled over the question of the lower boundary of the Silurian.

Also in 1853, the Geological Society made Harkness a Fellow, a distinction not lightly conferred in those days. This was followed in 1854 by inclusion in the Royal Society of Edinburgh and in 1856 by his election as a Fellow of the Royal Society.

The move to Ireland did not lead Harkness to forsake his interest in the rocks of Cumbria. Rather it allowed him to extend his knowledge of the older rocks in an area different from the Solway, whilst continuing his explorations of Cumbria during the vacations, especially after his sister moved to Penrith.

Initially Harkness' work in Cumbria had been predominantly concerned with the rocks of the Solway Basin, but from about 1856, he turned his attentions increasingly to the rocks of the Lake District. Sedgwick and Otley had laid the foundations, but much more detailed work was needed to fill out their general ideas of the structure. As usual, Harkness studied all the available literature and Sedgwick, now too infirm for fieldwork, placed the results of his own experience at Harkness' disposal. Sedgwick suggested useful contacts and possible fossil localities, and urged him to examine rocks in south-west Cumberland, raising questions over the pressure-only theory of cleavage development.

At an early stage, Harkness had assumed an axis matching south Scotland with north Cumberland. Having found graptolites in the older Palaeozoic of South Scotland he expected to find their equivalents in Cumberland. The results of his early investigations were read before the BA in 1857, in a paper on the geology of the Caldbeck Fells and the lowest sedimentary rocks of Cumberland. This area remained a source of particular interest throughout Harkness' life. He collected a fine suite of minerals as well as fossils, and his knowledge of the area probably remained unsurpassed until the work of J Clifton Ward.

During his increasingly frequent visits to Cumbria, Harkness came to recognise the full extent of the unconformity between the lower Palaeozoic of the Lake District and the flanking Carboniferous, realising that nearly five miles thickness of rock had been eroded. In an attempt to shed some light on this, he visited other areas where a time lapse had been implied. He communicated his intention of visiting the area of Hugh Miller's Old Red Sandstone to others. Back came letters from Sir Charles Lyell, lending him a copy of part of Sir Charles' field map and asking him to check some details for a student handbook; and from Murchison, entreating him to conduct a detailed examination of some rocks around Achintoul. The results of his investigations were communicated in several papers in 1862

Harkness next turned his attentions to the red rocks of the Eden Valley. At that time there were few records of the best exposures. It was necessary to traverse in every likely direction, record details and then attempt to collate the observations to discover agreements and differences. The findings then needed to be related to sections elsewhere, both in Britain and Europe. Harkness recorded his observations on a large map, which was probably the earliest large-scale geological map of this district. J G Goodchild, who later mapped the same area for the Geological Survey, commented of the map: 'Although here and there I have been led to put a slightly different construction upon some of the facts he has recorded, I can bear the fullest testimony to its accuracy as a whole'.

The results of his Edenside researches appeared in the Quarterly Journal of the Geological Society (QJGS), followed the next year by a paper on the Skiddaw Group with notes on the fossils by Salter. The fruits of Harkness' careful searching are now in Carlisle Museum.

Not long after came a paper that Goodchild considered to be one of the most important contributions to the geological history of Edenside, marking a great advance beyond the contributions of previous writers. It concerned the older Palaeozoic rocks associated with the Pennine faults between Warcop and Gamblesby. Later Survey mapping differed in minor detail, but there were numerous points of agreement.

In 1865, Harkness took Murchison to the main locations of his paper on the New Red of the Basin of the Solway. As a result Harkness seems to have been induced to make important modifications to his scheme of classification concerning the dividing line between the Palaeozoic and the Secondary rocks. Red-stained Carboniferous fossils had been assigned to the New Red, but the higher New Red had affinities with the Secondary rocks, especially around Carlisle. This suggested that the dividing line should be drawn through the New Red but in the joint paper that was published in the QJGS, it was Murchison's views that prevailed. Harkness never again wrote on the stratigraphical relations of the New Red rocks.

At the same time, Harkness was working on the older Palaeozoic with Dr H A Nicholson, later to become Professor of Natural History at Aberdeen. They had succeeded in discovering fossils below the Coniston Limestone, in rocks previously considered barren. Together they produced four joint memoirs bearing on the older rocks of Cumbria.

Alarm over the possible exhaustion of coal resources was at that time occupying the concerns of a large part of the scientific world. Harkness was asked by the Government Coal Commission for his opinion on the possibility of Coal Measures beneath the New Red of Cumberland and Westmorland.

Always a regular attendee and contributor to the meetings of the British Association for the Advancement of Science, Harkness was elected President of the Geological Section in 1869. In his Presidential Address on the relations between the Devonian and its adjacent strata, he summarised all his observations on those strata missing from Cumbria, giving rise to the unconformity between the older and newer Palaeozoic.

Harkness had been busy collecting evidence of the distribution beyond outcrop of boulders of Shap Granite, publishing the results in an 1870 paper. He was also puzzled as to how boulders of Brockram and other low lying Eden rocks could have crossed Stainmore to the North Sea, corresponding with Prof J Phillips on the subject.

At around this time, the question of the base of the Silurian was being argued over. The Ordovician had not yet been proposed, and the base of the Silurian had been taken as the lowest level at which fossils had been found, the underlying Cambrian being considered lifeless. As fossils were found at lower and lower levels, Murchison simply moved the base of the Silurian lower; but not all scientists agreed, because of the existence of a stratigraphic break above the lowest fossils. With Dr Hicks, Harkness had collected fossils below the Lower Lingula Flags and their conclusions were read before the Geological Society in 1870. Murchison is unlikely to have been pleased.

We must not forget that during all this time, Professor Harkness had been diligently carrying out his duties in Cork. Somewhere around the mid 1870s, he was required to teach not only geology but also physical geography, mineralogy, palaeontology, zoology and botany. Since his interests had been widespread, there is little doubt that he was capable of fulfilling this duty, but to do so as well as he wished put a great burden on him. When the prospect of a Chair of Geology at Edinburgh seemed likely, Harkness had hopes of winning the appointment with the support of Sir Roderick Murchison; but Murchison had already thrown his support behind Archibald Geikie - and in any event, the Chair never materialised.

This left Harkness with retirement as the only option of escaping the burden of his duties at Cork. In October 1878 he made the necessary arrangements and said goodbye to his students and colleagues. In Dublin, on his way back to Penrith to join his sister, he died of the heart disease that had been troubling him for a few years.

It is perhaps difficult for today's geologists to really appreciate the problems faced by those early men. Transport was considerably poorer and Harkness must have walked many miles and climbed many thousands of feet over rough ground in the course of his investigations. Useful exposures had to be sought, necessitating many traverses and scrambling into every likely ravine. Only a limited amount of previous work was available to direct researchers to key localities. Moreover, fossils were rare and cleavage, metamorphism and dislocations obscured the stratigraphic relations. The physical effort involved, together with the intellectual burden of his duties at Cork had taken their toll on Harkness, and his retirement came too late to give him the rest he had hoped for.

Robert Harkness was laid to rest in Penrith Cemetery. At Queen's College a window was erected in his memory. Some of Harkness' Scottish material had already been given to the British Museum (Natural History) and to the Geological Society, but the remainder of his collection was presented by his sister to Carlisle Museum.

His last published paper, on the Borrowdale Series and Coniston Flags, was written with Prof Nicholson and appeared in the QJGS in 1877. In July of the year he died, he read a paper on Cotterite, a new form of quartz, to the Mineralogical Society.

Professor Robert Harkness wrote over 83 papers, for the most part appearing in the QJGS and the Reports of the British Association. His original memoirs on the Solway Basin rank among some of the most important contributions to the geological literature of the time. His knowledge extended not only to the geological structure of an area but also fossils, minerals and natural features. He had an extensive knowledge, too, of the early history of mankind. But those who were fortunate enough to meet him remembered him as much for his personal qualities as for his contribution to geological knowledge.

Goodchild, who first met Harkness in 1887, considered that the professor was gifted 'with the power of rapidly taking in structural details ... and ... the facile pen of a practised writer.' He commented on the fact that Harkness was always ready to discuss, in perfect good temper, any point that was made to him contradicting his own published ideas. Goodchild also felt that Harkness relied to a large extent on his memory, for his field notebooks have sketches and data but only very condensed notes.

But perhaps the strongest tribute to his personal qualities came in that oft-quoted note written by Sir Archibald Geikie and published in Nature the week after Harkness' death:

'Who that has been privileged with his friendship will not cherish the memory of his earnestness over even the driest of details, his quiet enthusiasm, his genuine admiration for the work of others, his unfailing cheerfulness? Who will forget that beaming ruddy face, never absent from the platform of Section C at the British Association meetings, always ready to rise among the speakers there and to reappear at the festive gatherings in the evening? There have been men who have graven their names more deeply on the registers of scientific thought and progress, but there have been few whose sunny nature has more endeared them in the recollection of their friends than Robert Harkness.'

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M. Fox
[redacted]

JAMES CLIFTON WARD (1843-1880)

AN EARLY 'POPULARISER' OF GEOLOGY

Dr. Alan Smith

Clifton Ward's association with geology in Cumbria was rather like his life as a whole; short but active and influential. In barely ten years he had completed the first mapping of the Keswick area for the British Geological Survey, written the accompanying Memoir, published 22 papers on the district, become a pillar of the scientific community in the County, changed profession and moved.

He was born on the 13th April 1843 at Clapham in South London, the son of James Ward, a schoolmaster. It appears his health was always delicate and, as a result, he was sent to school at Hastings. The bracing air of the Sussex coast did not improve his health and for a long time he was taken out of school and given free rein for an outdoor life on the Sussex Downs. He learnt very early in life the joys of observing natural history. He came back to London in 1861 and entered the Royal School of Mines, gaining the Edward Forbes Medal in 1864. Ill health continued to trouble him and consequently he never graduated, but was granted the Associateship of the Royal School of Mines. In 1865, at the age of 22 he was appointed to the Geological Survey and was sent to the West Riding of Yorkshire where he worked on the Millstone Grit and the Lower Carboniferous. In 1868 he was transferred to the Lake District and was based in Keswick. It was there that his life as a professional geologist blossomed.

His task for the Survey in Keswick was to carry out the first professional mapping of the area (Quarter Sheet 101 SE), covering over 200 square miles of the northern Lake District. It stretched from Ennerdale in the west, to Ullswater in the east and included the high fells from Great Gable and Helvellyn to Skiddaw and Blencathra. It seems clear Ward did this single-handedly. Although he was 'under the superintendence' of the District Surveyor W.T. Aveline, examination of the field slips still in the BGS archives reveal the work was Ward's alone. (D.Oldroyd : Personal Communication). His map published at one inch to one mile scale in December 1875, and the Memoir *The Geology of the Northern part of the English Lake District* published in June 1876 remained the only official Survey work on the area for 123 years.

Ward's map bears comparison with the new re-surveyed map which BGS published late in 1999 (Keswick Sheet 29 at 1:50,000 scale). In very few areas is the pattern of outcrops at odds. Ward's interpretation of the Castle Head intrusion south of Keswick, the eastern margins of the Threlkeld microgranite, the size of the Skiddaw Granite exposure in Sinen Gill and some of the minor dykes in the Skiddaw Group outcrop are very slightly different from the modern sheet. Modern work on the Crummock Water Metamorphic Aureole at the southern end of Mellbreak has led to a different interpretation of the outcrop pattern there. Nevertheless the broad outlines of the surface outcrops, the complex junction line between the Skiddaw Group and the Borrowdale Volcanic Group, and the Devonian and Carboniferous margins remain as Ward drew them a century and a quarter ago.

However, Ward's interpretation of the major rock groups and the structural geology did differ considerably from present day thinking. Given the level of geological knowledge at the time, for a man still in his late 20's and with relatively little geological experience his descriptions of what he saw were very accurate and the questions he posed highly perceptive. Interpreting the Skiddaw Group posed problems for him, as in fact it has done for geologists ever since. He saw they were structurally very complex, but the series of sketch sections drawn in the Memoir paint a simpler picture than we now know is the case. He did not subdivide them, but went into considerable detail on their alteration by lateral pressure, action of igneous rocks beneath, alteration close to quartz veins and the numerous exposed igneous intrusions. He estimated their thickness as between 10,000 and 12,000 feet, and suggested they originated in marine conditions ("in a more or less shallow sea") with a probable proximity to land. He appeared uncomfortable with the palaeontology, only fleetingly refering to the "scant remains of life forms". The final chapter of the Memoir produces a list of known fossils and locations (largely based on the work of Nicholson) and there is an appendix by R. Etheridge describing the new finds.

Ward paid more attention to the volcanic rocks. It was he who first described them as "the Volcanic Series of Borrowdale". His training in petrology and the influence of H. C. Sorby is very evident in the Memoir, which is one of the first to use thin section slides in the text. He subdivides the Series into nine units, which are difficult to equate precisely with modern views. However, his descriptions of many of the lavas and pyroclastics remain clear today. His travels to Vesuvius and other volcanic sites in Italy had clearly been a seminal experience with which he drew parallels with the Lakeland rocks. He was convinced that Castle Head just south of Keswick was an important vent - relating many of the sequences (including the Eycotts) to eruptions from this source. He interpreted the sequences as possibly of sub-marine origin in the very early stages but obviously sub-aerial for most of the period.

On the relationship between the Skiddaw Group and the overlying volcanics, he was convinced that everywhere the junction was a faulted one. In terms of dating he placed the Skiddaw Group in the Cambrian and equated them with the Manx Slates. The volcanics he suggested were Tremadoc and Arenig in age.

Of equal interest to Ward was the glacial history and the relationships between the scenery and the geology. Almost a quarter of the Memoir is devoted to these topics. Much of the material is primarily descriptive, but he clearly appreciated the great differences between the various rock types and their response to the forces of weathering and erosion. He was intrigued with what he calls ' transported and perched blocks', and with the location of glacial striae. The Memoir is still the most detailed catalogue of erratics and striae alignments in the district. Ward did not however subscribe to the new theories of land-based ice that were being propounded at the time to explain glacial phenomena. Instead he retained the view of glacial-submergence theory, invoking subsidence beneath the sea after a period of intense cold, the district gradually being converted into an archipelago with powerful currents circulating among the islands. When depression had gone on to the amount of 1000 feet or less, the cold returned and ice rafts bore blocks from one part to another. These were very much the views propounded by A. C. Ramsay at the time and perhaps significantly the line taken by all the Survey geologists at this period.

Apart from his work for the Survey, Ward was also a prolific writer and lecturer, not just on geological topics. During his short stay in Yorkshire before coming to Keswick he produced an elementary school book on Physics. During his Keswick years he repeated a similar exercise for Geology, the text being essentially nine talks he first delivered to schoolchildren and as public lectures in Keswick. Between 1870 and 1879 he published 22 papers in a variety of scientific and geological journals, all essentially stemming from his Survey work and developing his ideas on Lakeland rocks and landscape. Around half of these papers related to glacial phenomena (see bibliography).

The character and dynamism of the man is best exemplified by his contributions to popularise science, and geology in particular, in Keswick and Lakeland society of the day. Close to his time of arrival in the northern Lake District the Keswick Literary Society had been founded. His name was not on the original list of members in 1869 but in the second session in 1870 he gave a lecture on 'The Geological History of Italy'. From that point on his name appears frequently in the Society Minutes. By 1872 he had proposed the Society should become 'The Keswick Literary and Scientific Society' which it eventually did in 1874, with James Clifton Ward its President in 1874, 1875 and 1876. The Society still exists as 'The Keswick Lecture Society' and has currently just completed its 131st Season. Ward's name appeared frequently in the list of speakers and it is remarkable the range of topics he was able to speak upon, apart from the geological ones. In 1874 he spoke on 'The Ear, its structure and Development', in 1876 on 'Electrochemical Decomposition' and

'Some Analogies between Sound and Light - experimentally illustrated', and then in 1877 on ' The Life of Faraday '.

In 1873 Ward was instrumental in forming a Committee to set up a local Museum in Keswick, which came to fruition with Ward naturally being responsible for the rock and mineral collections. This too still exists and contains many of Ward's original specimens, as well as some of the physical models of the district made by Ward to illustrate his Survey work.

In June 1873 he instigated geological field trips into the local area and the press reports in the West Cumberland Times of the day make fascinating reading of Ward's irrepressible leadership in the field. They paint evocative pictures of Victorian life - 170 people to Borrowdale in 1873 where 'the grass fields of the Howe at Rosthwaite provided a convenient auditorium for Mr Ward to describe The Geological History of Borrowdale'. In 1874 on a trip to Greenside Mine, Glenridding, he led a large section of the party first over Sticks Pass on foot where 'the inquisitve hammer was in constant requisition to enquire within'. Or, in 1875 'Mr J.C. Ward took twenty men and nine women in three waggonettes to Seathwaite and on foot "by easy stages" to the summit of Sca Fell Pike. There were still large patches of snow and ice in Piers Ghyll and, needless to say, Mr Ward took the opportunity of making remarks at suitable places upon the geological features of the district'.

One of Ward's most valuable contributions to scientific life was the setting up of 'The Cumberland and Westmorland Association for the Advancement of Literature and Science' in 1875. This was done at Ward's instigation. He became its first Secretary and Editor in 1875 and continued to hold both offices until 1879 when the Editorship was taken over by another geologist, T. G. Goodchild. The published Transactions of the Society became a significant record of local scientific research for many years. Unfortunately it has not survived.

Ward's work with the Survey in Keswick was completed in 1876 with the publication of the Memoir. For a short time he was transferred to the Carlisle office and worked in the Bewcastle area. There is some indication that his health was not good in 1876-7 and that he was seeking a less physically exhausting job than a field geologist. Throughout his life he had held deep religious beliefs. The next biographical record of him was his ordination into the Church of England at Carlisle Cathedral in 1878. He gave up his position with the Survey in 1877 and became assistant curate at St John's in Keswick. In 1880 he was appointed Perpetual Curate at Rydal in south Lakeland. Within a few weeks of taking up the post he caught a chill and died on the 16th April at the age of 37.

Tributes to him were lavish. The Cumberland and Westmorland Association raised money to mount a tablet to his memory in Rydal Church, with £300 surplus money going to assist with the education of his two young daughters. Fittingly he is buried at St John's, Keswick where a similar memorial plaque in the church reveals his contribution to geology and life in Keswick.

Canon Rawnsley, an eminent Keswick figure and later to be one of the founders of The National Trust wrote a sonnet to his honour for his funeral. This was a fitting tribute to an indefatigable man.

'The Geologist's Funeral'

Bury him here, and let his body's dust
Be ash to ash in this volcanic land
Whose fiery secrets he could understand
Right well may we his dissolution trust
To that same Will that through the lava crust
Spouted the granite fountains God ! whose hand
Of this earth's waste new continents hath planned,
Into thy potter's clay a gem we thrust.
No more his feet we follow up the cleft,
Or hear his questioning hammer tap and ring,
And learn which way the primal bergs were rolled;
But, till the Greta ceases sorrowing,
We leave him here, contented to be left,
Schooled in a lore whose days are aeons old.

Acknowledgements

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I would also wish to acknowledge the help of George Bott of Keswick. His small booklet 'Sponsored Talk - Keswick Lecture Society 1869-1968', (published by Ferguson Bros. Printers Ltd , Keswick, May 1971, 72pp) is a useful background history to Ward's involvement with the local scientific community in Keswick.

Volumes 1 and 2 of the Minute Books of the Keswick Lecture Society have also been made available to me by the Cumbria Record Office in Carlisle Castle.

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[redacted]

HENRY ALLEYNE NICHOLSON (1844-1899)

A REKNOWNED CUMBRIAN POLYMATH

Dennis Dickins

Henry Alleyne Nicholson is regarded as one of the greatest Cumbrian pioneers of geology from the Victorian era. He was born at Penrith, Cumberland, where his father, Dr. John Nicholson, was a well-known biblical and oriental scholar. He received his early education under Francis Newman and at Appleby Grammar School and although little is known of his boyhood it is assumed that his interest in natural history was stimulated by his childhood surroundings. His ambles into the Lake District in his youth initiated his subsequent interest in geology, especially palaeontology and stratigraphy, and led to his future research publications on the various aspects of the geology of the area.

His higher education commenced at the University of Gottingen, where he worked under Professor Keferstein, the distinguished zoologist. He then studied medicine at the University of Edinburgh from 1862 to 1867 and graduated as a Bachelor of Medicine and Master of Surgery, taking first-class honours in all subjects and in 1869 he received the degree of Doctor of Medicine. He was additionally awarded the Ettles Medical Scholarship of the University as the most distinguished student of his year in medicine. Simultaneously, whilst studying medicine, he found the time to get involved in the study of the natural sciences and was taught by Goodsir, Ailman and Balfour. He graduated as a Bachelor of Science in 1866, receiving the Baxter Scholarship in the Natural Sciences. In the following year he took the degree of Doctor of Science and received the University Gold Medal for his graduation thesis, *On the Geology of Cumberland and Westmorland.* This was subsequently published, with a dedication to his friend and teacher, Professor Harkness of Queen's College, Cork, with whom he had undertaken the fieldwork.

His enormous appetite for assimilating knowledge as a student set the tone for the hard work of research which he continued throughout his life, in addition to the variety of posts which he subsequently held. His first position was that of Lecturer in Natural History at the Extra-Academical School of Medicine at Edinburgh where, initially, he also practiced medicine. In 1871 he accepted the Chair of Natural History at the University of Toronto, which he held for three years. During his time in North America he collected geological material, particularly the varied forms of corals and monticuliporoids, which he used for further research after his return to Britain. He also undertook, at the request of the Provincial Government of Ontario, an investigation into the fauna dredged from Lake Ontario, as well as an examination of the fossils of the

Silurian and Devonian rocks of the Province. The collection was described and featured in two reports which were published by the Government of Ontario. He was also commissioned by Dr. Newberry, the State Geologist of Ohio, with the description of the fossil corals and polyzoa of that State. This appeared in the Second Volume of the *Palaeontology of Ohio* and was illustrated by Nicholson. Here he displayed yet another talent with his ability to provide precise illustrations of his fossil subjects. In addition to his post and the above works, he found time to produce his *Manual of Palaeontology* and the first part of a detailed treatise of British Graptolites, both of which were published in 1872.

The isolated nature of Toronto, in comparison to Britain, which was at that time the hub of research in geology, resulted in Nicholson accepting the position of Professor of Comparative Anatomy and Zoology at the Royal College of Science, Dublin, in 1874. However, before taking up this post he was offered the position of Professor of Biology at the Durham College of Physical Science and Medicine, which he accepted. Additionally, for two sessions he lectured at the University of Newcastle-upon-Tyne and then, in 1875, he took the offer of the Chair of Natural History at the University of St. Andrew's, where he remained for seven years.

He was largely responsible for establishing the study of Natural History and, likewise, he also took a very active part in the extension of University teaching to Dundee. He also undertook an immense amount of research, mainly into fossil corals, producing numerous minor papers, two major Monographs, one in 1879, *On the Structure of and Affinities of the 'Tabulate Corals' of the Palaeozoic Period* and, in 1881, *On the Structure of and Affinities of the Genus Monticulipora and its Sub-genera*. Another important Monograph of this period was a joint production with Mr. R. Etheridge, Jun., on the *Silurian Fossils of the Girvan District in Ayrshire*. Additionally he wrote a popular volume entitled *The Ancient Life-History of the Earth*, new editions of the manual and textbooks of zoology and in 1879, a second edition of the *Manual of Palaeontology*.

In 1878 he was invited to deliver the natural history lectures at his former University in Edinburgh for three sessions, but was disappointed at not being recommended for the appointment of Chair of Natural History at the University when it became vacant. In 1882 he accepted the appointment of Regius Professor of Natural History at the University of Aberdeen, which he held for the remainder of his life. His output of research papers continued and apart from his official work he maintained his interest in research into fossil corals and Monticuliporoids. His most important publication in this period was his *Monograph of the British Stromatoporoids*, which was published by the Palaeontological Society between 1886 and 1892. He also introduced courses on systematic and practical geology and such was his enthusiasm, ability as a teacher and a lecturer that his classes increased fourfold. He was also invited to deliver the Swiney lectures at the British Museum in South Kensington between 1878-82 and 1890-94.

Professor Nicholson's greatest academic strengths lay in field geology and invertebrate palaeontology and he chose to conduct his field researches in his boyhood Lake District. In addition to his thesis he produced, in association with Professor Harkness, a paper on *Additional observations on the Geology of the Lake Country* and also *On the Coniston Group* [he discovered the rich graptolite fauna of the Coniston Flags of Sedgwick]. Other papers included those on the Green Slates and Porphyries of the Borrowdale Series and on the Coniston Flags which were published in 1871 and 1877. Additionally he produced a memoir on the Lower Palaeozoic Stockdale Shales and their division based on lithological characteristics and their contained fossils, mainly graptolites, which could be correlated with similar sequences in other areas. He produced this in conjunction with his friend Professor J. E. Marr in 1888, and they subsequently produced a paper on the age and the fossils of the various formations within the Cross Fell Inlier. He was the first to recognise the similarities of the graptolites from the Skiddaw Slates with those of the Quebec Group of Canada.

The Monograph of the British Stromatoporoids will probably be regarded as Nicholson's most important contribution to palaeontology. Also, he further developed the making of thin sections because he recognised the advantages of using this method to describe in detail the interior structure of fossils and personally made more than a thousand to use in compiling the above treatise.

Professor Nicholson drew excellent illustrations, including those of microscopic structures from thin sections and produced 138 single papers and 27 joint papers. He was elected a Fellow of the Geological Society in 1867, of the Linnaean Society in 1876 and of the Royal Society in 1897, whilst, in 1879 he received an award from the Lyell Fund and in 1888 was awarded the Lyell Medal. His intellectual ability, teaching and fieldwork skills were supplemented by a genial and sympathetic personality which won him many admirers, because he was always approachable and willing to give advice and assistance to fellow workers. Professor Nicholson had a high capacity for work, which could have resulted in his sudden death, since he was at his post until the week before he died.

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D.R.E. Dickins
[redacted]

JOHN GOODCHILD (1844-1906) AND FREDERICK TROTTER (1897-1968)

PIONEERING WORKERS ON THE GLACIATION OF CUMBRIA

Dr. Angus Lunn

The lives of John Goodchild (1844-1906) and Frederick Trotter (1897-1968) together spanned more than a century. Each produced a major classic paper on the glaciation of respectively the southeastern and northeastern parts of Cumbria, with Trotter building upon and extending geographically the work of Goodchild. Between them - exploiting their good luck in the number of distinctive lithologies incorporated in glacial deposits - they established broad ice-flow patterns for the last glaciation. Inevitably, however, in a region such as this of great topographical complexity, and receiving ice flows of temporally varying strength from several adjacent upland areas, there remain even now many unanswered questions in this regard. Goodchild was himself extending the glaciation work of Tiddeman (1872) in north Lancashire. While some of Goodchild's and Trotter's interpretations of Quaternary events and processes would not now be accepted, including the latter's account of deglaciation in northeast Cumbria, the two men were responsible for an enormous body of original observations on glacial features. Both, also, had diverse interests in other fields of geology, Trotter particularly in economic geology. Their careers followed similar paths, as career-long officers of the Geological Survey.

John George Goodchild was born in east London, and although apprenticed as an engineer was attracted to geology partly by being present at the discovery of Quaternary mammals in Kent brickyards. Following private study, he was appointed to the Geological Survey in 1867. His first posting was to Westmorland as an assistant to Professor McKenny Hughes in mapping work, but unfortunately his enthusiasm for hill-climbing had an adverse and enduring effect on his health, such that his field career lasted only sixteen years. During his time in Cumbria he became involved with the Cumberland and Westmorland Association for the Advancement of Literature and Science, whose Transactions he edited, and with Carlisle Museum, for which he obtained its main geological collection (the Harkness Collection). Such extra-mural professional activity was a feature of his life.

In 1883 he was transferred to the London headquarters to help with the production of maps and memoirs. In London he became deeply involved in adult education for disadvantaged members of society, through the new Toynbee Hall Universities' Settlement in Whitechapel. Here he was also able to develop an earlier interest in (non-geological) natural history. In 1889 he was appointed as Curator with the Scottish Geological Survey based in the Edinburgh Museum of Science and Art, where he specialised in mineralogy.

From Edinburgh too, he continued lecturing to the public and leading excursions widely through southern Scotland. He was buried at Milburn in Westmorland.

Goodchild's extensive publication list (some 200 papers) includes contributions not only on glacial geology but also on the New Red Sandstone, igneous rocks and mineralogy (he discovered wulfenite at Caldbeck and wrote a three-part description of Cumbrian minerals) and geological time. His best known publication, however, is his 1875 paper on the *Glacial phenomena of the Eden valley and the western part of the Yorkshire-dale district*, based both upon official survey work and what he described as "holiday rambles". Later he published a summary (*Ice work in Edenside*, etc.) of his Cumbrian glacial work (Goodchild, 1887).

In the 1875 paper he presented evidence confirming the flow of land-ice from the Vale of Eden through the Tyne Gap and over Stainmore. The latter ice stream had originally been suggested by Buckland (1840) on the basis of the distribution of Shap granite erratics, but since then submergence and iceberg drift had become fashionable as explanations of glacial phenomena. Then Croll (1871) and Tiddeman (1872) published evidence for the existence of land-ice in the region, and Goodchild in turn was able to demonstrate that the transport of Permian Brockram uphill towards Stainmore could not be explained other than by the flow of land-ice.

He mapped striae, and boulder and drift limits, over a wide area and drew in, on the coloured map accompanying his paper, an inferred main ice divide. He showed that, at some stage, southwest Scottish ice (as well as local ice) had flowed up the Eden valley and over Stainmore. Apparent anomalies in flow patterns in the Vale of Eden led him to advance the idea of "cross glaciation" or "undercurrents" (layers of ice within the same sheet flowing in different directions), and later (1887) "circulatory flow". Nowadays such ideas are glaciologically unacceptable, and shifting divides are called in aid. He accepted the existence of local ice caps in the Pennines, but considered glaciation of the highest ground unlikely.

Goodchild advanced an entirely original theory on the origin of much of the drifts and was one of the first to recognise their complexity. The theory was based largely on numerous figured sections, some through drumlins, along the line of the Settle & Carlisle Railway that was then under construction. He suggested that the drifts were emplaced by what would now be called melt-out - the rapid release of abundant englacial debris from a stagnant ice sheet. In this way complexly interstratified tills and water-laid sediments were deposited, the latter by powerful subglacial streams. Otherwise puzzling steeply inclined or contorted laminated clays were also deposited subglacially. Debris had become englacial as a result of layering within the ice sheet, with tributary ice streams flowing over trunk streams, so presaging Carruthers' (1953) controversial ideas, and also through the thrusting up of basal debris. The lowest tills, however, were *moraine profonde* (now lodgement till). He also identified ice-contact meltwater deposits in the Vale of Eden. His interpretation of the drifts was based partly on clast shape and clast fabric, and it is remarkable how many modern techniques and interpretations feature in Goodchild's work, and how many of his conclusions are either accepted today (for example final ice stagnation in some circumstances), or remain actively debated.

Goodchild also tackled glacial erosion, and advocated a glacial erosional origin for cirques and also, with close argument in his 1887 paper, for the characteristic benching of dale-sides in the Pennines. He argued that not only could glacier ice deepen valleys, it could also make them shallower by "grinding down" intervening ridges. He was an early advocate of glacio-isostasy, and presciently suggested that switches in ocean currents were involved in climate change. He recognised from local evidence a final limited phase of glaciation (our Loch Lomond Advance).

Away from glaciation, Goodchild advanced radical ideas on the origin of dykes by replacement, related to alkaline solutions soaking downwards from the sea, and he also considered that volcanic action was related to seawater penetration. He recognised that the New Red Sandstone, with its evaporites, was deposited in a desert environment, as were other red sandstones. A notable insight was that the local haematite ores in the Carboniferous were due to the leaching (he thought by meteoric waters) of iron from the overlying red rocks followed by metasomatic precipitation. And Goodchild particularly addressed himself to the age of the earth. Noting how little topographic change had occurred in the Lake District since the end of glaciation, he placed deglaciation at 12,000 to 20,000 years ago, a pretty good estimate for his time. He also estimated 42 million years for the duration of the Cambrian period, based on calculated sedimentation rates; this is remarkably close to the duration based on radiometric dates.

Virtually all of Goodchild's official mapping work was in Cumbria and adjacent parts of Yorkshire, and he co-authored the *Appleby, Ullswater and Haweswater memoir* (1897). He received the Wollaston Fund in 1874.

Outside of geology he published papers on feather structure in bird classification (with his own meticulous illustrations), on the relationship between ants and flowers, on the depth-distribution of corals, on museum methods, on the Helm Wind, on Japanese clocks (an interest from his early engineering days) and on dialect, place-names and archaeology.

As an obituarist fairly put it (Gregory, 1909), "he was a walking note of interrogation". Goodchild was shrewd, original almost to the point of heresy, somewhat dogmatic, had an extraordinarily wide range of interests, and a keen desire to share his knowledge and enthusiasms with a wider audience. While some of his ideas on glaciation have proved very wide of the mark, others were spot on.

Frederick Murray Trotter was born in Gateshead and was a graduate (interrupted by war service) of Armstrong College, Newcastle (later the University of Newcastle). He joined the Royal Engineers, and, as a dispatch rider, lost an eye from shrapnel at Vimy. (So ended a promising footballing career). After a short spell of teaching, Trotter joined the Geological Survey in 1921, later becoming District Geologist, north-west England and, in 1955, Assistant Director. He retired in 1963. His early field career was spent in Cumbria under Bernard Smith, where he worked in the east (the Vale of Eden and the North Pennines), the north (the Carlisle plain) and the west (the Gosforth district), being co-responsible for *the Carlisle, Longtown and Silloth, Brampton* (1932a), *Gosforth* and *Cockermouth and Caldbeck* memoirs and 1" maps; he also contributed to the 3rd edition of the Northern England Regional Memoir (1953). Much of his work was in collaboration with Professor SE Hollingworth, who was a life-long friend. After 1933 Trotter worked in the Forest of Dean (near to which he retired) and South Wales before returning to the north-west.

He published his classic paper on *The glaciation of eastern Edenside, the Alston Block and the Carlisle Plain* in 1929 (1929a). This deliberately complemented Hollingworth's (1931) paper on western Edenside. Apart from his work on glaciation, Trotter was interested in denudation history and contributed a then influential paper on the denudation chronology of the Alston block (1929b). He argued that the radial pattern of the North Pennine dales was the result of late-Tertiary doming of a peneplain. Such interpretations, once popular, are now considered to be based upon rather little evidence.

His detailed account and interpretations of the glacial phenomena of eastern Edenside, etc. were, like those of Goodchild, based both upon his official survey work and unofficial work during vacations in the 1920s. The results were published in the 1929 paper and in the Brampton memoir. He established drift and boulder limits, based on hundreds of clast lithological analyses, and on drumlin (including rock drumlin) orientations - thus extending northwards Goodchild's equivalent observations. He recognised a "Cross Fell escarpment drift", and considered that it was emplaced by short glaciers occupying escarpment valleys and also, at the glacial maximum, by ice draining through these valleys from higher ground above. Although some escarpment valleys were shaped by these glaciers, others, without their own glaciers, retained a preglacial V-shape. Cold Fell, at the northern end of the escarpment, must have nourished its own ice cap judging by the erratic 'shadow' on it and to its east. Like Goodchild, Trotter considered that the ice flowed in different directions at different levels within the ice sheet. Also like Goodchild, he thought that small nunataks may have existed in the North Pennines at the glacial maximum - a possibility even now not ruled out for the last glaciation.

Trotter gave particular attention to deglaciation, where the model he used was that of Kendall (1902), invoking lakes dammed against a continuously retreating ice front and draining largely through overflow channels. Eskers, kames, ice-contact deltas and fans, fed by englacial streams and retaining essentially their original form, were deposited at the ice margin and provided evidence of its successive positions. Land streams also constructed deltas in the glacial lakes. A map depicts no less than 24 detailed ice-front retreat positions ("halt-stages"), based on supposed ice-frontal deposits, glacier lakes and their overflow channels (he mapped about 200 of the latter), as the ice sheet withdrew from the Pennines to source areas in the Lake District and south-west Scotland. This model of deglaciation is now largely superseded; most channels are now regarded as having formed subglacially and many of the Lakes were inferred on flimsy evidence. Rather, somewhat as Goodchild had suggested, the ice sheet may finally have stagnated *in situ* over a wide marginal zone (Huddart, 1991; Huddart, Tooley & Carter, 1977). The spectacular moundy deposits mapped by Trotter are now regarded as having formed in a variety of subglacial, ice-marginal fluvial and lacustrine environments amidst and against this stagnant ice. However, Trotter's observations, particularly in his "Brampton kame-belt", are an invaluable body of data, and some lakes undoubtedly did exist, both in proglacial and ice-walled environments (Huddart, Tooley & Carter, 1977).

Trotter recognised that on the basis of the extent of meltwater deposits in the Tyne Gap, a huge volume of meltwater must have drained from a vast glacial catchment area eastwards through this lowest col on the main British watershed between Derbyshire and central Scotland. He considered that after the ice had withdrawn west of the col at Gilsland, a Lake Eden was impounded between the ice and the watershed, although the evidence for this is not convincing.

Detailed mapping also led Trotter to the view that there had been a "Scottish Readvance" glaciation after the main ice sheet had retreated, across the Solway and advancing as far inland as Brampton (although later reconstructions are more restrictive: Huddart, 1991). The evidence took the form of an upper till, which overlay both "Middle Sands" and glacio-lacustrine deposits associated with the main retreat. He also mapped Scottish Readvance retreat stages. The existence, and status, of such a readvance remains a live issue.

Trotter (1929a) and Trotter & Hollingworth (1932b), suggested tele-correlations of the glacial events recognised in Cumbria, always a fraught business.

Much of Trotter's work was in economic geology. As regards the haematite ores he considered magmatic, not Goodchild's meteoric, waters to be responsible for ore genesis. Later, Rose & Dunham (1977) suggested that hypersaline fluids driven up from the Irish Sea basin leached the New Red Sandstone to produce the ores, so combining elements of both Goodchild's and Trotter's ideas. Trotter also worked on coal rank, including on the genesis of the low-volatile semi-anthracites of the Alston block, and on the relationship between mine gases and pneumoconiosis.

He was awarded the Geological Society of London's Murchison Medal in 1956, and his glacial work gained him his DSc.

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[redacted]

JOHN EDWARD MARR (1857–1933)

THE FOREMOST LAKE DISTRICT GEOLOGIST OF HIS ERA

Prof. David Oldroyd

Johnny Marr, as he was known to his acquaintances, was born at Bolton-le-Sands (Poulton), Lancashire, on 14 June 1857, youngest of the nine children of John and Mary Marr (née Simpson). His father, who retired in 1850, had been a Lancaster merchant trader and partner in a silk mill at Wray.

Following his family's removal to Caernarfon in 1863, Marr became interested in geology, and an Arenig fossil he discovered was subsequently named after him by Henry Hicks (the shrimp-like *Caryocaris marrii* (Hicks) [1876]). Marr's interest in geology was also stimulated during his studies at Lancaster Grammar School, when he met Richard Tiddeman of the Geological Survey, who was working in the area at that time, and accompanied him on field excursions in north Lancashire. In 1875, Marr went up to St John's, Cambridge, as an Exhibitioner. Three years later - and already with a paper on his Caernarfon fossils read for him at the Geological Society by his professor, Thomas McKenny Hughes (Marr, 1876) - he gained a First in the natural science tripos, with geology as his main subject. At St John's, he was tutored by the petrologist Thomas Bonney, who was at Marr's college.

After graduating, Marr worked as a university extension lecturer for four years, during which time he developed an interest in the relationship between geology and scenery. He worked briefly at Leeds University and in 1881 was elected to a fellowship at St John's. In 1886 he was appointed university lecturer in geology and in 1917 he succeeded McKenny Hughes as professor, a position he held until 1930 when he retired due to ill health.

Marr was elected Fellow of the Geological Society in 1879 and served as Secretary (1888-98), Vice-President (for several periods), and President (1904-6). He was a member of Council for thirty-four years and was awarded the Lyell Medal (1900) and the Wollaston Medal (1914). Marr was President of Section C (Geology) of the British Association (1896), was elected Fellow of the Royal Society (1891), and served on its Council from 1904 to 1906. He was awarded a Cambridge ScD (1904), an honorary doctorate from Prague (1908), and a Royal Medal (1930). In his prime, then, Marr was one of Britain's leading geologists, and - until he began to go blind in the latter years of his professorship, when he concentrated on Pleistocene geology and stone implements in East Anglia, and sought to evaluate the claims for the occurrence of Pliocene man - his chief area of research was Lakeland geology, for which topic his *Geology of the Lake District* (1916) was for long the standard text. The complete set of Marr's field notebooks is held at the Sedgwick Museum Cambridge, forming an invaluable source for students of the history of Lakeland geology.

Marr must have been a good lecturer, if the following newspaper report (of uncertain provenance) on a field excursion he ran near Keswick as an accompaniment to a series of lectures in Penrith (1881) is anything to go by:

> 'The learned but youthful lecturer (only a few years out of his teens)..... has won golden opinions from his numerous hearers, not only by his giving indisputable proofs of the perfect mastery of his subject, lucid arrangement, clear and distinct enunciation, but also by his striking modesty, total absence of pretension, pedantry, or dogmatism, as well as by his engaging affability and anxious desire to give full information to every one desirous of having any difficulty or obscurity elucidated; so that it may be safely asserted that if his hearers had not profited by his lectures it was not the lecturer's fault'.

The clarity of Marr's speech may, however, have been less evident in Cambridge, where a student who later became one of his colleagues, Tressilian Nicholas, recalled that Marr had a "burring Lake District voice which I found extremely difficult to understand. [Indeed, for] the first few lectures I really couldn't understand what he was talking about" (John Thackray, record of interview with T.C. Nicholas, 4 November 1975). His voice was also described as being rather high-pitched.

As said, Marr's early work was carried out in Caernarfonshire (1876). He also geologised in the Dee Valley (1880a), near Haverfordwest (1885), and did fieldwork in the Lake District for the greater part of his career. In his early years he also determined to examine the controversial work of Continental geologists in Bohemia and Scandinavia, to which regions he journeyed in 1879 and 1880 respectively, with the assistance of the Cambridge University Worts Travelling Fund.

In Bohemia, Joachim Barrande had proposed the notion of "precursoral forms" or "colonies", in cases where certain fossils appeared to be "out of order", according to the usual stratigraphic sequence (Horny and Turek, 1999). They had supposedly accomplished this by migration into a localised basin area, later dying out there when that basin subsequently filled with sediment. The same fossils might, however, reappear if and when appropriate conditions recurred in that area. This idea had regarded with some favour amongst British

Survey geologists such as Roderick Murchison (1872)[1]. It could help solve stratigraphic problems that sometimes arose in tectonically disturbed areas such as the Southern Uplands. But Marr showed that Barrande's "colonies" were in fact the result of younger rocks having been faulted into older strata. So there was no Bohemian contradiction of orthodox stratigraphic principles. (Like criticisms of Barrande's hypothesis had earlier been made by Charles Lapworth in connection with his work on the Southern Uplands of Scotland. See Oldroyd [1990].)

It is hard to know just how Marr knew how to reinterpret the Bohemian observations as he did. He was first shown around by Barrande's assistant, and later he was able to meet the eminent French/Bohemian palaeontologist and stratigrapher himself. Initially, the young Marr seemed persuaded of the ideas of his Bohemian hosts (Notebook IV, June 29), but already by July 3 he was drawing sections (see, e.g., Figure 1), which showed how the unexpected stratigraphic order might be explained by faulting.

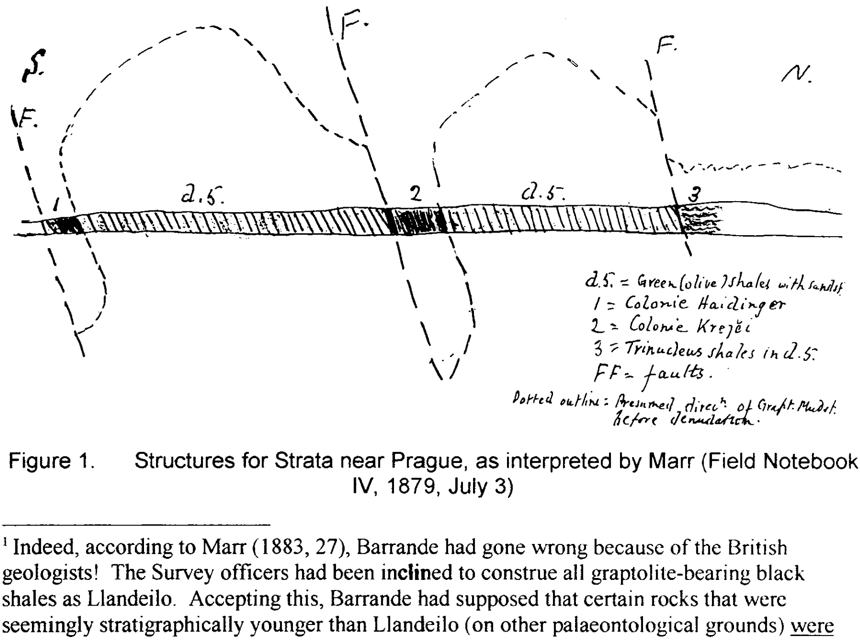

Figure 1. Structures for Strata near Prague, as interpreted by Marr (Field Notebook IV, 1879, July 3)

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[1] Indeed, according to Marr (1883, 27), Barrande had gone wrong because of the British geologists! The Survey officers had been inclined to construe all graptolite-bearing black shales as Llandeilo. Accepting this, Barrande had supposed that certain rocks that were seemingly stratigraphically younger than Llandeilo (on other palaeontological grounds) were Llandeilo simply because they contained graptolites. It was on this assumption that the notion of "precursorial" forms in colonies was developed. It is interesting that Barrande named his "colonies" after those who opposed his theories. So one of them was designated "*Colonie Marr*". I understand that it was situated on the slopes of a hill called "Smutný" near the town of Zdice in Bohemia.

It is significant that Marr used the stratigraphic succession known to him from the work of the Survey officers in the Lakes (Graptolitic [Skelgill] Mudstones / Pale Shales / Brathay Flags / Middle Coldwell Beds / Upper Coldwell Beds) as a guide to what he thought should be the correct sequence in Bohemia. Marr's ideas on Bohemian geology were published in 1880 (Marr, 1880b), and largely brought about the demise of the colonies theory, at least in Britain.

As a Lancastrian and Cambridge man, and a protégé of the Sedgwickian McKenny Hughes (who had worked for the Survey in the southern Lakes before gaining the Cambridge chair in 1873 and took members of the Sedgwick Club there, including Marr, in 1882), it is hardly surprising that Marr should have been sympathetic to the Sedgwick side of the Sedgwick–Murchison controversy concerning the placement of the boundary between the Cambrian and Silurian[2]. Marr's Sedgwickian views were particularly manifest in his prize-winning Sedgwick Essay on the classification of Cambrian and Silurian strata (Marr, 1883), in which he divided the stratigraphic column as follows:

Downtonian	Silurian
Salopian (Wenlock and Lower Ludlow	
May Hill (Valentian)	
Upper Bala	Cambrian
Middle Bala	
Lower Bala (Llandeilo)	
Llanvirn	
Arenig	
Tremadoc	

[2] Evidence in the Hughes archive, recently donated to the Cambridge University Library, reveals that Hughes's Sedgwickian ideas lay behind his resignation from the Survey, though there were other factors also involved, and some official dissatisfaction with his performance. He made apparently inflated travel allowance claims, and wanted to be in the London office for periods longer than his superiors thought warranted.

It will be noticed that Charles Lapworth's (1879) proposal for an Ordovician System to occupy the contested ground in the middle of the foregoing sequence was not adopted. The Cambridge Sedgwickians had their own turf to protect, as did the Murchisonians in the Survey.

But things were not to stay thus. The Upper Bala were to become the Ashgillian, at the top of the Ordovician; and Marr was to play an important part in this change. The first hint of the Ashgillian appeared in the *Catalogue . . . of Cambrian and Silurian Fossils . . . of the University of Cambridge* by Sedgwick and his assistant John Salter (Sedgwick and Salter, 1873), where Salter had proposed dividing the Upper Bala into: 1. Hirnant Limestone of Merionethshire (supposedly above the Bala Limestone) and 'Ash Gill Slates, &c., above the Coniston Limestone'; and 2. Llandovery Rocks. The fossils at Cambridge on which he made this suggestion had come chiefly from the area of Ash Gill, near Torver, to the west of Coniston Water. They were evidently at a lower horizon than the Brathay Flags, recognised near Ambleside, and the two units were placed in the Upper Cambrian and Lower Silurian respectively.

Marr visited Ash Gill and the nearby Ashgill Quarry in 1877 (Notebook II) and in 1878 published a paper suggesting characteristic phacopid trilobites for strata (excluding the "Green Slates" or Borrowdales) all the way from the Kirkby Moor Flags right down to the Skiddaw Slates. He had been told by Hughes in 1876 that there were beds near Sedbergh that resembled those at Ash Gill, suggesting that the unit might be of more than local importance. It was suggested that there was an unconformity above the Ash Gill beds, and so it was (for the Cambridge Sedgwickians) at this horizon that the boundary between the Cambrian and the Silurian was to be drawn.

In 1887, Marr began collaborative work with Henry Alleyne Nicholson, Professor at Aberdeen, who had published the first book on Lakeland geology in 1868, and was an expert zoologist, palaeontologist and stratigrapher. The two were introduced by Lapworth and soon became great friends - to the extent that Marr later named his son Alleyne. In 1887, they reported the discovery of fossils in brown shales - the Drygill Shales - to the northwest of Carrock Fell in northern Lakeland (Nicholson and Marr, 1887) and placed them in the Ordovician. (Perhaps Nicholson, who was a friend of Lapworth, urged Marr in the direction of accepting the Ordovician.) They were thought to be intercalated with the lavas and ashes of what are now called the Eycott Volcanics, which were at that time not distinguished from the Borrowdale Volcanics. So this appeared to provide the first palaeontological evidence for the age of the Lakeland volcanics. Today the Drygill Shales are regarded as having been emplaced by faulting rather than having been originally intercalated with the volcanics.

In conjunction with Nicholson, Marr carried out further exemplary studies of the Cumbrian Palaeozoics, working out successions at other key sites such as Skelgill near Ambleside (Marr and Nicholson, 1888), Stockdale in Longsleddale (ibid.), and in the Cross Fell area (Nicholson and Marr, 1891). Graptolites were used as zone fossils according to the techniques developed by Lapworth in the Southern Uplands (Oldroyd, 1990: 226–234), and the evolutionary history of these organisms was investigated. Attention was given to the conditions under which the ancient rocks were deposited. In his Presidential Address to the Geological Society, Marr (1905) introduced the concept of the Ashgill Series as the top of the Ordovician, and subsequently published his definitive account of the strata at Ash Gill, with the boundary there between the Ashgill Shales and the overlying Skelgill Beds (Lower Silurian, Llandovery) visible in Ashgill Quarry (Marr, 1915)[3]. In 1892, he published three papers (Marr, 1892a, b, c) in which the stratigraphic work was extended into the Silurian. All was accomplished with fine palaeontological control.

Marr (1894) also published on the Skiddaw Slates, where Nicholson and other geologists such as Robert Harkness had earlier spent much time on the tedious task of collecting graptolites and trying to establish the stratigraphy. It is interesting to remark that Marr was by then familiar with the whole range of Palaeozoic graptolites and was evidently trying to discern some kind of evolutionary pattern in the ever-growing collections. As a broad generalization, it seemed that there was a gradual reduction in the number of stipes, so that one had eight-branched *Dichograptus* low in the Skiddaws (Ordovician) gradually giving way to the single-stiped *Monograptus* towards the top of the Silurian[4]. Marr mused on the problem in some interesting doggerel verses and accompanying sketches in his Notebook XXIII (30 July, 1892), which are reproduced on the facing page (Figure 2).

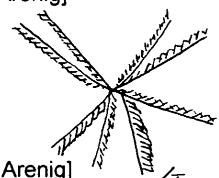
[3] Today, the contact in the quarry is rather overgrown, but the boundary is seen quite well by a small waterfall in Ash Gill itself, nearby.

[4] Subsequently, the retiform *Dictyonema pulchellum* (Hall) (Tremadoc) has been found by Adrian Rushton (1985) at Trusmadoor in the northern Uldale Fells.

Figure 2 – Sketches and Lines of Verse from Marr. Notebook XXIII. 1892

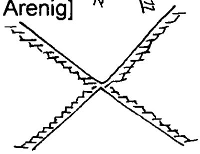
How first of all it came about
I do not care a fico [fig];
But something turned without a doubt
To octobrachiate *Dicho*.

[*Dichograptus*: Arenig]



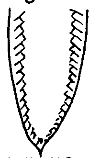
Then 'Evolution once again
Came into play', &c.
And thus we find our old sea-pen
Is posing as a *Tetra*.

[*Tetragraptus*: Arenig]



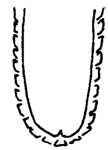
Another pair of branches drops
As Mother Nature bid em, oh!
And in the sea are many crops
Of double-branching *Didymo*.

[*Didymograptus*: Arenig/Llandeilo]



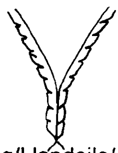
Through nearly half a circle sweeps
Each stipe from off its fellow
And from each hydrotheca peeps
The flesh of a *Dicello*.

[*Dicellograptus*: Llandeilo/(Caradoc)]



Now trouble comes about and s[d]wells
In corpore non sano
So back to back the early cells
Unite to form *Dicrano*.

[*Dicranograptus*: Llandeilo]



The distal thecae follow suit
Unto the very tip. So!
The first Diprionidian brute
Emerges as a *Diplo*.

[*Diplograptus*: Arenig/Llandeilo/
(Caradoc)/ Llandovery]

Each theca finds opposing cell
Is to itself a sore foe;
So some are dropped, and all is well
At first with the *Dimorpho*.

[*Dimorphograptus*: Llandovery]

But not for long, and so at last
One row of cells is gone oh!
Our beast (through many stages passed)
Becomes the perfect *Mono*.

[*Monograptus*: Llandeilo/Caradoc
/Llandovery/ Wenlock]

Such musings can sometimes tell us more about a geologist's ideas than many pages of technical writing; and I think they do so in this case. They are also interesting because they hint at what Marr was very likely teaching in his classes at Cambridge. The idealised evolutionary model seems to have been picked up by Marr's student, Gertrude Elles, who was to become one of the aficionados of graptolite studies in the first half of the twentieth century. Moreover, according to a later authority on Lakeland graptolites, Dennis Jackson (record of interview, 4 July, 1998), some of Elles's work, based on museum studies as much as her own field investigations, took a wrong turn because of undue adherence to such an evolutionary model. But I do not seek to pursue this question here.

Another of Marr's co-workers in the Lake District was his St John's colleague, the petrologist Alfred Harker. They worked on the igneous rocks at Shap, Marr being chiefly responsible for the map work and stratigraphy, while Harker concentrated on the petrology (Harker and Marr, 1891). Marr was much more at home with palaeontology, stratigraphy, and geomorphology than with igneous petrology. Indeed, he did not find the latter field particularly congenial, as the following rhymes from his notes (Book XXII, 24 September, 1890), when he was visiting Mardale with Harker, reveal:

A plague upon lavas and ashes,
Agglomerates also be banned,
Away with contortions and smashes;
Such games I don't understand

Let thrusts be consigned to the devil,
May 'tears' go along with them too;
Let imps of Beelzebub revel
In rocks which are twisted askew.

Accurst be the lavas of Stanah;
The rocks of Galleny be blowed;
Whilst as for the Eycotts, how can a
Man tell where the mischief they're stowed?

The White Stones agglomerates, drat 'em,
As also the tuffs of Bowfell:
I dedicate every atom
To innermost recesses of h[ell].

The rocks which occur on Torpenhow
Make any geologist swear:
Oh! send the whole lot to Gahenna,
To fuse and solidify there.

In Hades there may be a Johnny
        Would venture such rocks to descry
For instance, our underground B[onney]
        Might work his experienced eye.

For my part I hold the volcanic
        Deposits are rather too much;
Beds furnishing relics organic
        Alone, in the future I'll touch.

Yet needless to say, Marr could not avoid igneous petrology and problems of structure in Lakeland geology. Let us consider a couple of examples where he got into a little difficulty in this area.

As mentioned, Marr and Harker produced a paper on the geology of the Shap area in 1891; and a supplement to this was published in 1893. The first paper included a map that was particularly detailed in the immediate vicinity of the Shap Wells Hotel (on which see below), but as I have argued elsewhere (Oldroyd, 1999a) the map was somewhat schematic, making considerable extrapolations beyond what could actually be seen in the field. Marr also exhibited some of his Shap specimens at the Geological Society in 1902. The paper of 1893 involved some significant modifications to the statements made two years earlier. By 1893, the rocks to the north of the pink granite of Shap had become more basic—even basaltic—having earlier been represented as intermediate andesites. This change was said to have been made in response to the examination of more basic rocks in the interim. These would clearly be the exposures of the Eycotts that Harker and Marr worked on in the years 1890–93, sometimes together and sometimes separately. But it should be emphasized that what they had as Eycotts were not necessarily the rocks mapped as such today[5].

[5] The conflation of Eycotts and Borrowdales went back to the time of Otley and Sedgwick and was also made by Nicholson, who may indeed have had an unhelpful hand in the development of Marr's structural theory of the Lake District. Correspondence between Nicholson and Lapworth, preserved at Birmingham University, reveals that in 1883 Nicholson supposed that the Drygill Shales formed a unit at the base of the Eycott Series; and that the Eycotts ran all the way from St John's Vale, though Borrowdale, over Honister, and on to Ennerdale! It seems possible that some erroneous structural ideas, never published by Nicholson, passed from him to Marr in the field or in correspondence.

Harker (Notebook 17, 1890, Sedgwick Museum) was looking round the northeastern side of the Lakes, and so too was Marr (Notebook XXII) when he scribbled his verses above. They were trying to make sense of the structure of the area between Ullswater and Haweswater, supposing that the Eycotts were appearing in this region; and they were invoking various tear and thrust-faults to make sense of it all. Harker prudently never published the complicated structural ideas that the two friends were trying to develop, but in the 1893 paper just talked about the metamorphism in the Shap aureole, claiming that chemical and mineralogical evidence suggested that it did not involve changes in the bulk chemical compositions of the rocks in the aureole. Marr said something about the fossils recently found by Nicholson near Shap Wells, but kept quiet in the discussions following the presentation of the paper at the Geological Society about petrological questions. Subsequently (1902), he did offer the suggestion that the certain vein-like structures near the Shap granite represented pre-existing metalliferous veins that had been altered when the granite was intruded - an idea that found no favour with later workers such as Ronald Firman (1954), who did his PhD on the problem of the metasomatism and metamorphism associated with the Shap (and Eskdale) granites. (He regarded Marr's suggestion as "untenable".)

As said, Harker never made public any ideas he may have had about thrust-faulting in the Lakes, but Marr certainly did (claiming that his speculative theory had Harker's support). Marr, as we have seen, first made a name for himself by showing that Barrande's ideas could be explained more satisfactorily by invoking faulting rather than colonization, and perhaps this was why he was willing to offer the bold hypothesis, outlined below. In his paper with Nicholson on the Stockdale Shales (1888), Marr suggested - quite reasonably - that rocks of different competence might move differentially in response to lateral forces. The idea was developed further in a speculative paper on the overall structure of the Lake District, designed to account for the presence of the Drygill Shales (Caradoc) in the northern Lakes, near Carrock Fell, well away from the also fossiliferous, but younger, rocks of southern Lakeland; and in addition the problem - one that is, even now, not fully settled - of the relationship between the Borrowdale Volcanics and the Skiddaw Slates (Marr, 1900).

The relationship between the Skiddaws and the Borrowdales was already causing trouble in the nineteenth century, long before it became a really hotly debated issue in the 1970s (Mitchell et al., 1972). The early investigators such as Nicholson (1868) thought that the relationship was one of conformity. The surveyor John Dakyns (1869) claimed, however, that there was a marked unconformity between the two. His colleague Clifton Ward (1876) thought the contact was faulted, and his Survey maps (e.g., the Keswick Sheet, Sheet 101 S.E., 1875) showed a string of interconnected high-angle faults along the line of contact between the two units.

By the end of the nineteenth century, as a result of the work of Lapworth, Peach and Horne, and others in northwest Scotland, the idea of thrust-faults was well established in Britain, and was quite frequently invoked. Marr's view was that there had been a pushing of the Lakeland rocks from the south; but because of the different natures of the three principal units the underlying Skiddaws had been pushed furthest; then came the Borrowdales; and then the Upper Slates (Windermere Group in modern parlance). Put another way, the Borrowdales had lagged behind the Skiddaws; and the Windermeres had lagged behind the Borrowdales. Thus (so far as I am aware) Marr introduced a new kind of fault into the geological literature: "lag-faults". These, like thrust-faults, were low-angled; but there was no inversion of the strata during their formation, as was the case with thrust-faults as envisaged by Lapworth and others for the Northwest Highlands of Scotland. Because of the supposed differential south-to-north movement in the Lakes - unequal at different points from east to west—there were also high-angle faults, striking approximately north–south and producing erodible shatter belts - fracturing the outcrop of the Coniston Limestone, for example - as had long been known.

But to make such a differential lagging movement geometrically possible, there had to be compensating thrust-faulting. Marr had no direct evidence for such a fault (though he drew some in his field notebooks), but the occurrence of the Drygill Shales seemingly allowed a "way out" of his problem. His students Gertrude Elles and Ethel Wood had suggested on palaeontological evidence - especially that of graptolites - that these Shales were of the same age as the Coniston Limestone in the southern Lake District. With these factors in mind, Marr developed the model shown in Figure 3. It repays close study.

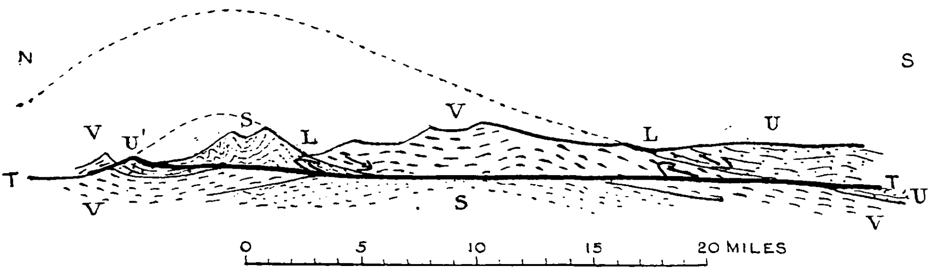


FIG. 3.

S. Skiddaw Slates.
V. Volcanic Series.
U. Upper Slates.
U' Upper Slates below Thrust Plane at Drygill.
TT. Thrust Plane.
LL. Lag Planes.
For clearness sake, the amount of thrust has been represented as much less than the probable actual amount.

Figure 3 - Marr (1900a: p. 468)

What we have here is the idea that Ward's zig-zag chain of high-angle normal faults between the Skiddaw Slates and the Borrowdale Volcanics was representable by a low-angle "lag" fault (L); and there was a similar one between the Volcanics and the Upper (= Windermere) Slates. But at the same time this differential movement was compensated by the movement along the large (hypothetical) thrust fault (T–T), which supposedly underlay the whole of the mountain range (but being beneath the exposed outcrop of the Skiddaws it was invisible, except, one must suppose, near Drygill). Put another way, above the thrust plane there had supposedly been a general northward movement of the main sequence (Skiddaws, Borrowdales, and Upper Slates), but of these the Skiddaws had travelled further than the Borrowdales, which in turn had travelled further than the Upper Slates. The Drygill Shales were to be seen further north than the Skiddaws, as a small exposure of the youngest of the three main units. They had not been pushed forward by the thrusting but had been there all the time, and were now visible "peeping through" where erosion had cut down to below the level of the hypothetical thrust. It will be noted that Marr had the northernmost volcanics (the Eycotts) as belonging to the same unit as the Borrowdale Volcanics; but, as said, that was usual at that time.

It is, I think, virtually impossible to envisage a system of forces that would give rise to such a state of affairs[6], but by the early years of the twentieth century Marr's reputation and position were such that he could command assent—or at least he could get his ideas published by Cambridge University Press! He took members of the Geologists' Association with him to the Lakes in August 1900, and proposed the idea of the major thrust-fault (Marr, 1900b: 530). Whether it was received positively by the excursionists I do not know, but I would say that the sketch map produced for their benefit (Marr, 1900b: Plate XIII) is almost impossible to reconcile with the section of Figure 3 above. However, Marr's ideas remained in the public domain for some twenty years, being re-affirmed in his *Geology of the Lake District* (1916). It will be noted that his structure (Figure 3) rightly allowed for a syncline in the high fells around Scafell. His idea was that the main body of these fells was produced by a kind of "tectonic accumulation". The ashes and lava flows had, so to speak, been gathered together where they now stood by means of tectonic activity (not by the accumulation of volcanic debris from a volcano in the locality of the highest mountains). This idea was odd too, even for its time.

As for the thickness of the Borrowdales, Marr (1916: 7 and 17) estimated that they were of the order of 10,000–20,000 feet, the higher figure being more likely. For while the rocks were supposedly thrown into broad folds, they were not held to be repeated by faulting (the supposed "tectonic accumulation" notwithstanding) so the apparent thickness was approximately the real one, so to speak.

Marr's structural ideas were challenged by the amateur geologist J.F.N. Green in one of the great brouhahas in the history of Lakeland geology. In 1908, Green had successfully sorted out some major geological problems in Pembrokeshire (Oldroyd, 1990), and he then turned his attention to the Lake District, starting work in the area of the Duddon Valley. Green read a paper on his Duddon work to the Geological Society on November 15, 1911, proposing a new classification for rocks of that area. He claimed that the Skiddaws passed conformably into the Volcanic Group. Further, he maintained that the succession of rocks was thrown into folds striking northeast–southwest. Green also suggested that there was an unconformity below the Coniston Limestone, not a lag-fault.

In the event, the Geological Society only published Green's paper in summary and the full version was rejected. According to the Society's archives (COM/P3/2), the referees were Harker, Marr, and William Watts of Birmingham University - a reasonable choice, given that potential Survey referees such as Bernard Smith, who had been re-surveying in southwest Lakeland, had a kind of

[6] Such a fault system is rather rare in the theoretical armoury of the structural geologist. But see for example: Soper and Anderton (1984).

vested interest in the issue. But so too did Marr, given his published views on Lakeland structure, with his system of lag-faults, with one at the base of the Coniston Limestone. Whether Green was offered the chance to revise his paper is not known, but in the event he withdrew his contribution and published privately (Green, 1912). The paper contained a sketch map, which is almost impossible to reconcile with any other map known to me, ancient or modern, and his hypothesis of low-angle folds with repetition of beds may have arisen from the fact that he did not achieve a precise characterisation and differentiation of the various units in the volcanic sequence. On the other hand, Green did recognise the occurrence of different lenticular sheets of andesites within the sequence; and his idea that there was a kind of transition of conditions from the Skiddaws to the Volcanics was worthwhile and has attracted later support.

Undeterred by his rebuff by the Geological Society, Green turned to the more difficult area of the eastern Lakes around Haweswater (Green, 1915). Lakeland andesites, he pointed out, frequently had a brecciated structure, attributable to the shattering of a cooling and solidifying crust on a flowing lava. So the brecciation would be expected to occur on the upper surface; but he also envisaged the possibility that it might occur more rarely in the emplacement of sills. Here he was on the right track, perhaps groping his way towards the notion of what today are called peperites, but his application of his Duddon Valley stratigraphic sequence to the eastern Lake District led to problems and errors. With broad-brush mapping, he summarily dismissed Marr's theory of lag-faults, saying that it was a "task of great difficulty to conceive the peculiar system of mixed pressures and tensions apparently required to produce lag-faults in association with a great thrust in rocks that are not behaving as viscous fluids". Rather, drawing on early ideas of Robert Harkness (1863), he supposed that the region had been thrown into a series of isoclinal folds. This meant that the overall thickness of the Borrowdales would be much less than that estimated by Marr.

The effect of all this on the history of Lakeland geology was curious. Geologists did not take up Marr's structural suggestions, and seemingly began to wonder whether Green might have been right after all about the geology of the Duddon area, even if his mapping was crude. So it was that Green's anticlinoria theory held the field for many years, being deployed by G.H. Mitchell in the 1920's and 30's for example and only relinquished by him in the 1950's.

In his Lakeland work, Marr also gave particular attention to the effects of earth movements and glaciation on topography and scenery, considering their roles in the formation of lakes and drainage patterns. In his earlier work, he ascribed much of the topography to erosion along "shatter belts", but after visiting the Lakes with the American geologist W.M. Davis in 1907 Marr placed greater emphasis on the erosive powers of glaciers.

In the late nineteenth and early twentieth centuries British geologists such as James Geikie were endeavouring to apply the idea of multiple glaciations to British geology, according to the Continental observations of the likes of Albrecht Penck and Eduard Brückner (of Günz, Mindel, Riss, and Würm fame), and the astronomical theory of the ice ages of Geikie's Survey colleague, James Croll. From such a perspective, one might have hoped to find a series of tills and various deposits representing interglacials (Oldroyd, 1999b). But Marr could find little evidence for such sequences in the Lakeland deposits. He rightly pointed out that in the Lakeland mountains the deposits left by earlier glaciations would be likely to be obliterated by later ones. He did mention a section near Elterwater Bridge where red boulder-clay underlay a grey variety, with stratified gravels between (Marr, 1916: 194). But such a sequence cannot be seen today, as the left bank of the river near the bridge is disturbed by human habitation while the right bank is covered with slate quarry waste[7].

On the whole, then, Marr (1916: p. 147) doubted the idea of multiple Lakeland glaciations. However, in a late paper (1924), he did offer some interesting evidence for at least two glacial epochs. In Church Beck, running down from Coniston Old Man to Coniston Water there is a gorge near the Miners' Bridge; and there are (according to Marr - but I have not been able to locate them) glacial striae on some of the rocks within the gorge. The beck runs down from what is evidently a hanging valley, produced in some earlier glaciation. The gorge could plausibly have been cut during an interglacial epoch; and then a later cold period had ice working within the pre-formed gorge. Interestingly, though Marr was somewhat out of step with his fellow geologists on the question of multiple glaciations in northern England, he would appear to be vindicated by recent thinking, which allows "firm and extensive evidence for only two glacial events: the Anglian and the Devensian" in the British Isles (United Kingdom Nirex Limited, 1997: 11).

Marr's other special interest was sedimentology, which he treated in a textbook of his old age: *Deposition of Sedimentary Rocks* (1929). This work gives a good idea of the stratigraphic principles being taught at Cambridge in the 1920s, under the influence of the likes of Johannes Walther and William Henry Twenhofel. Marr was at once a uniformitarian (using knowledge of present modes of deposition to understand stratigraphic problems) and a progressionist (being a Darwinian evolutionist). Different kinds of deposits, with different organic remains, were formed simultaneously in "belts", at different

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[7] Upstream, near Chapel Stile, there are some unimpressive deposits, possibly related to what Marr saw and described.

distances from the shore-line. So a horizontal cut through a series of sediments did not necessarily mark a time horizon. By the same token, fossils of the same kind, found at some considerable distance from one another, might well be separated in time as sedimentation proceeded oceanwards. Harking back to his old thoughts about Barrande, Marr gave special attention to the formation of deposits in isolated ocean basins. In general, he displayed a sophisticated understanding of the principles of sedimentology and stratigraphy, which he had come to understand so well after years of practical experience, much of it in the Lakes. The topic, though not one that was then specially popular, required as clear a head as that needed for studies in tectonics or petrology, which, by his own admission, Marr had found perplexing.

Marr wrote a considerable number of popular essays, lectured regularly to amateurs, and conducted excursions for them, but there is little record of his doing much other than working single-mindedly at his science. Apart from the books previously mentioned, he wrote a volume on the geography and natural history of Westmorland (Marr, 1909) and one on Cumberland (Marr, 1910); and textbooks on *The Scientific Study of Scenery* (Marr, 1900) *and Agricultural Geology* (Marr, 1903), the former being essentially a volume on physical geography and the latter on general geology and British stratigraphy. In his later years, as blindness came upon him, and he could no longer work up in the Lakes, he turned his attention towards prehistoric archaeology, studying the Pleistocene deposits in the neighbourhood of Cambridge; but this work lies beyond the scope of the present paper.

Marr married Amy, daughter of the late John Stubbs of Shap Wells, Westmorland, early in 1893, which explains why - according to the evidence of his field notebooks - he seemed to find it necessary to spend so much time in the Shap area in the years 1890–1892. Curiously, having proposed to Amy, he seemed to have had serious regrets about his action (Notebook XXII, July 15–20, 1891). The first night of their marriage was spent at the unromantic Midland Grand Hotel, St Pancras.

However, to the best of my knowledge the marriage was successful and Mrs Marr is recorded as acting regularly as hostess to her husband's appreciative students in Cambridge. But I would not be surprised if she found the move from the remote locality of Shap Wells to the garden parties of Cambridge quite a strain. Their son, Alleyne, who as a lad used to help his father in his Lakeland fieldwork, fought in World War I and was killed in the World War 2. Marr died of a stroke at Cambridge on 2 October, 1933.

Acknowledgements

I am grateful to Michael Dorling, of the Sedgwick Museum, for permission to reproduce material from Marr's field notebooks. Not long before he died in 1999, the late John Thackray, archivist at the Geological Society and the Natural History Museum, London, very kindly made available to me his transcript of his interview with T.C. Nicholas in 1975, for which I am most grateful. Thanks also to the Keeper of the Lapworth Archive at Birmingham University for allowing me to consult correspondence there from Nicholson to Lapworth; and to the Cambridge University Library for allowing me to consult the McKenny Hughes papers. My correspondent Dr Josef Haubelt of Prague has provided information about the location of "*Colonie Marr*". A good many friendly Lakeland geologists have also assisted me in my on-going project of writing a book on the history of geological research in the Lake District. Specifically, I am indebted to Angus Lunn for his careful reading of the paper and his critical comments thereon; and to Chris Thompson for his editorial work. Also, needless to say, no one can get anywhere in the study of the history of Lakeland Geology without utilising Alan Smith's two notable bibliographies. The help of all is greatly appreciated.

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ALFRED HARKER (1859-1939)

THE 'FOUNDING FATHER' OF MODERN PETROLOGY

Mervyn Dodd

Alfred Harker spent almost all his long adult life (61 years!) at St John's College, Cambridge, where he arrived as an undergraduate in 1878. His first degree was in Mathematics in 1882 as the 8th Wrangler, the 8th in order of merit in the First Class Honours in Mathematics in the University, He then read for the Natural Science Tripos, specialising in Physics with Geology, which he first read as a subsidiary subject in his final year. His 'Double First' in both parts of the Tripos in 1882 and 1883 was followed by his unexpected appointment as University Demonstrator in Geology in 1884. This involved him teaching Mineralogy and Lithology, supplementing his miserable pay by coaching undergraduates, probably in Mathematics and Physics. He was elected to a Fellowship at St John's College in 1885, which position he retained until retirement in 1931. In 1904 he became a University Lecturer and in 1919 the University created for him the special post of Reader in Petrology. His interests were academic, being particularly interested in research. Thus he preferred to remain a Lecturer to give his time to scholarship rather than become an administrator or get involved in University politics. He was much more effective in lecturing to the knowledgeable and committed than in giving elementary lectures to beginners. After retirement he became Honorary Curator of the Cambridge Petrological Museum (now part of the Sedgwick Museum) much of the collection being rock slices he had provided. He was the guest of honour at a dinner organized for his 80th birthday by a group of eminent geologists. A few months later he died in Cambridge.

Harker's initial researches (1886-9) were into the volcanic rocks of Snowdonia, where his approach was mathematical with an accompanying insistence on crustal processes and relating these rocks to the regional cleavage. This was unusual then. He worked with Marr around Shap and Carrock Fell between 1889 and 1894. His study of the Shap contact aureole was an early excursion into thermal metamorphism, where he analysed the sequence of mineralogical changes (which he found to be much less than was generally thought), and drew attention to the survival of quite small scale sedimentary structures. I recently read the paper written by Harker and Marr about the Shap Granite and its metamorphic aureole, and found it to be very lucid, clearly and convincingly argued, with relevant detail, reflecting thorough fieldwork and laboratory analyses. They had written without unnecessary jargon and with an easy flow of language. It is a classic paper that remains usable today, over 100 years after publication, with its map of the Shap Granite and the rocks around still being reproduced for at least one field course. Other workers at the time found his work on the Carrock Fell gabbros and granophyre contentious. He attributed marginal variations in the gabbros to localized concentrations of the early crystallizing minerals, and thoroughly investigated mutual reactions between the gabbro and granophyre

Harker's main area of research was in the volcanic districts of Western Scotland, particularly in Skye, Rhum, Eigg and Muck. Between 1895 and 1905 he worked on a part-time basis for the Geological Survey, something previously unheard of. His skills as an expert petrologist and field geologist mapping on the 6-Inch scale, combined with his exceptional stamina, allowed him to make an outstanding contribution to the understanding of these complicated rocks. His work was published in parts of at least three of the Survey memoirs that appeared between 1900 and 1910. Some of his interpretations did not find favour with the autocratic Director of the Survey, Geikie, leading to an acrimonious and pungent correspondence. In a then unfashionable way he recognised and emphasised the erosive action of ice in the Cuillins. The Western Highlands of Scotland were his favourite region, which he visited two or three times a year, leading study parties and continuing his researches.

His output of research papers was considerable, appearing in a very wide range of learned journals and spanning the years 1886 to 1939. Harker's elementary textbook *Petrology for Students* appeared first in 1895 and its final edition was in 1935, such was its very considerable impact. More advanced texts were *The Natural History of Igneous Rocks* (1909) and *Metamorphism* (1935). These works established the claim for him to be regarded as the founding father of modern Petrology.

The world of Science recognised Harker's eminence early, electing him as a Fellow of the Royal Society in 1902. The award of a Royal Medal in 1935 was the honour he most treasured. The Geological Society of London, of which he was President between 1916 and 1918, awarded him the Murchison Medal in 1907 and the Wollaston Medal, their highest award, in 1922. The University of Edinburgh and McGill University both gave him honorary doctorates. He was an honorary or corresponding member of many foreign scientific societies and academies but rarely attended international scientific conferences or foreign study tours. The most significant of these was his visit in 1906 to Oslo Fjord, a particularly fine source of unusual petrological specimens and a great fillip to his developing ideas on igneous petrology. He maintained a considerable interest in his native Yorkshire, serving as President of both the Yorkshire Geological Society and the Yorkshire Naturalists' Union, writing many papers for both societies.

Harker was a rather a retiring individual, often shy and diffident in company, remaining a bachelor. He had an exceptional capacity for enjoying his own company, but after retirement came out of his shell, expressing trenchantly and unexpectedly strongly held views. While he was not a man inclined to enjoy a wide circle of acquaintances he had several close friends to whom he remained loyal.

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EDMUND JOHNSTON GARWOOD (1864-1949)

CARBONIFEROUS BIOSTRATIGRAPHER

Murray Mitchell

Born at Bridlington, schooled at Eton and educated at Trinity, Garwood studied geology at Cambridge as an extra subject to supplement courses in chemistry and physics. To his professor T. McKenny Hughes, he owed his introduction to fieldwork in the Ingleborough area; and with his lecturer, J.E. Marr, he formed a life-long valued friendship. It was Marr, with his vast local knowledge and scientific enthusiasm, who initiated Garwood into the geomorphology and stratigraphy of the Pennines and Lake District.

After leaving Cambridge in 1887, Garwood followed family interests and for a few years was engaged with the Jarrow Chemical Company before becoming a Cambridge University Extension Lecturer in 1892. While resident in Northumberland, he had begun studies of the local Carboniferous. He then extended work to the collecting of fossils from the Lower Carboniferous of the Ingleborough area. This work initiated the zonal stratigraphy of the Lower Carboniferous (Dinantian). In 1895, he communicated his preliminary results before the British Association and published them in a joint paper with Marr. Following this paper, a B.A. Committee was formed to investigate Lower Carboniferous zoning, with Marr as chairman and Garwood, for a few years, as secretary. During these years, he met other workers on the Lower Carboniferous, and developed his interests in glaciation and exploration. In 1901, Garwood was appointed to the Chair of Geology at University College London, and devoted himself to the building of the department, almost from its foundation. His success in this task is a lasting memorial to his energy and commitment. From 1903, Miss Edith Goodyear became his assistant, and was to be co-author of some of his important zonal contributions.

During the short period when Garwood's interest in Carboniferous faunas was in abeyance, Vaughan (1905) published his work on Lower Carboniferous zones, which was based on the Avon Gorge section at Bristol. There were serious problems particularly with the middle (C_1 C_2; Chadian & Arundian) part of the Avon sequence where there is much oolitic and dolomitic rock with few, mostly non-diagnostic, fossils. This led to confusion and criticism when attempts were made to use the Avon-based zones to classify sections as close to Bristol as the Mendips. It is now known that these problems arose because the Avon section is incomplete, with important faunas not present, and was an unfortunate choice as typical section. However, Vaughan continued with his work, and with the help of many fellow workers studied sections away from Bristol. Frequent revisions and modifications were made to his zonal scheme to accommodate faunas not found at Bristol, but the principle of zoning by means of faunal assemblages was established for the Lower Carboniferous.

Garwood and Miss Goodyear, together with other students, began work again in the north and chose the Ravenstondale-Shap succession as their standard. Thousands of fossils were meticulously collected, registered and named, and many of these are now housed in the British Geological Survey Collection at Keyworth, Nottingham. Garwood was able to describe a succession of zonal assemblages within a framework of well-defined faunal bands. Provisional correlations were published in 1907, followed by full details in his classic N.W. England paper (1913) which established Garwood's geological eminence. In 1913 he was President of Section C of the British Association, and 1914 was elected to fellowship of the Royal Society.

Garwood's 1913 paper set the standard for all subsequent work on the Lower Carboniferous rocks round the Lake District, and his 1924 paper with Miss Goodyear equally became the standard for Pennine areas. Although Garwood attempted to correlate his N.W. England zonal sequence with Vaughan's (1905) Avon Gorge sequence, there were problems with detailed correlation, particularly with the middle part of the sequence. The analysis by Hudson and Dunnington (1945) was of major importance to the understanding of this confusion, with C_1 and C_2 having different meanings in the south and north of England, and they contributed greatly to our knowledge.

Four important Lower Carboniferous faunas have not been recorded from the Avon Gorge. They were described in detail by Garwood (1913) and precisely recorded in the sequence. Perhaps the most important of these faunas are those of the *Michelinia grandis* Zone from the Kendal - Arnside - Grange-over-Sands area, the descriptions of which are essential to the understanding of the Bristol sequence. The range of the distinctive brachiopod *Delepinea carinata* (Garwood) proved to be of particular significance. The details of the faunas and lithologies in the *M. grandis* Zone part of the succession are also critical to the present understanding of the stratigraphy and structure of the Carboniferous Limestone of South Cumbria.

The recognition that these northern England faunas were missing at Bristol, together with the new synthesis of regressions and transgressions in the British Dinantian by Ramsbottom (1973) were important steps leading to the erection by George and others (1976) of Regional Stages, for the correlation of British Dinantian successions. It was no coincidence that three of the six stages are based on localities in N.W. England where more complete sequences are known.

In addition, Garwood and Goodyear's 1924 (Settle) paper showed that the upper part of the Lower Carboniferous (D2 of Vaughan) is thicker, more fossiliferous and more complete in the Yoredale facies rocks of the north Pennines. This led to later work by Hill (1938) who proposed three coral zones for this part of the sequence.

After the Settle paper, his role became something of an 'elder statesman'. He was President of the Yorkshire Geological Society for 1924 and 1925, and of the Geological Society of London for 1930 and 1931. In 1931, he retired from the Chair of Geology at University College, London, and retired from active field work. He then spent many happy hours arranging his collection of fossils which numbered some 85,000 specimens and reviving old memories. In 1938, the Yorkshire Geological Society celebrated its Centenary and chose Professor Garwood, their most honoured and respected member, as Centenary President.

In summary, Garwood published two major contributions on the faunal zones of the Lower Carboniferous of northern England, the N.W. England paper (1913) and the Settle paper with Miss Goodyear (1924). The value of these is two fold. Firstly, they established standards for all subsequent research into the stratigraphy of Lower Carboniferous rocks in the Lake District and N.W. England. Secondly, and perhaps of more lasting significance, the detailed descriptions of precisely located faunas were of vital importance to our present understanding of the biostratigraphy of the Lower Carboniferous (Dinantian) rocks of Britain.

A fuller account of Garwood's work is given by Hudson (1950).

Acknowledgements

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THOMAS HAY (1873-1957)

LAKE DISTRICT PHYSIOGRAPHER

Chris Thompson

Thomas Hay was one of the more important writers on Lake District landscapes and landforms, publishing twelve papers from 1926 to 1951. His work spanned the time from Marr to Hollingworth, Mitchell, Raistrick and their colleagues. Hay was born in 1873 of a Scottish Border family settled on Tyneside. He read mathematics with distinction at St John's Cambridge, graduated in 1895 and became a schoolmaster. Two years later he took a London external B.Sc. Following family holidays at the Dun Bull in Mardale he bought Moss Crag, the house in Glenridding which became the base for the exploration of lake shore, dale and fell in which he had been encouraged by Professor Marr and H.R. Mill.

In 1928, Hay resigned his headship at Chelmsford. For twenty-five of his thirty-three years in teaching he had been a headmaster. The prospect of mostly lone excursions among the hills proved more attractive than some ten more years of school with little or nothing more to prove there. He left Glenridding at the close of the Second World War with great sadness, moving to his wife's family home in Nailsworth in the Cotswolds. His last Lake District note appeared in 1951 when he was 78. He died in November 1957.

In **1938** he received the Back Award of the Royal Geographical Society for promoting understanding of Lake District landscapes and for demonstrating analysis of glaciated landscapes to members of inter-war Arctic expeditions. Alongside his physical landscape papers there are twelve in the Transactions of the Cumberland and Westmorland Antiquarian and Archaeological Society.

His work was described as 'revealing delight in close argument and compact results - a sense of dynamic landscapes, processes at work - all landscape features to be read, to contribute to the story.' His interests took in contemporary landscape processes, notably high magnitude-low frequency events such as major floods: he examined links between rainfall, discharge and their morphological consequences - what, when and where. But he persistently pursued certain major themes, especially the work of glacier ice, the effects of freeze and thaw of ground water, the formation and development of the high-level areas of rather subdued relief.

Early studies concentrated on comprehensive description and classification of lakeside landforms. He was encouraged in this by Marr and by H.R. Mill of the Lake District Bathymetric Survey. The ensuing papers (1926, 1928, 1930) remain the most comprehensive accounts of lakeshore forms. Interest in process is exemplified by attempts to explain the sometimes complex and apparently perverse planforms of lakeshore deltas. Among the sorts of feature that puzzled him were masses of waterlaid sands and gravels, their level tops some metres above present mean lake levels, 6m at the head of Ennerdale Water. Possible relations with old higher lake levels were mooted but in general there is little evidence for persistent higher levels. Impounding effects of residual ice masses were also considered. The Ennerdale features, as others, remain to be explained: they need not be linked to levels of the present lake but perhaps to events during loss of glacier ice.

The more interesting features he encountered along the shores owed more to the work of ice, frost, and rivers than to shoreline processes. Hay turned from the constraints of the lakes to broader prospects for his curiosity and to the themes and problems he then pursued to the end of his time in the Lake District. The first of the 'new' papers (1934) dealt with glacial landforms in the Ullswater area concluding, in complement to Marr (1916) and Clifton Ward (1875), that erosive ice crossed ridges up to c. 680 m O.D. and that the whole area had been ice covered. He thought that at the end of the last major glaciation dwinding valley glaciers became separated from upland ice masses that sustained a 'Highland Glaciation'.

He considered there was evidence for two glaciations on the basis of variation in till character and the local presence between tills of water-sorted sands and gravels. The till-gravel-till exposure at Rattlebeck, Glenridding, important in Hay's argument, may have only local significance but, nevertheless, is a fine example of such a succession.

The presence of esker-like features among the drumlins of the lower Ullswater area was seen as indication of stagnation in previously active ice. The Ullswater drumlin tract, with the neighbouring Matterdale tract, adjacent to the field of drumlins from southern Vale of Eden round to the coast between Silloth and St Bees, shows that the ice-sheet conditions which led so widely to drumlin formation extended well into the hill country.

In the heart of the fells, in the neighbourhood of uppermost valley-head moraines, Hay acutely recorded 'fascinating high-level marginal lines which reveal the old locations of the edge of a stream of ice - seen in certain lights or when the ground is covered in snow'. Though he mapped some associated valley head moraines and knew the 'marginal lines' matched old glacier limits he did not use them to plot the successive limits of valley-head glaciers. Almost fifty years were to pass before Sissons (1980) mapped the maximum extents of the many Lake District valley glaciers he ascribed to the short severe Loch Lomond Stadial that concluded the Pleistocene.

Hay recognised the similarity of hummocky moraines in the Scottish Highlands, Torridon for example, and in Lake District dale heads but never overtly associated them with a discrete late episode of glacier formation. Nevertheless, he did record that the apparent chaos of hummocks could be caused by gullies 'breaking up the orderly array of ridges into a disorderly patchwork of more or less isolated mounds, plateaux and ridges.' The 'orderly array of ridges' marks out, as do marginal lines, successive ice margins. Hay, like Manley (1959), was content with general indications of glacier sites rather than plotting the successive margins of individual glaciers. That has been a task for this decade (e.g. Bennett 1990, Bennett and Boulton 1993).

In the 1934 paper Hay distinguished between ordinary 'real scree' and what he termed 'great taluses', the localised collection of huge angular boulders he associated with joint patterns that 'help the slow forces - in loosening and discharging' the massive blocks and with sites 'where local cliff ice or a combe [corrie] glacier - brought down local short-distance erratics'. On a visit to the Dolomites he discriminated between an inner hillfoot 'real scree' on Sasso Beacie and an outer zone of angular, unabraded, unstriated large local boulders which, arranged in a mass of arcuate ridges and furrows, he took to be the moraines of a hillside or 'wall' glacier (1935). He applied this interpretation to Lake District great taluses as at Auterstone near Ullswater, though his Dolomite example was more probably a rock glacier site below a massive rockfall. At that time dynamics of rock glaciers and rockfall were little known. The Auterstone and many other Lake District great taluses were probably from rockfalls, some within the limits of and thus post-dating the last glaciers.

In the 1930s through the work of Carl Troll and other continental geologists Hay became interested in periglacial processes. Patterned ground resulting from orderly segregation of finer and coarse particles into nets, circles and stripes attracted attention. Hay (1936) proposed an explanation of sorted stripes. The essential problem was not the maintenance but initiation of sorting. Hay said stripes, lateral separations of coarse and fine particles, became fixed only where a subsurface set of downslope corrugations had become stable and that this happened where vegetation had recently been disrupted and eroded. Werner and Hallet (1993) produced patterns by computer simulation of sorting in a notionally unsorted mixture of variously sized particles. Hay (1937) had said 'assemblages of small particles may become the focus of collection [sorting] and its operation a 'self-reinforcing process". Werner and Hallet wrote of self-organisation from local feedback - over fifty years, and computers, later.

The 1937 paper also recorded the first British examples of sliding (gliding) blocks, long known in continental Europe. These are the surface boulders which slide down hillsides - as some still do in hard winters - with bow waves of turf and soil and furrows behind showing distances most recently moved. In 1942 Hay considered several types of upland landform including high altitude movement of glacial erratics on the western fells near the ice shed, the influence of lithology on development of high altitude blockfields, the first British record of stone flats (Hay described how frost-riven blocks at suitable sites tend to 'level themselves out in a flat spread'), and the 'oversteepening of ice outlet valley sides'.

The 1943 paper considered freeze-thaw processes and sorted stone stripes, how asymmetric forms may be produced by moving ice, and the value of U and V valley cross-sections in discriminating between fluvial and glacial influences. Hay noted the difficulties experienced on the north Pennines, certainly glaciated, in determining that fact from the shapes of local valleys, and also that certain Lake District dales have both wide open 'U-shaped' and constricted 'V-shaped' reaches.

The two 1944 papers were the last substantial Lake District contributions. The first returned to several old topics, high altitude ice transport, the Rattlebeck exposure, but particularly to valley moraines. The second paper is a wide-ranging discussion of the shapes of the Lake District mountains. Hay recognised contrasts in intensity of ice erosion in and adjacent to the Lake District fells. While erosive ice had sufficient power to reshape hills marginal to the main fells there were areas within the central fells that seemed little affected by ice erosion. He outlined the decline in intensity of modification northwards from the ice-shed area, by way of the Helvellyn ridge, to beyond Raise, the northermost place 'where ice action has had much influence on the summit land'.

His views on the summit surfaces became somewhat complex. He knew evidence pointed to ice-erosion having occurred close to the ice-shed, the top of Great Gable for example, but also to survival of summit block fields through an episode of glaciation. The inhibiting notion that thinner ice over high crests would everywhere and always be cold-based and thus erosively ineffective, field evidence to the contrary, was to come later.

Retrospect

Hay's Lake District physiography should be considered in the context of its time. The discursive, essay-style was not displaced by the formal almost stereotyped structure of scientific papers until well after the Second War. Possibly professional papers of his time were more often controlled in construction than some of Hay's but comparisons with those by his contemporaries and immediate successors on similar topics might show choices of word and phrase to be the more obvious differences.

The essential quality, noticeable even in the earliest papers, was curiosity - the recognition that there was something needing to be understood and thus, as teacher, to be explained. His papers sustain much of their value and are still cited, as by Ballantyne and Harris (1994), Gurney (1995) and in Boardman (1997). They are a record of things seen, questions posed, answers proposed. It is still appropriate to read Hay, as Marr, for a perspective on what has been said and thought about local landscapes and, importantly, for what there may be still to do.

Acknowledgements

This article is a précis of a much more comprehensive paper (which contains a full list of references) written by Dr R.Clark and is included in Volume 6 Part 2 of the Proceedings of the Cumberland Geological Society.

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JOHN FREDERICK NORMAN GREEN (1875-1949)

AN EMINENT AMATEUR GEOLOGIST

Margaret Bennett

John Frederick Norman Green was educated at Bradfield College and Emmanuel College, Cambridge, where he studied Mathematics and Natural Science. In 1896, after university, he joined the Colonial Service. He was a member of the British Delegation to the Paris Peace Conference in 1919 and became an Assistant Secretary in 1920. He showed great interest in the Colonial Geological Survey throughout his career, retiring in 1933.

Green joined the Geologists Association in 1904, was President 1918-1920 and became an Honorary Member in 1940. He became a fellow of the Geological Society in 1908, was awarded the Lyell Medal in 1925 in recognition of the value of his research, and became President of the Society in 1934. He left an impressive series of researches on Wales, the Lake District, the Highlands of Scotland, and river deposits in Southern England. Green belonged to that group of geologists, both amateur and professional, who believed there is no substitute for in depth fieldwork and accurate mapping.

His first published work, in 1908, was on the St. David's area where he looked at the problem of succession. This was an area that had been bitterly contested by rival groups of theorists. Green mapped the whole area in detail, on six-inch maps. He covered both the coast and inland areas. The resulting maps clearly demonstrated that the basal Cambrian onlaps different lithological horizons in the Precambrian. The maps also highlighted and clarified the complicated relationships between the St. David's Granite and the surrounding rocks.

Green subsequently turned his attention to the Lake District, publishing nine papers between 1912 and 1921. First he became interested in the junction between the Skiddaw Slates and the Borrowdale Volcanics, which were mapped at the time as faults. His work kept him in London, so he studied the Geological Survey's six-inch maps at their Jermyn Street office. He doubted the interpretation that had been put on these maps. The area between Millom in the west and the Duddon in the east was comparatively free from major intrusions, appeared to be undisturbed by folding and was most easily accessible from the south.

He gave his first paper on the Lake District, *The Older Palaeozoics of the Duddon Estuary*, to the Geological Society in 1912. His work clearly showed that the succession could be traced, without a break, from the Skiddaw Slates into the volcanics without any sign of the great faults shown on many older maps. It met with so much animosity that the Society declined to publish it in the Journal and Green had to have it published privately. He next turned his attention to the junction between the Borrowdales and the overlying Coniston Limestone, maintaining that the junction was an unconformity. This directly challenged the work of Professor Marr and the Cambridge school who had interpreted the junction as a series of faults. Green then attempted to prove that the volcanic succession was not as thick as many supposed by applying the succession he had worked out to the rest of the Lake District.

In 1915 his paper *The structure of the eastern part of the Lake District* was published in the Proceedings of the Geologists Association, and *The Garnets and streaky rocks of the English Lake District* in the Mineralogical Magazine. *The age of the chief intrusions of the Lake District* followed in 1917 along *with The Mell Fell Conglomerate* and *The Skiddaw Granite: a structural study* again in the Proceedings of the Geologists Association in 1918.

"The Vulcanicity of the Lake District" (1918) and "The Geological Structure of of the Lake District" (1919) were Presidential Addresses to the Geologists Association. In these he suggested that much of the vulcanicity had been of a submarine kind and that many of the rocks then considered to be explosion breccias were actually flow breccias; that subsequent folding had exaggerated the thickness of the sequence; and that rhyolites belonged almost exclusively to, and clearly indicated, the upper parts of the volcanics.

His work on the great intrusions and on the garnets and associated streaky rock caused fierce debate, which was always conducted in a friendly manner on his part. He was always ready to acknowledge help received from the work of others. His work tended to over simplify, in particular on structural matters, but it was the stimulation and starting point for a tremendous amount of patient mapping by many workers in and around the English Lake District.

The second World War confined Green's work to the South of England where he investigated the Weald Clay and continued publishing papers up to 1948, the year before he died.

In Cumbria and the Lake District he is best remembered for his work questioning the early interpretation of the rocks and for his role in stimulating others to look more closely, and with an open mind, at the rocks and structures.

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CHARLES EDMONDS (1885-1964)

A MAN OF MANY PARTS

Mervyn Dodd

I met Charles Edmonds in 1962 when he and Edgar Shackleton were joint leaders of a Society excursion. He was in his late 70's at the time and set the scene geologically rather than taking us to the outcrops, as he was not in the best of health. He was articulate and concise, a model of accuracy and precision. In later conversation with him I appreciated how tolerant he was of a keen but all too ignorant a new member, being ready to explain basics simply and clearly.

Charles Edmonds was a man of many parts. A very competent amateur geologist, trade union organiser, Labour Party County Councillor, Chairman of Cumberland County Council Education Committee for many years, a J.P. - these were the main aspects of a very full and active life. Another interesting aspect, beside his dialect poetry, is the play in Cumbrian dialect he wrote and produced in 1921 at Cockermouth for his trade union, then the Cumberland Iron Miners' Federation. Yet his only formal education was in the village school at Bigrigg, his birthplace.

His working life began in the village post office in Bigrigg, delivering mail to the iron ore 'bosses', before becoming an iron ore miner. By 1919 he was already an active Labour Party member, being elected then to the Cumberland County Council, of which he remained a member until his death. He became an Alderman in 1934. In his later working life he became the fulltime county organiser for the General and Municipal Workers' Union. Like Lord Adams of Ennerdale he negotiated long and hard for the iron ore miners. He was a member of the group which campaigned successfully for the recognition of silicosis and pneumoconiosis as industrial diseases caused by use of compressed air drills without dust suppressors, winning compensation for affected miners.

Also in 1919 he was co-opted onto the Cumberland County Council Education Committee, remaining a member until his death. From 1937 to 1961 he was its Chairman, and was an employers' representative on the Burnham Committee which controlled teachers pay. As expected, he was a member of many of the Education sub-committees and, interestingly, laid the foundation stone of Whitehaven College in 1957. In 1954 the University of Durham gave him an honorary M.Sc for his services to education. The local library in Egremont was named the Charles Edmonds Library in his memory as a tribute to his dedicated work for local education.

As an amateur geologist his particular expertise was in the Carboniferous Limestones of West Cumberland. Before he wrote his considerable paper *The Carboniferous Limestone Series of West Cumberland* (1922) he had long discussions with Dr Vaughan and his co-workers at the University of Bristol who had recently established the palaeontological zonation of the limestones of the Avon Gorge. His article was the first serious discussion of the local limestones since Kendall (1885), who had concentrated on describing the succession. Edmonds' work was based on field work begun in 1910, concentrating on the palaeontology, relating the fossils of Garwood's 'life zones' and Stanley Smith's index fossils. This allowed him to correlate West Cumberland limestones with those of the North Pennines. He pointed out the generally shallow water nature of the local limestones, with intervening sequences showing emergence. Interestingly also he noted how the limestones formed ridges with the hollows between containing clastic rocks. His paper lacked the photographs and maps normal to modern papers. In their place were appendices listing the fossils of individual formations together with the age ranges of rugose corals present and a particular useful list of the exposures of the various formations. In 1924 he helped, as the only amateur amongst the professionals then mapping the area for the Geological Survey, to lead a week-long excursion to West Cumberland reported in 1925 in the Proceedings of the Geologists' Association Vol. 36, Part 1.

His detailed knowledge of the limestones of West Cumbria was recognised by the Geological Survey workers and the memoir of Whitehaven and Workington contains a number of acknowledgements recognising his expertise in this area "our work (on the Carboniferous Limestone) merely confirms that of Edmonds". Further recognition is recorded in the naming of two corals – *Nemistium edmondsi* (the type genus and species) and *Orionastraea edmondsi* from the quarries at Eskett and Clints respectively. His collection also provided the type material figured in the formal description by Bisat (1924) of *Gastrioceras (now Cancelloceras) cumbriense* collected at Bigrigg, and which is the emblem of the Cumberland Geological Society. He was also involved in educating the public about the decline of iron ore mining in Cumbria, writing a long series of quite authoritative, demanding articles in February and March 1924 for the Whitehaven News, which stimulated many questions from readers to which he replied. In the late 1920s he was elected to membership of the Geological Society of London and the Geologists' Association. In 1929 he was awarded the Lyell Fund by the Geological Society of London. In 1936 he was an invited guest at the International Geological Congress where he had been commissioned to read a paper on the limestones of West Cumberland. He visited Russia twice! What amazed him on his second visit was that Russia was then producing 600-700 graduate geologists annually, making him think that the UK, even then, was training far too few.

The opening of the Whitehaven office of the Geological Survey in 1920 must have been 'manna from heaven' for him, a place where he could relax from the stresses of his public life. The professional geologists, led initially by Bernard Smith and then by Tom Eastwood, kept open house to interested amateurs. Many a time Charles Edmonds and his son were there, happily talking geology. Tom Eastwood in particular encouraged him, giving him many of the maps, papers and books that formed part of Charles' collection. At that time he rubbed shoulders with Dixon, Trotter and Hollingworth, who were working locally for the Survey. In later years when he had meetings to attend in London he often made time to visit the Geology department of University College to chat with 'Syd'(Hollingworth) or Eric Robinson.

Before the Cumberland Geological Society was established he and Edgar Shackleton between them led all the occasional excursions of the rather small West Cumberland Geology Group. Edgar wrote of Edmonds' encyclopaedic knowledge of almost every quarry between Millom and Alston Moor, to which he must have travelled by train, bus, bicycle or on shanks' pony. His observational skills certainly impressed Edgar. Charles Edmonds was the first President of our Society in 1962 and its original Honorary Life President in 1963. He was inspirational, yet a very unassuming and relaxing person with whom to be. No wonder then, that both his son and granddaughter became professional geologists.

Edgar Shackleton, who knew him well, wrote an appreciation of him (published in our Proceedings 1964, Part 1) on which I have drawn heavily in this article. In the same year Edgar suggested the Society establish a prize in his memory, which became a reality in 1965. Since then it has been awarded every second year or so, - a fitting memorial to a rather special person.

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TOM EASTWOOD (1888-1970)

AN EMINENT SURVEY GEOLOGIST IN CUMBERLAND

Mervyn Dodd

Tom Eastwood's career as a geologist spanned the two World Wars and was interrupted by 3 years' service in the Royal Army Medical Corps in France, 1915-1918. He was one of a group of eminent members of the Geological Survey who spent over 10 years working in Cumbria before promotion to more senior roles. His colleagues working in Cumberland included Bernard Smith, E.E.L. Dixon, 'Syd' Hollingworth and F.M.Trotter. Eastwood was posted to what was the temporary Whitehaven office in 1920, becoming Senior Geologist in 1922. After the closure of the Whitehaven office in 1927 he became District Geologist in 1930, succeeding Bernard Smith as leader of the Cumberland Unit. In 1937 he became Assistant Director (England and Wales) of the Survey, a position he held until his retirement in 1949.

Eastwood, a bluff Lancastrian, was very much at ease socially and a good raconteur. He began his service in the Geological Survey mapping the Warwickshire and Staffordshire Coalfields, experience very helpful to so much of his work in Cumberland. His particular strength was in coalfield geology, but economic geology in general played a large part in his work, for example he wrote in 1921 'The Lead and Zinc ores of the Lake District'. During the Second World War, while he was Assistant Director in charge of the economic mineral investigation of England and Wales, he initially concentrated half the available manpower of the Geological Survey on basic mapping and surveys of groundwater resources, previously very neglected. This was followed by investigation by specially equipped units of the reserves of Jurassic iron ore in the Midlands and assessment of non-ferrous and other strategically important minerals. 1943 saw the assessment of coal resources with publication of 1 inch to 1 mile maps of the major coal seams. In the immediate post-war years he obtained funds from the powers that be for the then almost unheard of sinking of deep exploratory boreholes for 'purely' scientific purposes. This led to the discovery of a concealed coalfield near Lichfield. His career in the Geological Survey spanned the change from gentleman to player, "the labourer is worthy of his hire, laddie" being one of his favourite phrases.

Eastwood was author or co-author of the Geological Survey memoirs for the Maryport District, Whitehaven and Workington, Cockermouth and Caldbeck (delayed printing taking place in 1968), produced with the appropriate maps, largely in the 1930s and based on field work in the 1920s. He was co-author of the British Regional Geology volume on Northern England. There are several papers written by him in the Summary of Progress of the Geological Survey, including discussions of the South Cumberland, Furness and Cartmel areas.

He read a paper about the Lake District at the Blackpool meeting of the British Association for the Advancement of Science in 1936. While working in Cumberland he was one of the joint leaders of a weeklong excursion to West Cumberland, reported in Vol. 36, Part 1, (1925) of the Proceedings of the Geologists Association. In the 1930s he led a similar excursion to South Cumberland and Furness for the Yorkshire Geological Society. In 1928 his paper about the Cockermouth Lavas was the first recognition of this Carboniferous episode. After retirement he was a consulting geologist with Messrs Craelius and was the author of the Stanfords Geological Atlas of Great Britain published in 1965.

His skills in man management were considerable. He knew how to encourage and support, as shown in particular by Charles Edmonds' involvement with the Survey in West Cumberland and frequent visits to the Whitehaven office. Youngsters like Charles Edmonds' son were equally welcome. At the same time he got on well with the coal masters and mining engineers. These management skills were operating even though he had to wait for housing in West Cumbria and travel in the countryside was largely by bicycle. He got the best out of his colleagues, on field trips to solve specific problems and in the office discussions that followed. He was both a good organiser and farsighted, able to take an overview of likely future requirements

Eastwood maintained his interest in geology after retirement. He served as Vice-President of the Geological Society of London, which awarded him their Murchison Medal. He was a Vice-President of the Institute of Mining and Metallurgy and served as President of the Geologists' Association. In addition he was a member of the Yorkshire Geological Society.

The Cumberland Geological Society came into being long after his retirement, but his generous gift of books and maps in 1964 formed the nucleus of our Library. This was recognised by electing him as an Honorary Life Member of the Society in that year.

As far as we know no current member of the Society met Tom Eastwood, so this article has relied very heavily on an appreciation of him written by the late J.M.Edmonds published in Vol 3 Part 1, 1970 of our Proceedings, and by comments from Eric Robinson.

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SYDNEY HOLLINGWORTH (1899-1966)

AN EXEMPLARY FIELD GEOLOGIST

Dr. Eric Robinson

When reviewing the progress of Geology, there is a tendency to say that the present lacks the great figures who shaped our science in the heroic years of the 19th century -the polymaths who knew no specialisms but were content to call themselves 'geologists'. Against that, it may only be a matter of time before a time perspective gives due credit to Sydney Hollingworth for the range and diversity of the work he achieved in his life. What is even more of a recommendation must be the influence which he had on so many of the 'specialists' of our generation as a teacher able to infect students with some of his enthusiasms. This present occasion is an opportunity to list and analyse a fraction of his contributions

Born in Northampton and educated at the Northampton Grammar School in the years up to the First World War, he was called up for military service, wounded and discharged to take up his studies at Clare College, Cambridge. Taught by Rastall and Harker he achieved a First Class Degree and the Harkness Prize, but as important, from those distinguished researchers, he gained his first insights into Lake District geology in a Department run by J E Marr. At the end of those student years, 'Hollie' as everyone tended to call him, went on a continental journey through a Germany under Allied occupation and just recovering from economic devastation in company with a fellow graduate, Tilley. There was a strange contrast in the character of the two which makes one wonder why they struck up the notion of the joint expedition, but a diary which Hollie kept gives an early insight into his character which was to continue into his later life. Their objectives were to take in as much of the Rhineland and Eifel volcanic rocks, and, if possible, to meet and talk with petrologists in the German universities. Their itinerary was full and one which would constitute a first rate excursion at the present time. Notes and records of a wide range of volcanic rocks and minerals prove that Hollie was quite comfortable with the finer points of rock classification and field identification of hand specimens, thanks to the grounding acquired from the Lab work instigated by Harker. Humanity emerges in the careful record of the food, beer and cigarettes consumed at meal times and in the hours of rest.

When they went to the famous quarries at Niedermendig, the well-known source of Roman millstones for the legions, he relates,

"across country to Herschenburg with basalt tuffs on upper trachyte tuffs around a basalt dyke with melilite on the SW side. Day very hot; met a man on the way with whom I conversed under difficulties using a mixture of English, French and German. From Herschenburg to Nieder Tissen where I consumed a pork chop with two fried eggs, salad, and innumerable fried potatoes, two cigars, three glasses of beer. I passed on cheerily towards Laacher. Collected a little schist on the Drachsbusch Hill; consumed three more beers and a cigar at Maria Laach .... having been walking a good four hours.... a beer at Niedermendig and another at the station restaurant and a packet of chocolate and a cigar.."

Although this was 1921 when he was twenty-two, this was a pattern which continued through later life; he was never an ascetic as any of his students at University College could affirm.

Returning from the unlikely continental journey with Tilley, he joined the Geological Survey and was sent to the Lake District, a move which was to focus his whole life as a geologist. In the first instance, he was being asked to scrutinise and make decisions on field relationships which had been written upon by his Cambridge teachers, J E Marr, and Alfred Harker. Most of his decisions hinged upon accurate field mapping which proved to be his forté whatever he had to deal with. Nowhere is this better demonstrated than in his work on Carrock Fell where he built upon work done by Rastall, defining metamorphic mineral zones and consequently, was able to outline the limits of the Skiddaw Granite and more especially, the complex which is the gabbro intrusions. It remained work of which he was proud throughout his life.

No greater contrast could be found than in the work which he did with F M Trotter on the glacial deposits of the Lake District and the Vale of Eden in particular. Glacial cover excited few Survey officers at the time, compared with the challenge of solid geology units, but Hollie was inspired by Dwerryhouse and Lamplugh and soon became absorbed in the mapping of drumlin distributions and orientation. As he and Trotter worked closer and closer to the Pennine Escarpment and the Cross Fell Inlier, he became aware of the drainage channels which notched the slopes and, in places, cut in and out of the solid outcrops. The work was published by the Geological Society in their journal in 1931, and remains a classic in the literature of glacial geomorphology and field mapping. In the pattern of Geological Survey work, it might be said that it gave respectability to time and effort devoted to 'superficial' Geology when there was a natural impatience to get to grips with the 'solid' units beneath that cover.

A similar willingness to pay attention to what often seem unrewarding sequences led to Hollie identifying evaporite cycles within the red rocks of the Permo-Trias of the Vale of Eden with the appreciation that such cycles could provide a framework for correlation across the Pennines and into the Irish Sea in the absence of palaeontological evidence, ideas first floated in the Brampton Memoir (1932), expanded in the Proceedings of the Geologists' Association (1942), and rounded off in the work of one of his research students, Henry Meyer (1965).

Like all who worked for the Survey, duties in Cumberland required him to tackle the correlation of the Upper Limestone Group and Millstone Grit of North East and West Cumberland, with its unique tradition of numbering from top to bottom. A task he shared with F M Trotter, it brought him into contact with the acknowledged local experts and was the beginning of a life-long friendship with Edgar Shackleton and Charles Edmonds. Such friendships and the diversity of the Geology made the ten years spent in the Whitehaven Office years which he remembered with much satisfaction when he converted to being an academic geologist. In part, it was the separateness of the location and the spirit which was engendered in the company of colleagues such as Tom Eastwood and Bernard Smith, but as much it was the diversity of the geological experiences which came his way for which he was always grateful. With Trotter, in a short paper in the Geological Magazine, he set down the notion of the Alston Block as an influence upon local stratigraphy in the Carboniferous and a tectonic entity in subsequent structural history (1928). His work on the glacial deposits was later extended into the Cheshire Basin and continued by his research student, Arthur Whiteman, one of several who followed his example by working for the Geological Survey.

Wartime saw him transferred to work seeking to exploit our mineral resources. Working from the West Midlands and, later, Cambridge, this work took him back to his native Northamptonshire and the Ironstone Fields of the Middle Jurassic. With J H Taylor and G A Kellaway, he came to understand the nature of superficial ground movements in areas of valley slope and the distortions which large-scale superficial structures can cause in predicted thicknesses and total reserves. Again, this resulted in an elegant and well-draughted paper presented to the Geological Society and subsequently incorporated in the Memoir for Kettering, Corby and Oundle (1963). As a direct result of this work, gulls and valley bulges became recognised structures in field mapping in all parts of the World.

The Geological Society played a large part in the Hollingworth life and in his contribution to Geology. Joining as a junior Survey officer in 1922, he rose to being Secretary between 1949 and 1956, and President in 1961-62. He was one of the founders of the Engineering Group in his belief that Applied Geology was a vital element in the health of Geology in general (something he credited to the influence of Tom Eastwood from those Whitehaven years). Through the Society, he found a way of maintaining his contacts with all those active in the many aspects of Geology which appealed to him. Always a social animal, the atmosphere of a good London club was for him to be found in Burlington House. The Society and its circle became still more important to him when in 1946, he became the Yates-Goldsmid Professor of Geology at University College London in Gower Street. A radical place in its 19th century foundation, it had a post-War atmosphere of academic freedoms which allowed Hollie to work out his best strategies for teaching while other ex-Survey colleagues inherited traditions which were far less comfortable. Never a great lecturer, Hollie scored triumphs by vastly increasing the amount of fieldwork involved in all courses throughout the three years of study. Handling the small classes of students of the post-war years (all UC students were deemed Honours Students, there were no Pass Degree classes until much later), he naturally took them to his favourite ground of Carrock Fell and the Cross Fell Inlier, and later, North Wales. Back in Gower Street, he linked up with S W Wooldridge to make geomorphology a main plank of all Geology degree courses and became recognised in that field at World level. One of the benefits to students from this fame became regular visits by the South African Lester King, who had much in common with Hollie in his enthusiasm for the subject, but the added virtue that he could give first-rate lectures from which good notes could be taken. While all agree that lectures by Hollie were 'difficult' as they were often delivered to the blackboard or screen, field classes were a different matter as he instructed in the keen observation which was the basis for his field mapping. Equally winning was his informality away from College and on the fell-sides in all weathers. Students were allowed to buy the drinks and learnt that a constant supply of cigarettes was expected (Hollie often produced a packet containing but one cigarette as if to underline a predicament). Looking back on the years between 1954 and 1966, Hollie initiated several ambitious research projects overseas which usually involved both undergraduates, research students, and members of the staff at UCL. A large area of Norwegian Caledonides straddling the Arctic Circle was a long-term commitment culminating in a remarkable map draughted with skill by Maurice Wells. Over the years, the work involved Reg Bradshaw, Maurice Wells, Roye Rutland, Robin Nicholson, Keith Ackermann and Brian Walton, all of whom went on to individual work on related topics in structural geology and petrology. His ability to recognise the potential in students was one of Hollie's strengths, best illustrated in another ambitious mapping project developed in northern Chile. The aim was to map the volcanics of the Andean chain adjacent to the northern Atacama Desert but linking such pure geology with the economic geology of the copper and sulphur deposits which are the commercial driving force in the Chilean economy.

He himself worked closely with George Muller, an Hungarian geologist who had come to London in wartime, but became Professor in Santiago in the early 1950's. The other members of the party were 2nd year Geologist, John Guest, and 2nd Year Geography student, Ron Cooke, who at the time had done Ancillary Geology. John was to study the volcanics; Ron to undertake the desert geomorphology. Both have subsequently become leaders in their chosen field in their own right. (John moved from terrestrial volcanoes to lunar craters and then planetary surfaces, as they became available through NASA; Ron has made deserts his speciality). All his students acknowledge his help but what is equally clear must be Hollie's ability to identify true talent.

One approach which he adopted in the training of his students was to persuade them to become Junior Associates of the Society, simply so that they would have the opportunity to attend the Wednesday evening meetings and listen to the leaders of our science debating. With the old arrangements of benches lengthwise along the meeting room, 'debate" was the procedure followed, the papers being followed by questions and answers in a fashion which added greatly to the interest and understanding of the occasion. This was Hollie's chance to probe and explore a presentation, sometimes with a slightly mischievous purpose without being either unfair or unkind.

Given his birthplace in Northampton and his purchase of his retirement home in the Northamptonshire village of Flore, it might have been expected that Hollie would buried there. In fact, after cremation, his ashes were taken by geologists involved in the Chilean research project, and scattered on an elevated ridge on the edge of the Atacama Desert. Close to the spot, stands a cross bearing a brass plaque. The history of this circumstance is best told by John Guest in a recent reminiscence of working in Chile with Hollie;

"Driving across the desert to San Pedro, one crosses a mountain range, the Altos de Purilactis. From the crest of this range there is a stunning panorama of the High Andes, the great slope of massive ignimbrite surface rising up to the Puna surmounted by the cones of andesitic volcanoes, most of which top about 6,000 m. This was my field area. When Prof. and I drove to the field area, he would stop at that particular vantage point to admire the scene. Many times he expressed the desire that when he died, his ashes should be spread at this site, his favourite view in the world. He also expressed this wish to his wife...."

John has subsequently visited the spot and reports that the cross survives where it was placed by Chilean colleagues, but further adds another form of record which any geologist would appreciate.

John adds,

"the name of Hollingworth will remain in geological history because the Servicio (Geological Survey in Chile) has named an important rock unit exposed near his cross, the Hollingworth Gravels. The unit is Miocene in age and consists of gravels thought to have formed during an interval of pedimentation in the evolution of the Andes. To name this unit in this way was a very gracious and touching act by our longstanding geological friends in Chile."

Hollie had a wicked sense of humour betrayed by a twinkle in the eye ably caught in the photograph which accompanies his obituary in the first part of the Quarterly Journal of Engineering Geology (1967), a publication which he had greatly encouraged. Interestingly, in this quizzing role, Hollie was following almost exactly the approach of George Bellas Greenough, a founder of University College London in 1829, and referred to in a history of the Society as a consistent 'Objector General' at their meetings.

Probably the best summary of his scientific life was given by Hollie himself when responding to the award of the Murchison Medal in 1965:

"In reflecting, as one does on such an occasion as this, I appreciate not least that our science can still honour the "general practitioner". Having an inclination towards pastures new (I am almost a one-paper-per-topic geologist) gives little opportunity for that popular and even elevating pastime of recantation".

Recantation ? The irony is that such thoughts would never have been in his mind. Much of his geology was done on the backs of envelopes or refined through lengthy discussions in one of his favourite pubs. If there were 'corrections' or reinterpretations, he probably took as much satisfaction from the thought that he had provoked the response which moved understanding forwards. Our science has need of such facilitators. In his life, Hollie made a substantial contribution which ought to be recognised.

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GEORGE HOOLE MITCHELL (1902-1976)

PIONEER MAPPER OF THE BORROWDALE VOLCANIC GROUP

Dr. David Millward and Dr. Jack Soper

Known affectionately to friends, colleagues and family alike as 'Mick', Dr George Hoole Mitchell is best known for his contributions on the Borrowdale Volcanic Group, arguably one of the most exquisitely preserved subaerial volcanic successions in the geological record. In the year that remapping of the entire outcrop of these rocks has been completed by the British Geological Survey, it is fitting to remember Mitchell's contribution to our understanding of these complex and difficult rocks. Though he spent his working life with the Geological Survey, none of his research in the Lake District was officially for that organisation. Thus, his immense contribution is all the more impressive because much of it was achieved through fieldwork carried out during his annual leave.

Born in 1902, the son of a Liverpool teacher with an avid interest in landscape and geology, Mick's own interest in the Lake District developed during his childhood, when from the age of about 6 or 7 he spent most summers with the family in Little Langdale. During this time the young Mitchell developed an affection for the Lake District and its people, and also an interest in the geology that was to become a lifetime's enjoyment. Inevitably, it seems, he read geology at Liverpool University, and then embarked on a study of the Coniston Limestone in the Kentmere area (published in 1925), for which he was awarded his MSc. However, this line of research went no further, because it strayed into the influential realm of T. C. Nicholas. Instead, Mick set about tackling the volcanic rocks and the geomorphology of the eastern Lake District. He subsequently gained his PhD at Liverpool and a Diploma of Imperial College, before becoming a demonstrator at the latter institution. On joining the Geological Survey of Great Britain in 1929, he was thus well placed to work in that organisation's Cumbria office, but following Survey tradition, he was set to map elsewhere. During a distinguished career that followed with the Survey, he became an expert on coalfields in the English Midlands and Yorkshire. Latterly, he was firstly District Geologist of the South Lowlands field unit in the Survey's Scottish Office and then its Assistant Director in charge of the Survey's work in Scotland.

Mick believed that the key to the interpretation of the complex and difficult Lake District volcanic rocks lay in systematic and careful field mapping of the rocks and their structure, and in setting up a lithostratigraphical succession. This same methodology is at the heart of the recent work by the British Geological Survey and has formed the basis of other important contributions by, for example, R. L. Oliver at Scafell and M. J. Branney in Langdale. Mitchell's six-inch field maps, archived at the British Geological Survey, Edinburgh, are meticulously detailed and a testament to the excellence and quality of his field craft. He was an astute observer; for example, he was the first to find trace fossils in volcaniclastic sandstone beds at Lum Pot, in the Lickle valley, one of only two records of macrofossils in this sequence. (Recently, these have been described and illustrated as the earliest known arthropod tracks and trails.)

Mitchell's early interpretations of the structure of the Borrowdale Volcanic rocks were naturally coloured by current thinking, particularly the influential ideas of J. E. Marr and J. F. N. Green. For many years, Marr and his co-workers at Cambridge had disputed the earlier interpretation of W. T. Aveline and his Geological Survey colleagues that the base of what is now known as the Windermere Supergroup represents an intra-Ordovician unconformity; they regarded it as a lag-fault. Green, on the other hand, accepted the unconformable relationship and related it to NNE-trending 'pre-Bala' folding and erosion of the volcanic rocks. Mitchell's major life work involved mapping the volcanic rocks adjacent to their boundary with the overlying Coniston Limestone across the whole district from Shap to Dunnerdale, with the exception of the Langdale–Grasmere area, surveyed by J. J. Hartley. The results are recorded in a remarkable sequence of research papers in which the evolution of his ideas can be traced: Kentmere (1929), Longsleddale–Shap (1934), then westwards to Coniston (1940), Dunnerdale (1956) and finally northwards to the Seathwaite Fells (1963).

The early work established the reality of the unconformity, and his structural interpretation accepted Green's pre-Bala folds, particularly in the ground north of the Garburn Pass, west of Kentmere. It also incorporated another of Green's influential ideas, again at variance with Survey views, that the Lake District rocks were isoclinally folded and disposed in great anticlinoria and synclinoria, thus preserving low sheet-dips, with a much thinner volcanic succession than implied by the Survey view of open folding. Mitchell initially tended to map sequences of tuffs and andesite as repetitions of the same units by isoclinal folding: a good example of this is on the ridge of Shipman Knotts, east of Kentmere. It must be remembered that this work predated the general use of sedimentary structures as 'way-up' criteria. Thus in his 'middle' period Mitchell often mapped natural terminations of volcanic units as fold closures. He gradually abandoned this approach; the last example is probably the termination of the thick andesite sill that makes Dow Crag, near Coniston. The concept of NNE-trending pre-Bala folds was also abandoned, probably as a result of mapping the pre-Coniston Limestone Ulpha syncline which trends E–W. Mitchell's last map, of the Seathwaite Fells, has a very modern appearance, with a far from layer-cake stratigraphy, and the structure is dominated by block faulting with some volcanic units thinning across faults, presaging current thinking on the evolution of these rocks.

In his Presidential Address to the Yorkshire Geological Society (1956, p.425) Mitchell expressed a desire to go back over some of his old ground to revise the structural interpretation. Unfortunately, that opportunity did not arise, but in the address he outlined his changing thoughts on the structure of the Coniston area as a result of his work in Dunnerdale. He also recognised then the implications for the thickness of the volcanic succession. Despite the differences in interpretation, his maps have proved of great value during the systematic resurvey of the Borrowdale Volcanic Group, recently completed by the British Geological Survey.

Mick kept abreast of the developments in volcanology during his work. He recognised early on the truth of Green's view that many of the fragmental rocks are flow breccias, produced by the break-up of the solidified carapace to lava-flows during eruption, and he developed criteria for separating them from pyroclastic deposits. Later, Mick was greatly impressed by the work of the New Zealander R. L. Oliver in the Scafell area, who recognised that streaky textures in some of the silicic volcanic rocks are similar to those observed in welded tuffs from his homeland. Mick soon recognised similar textures in his field area. Thus flinty rhyolites were reinterpreted as the products of 'nuées ardentes', and the terms 'welded tuff' and 'ignimbrite' entered Lake District literature. Many other features diagnostic of pyroclastic and sedimentary deposits remained generally unrecognised in ancient successions such as the Borrowdale Volcanic Group for many years after he completed his work. It has also recently come to light that many sheets mapped as lava flows are in fact shallow sills, having considerable implications for understanding the stratigraphy.

Mitchell's publication record, for which he won many plaudits, is impressive. His honours include: the Bigsby (1947) and Murchison (1964) medals of the Geological Society of London; the Sorby Medal of the Yorkshire Geological Society (1965); the Clough Medal of the Edinburgh Geological Society (1970). He was elected FRS (1953) and FRSE (1955), and made CBE in 1967. He was a very able communicator of his science, particularly enjoying field discussions; he was Field Meetings Secretary of the Yorkshire Geological Society (1935 to 1938) and President (1955-56). As President of the Geology Section of the British Association meeting in Dublin in 1957, his subject was naturally Ordovician volcanism in the British Isles.

Why should Mitchell be considered as one of the icons of twentieth century Lake District geology? In mapping such a considerable area he had an unrivalled knowledge of the geology of the Lake District. Though mostly known for his work on the volcanic rocks, including its petrography (1930), his early work on the Coniston Limestone (1925) and on the geomorphology of the eastern Lake District (1931) should not be forgotten. He was thus well placed to give an account of the geological history of the Lake District, as Presidential Addresses to the Yorkshire Geological Society in 1955 and 1956, in which he included a lithostratigraphical model of the volcanic succession. The paper was a worthy successor to Marr's classic Geology of the Lake District (1916) and remained the most authoritative account of Lake District geology for the next 20 years. However, unlike Marr and Green before him, Mitchell did not produce a novel interpretation that could be especially associated with him as a significant breakthrough in the development of the understanding of Lake District geology. To our knowledge, he did not travel to any modern volcano to examine its products, which would have been very beneficial. Also, his contribution to the volcanology of the Lake District rocks has to be seen in the context that during Mitchell's era volcanology was essentially an observational, rather than interpretative, branch of our science, and it remained so until the 1970s. His legacy then is that through detailed field mapping it is possible to understand and interpret such complex and difficult ancient subaerial volcanic successions. The recent lithofacies interpretations of the Borrowdale Volcanic Group owe much to his example.

Acknowledgements

Biographical details are from Sir James Stubblefield's account of G H Mitchell in the Biographical memoirs of Fellows of the Royal Society (Volume 23, 1977). We are grateful to Mr Murray Mitchell for his advice and comments.

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FRANCIS J MONKHOUSE (1915-1975)

LAKELAND GEOGRAPHER

Mervyn Dodd and Fred Lawton

Frank Monkhouse was born in Cumbria and educated at Workington Grammar School, where Herbert White, a former Treasurer of this Society, taught him and found him to be a quite exceptional pupil. He read Geography at Cambridge where he obtained a good degree. Before the Second World War he enjoyed and successfully taught geography at Wakefield Grammar School. His career was both interrupted and enhanced by that war. He was drafted to the Intelligence Division of the Naval Staff where he worked on the production of the highly regarded Admiralty Handbooks. In 1946 he was appointed as a Lecturer in the Department of Geography at Liverpool University, also teaching in the Department of Education where he supervised students on practice, critically but kindly. While at Liverpool University he became the Chief Examiner in Geography for the Cambridge Syndicate 'A' level, reorganising the examination of physical geography and encouraging the development of practical examinations. In 1954 he became Professor of Geography at Southampton University, a post he held until he took early retirement in 1966.

Early retirement allowed him to develop a new, equally busy career. He and his wife settled in and modernised Crag Farmhouse, Ennerdale, a return to his beloved Lake District, which a kindly reviewer of one of his books likened 'to a Herdwick returning to his heaf'. During retirement he worked as a visiting professor at American Universities, travelled widely, lectured extensively and enjoyed rock climbing. Together with J. Williams he *wrote Climber and Fell Walker in Lakeland* in 1972. In its way this was an unusual book. Besides the 'usual' history of rock climbing and accounts of individual climbs there was quite a long chapter, actually 'a mild dose of physical geography', as one reviewer put it. This related rock climbing to rocks and structures, and very interestingly wrote of rock climbing as applied geology, or in his case 'geology at his fingertips', with convincing references to the changing effects of differences in rock characteristics on individual pitches. His death in 1975 was sudden, while he seemed still to be a fit man at the height of his intellectual powers.

He was a man of wide interests and many parts, a talented amateur sportsman in his youth. Simply, he never had enough time, nor the inclination, to become and remain a dedicated researcher. Early in the Second World War he had at least three articles about the history of mining in the North Pennines published in respected journals like the Transactions of the Cumberland and Westmorland Antiquarian and Archaeological Society. His most respected piece of research was the monograph *The Belgian Kempenland*, published in 1949.

This was regarded as one of the very best contributions to regional geography. In 1952 he was joint author of *Maps and Diagrams*, a long running university textbook. Much the most important and the most successful of his textbooks was the *Principles of Physical Geography*, well suited to the needs of A level and first year University students. This first appeared in 1954 and the much-revised 8th edition was published in the year of his death. His other magnum opus was his authoritative *Regional Geography of Western Europe*, the University level text appearing in 1959 and the intermediate (A-Level) text in 1964. He also found time to write in 1960, the concise but very effective *The Lake District*, the first volume in the British Landscapes through Maps series, published by the Geographical Association. His *Dictionary of Geography* was for long the basic reference and authority on geographical terminology.

His greatest scholarly strength lay in his writings in regional geography. He was a craftsman in this art of regional description and explanation, using geology and physical geography as part of the background to the area's economic development with its historically changing landscapes, natural and human. His material was supremely well organised, showing great skill in deductive and inductive reasoning, using a wealth of pertinent, well chosen examples. He had an easy style, with a judicious mixture of long and short sentences. His writings were always eminently readable. Terms were briefly and clearly explained, jargon avoided and in many respects he was a master of geographical synthesis. He retired when human geography started to change. He was not interested in the 'young turks" insistence on models and scientific method with mathematical measurement of every phenomenon, irrespective of whether it was suitable or the feature had any significance.

His *Principles of Physical Geography* appeared when the initial post-war expansion in the numbers of A-Level Geography students was beginning. It was so much more appropriate for this niche market than the competitors, which were either trivial or unnecessarily erudite. It was so much better illustrated by well-drawn, apposite, simple diagrams and well printed photographs. His clarity of thought and expression made many a difficult concept far easier to understand. Wherever suitable he used most convincingly examples from Cumbria. The relationship of drainage patterns to structure, glacial and periglacial landforms and most notably the different types of lakes with their different histories were sympathetically illustrated in this way. A particularly memorable example was his description of how lakes came and went in the Kentmere valley. His *The Lake District* was a very effective introduction to Lakeland rocks and landscapes. These two books played a major part in stimulating geographical studies in Cumbria and a wide range of field courses in Lakeland. Thus, rather like Edgar Shackleton in Lakeland geology, his great contribution is as an academic populariser and an inspiration to study of the physical and human landscapes of Cumbria.

Frank Monkhouse was outgoing, an extrovert who respected others. A fellow Lecturer at Liverpool University wrote of him... "as a congenial colleague and a wise counsellor whose judgement could always be relied upon", and "as a great enthusiast in all he did". I remember him coming to talk to A-Level students at Whitehaven Grammar School when I taught Geography there. There was no question of him charging a fee, as he knew well enough local schools had insufficient funds to pay the fee he could command. He was highly organised, graphic, relaxed and riveting in an easy conversational style, striking an instant rapport with his audience. Such were his considerable personal skills, undeniable kindness and integrity.

Fred Lawton adds his own personal recollection of Frank Monkhouse from 1973.

> "On a rather damp January day with visibility down to 30 feet, four friends and I decided to walk up Fleetwith Pike. In the group was Frank whom I had met for the first time a week earlier. There was not any real enthusiasm in the party due to the weather, but Frank urged everyone to carry on. He also suggested that all would be well at 1500 feet when we would emerge into brilliant sunshine. There was a great deal of good humoured scepticism to this remark, to which Frank responded by accelerating his pace until he disappeared into the mist muttering about the company he kept. Half an hour or so later, a shout from above stating in unequivocal terms that there was indeed brilliant sunshine at that level and not, as pessimistically forecast by that unbelieving group following behind.
>
> The rest of the day continued above cloud level and in sunshine with temperatures well above normal. In fact it was warm enough to scramble on the crags of Little Round How before walking onto Haystacks.
>
> Throughout the day Frank was extremely good company (contrary to the impression I may have given earlier), stopping to explain in layman's terms, how to interpret the landscape both geologically and geographically and describing the phenomenon of a Brocken Spectre which we had witnessed that day.
>
> On subsequent walks in the mountains he was always a very friendly and informative companion, but I shall never forget that earlier meeting and especially his interpretation of the weather pattern and his 'prediction' which provided such a memorable day".

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EDGAR HOWARD SHACKLETON (1903–1991)

FOUNDER AND PRESIDENT OF THE CUMBERLAND GEOLOGICAL SOCIETY

Tom Shipp

Edgar Howard Shackleton was a quite remarkable person. The writer, as one who came to know and respect Edgar through the last 30 years of his long life, was greatly impressed by his infectious enthusiasm and encyclopaedic knowledge, largely self-taught. He was a prolific lecturer and writer, communicating his opinions on geology, botany, north country life, dialect and literature through the media of books, magazine articles, newspapers, evening classes and meetings in the field. His speech betrayed his origins; he was born at Great Harwood (*Snotty 'arrod* as he termed it) in East Lancashire just after the turn of the 20th Century. Soon after the outbreak of the First World War he left school at the age of twelve to start work in a Lancashire cotton mill, and at fourteen commenced a textile engineering apprenticeship, attending evening classes in Blackburn where his favourite subjects were geology and botany. This seems to have marked the end of his formal education, but not of his enthusiasm for geology, for he was soon involved with the newly formed East Lancashire Regional Group of the Geologists' Association as its secretary.

By the mid-1920s Edgar had married and moved to Windermere, earning a modest living as a lecturer and mountaineering guide. One of his climbing clients of those days later reached the exalted rank of Lord Chancellor! By 1934 he had found rather more security as a local representative with Hoover Ltd., soon becoming area supervisor for the region from Whitehaven to Penrith.

During the Second World War he was drafted into ordnance work at Drigg, manufacturing materials for explosives, and he remained in West Cumberland, joining the United Steel Company at Workington, officially as an instrument engineer and perhaps less officially as a geological adviser on such matters as faulting and drainage in local iron ore mines, assessment of clays and refractory sandstones, and the mineralogy of imported ore supplies, many from India, from which he collected and documented several rare manganese minerals.

It was at about this time that he met up with the late Charles Edmonds, a miners' union organiser from Cleator Moor, with an unrivalled knowledge of the stratigraphy of Carboniferous Limestone in West Cumberland. Together they instituted Workers' Educational Association classes in geology, attracting and enthusing a group of people to form a West Cumberland Geology Group which in 1961 formally became the Cumberland Geological Society.

During the following two decades he led this Society as its President, contributing lectures, field excursions and written articles to its activities (listed in Proceedings CGS; Vol 5, part 3, p 397). He was also prominent as a lecturer in the weekly programmes organised by the Newcastle University Department of Adult Education for summer visitors to the Lake District. He served on the Regional Committee of the British Association for the Advancement of Science and also gave valuable service to the Lake District Naturalists' Trust, his particular concern being for the conservation of valuable geological sites (pre-empting RIGS). Of his publications, The Carboniferous Limestones of West Cumberland (1962), Lakeland Geology (1966) and Geological Excursions in Lakeland (1975) have been republished several times, and reflect his enthusiasm for geological matters.

In 1980 he was awarded the Cumberland Geological Society's Charles Edmonds Prize, whilst in 1981 due to failing health he relinquished active Presidency, the Society conferring upon him the title of Honorary Life President in recognition of his unique involvement in its development.

He was further honoured by being awarded the R. H. Worth Prize of the Geological Society of London in 1981, in recognition of his many contributions to the science of geology.

Throughout the years he contributed generously from his collection of rocks, fossils and minerals to universities, museums and other educational institutions. His home in Hensingham was almost a private, lovingly tended geological museum in its own right. It is particularly gratifying that much of his geological collection is now held by the West Cumbria Mines Research Group in Egremont.

Edgar Shackleton died at Whitehaven on 14 March 1991. The Society mourned the passing of a generous and knowledgeable benefactor and leader whose views, however idiosyncratic, were always worth acknowledgement and discussion. Those closest to him miss his unaffected friendship and inspiration.

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T. Shipp
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EXCURSIONS

THE GEOMORPHOLOGY OF AUGHERTREE FELL

Leader: Darrel Swift (Glasgow University)

22 April 1998

This excursion visited the Late Devensian meltwater channel system near Aughertree Fell. Volume 6 Part 2 of these Proceedings contains an article, written by the excursion leader, which provides details of the origin and significance of the system.

EVOLUTION OF MOUNTAIN SUMMITS IN THE NORTHERN LAKE DISTRICT

Leader: Dr Jeff Warburton (University of Durham)

25 April 1998

The excursion was focussed on two sites, High Pike (NY 318 310) and Iron Crag (NY 304 342) where the University of Durham have on-going research projects examining contemporary processes of weathering and erosion. Work to measure rates of erosion processes and to try to establish the age of some of the surface features is in progress.

On High Pike an area of striped scree is being monitored. First described in the 1930's preliminary observations seem to indicate stability of these features over the last 60 years. A section showing about 40 almost parallel sorted scree ridges was examined. Fines were very clear along the ridges, but were absent in the lines of the coarser angular debris in the gutters. The amplitude of the features increases in winter as ice lenses build up. The age of the features has not yet been ascertained - whether they can be formed in the present climatic regime or date from a periglacial phase in the late Pleistocene is not yet clear. The turf cover surrounding the open scree and convex turf bank rolls at the foot of the exposure are also being continuously monitored, hopefully to see whether the features are degrading or expanding. The leader explained the monitoring work in progress and compared these features with other known sites of striped scree on Grassmoor, Helvellyn and Skiddaw.

A traverse across the top of Hare Stones and Great Lingy Fell brought the group to the top of Iron Crag where it was possible to look down on the heavily gullied valley head. Here is an example of a debris-flow channel, a fluvial system dominated by huge volumes of easily moved, unstable loose debris. The channel is now instrumented so that every event that changes the channel can be continuously logged. The channel system is a very dynamic one. The heavy sediment supply is related to heavily shattered and haematised bedrock (Eycott Group lavas and Skiddaw Group material). Debris flows appear to be triggered not only by high precipitation but are also related to the critical mass of loose debris waiting in the system. Debris flow down the channel is usually followed by phases of downcutting and channelling. The accumulated debris at the foot of the system was also examined - a whole series of levee deposits line the channel and an extensive fan of debris is now accumulating in the old mine ponds area at the head of Roughten Gill.

The route out of the valley contained interesting landforms. Much discussion ensued about a possible slip feature on the east side of the Dale Beck valley opposite Wet Smale Gill (NY 301 353). A fine arcuate scar feature is visible, but some flat-topped areas of debris alongside posed problems of explanation.

The group completed the walk back to Fell Side Farm where the leader was thanked for a very informative and stimulating excursion.

(A lecture given by Dr Warburton entitled 'Geomorphology in the Last Millenium' is summarised in the lectures section of this volume of the Proceedings)

ROUGHTEN GILL AND SILVER GILL MINES

Leader: Tony Rigby (CGS)

23 May 1998

Fifteen members met at Fellside Farm (NY 304374) on a rather dull and drizzly morning, although the forecast was for better conditions during the afternoon. Following the President's introduction the party set off via the old mine road to walk up the Dale Beck valley. After some 200 yards a stop was made to look at a large exposure of boulder clay, here being at least 40 feet in thickness. Much of this material covers the slopes of these fells, so one could see why the old prospectors first discovered the mineral veins in the deep gills. Numerous small holes in the top part of this exposure have been made by nesting sand martins.

The leader then gave a brief description of the geology of the area, with the underlying rooks belonging to the Eycott Group. At the head of the valley the Carrock Fell Igneous complex occurs, whilst further to the west high up in the gills the Skiddaw Group outcrops. Looking back towards Uldale, the Carboniferous limestone 'steps' of Aughertree Fell could be seen through the mist.

Continuing to the first footbridge crossing Haygill, the party then paused to view the remains of a late 18th Century lead smelter. Here the collapsed chimney flue was seen running up the fellside to the east. A grinding mill was erected on this site around 1890 by the Cleator Iron Ore Company, for the purpose of processing Barite and Umber. Some small samples of white Barite were traced in the roadway. Interestingly, a member of the party (Fred Lawton) indicated that he had a full plan of this mill, which was back in his car. This document was reviewed later in the day on our return. Turning to look at the west side of the valley, the party then viewed an excellent example of an old miners 'Hush' on Braefell. This was a channel dug out by the miners, usually with the aid of a sudden release of a large volume of water in order to expose the bedrock, thus locating any veins.

Moving on to the foot of Swinburn Gill, an old copper dressing floor was then examined which produced a few small samples of the colourful blue/ green mineral Chrysocolla. Higher up in this gill, the Red Gill mines could just be seen, these are a world famous locality for the beautiful minerals Linarite and Caledonite.

On arrival at the extensive lower mine dumps at Roughtongill, the two main mineral bearing veins which run in a north-east / south-west direction were pointed out and a brief history of the mining activities was given by the leader. Initially, these mines were worked for the primary ores of lead and copper, but later some zinc ore was obtained and several of the old dumps were reworked for the secondary ores of lead and copper, having previously been discarded by the ancients. In the last few years of mining some Barite and Umber were also obtained. From a mineralogical aspect the mines have provided many rare and beautiful secondary minerals. Time was then spent searching over the old waste tips and whilst one has to dig nowadays to find good specimens, the following minerals were identified on the day: - Quartz, Calcite, Galena, Chalcopyrite, Sphalerite, Hematite, Goethite, Malachite, Brochantite, Chrysocolla, Pyromorphite, Linarite, Barite, Cerussite and an excellent specimen of Hemimorphite!

As the weather showed little improvement, rather than visit the higher workings in Silvergill which was still in cloud, it was decided to move east. The party climbed up past the site of the Lainton's Engine Shaft beneath Iron Crag, seeking shelter in an opencut situated just to the west of the Higher Mexico level. Within the last twenty years this opencut has produced some fine Pyromorphite and it was first discovered by the late Richard Barstow, a Cornish mineral dealer, in 1978. It is now named after him and is known as 'Barstow's Trench'. Lunch was taken near here and several members of the party managed to find some small, but reasonable samples of Pyromorphite showing various crystal forms.

The vein was then followed further to the east where more Pyromorphite and some good Malachite was obtained. Moving on to the waste dump at the Higher Mexico level, two specimens of brown Mimetite were recovered. After descending to the Lower Mexico mine, the dump here proved to be rather barren. By now the weather had improved, so it was decided to visit an old 'Coffin' level. This was situated half way up the Roughtongill waterfalls, cut in the east bank of the stream. It is by far one of the best examples in Lakeland, having been cut by hand using hammers, picks and wedges long before the days of gunpowder. Only the minimum amount of rock was removed, being much wider at shoulder height, but narrower at head and floor levels, thus giving a coffin shaped appearance.

As there was a little time in hand on the return journey, the majority of the party made a brief visit to the Redgill mine. Here some diligent searching of the 'Old Dutch Level' dump produced samples of Galena, Chalcopyrite and two small pieces of Linarite being readily identified by the beautiful deep blue colour. Clearly this rather shallow dump has been scoured by numerous mineral collectors over the years, making it extremely difficult now to find some minerals recorded from here. Indeed, the leader could recall visiting this mine when he was a boy during the 1950's in the company of the late Edgar H. Shackleton and excellent specimens could be found then with relative ease.

Judging by the appreciation which was shown by many of the party throughout the day, this was a very enjoyable excursion and warm thanks were kindly expressed to Mr Rigby on behalf of the members by the President, Mervyn Dodd.

THE COCKERMOUTH LAVAS AND OTHER FEATURES AROUND ISEL

Leader: Mervyn Dodd (CGS)

20 June 1998

The whole of this visit was in Park Wood, part of the private land of the Isel Hall estate. The visit was possible through the kind permission of Mary Burkett and estate manager Nigel Harris who accompanied the party.

The first site visited was Blumer Beck. Here a variety of drift deposits show rapidly changing, mainly fluvial or fluvioglacial conditions. At Bewsgill Bridge (NY 163 343) the top of the deposit contains 10 - 25cm disc-shaped clasts of various lithologies lying horizontally. Below this the mainly Skiddaw Group clasts are smaller and fewer, possibly indicating lower energy levels. 50-100m upstream from Bewsgill Bridge close to a prominent incised meander; the lowest deposit may be a boulder clay with Borrowdale Volcanic Group clasts up to 75cm. Above this is a 25cm thick, surprisingly hard conglomerate with a blackened (? carbon rich) shelf like form which could be fragipan. Above this is a cross-bedded deposit with pebble sized clasts.

The second site visited was in Bloomery Beck (NY 157 343). Here active tufa formation is seen around twigs, roots etc., giving a step like gradient to the small stream. The calcium carbonate comes from supersaturated solutions formed underground by dissolution of limestone. Where streams reappear at the springline the carbonate precipitates out (especially in dry spells) to form soft, fibrous material. This is easily eroded in wet years, as shown by the spreads of broken tufa close to the stream. There may also be a biological aspect to the precipitation of the tufa.

The third site was below the forestry track, opposite some rhododendrons at NY 161 344, where the Cockermouth Lavas are exposed. These are Lower Carboniferous (Courceyan) in age, occurring below the Dinantian Limestones. The lavas strike west-southwest / east-northeast and the beds are almost horizontal. They are 'tholeiitic' (low in quartz) basalts and are thought to have resulted from rifting of the crust as it was stretched more or less north to south. The lack of associated tuffs or ashes suggests that these were probably quiet eruptions. Maximum thickness was probably of the order of 100 metres, thinning to the northeast. The top and bottom of flows are often vesicular, the tops scoriaceous, the centres fine grained and uniform, almost like a dolerite. Slightly reddish weathering horizons or "boles" separate the flows. The main minerals in little changed rock are plagioclase, olivine and augite, but locally it has been much altered with greenish mica and chlorite. At this locality at least 2 flows can be seen. The upper flow showing both vesicular and uniform textures, indicating respectively the edges and centres of flows. Calcite amygdales (infills) are fairly common, sometimes in buff to sandy coloured material. Flow centres have purplish weathered uniform massive rock with quite rounded forms, unlike the very angular jointing of flow edges. The lower flow is thicker with more pronounced vesicles and the rock is generally darker. Both the flows show up as small cliffs, the intervening weathering horizon being obscured by forest litter.

2 - 300 metres further east above the forest track at NY 166 347 the 'cliff' is 5-7m high and the rock surface is quite yellowish. It is strongly jointed in a spherical pattern and probably reflects a location close to the centre of a flow.

The party then returned to Blumer Beck at NY 169 347, approaching by a rough forest ride north of the stream. A river cliff on the outside of a meander on the south bank is being rapidly altered by stream action. The Carboniferous Basal Conglomerate lies unconformably above thinly bedded, slump folded, Skiddaw Group distal turbidites. The junction rises steeply and irregularly towards the east at about 45°, but is obscured by vegetation in places. However it is appreciably larger and more obvious than when surveyed for the Cockermouth Memoir. The Carboniferous rocks here are described as reddish sandy shale.

THE ST BEES SANDSTONE ABOVE BARROWMOUTH

Leader: David Kelly (CGS)

1 July 1998

The St Bees Sandstone Formation (Triassic) is the lowest formation of the Sherwood Sandstone Group in West Cumbria and can be examined in the cliff sections above Barrowmouth, Whitehaven between NX 960 158 and NX 958 155. Much of the formation is of red, cross-bedded sandstones deposited on a sandy braidplain in semi-arid conditions. Close to Birkham's Quarry at the southerly end of the section the exposures are about 100m above the base of the formation. Excellent examples of sedimentary structures can be examined, notably strongly cross-bedded sandstone units with erosional bases which represent migrating channel bars. Palaeocurrent directions show a predominantly southerly source. Other structures include planar beds of upper flow regimes and soft sediment deformation features. This particular locality provides panoramic views of the Solway Basin.

The southwesterly dip exposes progressively older beds further north along the section. Shale partings become increasingly thick and mudstone-clast conglomerates become more common. This demonstrates a transition to sheetflood, flood plain deposits. Interpretations of borehole evidence collected in the Sellafield area for UK Nirex Ltd identified a unit approximately 100m thick at the base of the St Bees Sandstone referred to as the North Head Member. Numerous siltstone and mudstone layers, possibly associated with sheet floods, produce much higher gamma ray responses, due to higher concentrations of radioactive clay minerals. It may be that the section studied on this visit lies almost entirely within the North Head Member.

The transitional boundary between the St Bees Shale and the overlying St Bees Sandstone is taken as the arbitrary Permian-Triassic boundary in West Cumbria. This transition is well illustrated in the disused quarry behind the Marchon chemical factory at NX 962159. Lower in these exposures shales begin to dominate the inter-bedded sandstones. Both rocks are highly micro- micaceous, indicating the subaqueous nature of the deposits. The laminated beds show good examples of symmetrical, wave ripples and desiccation cracks. Asymmetrical, current ripples also occur and rip-up clast conglomerates are common. Paler beds indicate reduction of the iron compounds.

The St Bees Shales form the steep, grassy slope from the base of the cliffs down towards the shore, lying beneath the cap of sandstone cliffs above. The shales are not exposed here but their incompetent nature means that they are prone to slope failure and this is illustrated by land-slip scars, a deformed mine tramway and old mine buildings tilted back towards the slope at 15° as a result of rotational slippage.

HILTON AND SCORDALE BECK

Leader: Alan Smith (deputising for Eric Skipsey who planned the Excursion but was unable to lead because of illness).

12 July 1998 - A joint meeting with the Leeds Geological Association.

Hilton and Scordale Becks trench into the North Pennine escarpment and provide a cross-section extending in the west from Hilton village on the St Bees Sandstone, across the faulted Cross Fell Inlier and up through the Lower Carboniferous succession as far as the Whin Sill, which closes across the the head of the valley in the east.

The car park at Hilton provided an excellent viewpoint to start the excursion and set the geological scene. It lies on the St Bees Sandstone on the extreme eastern edge of the Eden Basin - the sandstone was examined in the stream bed here and the faulted boundary with the Dufton Shales of the Cross Fell Inlier can be well demonstrated. The Inlier occupies the low ground in front of the Pennine escarpment. The distant views of the overlying, near horizontal strata of the Lower Carboniferous gave the group a foretaste of what was to come later in the day.

In the traverse up the valley there were constant reminders of the rich industrial and mining history of the area. The site of Hilton Smelt Mill was examined along with the remains of its chimney and flue on the hillside above.

Small areas of the Murton and Kirkland Formations (part of the inlier) were located in the valley floor, but the exposures are all poor and warranted little time. A series of gravel and sand mounds along the southern slopes of the lower valley provoked a great deal of interest and discussion. Ice movement in the Upper Eden was up-valley towards Stainmore, but a basal ice shed must have existed a short way north from Hilton. The phasing of this is unclear. Downmelting of the ice and meltwater movements are equally complex and not fully understood - the nature and date of these fluvio-glacial mounds is yet to be fully documented.

Good distant views of the Low and High Hause areas on the southern flank of the valley afforded some excellent examples of faulted Lower Carboniferous terrain where the Roman Fell Sandstones, resting on underlying shales, have undergone major rotational slipping.

The middle section of the valley becomes gorge like with limestone cliffs on either side. The valley bottom is occupied by Lower Carboniferous Basement

Beds, although they are largely concealed by scree debris. Above are the lowest marine limestones (Ravenstonedale and Hillbeck Limestones of the Orton Group), overlain by the thick Melmerby Scar Limestone, together comprising the Great Scar Limestone of the Askrigg Block. This section has a series of ancient opencast and underground mining relics. Hushes cut great gashes on the hillsides. Additionally there are several examples of landslipping and tilted blocks.

Above Stow Gill the Whin Sill becomes visible in the hillsides towards the valley head. Sections demonstrate that the sill occurs above the Robinson Limestone, but then rises to below the Little Limestone. Evidence was seen of a thick channel sandstone above the Robinson Limestone that during intrusion deviated the dolerite magma.

The head of the valley is dominated by the old mine buildings, spoil heaps and remnants of a once prosperous lead extraction industry. Time was spent examining specimens of barite, galena, amber coloured fluorite and quartz. Finally the fine exposure of the Whin Sill in the Melmerby Scar Limestone was examined where the beck tumbles over a fine series of major falls at the head of the valley.

THE RIGS SITE AT BECK WYTHOP

Leader: David Kelly (CGS)

15 May 1999

This visit was hastily arranged when the excursion planned for that day had to be re-arranged at short notice.

The party met at the old road alongside the A66 at Beck Wythop (NY 216 282). It was noted that the exposures of sandstones, siltstones and mudstones here lie in the Kirkstile Formation of the Skiddaw Group and are a series of distal turbidites.

At the north end of the old road cutting thinly bedded, fine grained rocks dip south-east. Examples of parallel lamination are common but cross lamination is more difficult to find. Scours and minor crenulations also occur. The dip of the rocks is at right angles to the line of the cutting and does not pose stability problems. However, widely spaced cleavage planes run parallel to the cutting and are a potential problem.

In the middle section of the old road cutting an upright anticline, steeper on the south limb is seen with minor folds on the limbs. Well-developed boudins occur in the sandstone units.

At the south end of the cutting a gentle anticline occurs along with minor folds.

The section on the A66 was omitted because of traffic difficulties but the lakeshore exposures were examined and matched with the features found in the old road cutting. These are free from lichen and are accessible when the level of the lake is low. In addition to features seen by the road, a small patch of conglomerate was noted.

THE BUILDING STONES OF KESWICK

Leader: Terry Blanchard (CGS)

16 June 1999

This excursion covered the main features of the town and was wholly based on the information contained in the article 'THE BUILDING STONES OF KESWICK' by Alan and Kath Smith published in Volume 6, Part 2 of the Proceedings.

THE CARBONIFEROUS LIMESTONE OF WHITBARROW

Leader: Murray Mitchell (University of Leeds)

26 June 1999 - Joint meeting with the Liverpool Geological Society

The visit began at Witherslack Hall Lane End (SD 437 859) where the leader explained that the whole of Whitbarrow (norse: white hill) has been designated a Rigs site. In south Cumbria a series of fault blocks dip to the east; north - south Hercynian faults form the eastern margins of the blocks and on the west sides the Carboniferous Limestone rests unconformably on the Bannisdale Formation. The Whitbarrow Fault lies in the Gilpin Valley. The tensional Hercynian faults have been re-activated at various times and are partly connected with the opening of the North Atlantic Ocean. The excursion was to start from Witherslack Hall and follow the track that leads above Black Yews Scar to the summit of Lord's Seat.

The first locality visited was just beyond the gate into the field past Witherslack Hall. To the south of the path lies the former site of the glacial lake of Witherslack Tarn, now filled with about 10m of post-glacial sediments. The basal Carboniferous unconformity is not exposed here. The Martin Limestone, the dolomitic, well-bedded building stone of the Furness Railway, is exposed close to the gate. 100 metres further on in the same field, the Red Hill Limestone is exposed to the left of the track. This unit lacks shale partings, is good for lime burning, and is one of the principal host rocks for the Furness hematite deposits.

The Dalton Beds form the scarp and bench topography seen along the wooded path up the western flank of Whitbarrow. The lower part is massive and darker than the Red Hill Limestone. At other localities a rich fauna including the distinctive chonetid brachiopod *Delepinea carinata* can be found. The path follows a bench in the middle Dalton Beds where shale partings lead to perched water tables and springs. The massive, upper Dalton Beds form the main crags of the Whitbarrow escarpment. The rock shows a reticulate weathering pattern and is an important building stone in Kendal.

Immediately after entering the Hervey Nature Reserve at the top of the escarpment, silver birch and juniper flourish - the latter being important for producing the charcoal used in the gunpowder industry that was important in the area. Yews flourish on the dry limestone crags. This is an excellent vantage point to view the Yewbarrow Carboniferous fault block to the west and the higher relief of the Silurian rocks of Cartmel Fell beyond.

Following the track to the top of Lord's Seat, the upward succession from Dalton Beds to Park Limestone and to Urswick Limestone was traced. The upper Dalton Beds are sandy in places and contain brown dolomite crystals. The lower part of the Park Limestone appears to be very similar and contains black crinoid ossicles. The Park Limestone weathers to produce platey fragments that make ringing notes when struck. West of the Lord's Seat cairn the Park Limestone produces distinctive relief of small rolling ridges and furrows. No significant crags occur and the rock is not a good building stone. The fauna, not seen on this visit, is often of a limited range of species, possibly caused by stressful conditions of salinity. Corals include *Lithostrotion* - a genus only found in Holkerian and younger rocks.

The surprising occurrence of heather in the hollows on the upper slopes of Whitbarrow is attributed to accumulations of lime-free loess. Near the summit dark strings of calcite occur in very fine-grained limestone near the top of the Park

Limestone, these are attributed to shrinkage on drying indicating very shallow water conditions.

East of the summit a change to very pronounced scarps and dips marks the transition to the strongly cyclical Urswick Limestone.

Lunch was taken at Argles' Tarn where the water is held by a shale bed on a palaeokarst surface, and a faulted boundary to the east which acts as a "backwall". Here the origin of the pavements was discussed and it was noted that clints are palaeokarst features hardened by calcrete during the time of deposition of the Urswick Limestone.

Walking north from Argles' Tarn a Borrowdale Volcanic Group breccia erratic was noted with its pale green lichen indicating an acid rock. There are relatively few erratics on the pavements of Whitbarrow.

Further north a 1 metre wide open cut along a mineral vein was examined. This is an extension of the fault which runs along the east side of Argles' Tarn. Further along the fault at Bell's Rake an old adit occurs. This is the trial pit for hematite that is shown on the 1852 map. Specimens of calcite and barytes gangues were found.

The party descended the escarpment by the path to North Lodge where the unexposed Carboniferous-Silurian boundary can be deduced from landform and vegetation evidence. The dry ridge with ash trees and dog's mercury gives way to wet ground with bog myrtle and birch. The Bannisdale Formation is exposed later along the path.

The party returned along the valley to Witherslack Hall.

THRELKELD MINING MUSEUM AND QUARRY

10 July 1999

Members enjoyed the opportunity to visit the exhibition of Quarrying and Mining memorabilia at Threlkeld Mining Museum. Wise use had been made of the larger space available than at the earlier base at Caldbeck.

A striking display of a large geological map of Cumbria with illustrative specimens on a large table was an effective centrepiece to the 'Quarry and Rock room'. Quarry artefacts, old maps and documents were supplemented by good recent colour prints, making a welcome supplement to what had been the 'Mines and Mineral ' room at Caldbeck. John and Philippa Tindal from Ambleside, who had recently joined the Society accompanied us on a circular tour of the Quarry, providing us with a sketch map, based on an article by Helma Tasker, "Jewels, Graptolites and Heavenly Views (OUGS Journal 16;1, Spring 1995).

The best contact between the Threlkeld Microgranite and Skiddaw Group rocks was near the entrance, at the north-east edge of the Quarry. As is well known the metamorphic aureole was only 2-3 cm wide. The thinly bedded and parallel laminated Skiddaw rocks (probably distal turbidites) were mainly very friable siltstones and shales, very highly polished in places. Near the first contact poorly developed sole and flute structures, with small slump folds were observed. There were 4 or 5 smaller contact zones along the north-east wall, with a strongly developed slump fold in more sandy beds and a detached metre size block of the microgranite. On a previous visit graptolites had been found, but no examples of these or trace fossils were found on this occasion.

The Threlkeld Microgranite was typically unspectacular, with small millimetre size patches of quartz and feldspars in a drab mid-grey background. Strongly marked, cooling joints were prominent, especially along the southern wall of the quarry. Generally these sloped down to the east, except in the west wall. In the south-west of the quarry were what appeared to be xenoliths, oval in shape, much darker in colour and up to 5-l0cm long and 3-5 cm deep. We thought these were clasts, distinctive because of partial mixing of the magma. Nearby several slickensides, up to 1 metre long were noted on fallen blocks

Mineral 'finds' were limited. In the south-east corner good quartzes were found, both 'bruised' pyramids about the size of a thumb nail and perfectly formed clear micromount style 5-l5 mm long pencil like forms. These last types were respectively transparent or with pale green and pale red tints. We saw no sign of the veins of magnetite, malachite chalcopyrite and calcite said to be present but avoided the dangerous loose blocks and rocks above the track. There were what seemed to be copper sulphate mineral stains in the south-west comer and pyrite mineralization on a 50 cm xenolith of BVG volcaniclastics in the same area.

On the west wall we found a later, rather dark coloured rock, recessed by weathering. It was generally conformable, but with short leaves cross-cutting the succession, about 50 cm metre thick. Our President interpreted it as a sill of more basic rocks. It contained parallel 10cm bands of what appeared to be calcite. Dilute hydrochloric acid produced a very limited, delayed reaction, suggesting a secondary aragonite development below lichen encrusted surfaces. Smaller cross cutting dyke like features further to the north-west appear to be similar in both rock colour and mineralogy so could be part of the same late intrusive episode.

VOLCANIC AND IGNEOUS ROCKS IN WASDALE

Leader: David Livesey (CGS)

14 July 1999

A large party of members and guests met in Gosforth and proceeded to Bolton Hall (NY 087 039) on the road to Wasdale. The first location visited was a rocky knoll in a field on private land some 200m south of the farm. This locality is near the western extremity of the outcrop of the Borrowdale Volcanic Group; 2 kilometres to the west in Gosforth the volcanics have been downfaulted and lie beneath 600 metres of younger sediments. On the knoll andesitic lava of the Birker Fell Formation is exposed. The well-developed columnar jointing led to a photograph of the knoll being used in the Observers' Book of Geology! The knoll is an excellent viewpoint and the leader pointed out the areas of outcrop of the three main rock groups in Wasdale: Eskdale Granite, Ennerdale Granite and the Borrowdale Volcanic Group.

The party then travelled to the road beneath Buckbarrow (NY 137 540) to view the contact between the Borrowdale Volcanic Group and the Ennerdale Granite. This site is described in the CGS Proceedings Vol 6 Part 2 pp269.

The final locality visited was close to the junction of the road from Greendale and the Wast Water shore road. The cars were parked immediately past the junction on the left (SD 151 054). In the numerous roche mountonnées the Ennerdale Granite is exposed having been downthrown to the lake level by a fault running along Greendale Gill. A short walk across boggy ground to the north leads on to the outcrop of the Borrowdale Volcanic Group. The two rocks appear similar in colour on the weathered surfaces but the joint patterns are different. The junction itself is not exposed.

GEOLOGY OF THE AREA AROUND FLOUTERN TARN

Leader David Kelly (CGS)

11 September 1999 - Joint meeting with the Manchester Geological Association

The party met on the road near Whins (NY 102 164) and followed the footpath to Floutern Pass and Floutern Tarn. It was explained that this route lies close to the line of the Causey Pike Fault, one of the major structural elements in the Lake District which trends east-northeast / west-southwest and lies within the Skiddaw Group. It is a wrench and thrust fault and movements have occurred in different directions over a long time period. In this area it divides the Kirk Stile Formation (of the Northern Fells Belt) and the Buttermere Formation (of the Central Fells Belt) of the Skiddaw Group and may have been a control on sedimentation. It may have a relief effect and be responsible for the valley system followed by the Floutern Pass route between Ennerdale and Buttermere. Its presence in this area is inferred and there are no exposures.

By the track above Whins (NY 106 168) small Skiddaw Group exposures show bleaching possibly indicating the presence of the Crummock Water aureole. The outcrop of the aureole is a strip 24km by 3km trending east-northeast / west-southwest on the north side of the Causey Pike Thrust. The bleaching is caused by a loss of carbon and there are other chemical changes (including tourmaline veining) in the rock. It is suggested that the aureole could be due to an elongate, buried granite emplaced along the line of the Causey Pike Fault, which is a major geophysical lineament and may be a weakness in the deeply buried basement complex. The fault displaces the aureole and therefore some movements occurred later then the formation of the aureole. Rb - Sr whole rock dating has produced an age for the aureole of c.400Ma, therefore the intrusion may be connected with Lower Devonian Shap and Skiddaw granites.

The Kirk Stile Formation of the Skiddaw Group was examined on Floutern Cop (NY 122 173). This consists of dark grey, laminated and thinly bedded (0.1 - 2 cm) mudstones and siltstones although other localities show coarser beds. The type area for the formation in on Whinlatter Pass. The age is Arenig - Early Llanvirn and the formation is interpreted as being a suite of distal turbidites with Bouma units D and E. On Floutern Cop the laminations show complex folding and the rock is strongly cleaved.

The next locality visited was the morainic bank on the north side of Floutern Tarn (NY 124 171) where there was much discussion of the form of the corrie containing the tarn which is one of McKenzie Clough's 54 distinct corries, defined as having all the corrie elements clearly represented. The corrie is atypical in that there are no side walls to the west and east. It may have been excavated along the Causey Pike fault, accounting for the elongate shape. Although the headwall crags of Floutern Crag face north, the central line faces east. The apparently natural outlet to the north (and to Whiteoak Beck) is blocked by a flat-topped hummocky drift-covered ridge. The outlet stream drains east through Skiddaw Group rocks, dropping steeply 100m to the head of Mosedale. The Buttermere Formation crops out south of the tarn and forms the western half of Floutern Crag while the Ennerdale Granite forms the eastern half. The amplitude is about 200 metres and its length is about 600 metres making very close to the mean size of a Lake District corrie. The floor lies at a relatively low altitude of about 380 metres above sea level, compared with, for example 500 metres for the Bleaberry Tarn corrie on the Buttermere-Ennerdale ridge. The basin is fairly shallow and lies 40m below the col to Ennerdale. Sissons maps a Loch Lomond Stadial glacier here - there is a thin hummocky drift south of the tarn. It was noted that the ridge on the north side of the tarn is littered with large granite boulders. It was suggested that these may have been deposited by ice moving northwards from the eastern part of Floutern Crag, or that they rolled down an ice surface from the summit plateau of Great Bourne or simply that the Skiddaw Group rocks forming the western part of Floutern Crag do not produce large resistant boulders.

The position of the boundary between the Skiddaw Group and Ennerdale Granite was viewed from the moraine, then the party made its way round the tarn for a more detailed examination (NY 124 168). The contact between the Skiddaw Group and the granite runs just to the east of the steep gully with scree on Floutern Crag before turning east, parallel with the tarn, suggesting that the edge of the intrusion is vertical or steeply dipping. Close examination of the exposures confirmed the vertical nature of the boundary. The Skiddaw Group rocks close to the exposed contact have been hardened to a fine-grained hornfels, but do not show the bleaching characteristic of the Crummock Water aureole.

A dark mineral found in fractures in the granite at this locality was tentatively identified as tourmaline, a mineral often associated with the Crummock Water aureole.

Fresh specimens of Ennerdale Granite from a recently fallen boulder were examined. The granite is intruded into the Skiddaw and Borrowdale Volcanic Groups, forms the summit of Great Bourne and reaches down to the valley floor of

Mosedale. This medium grained granite was formerly referred to as Ennerdale Granophyre. A granophyre is a micrograpite where the quartz and feldspar crystals are intergrown with quartz inclusions forming angular outlines to form a graphic texture sometimes likened to cuneiform writing. Of the Lake District intrusions, the outcrop of the Ennerdale Granite is second largest in area only to the Eskdale Granite and has a finer texture than might be expected for an intrusion with an outcrop of that extent. However the gravity data indicates that the volume of the Ennerdale Granite is much smaller than the outcrop might lead one to expect. It may have been intruded at a relatively shallow level. U - Pb analysis of zircons from the intrusion give an age of 425 + 4 Ma (Caradoc). This suggests it was connected with the subduction related processes which gave rise to the Borrowdale Volcanic Group. This is older than the late/post-orogenic, Lower Devonian Skiddaw and Shap Granites. A diagram illustrating the possible age relations of features around Floitern Tarn is provided as Figure 1.

In deteriorating weather the party moved on to view Red Gill (NY 128 169). The gill follows a dextral tear fault, with Ennerdale Granite west of the gill and finely-bedded Skiddaw Group rocks to the east. It follows a hematite vein, the exploitation of which occurred from around 1870 from now a collapsed level. The Skiddaw Group south of the tarn is part of the Buttermere Formation. This consists of mudstones, siltstones and sandstones and contains a fauna of late Tremadoc - early Arenig age. It is interpreted as an olistostrome - a deposit formed by masses of sediment slumping down the continental slope, although there is no evidence of this in the Floutern Crag area. The slumping may be late Arenig. West of the gill a 30cm patch of hardened unbedded mudstone within the Skiddaw Group was thought to be a diagenetic feature.

Figure 1. Possible age relations of features around Floutern Tarn

Period	Epoch	Age	Events	
---------------	-----------------	354Ma		
DEVONIAN			← Crummock Water aureole c.400Ma Skiddaw and Shap granites c.395Ma	
---------------	-----------------	412Ma		
	Pridoli			
	Ludlow			
SILURIAN	Wenlock			
	Llandovery			
---------------	-----------------	435Ma		
	Ashgill			
	Caradoc		← Ennerdale Granophyre 452Ma	
ORDOVICIAN	Llandeilo		Borrowdale Volcanic Group	
	Llanvirn			
	Arenig		Kirk Stile Formation	
	Tremadoc			Buttermere Formation
---------------	-----------------	492Ma		

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Other Excursions

The following excursions were also held during 1998 and 1999.

9 May 1998	Cockermouth Lavas and Carboniferous Limestones around Blindcrake Leader: Ron Lister
23 August 1998	The Borrowdale Volcanic Group in the Rydal area Leader: Dr Mike Peterson (BGS)
20 September 1998	The Geology of the Carnforth area Leader: Dr Neil Aitkenhead (BGS)
17 April 1999	Tendley Hill Quarry, Brigham
1 May 1999	Florence Mine, Egremont
5 May 1999	A GCE Advanced Level geology field investigation, Red Hills, Penrith Leader: John Rodgers (CGS)

LECTURES

THE GEOLOGY OF THE ISLAY AREA

A lecture by Angela Marchant and Margaret Fox,
Cumberland Geological Society
on 30 September 1998
at Cockermouth School, Cockermouth

Islay is one of the undiscovered jewels of the Northern Isles, and provides numerous attractions to both the geologist and the archaeologist, notwithstanding the fact that there are 7 distilleries (5 active) on the island.

From a geological point of view the major features seen on Islay are a result of the Caledonian Orogeny. Prior to the Caledonian Orogeny the Pre-Cambrian basement and the Early Palaeozoic cover of what is now the west of Scotland lay on the south-east side of the Laurentian plate. During the orogenic phase sediments on the fringes of the northern and southern shores of Laurentia were deformed and metamorphosed – the Moine thrust represents the most westerly limit of these metamorphosed sediments.

Islay is at a geological crossroads, with a junction between rocks originally thought to be Torridonian/Lewisian on the western side of the island and the Dalradian, forming a large anticlinal structure over the remainder. On the west quartzitesand phyllites of the Colonsay Group and acid and basic gneisses of the Rhinns Complex are exposed, with the Dalradian Argyll and Appin Group exposed to the east. The Gruinart fault separates these 2 areas.

There are several theories on the Gruinart fault – it may be an extension of the Great Glen Fault, it may be a displaced portion of the Moine Thrust, or it may not exist at all!

The Rhinns Complex, separated from the Colonsay Group by the Kilchiaran Shear Zone was originally though to be the equivalent of the Lewisian but the rocks have recently been dated at 1.8 billion years so this cannot be so. Isotope studies indicate that they are juvenile, mantle-derived material and not reworked Archaean crust. Acid and basic gneisses form the bulk of the complex, along with some sediments, but all of these have now been metamorphosed to amphibolite grade material.

The Colonsay Group has proved difficult to date, but recent information has indicated a date of >620my (Lower Dalradian). The Group comprises predominantly sandstones, a lower deltaic (arkosic) sequence, interleaved with phyllites and slates, with turbidites with very fine phyllites in the upper part.

The Lower Dalradian Appin Group comprises a sequence of quartzites, phyllites, limestone and slates and provides fine examples of brittle/plate folding.

The Islay limestone forms the uppermost unit in the Appin Group and occurs in the centre of the island. The limestone, which is used extensively for roadstone gives the island its green colour and enriches the peat soil and the acid water from the quartzite hills.

The Port Askaig Tillite is at the base of the overlying Argyll Group and has been correlated with similar sequences in Scandinavia and Greenland. There has been some discussion regarding whether the tillite was produced by land or floating ice, but the identification of what appear to be dropstones would appear to point to at least some element of the latter. The Bonahaven Dolomite overlies the tillite, and contains algal stromatolites, some of the earliest evidence of life in the UK. The Islay Quartzite overlies the dolomite and forms a ring of resistant rock around the eastern area of the island and extends across to Jura where it forms the Paps of Jura. The quartzite shows all the features of shallow water deposition including ripple marks. It is overlain by the Craignish Phyllite.

Tertiary dykes are also apparent on Islay, but do not have the orientation associated with normal Tertiary igneous centres, the inferred source is the submarine Blackstones Centre west of Mull.

Large amounts of peat (e.g. Duick Moss) have accumulated since the last Ice Age, this has provided fuel for islanders homes and the distilleries. Another recent feature is the raised beaches that are seen around the coast.

GOLD MINERALISATION IN THE SOUTH EASTERN DESERT, EGYPT

A lecture by Dr Gordon Taylor, University of Luton,
on 21 October 1998
at Queen Elizabeth's Grammar School, Penrith

(Doctor Taylor has prepared a paper on the subject of his lecture. Due to the thematic nature of the papers in this volume of the Proceedings it has been decided to hold the paper for the next volume of the Proceedings. A summary of the paper, which also serves as a brief summary of the lecture, is provided below – Editor)

The discovery, extraction and exploitation of Egyptian gold can be traced to the Pharaonic times. Nearly a hundred gold occurrences from the Eastern Desert are recognized and almost all of them have been previously attributed to an epithermal (sensu stricto) origin. However an epithermal model does not satisfactorily explain the origin of the gold-bearing quartz veins of central Wadi Allaqi, which were developed in a volcano-sedimentary sequence within a back-arc tectonic provenance.

Remote-sensed images and field observation show that the mineralized rocks of central Wadi Allaqi were restricted to the ubiquitous shear-zones, which were hosted in complex, regionally metamorphosed terranes. Relatively thin (a few centimetres to a metre) mineralized quartz veins, which occur along the shear-zones possess distinct but localised alteration zones, up to 5m in width, within the volcaniclastic country rocks. The spatial and temporal structural relationships indicate that the mineralised veins have developed as part of a brittle-ductile shear sequence in low-grade regional metamorphic conditions which was broadly synchronous with the earliest DI deformation of the Pan-African orogeny in central Wadi Allaqi. A further two distinct mineralization events are recognized subsequent to the earliest main event.

Investigations of the petrography, fluid inclusions and oxygen and hydrogen stable isotopes tend to support the preferred metamorphic provenance for the auriferous fluids.

THE METAMORPHIC HISTORY OF THE BORROWDALE VOLCANIC GROUP, NORTH-WEST ENGLAND

A lecture by Dr Nicola Meller,
London & Scandinavian Metallurgical Company Limited
(Formerly of the University of Bristol)
on 18 November 1998
at Cockermouth School, Cockermouth

The metamorphic history of the BVG was the subject of Dr Meller's PhD thesis which was funded by the Natural Environment Research Council and UK Nirex. The area of study traversed the exposed BVG of the Central Fells 'belt' of the Lake District and the concealed BVG sequence of the Cumbrian Coastal Plain, accessed by the Nirex Deep Drilling Programme.

Dr Meller provided a brief review of the geological history and palaeogeography of the Lake District region from the Skiddaw Group through to the Windermere Supergroup times and up to the Acadian Orogeny, noting that granitic intrusive events in the immediate post-BVG phase produced a batholith which now underlies most of the Lake District. Gravity Surveys indicate that the batholith is at its shallowest (1 km below the surface) in the central area of the volcanic sequence, falling to depths of 4 to 5 km to the north and south. From a structural point of view the Lake District Boundary Fault Zone which separates the coastal plain from the Lake District was noted, with the batholith only having been identified to the east of the fault zone.

Four main factors that influenced the metamorphism of the BVG were identified:

a) Hydrothermal alteration associated with volcanicity
b) Thermal (or contact) metamorphism associated with the Lake District Batholith
c) Burial within the Volcanic Pile
d) The early Devonian Acadian (Caledonian) Orogeny

Regionally, the maximum degree of metamorphism observed in the volcanic sequence is prehnite/pumpellyite facies, reflecting temperatures of <200-300 ^{0}C and pressures of a few kilobars. At this grade of metamorphism primary volcanic minerals such as plagioclase feldspar, pyroxene, garnet and Fe-Ti oxide are sometimes preserved

There are a number of problems associated with very low-grade (prehnite/pumpellyite facies) metamorphism: a lack of equilibrium; a lack of indicator minerals and fine-grained replacement is prevalent. However the preservation of primary minerals and the growth of secondary minerals together allows identification of both the volcanic origins and the subsequent metamorphic processes.

Tools that can be used in the investigation of the metamorphic history include petrography, mineral chemistry, whole rock chemistry, stable isotopes and fluid inclusions. All of these were utilised by Dr Meller with the exception of the last. Most of the rocks that were sampled from the Lake District were from the Lower BVG which is more basic, basic rocks frequently providing a greater number of secondary minerals. There is also a greater proportion of phenocrysts and vesicles, providing greater opportunity for the growth of coarser secondary minerals. Samples from the Nirex Boreholes were from the Upper BVG and were generally more acidic. Although not the ideal chemical composition, these samples provided good depth constraints enabling comparisons of mineral type, temperature, *etc.* with depth.

Data on the four metamorphic events were reviewed:

<u>Hydrothermal Metamorphism</u> - coincident with volcanic activity, dated at 457 Ma -chalcedony growing botryoidal structures subsequently pseudomorphed by later metamorphic minerals; feldspar veins and localised bleaching; possible celadonite.

<u>Contact Metamorphism</u> - occurred during intrusion of the Lake District Batholith, dated at 451 Ma - hornblende/biotite/cummingtonite assemblages. There is evidence that the contact metamorphism occurred prior to burial metamorphism. This is based on petrographic observations of replacement of contact metamorphic minerals by those associated with burial metamorphism.

<u>Burial metamorphism</u> - no date, but occurred between contact and regional metamorphic events - secondary minerals include epidote, prehnite, pumpellyite, actinolite, calcite, white mica, quartz and chlorite. This was the biggest metamorphic event (note that contact metamorphism attained higher temperature than burial metamorphism but was confined to the metamorphic aureole, less than few km from the batholith-volcanic contact).

Regional Metamorphism - occurred during the Acadian (late Caledonian) Orogeny, dated at 395 Ma. Production of oriented white mica (cleavage) and to a lesser, but more localised extent, pervasive calcite and hematisation.

Dr Meller then concentrated on burial metamorphism. Two distinct mineralogical zones were identified. Zone I, up to 15 km from the Lake District Boundary Fault Zone (LDBFZ) contains calc-silicate hosted assemblages - epidote, actinolite, prehnite and pumpellyite. Zone II, in the Eastern Lake District and in the coastal section contains calcite hosted assemblages. As most secondary minerals are hydrous, it is presumed the metamorphic fluid is predominantly hydrous. However it is known that the CO_2 content of the metamorphic fluid suppresses the formation of calc-silicates allowing calcite to grow. It is therefore postulated that there were two (predominantly hydrous) fluids present, that in Zone I having very low (almost zero) $C0_2$ with a resultant calc-silicate hosted assemblage, whilst that in Zone II had a higher $C0_2$ content, producing a calcite hosted assemblage.

The principles of geothermometry were explained, and results were shown from Nirex Borehole 2, illustrating a lack of any significant increase in temperature with depth. However, results from the Central Fells Belt indicated that there were significant variations, even taking account of the levels of uncertainty in the method. Temperatures of >320 ^{0}C were observed in the centre of the area, with a band in the region of 280-320 ^{0}C around this and temperatures below 280^{0}C on the periphery. When a map of the depth to the batholith was overlain on these data it was readily apparent that the batholith 'high' (thinnest section of overlying BVG) was coincident with the highest temperatures, with lower temperatures over the wall of the batholith to the north and south. However, an anomalous area in the west was observed where the batholith was relatively shallow but temperatures were low. This was explained by the fact that the lower $C0_2$ fluid in Zone I must also have a lower temperature.

Stable oxygen and hydrogen isotope data can be used to establish fluid sources and regional variations in fluid chemistry. A hydrous secondary mineral was required for the source of oxygen and hydrogen used in this type of analysis, one that was widespread (i.e. found in Zones II & II) and formed during burial metamorphism. White mica or chlorite are obvious choices, but since the mica had been seen in preferred orientation in some samples (an indication of regional metamorphism) chlorite was chosen (note that chlorite is known to form cleavage in the volcanics, but was not observed doing so in samples collected for the study of Dr Meller). An additional advantage of using chlorite was that the formation temperature was also known. The results obtained indicated a step increase in δ^{18}O values moving north-east away from the LDBFZ. This increase appears to align with the boundary between Zone I (low values) & Zone II (high values) and indicates that there were 2 different fluids with relatively little mixing. A plot δ^{18}O against δD placed Zone I in the crustal/surface source area and Zone II in the crustal source area.

The information derived from Dr Meller's work is summarised in Figure 1 below.

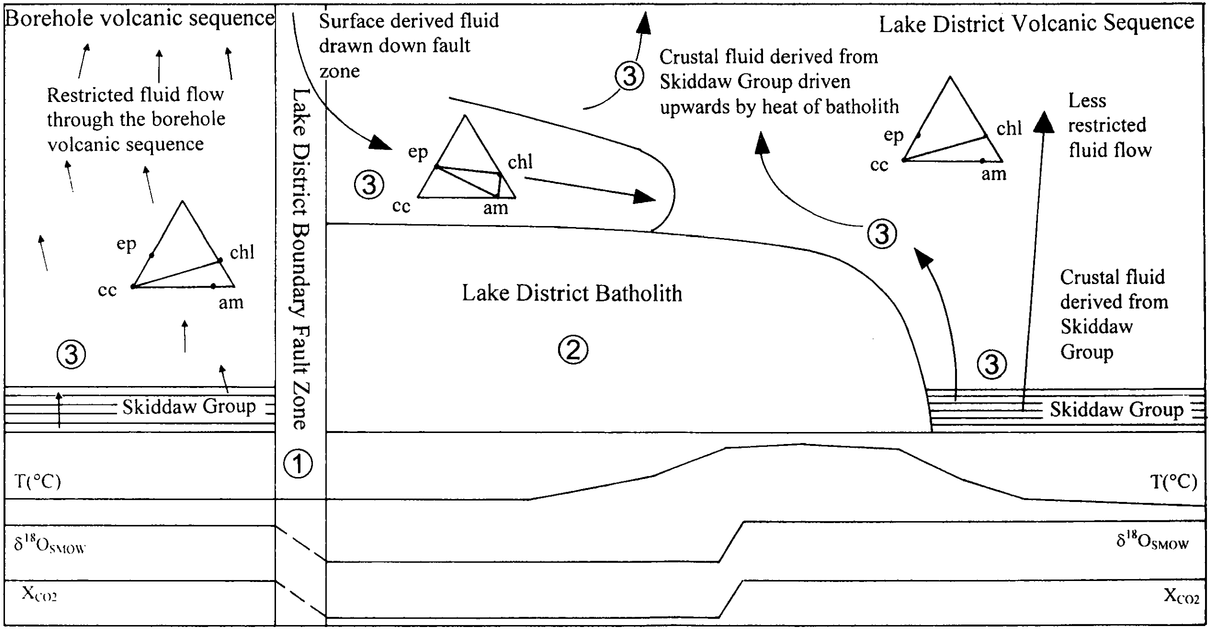

Figure 1. Fluid flow patterns (shown by arrows) in the Borrowdale Volcanic Group during burial metamorphism

THE GEOLOGY OF THE WEST CUMBRIA HAEMATITE DEPOSITS

Presidential Address given by Mervyn Dodd, President of the Cumberland Geological Society, on 3 December 1997, at St James Church Hall, Whitehaven

(This Presidential Address is the first of two given by Mervyn Dodd. The report of this lecture would normally have been published in the Volume 6 Part 1 of the Proceedings (published in 1998) but given the associated and complementary nature of the second address, the two lectures are presented in the same volume of the Proceedings).

The West Cumbria haematite deposits are now recognised as one element of a suite of such deposits in western Britain. Deposits are present in the Mendips, the Forest of Dean, North Wales (Prestatyn to Abergele), south and west Cumbria. The chemical composition of all the ores is similar, all occur within the Carboniferous Limestone (Dinantian) host rocks and all are located close to faults on the edge of Permo-Triassic basins.

The most productive area (after Cumbria) was the Vale of Glamorgan with 8 million tons of iron ore being mined, notably from the Llanharry mine. In contrast the maximum output from mines in north Wales was 450 tons. The total output from the Cumbria mines has been estimated at 180 million tons.

Mr Dodd then focussed on the Florence ore body, the only one still being worked in the West Cumberland ore field. One of the characteristics of the ore field is the molecule by molecule replacement of limestone with the iron ore. The high grade 'blue stone' which formed in the centre of the deposit is very pure, of the order of 98% by weight Fe2O3, and the very low amount of phosphorous meant that the ore was ideal for use in the Acid Bessemer process.

Other forms of the ore are textured, perhaps the best known being the kidney ores (80% Fe2O3) which grow towards the edge of the deposit and specularite, which contributes some 2-3% of the ore body and occurs in vugs. The deposit is monometallic and highly oxidised, the only other metallic components are occasional manganese dioxide and trace amounts of copper sulphides. Quartz is the main gangue mineral with subsidiary calcite and dolomite (derived from the wall rocks) along with significant fluorite and barytes. The barytes is unusual in that some specimens change colour from colourless to blue when exposed to natural light.

In addition to the West Cumberland deposits which occur in the exposed Carboniferous Limestone between Lamplugh and Egremont, and the concealed limestone which continues as far as Calderbridge, there are also deposits in South Cumberland in the Askham/Hodbarrow area (again in Carboniferous Limestone). Vein deposits occur in the Lower Palaeozoic rocks of the Lake District as far east as Grasmere. These deposits are identical to the West Cumberland area with the exception of the associated trace minerals.

Slides of the site of the Margaret mine (950 feet deep, located just outside Frizington) showed the presence of 2 oblong shafts. In order to keep mines dry one shaft was usually used as a pumping pit to keep the surrounding areas of mining dry. In the case of the Margaret mine the older Agnes pit was kept open for this purpose.

Elsewhere evidence of mining for iron is visible in Skiddaw Group rocks on Knockmurton, where tips from 5 open adits are readily seen. The mine operated between 1870 and 1914 and initially was excavated by pick and shovel. Drainage for this mine was via a channel that ran through the fell to the Cogra Moss adit. The iron ore mines in Eskdale are situated in Eskdale Granite. One legacy of the haematite deposit in the Eskdale Granite at Nab Gill is the La'al Ratty (Ravenglass & Eskdale) railway line which brought the ore down to the coast. Mining of haematite produced very little waste due to the very hard nature of the granite.

Mining of haematite has also occurred in the Carboniferous Westphalian 'D' at Keekle, and haematisation has also been noted in the Lower Permian Brockram and been recorded in all rocks up to and including the Magnesian Limestone.

The ore generally occurs in the coarser crystalline limestones. These are the 7th and 4th Limestones in the West Cumberland and the Martin and Redhill Limestones in the south of the county. The West Cumberland ore bodies are always associated with faults. In the north of the West Cumberland ore field the faults run north-west, further south in the Egremont area the faults trend east-north-east. In the south of the county the ore occurs in 'sops' - solution hollows in limestone which have been filled by soft haematite at a later date.

One of the consequences of such extensive mining was severe ground subsidence. This was prevalent in the Cleator Moor – Egremont area, one of the best examples being the 3-4 acres of ground at Longlands Country Park, which is now a lake.

The origin of the West Cumberland haematites has been a subject of much speculation and discussion over the past 100 years or so. Sir Kingsley Dunham (1983, 1984) put forward the theory that a heat source in the East Irish Sea Basin (EISB) was the driving force for fluids to passing through the St Bees Sandstones prior to precipitation in the limestone (the descentionist theory). Other workers have put forward theories, which invoke fluids ascending from below into the limestone. Shepherd (1973) postulated that either the Eskdale granite or the St Bees Sandstone could be the source of the mineralisation. He suggested ores in the Carboniferous Limestone and the Lower Palaeozoics of the Lake District may have had different source rocks. Recent research, conducted by Rowe (summarised in Volume 6, Part 2 of the Proceedings), refutes the Dunham hypothesis on the basis of palaeomagnetic and fluid inclusion data, and concludes that mineralising fluids generated by igneous activity associated with Permian rifting of the East Irish Sea Basin were the source of the haematite. A paper by Mildowski et al (1998) argues "that a least part of the haematite mineralisation post dates the deposition of the Brockram and St Bees Evaporites since it occurs as replacement ore within both these (Permian) formations" (p237).

There was early exploitation of iron deposits in Cumbria. At Drigg and Eskmeals slag and cinders provide evidence, along with associated artefacts such as pottery and glass from Gaul, of Romano - British smelting. Records indicate that the Duke of Albemarle made a gift of a furnace in Lorton and a mine in Egremont to the monks of Holme Cultram in 1179. The Cinderdale / Smithy Beck sites in Ennerdale reveal bowl furnaces which have been dated as 13th to 14th Century. There are more widespread indications of development in later medieval times and into the 16th and 17th centuries, but problems with impurities and the high melting point of the ore meant that full-scale exploitation of the deposits had to await the major technological advances of the industrial revolution.

THE IRON ORE MINES OF WEST CUMBRIA

Presidential Address given by Mervyn Dodd,
President of the Cumberland Geological Society,
on 9 December 1998
at St James Church Hall, Whitehaven

(Following on from his 1997 Presidential Address Mr Dodd turned his attention to the Iron Ore Mines of West Cumbria. Following a brief review of the early iron ore mining activities in the area Mr Dodd focussed on the challenges of the 17th and 18th centuries where new technology was required to address the problems of the high melting point of ores).

Demand for steel preceded the availability of a suitable process and the opening of the Cleator Moor blast furnace in 1842 along with the development of the necessary transport links (Carlisle to Maryport railway in 1846, Whitehaven, Cleator and Egremont railway by 1856) placed West Cumbria in an ideal position to respond to the introduction of the Acid Bessemer steel process in 1856. This process was ideally suited to West Cumbrian hematite since it required low phosphorous ores and the area enjoyed a boom period between 1860 and 1880, with 20% of the UK steel production coming from the area. There was a huge influx of workers from the countryside and an associated growth of towns such as Frizington and Cleator Moor. During this period new railways were being built (e.g. the Cleator to Workington line, using the Keekle viaduct) to remove what had been an earlier stranglehold on the area by the Whitehaven, Cleator and Egremont Railway.

However, the development of the basic Bessemer process in 1878 and the Open Hearth process shortly afterwards allowed the use of high phosphorous ores (e.g. from Jurassic strata) which were more cheaply mined and the area began to struggle in the face of fierce competition. Between the 1880's and the 1930's a long slow stepped decline ensued, with a massive outmigration of people as mines and quarries gradually closed. By 1945 only Cleator Moor and the concealed orefield to the south of Egremont remained.

Mr Dodd briefly review the occurrence and possible origins of the hematite in the Carboniferous Limestone, identifying that it mainly occurred in the coarse, crystalline sections of the 1st, 2nd, 4th and 7th limestones either as veins, flats or guts. Initially he described iron ore mines in the Lower Palaeozoic rocks before discussing a selection of mines in the Dinantian and Namurian of West Cumbria.

Mining in the hematite deposits of the Skiddaw Group was reviewed, noting the prolific production at Kelton and Knockmurton, which were worked between 1854 and 1914 (Kelton) and 1923 (Knock), where a total of 1.25 million tons was won. These mines employed some 140 people, mainly from Kirkland village. The vein ores followed faults, of which the SSE-NNW (at Kelton) trending were the most productive. At Knockmurton the veins trended N-S or NW-SE and were more erratic in their lateral continuity and width. The mines were worked by a series of shafts with a maximum depth of 600 feet and were drained by adits, which ran (in the case of Knock, to Cogra Moss). Transportation costs to Rowrah accounted for as much as production in the early days of the mines, so a railway was constructed between Kelton Fell and Rowrah in 1877 and on to Workington by 1878 which greatly improved the economics of the mines.

Other mines in the Skiddaw Group were noted – Martin Boundy's mine, between Knock and Croasdale (very unfavourable geology, and never yielding more than 700 tons per year and with severe drainage problems), Floutern Tarn (where a railway extension was proposed at one stage but again the geology was very complex and very little was achieved), a number of very small mines between Ennerdale Bridge and Pillar, and a number of mines above Crag Fell, up to 6-8 km from the Cold Fell road, all of which were small with a maximum output of 400 tons per year.

Mines in the Eskdale Granite, notably Nab Gill, were reviewed and a number of slides of the old shafts and adits were presented. The mine was worked on and off from 1845 with a maximum annual output of some 9000 tons. The stimulus of the Franco-Prussian War in 1875 provided enough revenue to build the 3 foot gauge Ravenglass and Eskdale Railway (Laa'l Ratty) but it was always an expensive mine and it closed in 1917. Ban Garth mine (above and to the north side of the Eskdale Outward Bound Centre) was worked between 1845 and 1874, initially by an open cut and later by an adit. Gill Force (across the river from St Catherine's Church) at the junction of the Gill Force and Gate Crag veins was only worked for 4 years. It is thought that the Gill Force vein is a continuation of a fault that extends through Nab Gill to the head of the Wastwater screes.

The Carboniferous Limestone of the Cleator Moor area was initially worked for haematite by quarrying at with Jacktrees, Todholes and Big Hill quarries in operation by 1797. In 1790 20 000 tons of ore was exported to the Carron Iron Foundry in Scotland. There were 3 major royalty owners, Crossfields (the poorest) in the area south of Moor Row and of the Cleator Moor railway, Montreal (the richest) between Moor Row and Cleator Moor, both north and south of the railway, and Leconfield (the latest) nearest the centre of Cleator Moor.

The Crossfield Royalty was worked between 1850 and 1919, mainly in shallow workings <400 feet from thin flats in the 4th and 7th Limestones. At its peak in the 1870's 100 000 tons per year of 50% Fe ore were mined. Serious subsidence resulted due to the shallow nature of the workings – an area 30m x 5m subsided around the main riliway line in 1871.

Montreal was worked between 1862 and 1925. The royalty was limited on its northern side by a fault which downthrows Coal Measures against the limestones. The 2nd (Namurian) to 6th (Holkerian) Limestones were worked with a notable very large flat in the 4th Limestone up to 30m thick and a deep 50m high vein in the 2nd Limestone. There was a huge output from this royalty in the 1870's with 2.5 million tons extracted in a 10-year period.

Leconfield was worked between 1865 and 1948, and was unusual in that the royalty owner was also the mine owner. Removal of pillars in the mines in this area resulted in significant subsidence in the area near Cleator Moor Square, Montreal School and St Patrick's, in spite of efforts to pump sand into the workings once the subsidence had started. Workings were in the 1st and 2nd Limestones in a series of fault blocks that stepped down to the north. A maximum annual output of some 75 000 tons was achieved.

The Longlands mine at the southern end of Cleator was a shallow 'difficult' mine (200 feet deep) alongside the River Ehen. The mine worked flats, up to a maximum thickness of 30 feet, in the 7th Limestone beneath alluvial and glacial drifts but was of limited extent due to faulting. The mine yielded very good (54% Fe) hard 'blue' ore which was often hand 'picked' to send to Sheffield for use in the manufacture of 'special' steels. Output was small at 10 – 15 000 tons via a single shaft. The River Ehen was diverted to allow safe working of the mine, but several collapses of the overlying sands and gravels into the mine (it was worked too close to the surface) and river flooding were constant problems which contributed to its abandonment in 1924. The recreational area of Longlands Lake is a legacy of the subsidence problems resulting from the mining activities.

Frizington boasted 3 major mines – Lonsdale, Margaret and Agnes. Lonsdale lay between the E-W 'Coal Fault' and the large (1 000' throw) Yeathouse fault. The mine worked flats in the Hensingham Grits and veins in the Dinantian limestones at depths up to 800 feet – maximum output was 45 000 tons per year, operating between 1878 and 1920. Margaret was on the downthrown side of the Yeathouse fault, with extensive vein ore and flats in the 1st and 2nd Limestones and also in the 4th Limestone. Maximum depth was 950 feet with the mine operating between 1890 and 1923. Agnes was the oldest of the mines, starting work in 1854 and latterly was used to pump water out of the Margaret mine. Joint production from Margaret and Agnes was up to 100 000 tons per year.

Parkside Mine, between Frizington and Cleator Moor was known as 'The El Dorado' of Frizington. A large number of companies were involved in Parkside and there were many shafts sunk. The mine was in a trough-faulted area bounded by 2 younger NW-SE faults and 2 older NNE-SSW faults. Two large ore bodies were located around Parkside Bridge, one very large flat in the 1st Limestone (60 acres extent, 20 feet thick), and a more extensive but thinner one in the 4th Limestone, east of the main road, extending almost to Frizington village. Early working of the area ceased in the 1860's, but the area was re-opened in 1890 and continued to operate until 1925. Production reached 160 000 tons per year. The area was noted for severe subsidence, as evidenced by the large number of 'ponds'.

THE 1996 VATNAJOKULL ERUPTION AND JOKULHLAUP AND THE GEOLOGY OF ICELAND.

A lecture by Dr. Chris Hunt of the University of Liverpool.
on January 27th 1999
at Cockermouth School.

Dr Hunt first presented an overview of the geology of Iceland. He explained its position to the east of the Mid-Atlantic Ridge and stressed that although there are volcanic materials up to 30km thick in the area the detail is complex. Acid rich rocks are present as well as the dominating basaltic flows. The fact that it lies above a mantle hot spot explains the excessive volumes of volcanic activity. The diversity within the basaltic sequences was explained, notably the contrast between the alkali basalts which originate from deeper positions than the tholeitic materials. Shield volcanoes are related to post glacial times because of the offloading of the ice.The relationship between magnetic reversals and the stratigraphy were explained.

The second part of the lecture was focussed on the the 1996 Jokulhlaup and in particular how the media had conveyed a rather misleading picture of events. With the aid of some excellent photographs and Internet data presented by the Icelandic authorities Dr. Hunt illustrated this spectacular event. Starting with a series of earthquakes, there then followed a a rise of magma beneath the ice cap. The detailed rise of the ice surface was chronicled and how subsidence bowls in the ice surface appeared. The escape of huge volumes of meltwater were tracked, culminating in the major escape southwards across

Skeidararsandur with consequent damage to roads and the transport of 100 milllion tons of sediment out to sea and a sediment plume extending 35kms offshore.

A large audience were greatly appreciative of a magnificently illustrated talk on a unique event.

GEOPHYSICAL LOGGING TECHNIQUES. A GEOLOGICAL PERSPECTIVE WITH EXAMPLES FROM WEST CUMBRIA

A lecture by Chris Thompson (CGS)
on 24 February 1999
at Cockermouth School, Cockermouth

Geophysical Logging (also called Wireline or Electric Logging) is a method of obtaining detailed information on the physical properties of rocks in the subsurface. Data is obtained by lowering devices (tools) down a borehole, with data being transmitted up a wireline cable to surface for storage, processing and interpretation.

Geophysical logging started in the early 1900's when Conrad and Marcel Schlumberger undertook surface electrical experiments as a way of defining the earth's subsurface structure. In 1927 the collaborated with Henri Doll and performed experiments in an oil well in Alsace, France. The experiment resulted in the first electric log and demonstrated conclusively that geological formations penetrated by a drill bit could be identified by electrical measurements. The electric log gave 'eyes' to the oilmen who before then could only rely on drill cuttings and core samples.

By 1945 Electric Survey Logs had become commonplace in the oil industry, but were very difficult to interpret. Between 1945 and 1970 more complex tools were developed using the new semiconductor technology. With the advent of computers there has been a rapid development of new tools and easily interpreted outputs. All of these developments have been driven by the oil industry's demand for cost-effective solutions to identifying economic oil reserves.

Slides of the equipment and logging tools used were shown, including some 'state of the art' equipment in use on the Nirex geological investigations at Sellafield.

Geophysical logs allow the determination of :

- Lithology/Stratigraphy
- Mineralogy
- Pore fluid / borehole fluid properties

- Formation density and resistivity
- Structures and sedimentary features
- Elemental chemistry
- Physical properties
- Rock Mechanical Properties
- Presence/nature/orientation of fractures
- Abnormal formation pressures/compaction
- Borehole conditions
- Geometry
- Deviation and direction of boreholes

They are generally the only source of definitive geological information from oil exploration wells – cores are extremely expensive to obtain and cuttings samples only provide an indication of the subsurface geology.

Examples from the Nirex investigations and from oil exploration wells in various locations were provided to show the varied and very valuable information that can be provided by geophysical logs. These included correlation of the Sherwood Sandstone sequence in West Cumbria and the East Irish Sea Basin, oil and carbon dioxide accumulations from offshore Tunisia, fracture identification and determination in the Borrowdale Volcanic Group in the Sellafield area and the use of compaction data from logs to determine palaeo-burial depths in Cumbria.

Examples of downhole seismic acquisition methods were shown to demonstrate the technique of seismic tomography, used to generate an image of the rock mass between 2 boreholes.

Despite the value of geophysical logging as a tool in hydrocarbon exploration it was emphasised that caution had to be exercised in interpreting the data. A particularly relevant example was provided to illustrate the point. In 1968 Gulf Oil drilled 2 wells in the Irish Sea. The second of these, 110/8-2X was drilled to test a predicted thick Permo-Triassic sandstone reservoir beneath a Triassic salt sequence. Gulf Oil encountered significant gas shows at the top of the Permo-Triassic reservoir. Downhole gas pressures were such that it took 4 days to control the well and drilling only continued after a significantly increasing the density of the drilling fluid. The end of well report concluded that the only significant gas show was in the top 20 feet of the reservoir. This conclusion was based on their interpretation of the geophysical logs. However, that interpretation required certain assumptions to be made about the resistivity of the pore water in the sandstone reservoir. On the basis of a calculated 20 foot gas column Gulf Oil relinquished the block and passed a copy of the logs to Hydrocarbons GB (now British Gas). British Gas did their own log interpretation and identified a major gas discovery (600 ft gas column).

Following a round of discussions involving British Gas, the Department of Energy, and Gulf Oil, Gulf realised their error and sought to withdraw their relinquishment. The DoE refused and subsequently awarded the block to British Gas. Subsequent exploration confirmed the presence of the largest offshore gas field in Europe, the Morecambe Field, with estimated reserves of 4,500,000,000,000 (4.5 $\times 10^{12}$) standard cubic feet of gas (the equivalent of 325million barrels of oil).

GEOLOGY AND RISK ASSESSMENT
- FROM OLD MINES TO NEW LANDFILLS

A lecture by Dr Jeremy Dearlove
(Westlakes Scientific Consulting Ltd)
on 20 October 1999
at Research and Graduate College,
Westlakes Science and Technology Park, Moor Row

Dr Dearlove started his lecture by stating that risk assessment is nothing unusual, we do it (albeit unconsciously) all the time. For example when crossing the road we would assess the risk of a car suddenly coming round a corner. We may take steps to reduce risk by for example using a pelican crossing. This subconscious assessment of risk is done in a purely qualitative way.

Science based risk assessment uses scientific risk principles to calculate quantitative estimates of risk and is commonly referred to as Quantitative Risk Assessment. Risk may be calculated as the probability of an action occurring multiplied by the severity of the harm done if the action does occur.

Risk = Probability x severity of consequence.

Quantitative Risk assessed follows a widely recognised four-stage approach

1. Hazard identification – what is going to cause the harm, How is it distributed?

2. Exposure assessment – How is this hazard transported, who might be exposed, how will they be exposed?

3. Dose-response (also known as toxicity assessment) – how, in numerical terms, will exposure to a hazard affect somebody or something?

4. Risk characterisation – estimating the magnitude of the risk and the degree of uncertainty (the probability of it occurring.)

Once a numerical value has been assigned the next step is Risk Management which also needs to take in other factors such as economics, politics, statutory and legal obligation and social factors.

This allows Risk Assessment to be used as part of an objective and informed decision making process, making it clear why action needs to be taken or not as the case may be. This is how the forthcoming legislation on contaminated land is intended to be used. When a hazard is identified consideration must be given to how that hazard can be turned into a risk by bringing it into contact with somebody (human health) or something (the environment).

This is achieved using the Source – Pathway – Target conceptual model.

The Source could be a landfill site, a mining activity or an industrial site.

Pathways could be	Air; as gases and particulates Ground; soils Water; Groundwater, surface waters and the sea and also via these media to food
Targets – include	The environment -fish kills/plant kills - damage to ecosystems - poor water quality

All three of these factors need to be in place for a risk to be present, but even when they are, the risk may not be deemed serious. For example, one study found levels of arsenic in soils with an average value of 64+/- 38 mg/kg of dry soil. This was against a UK average of 15 mg/kg with some areas as high as 45 mg/kg. In the study, the only pathway considered feasible was through children eating the contaminated soil. A calculated child ingestion rate of 20g/day of soil gives an intake of 1280+/-770 mg/day. Normal dietary intake in France, Canada, USA and UK ranges from 500 to 4200 mg/day, so although the source – pathway – target was established, it was unlikely that the arsenic in the soil would present a serious health risk.

The geologists role in Risk Assessment is to use their knowledge and skills to prepare Conceptual Models of the geological deposits beneath a site – these will control the movement of water and therefore of contaminants beneath a site. These deposits can also inhibit the transport of contaminants or change them during transport either chemically or biologically.

To produce these conceptual models a variety of tools are used to construct an interpretation of the relationship between the geological deposits found in boreholes and the subsurface geology.

Ultimately the information is used to produce a visualisation of the probable distribution of contaminants beneath a site, and this is usually done using computers to develop a number of possible scenarios based on the information available. Areas can then be identified where data is missing or where the same level of values keep appearing thus providing a higher level of confidence in the conceptual model.

Dr Dearlove then turned to a simple desktop risk assessment undertaken on the Carrock Fell Mine site for the Lake District National Park Authority. The mine had been operation between 1854 and 1981, the main minerals extracted were the tungsten ores wolframite and scheelite, but with a high proportion of arsenopyrite.

The key hazards identified were:

Surface Waters	Grainsgill Beck, Brandy Gill and the R. Caldew
Spoil heaps	Potential for landslips
Mine entrance	Blasted to prevent access to the mine, but with the hazards of discharging As, Cd, Pb & Zn bearing waters. Also with the build up of sediment within the rubble and hold up of water within the mine there is the potential for flash floods.
Ventilation shafts	some intersect footpaths (but are fenced and signposted).
Soils	peaty organic matter in these soils tends to accumulate metals that may be transferred to livestock (sheep eat about 30% soil when grazing)
Sludge lagoons	contain very fine grained waste from the 1980's ore processing plant

As part of the study data from the BGS stream sediment survey of the Lake District was used, the data showed that the mine waters contained high levels of As, Zn, Fe and Sulphate. However by the time the mine waters meet Grainsgill Beck only As remains above background which gradually decreases at the confluence with Brandy Gill and is at background levels in the River Caldew.

The key upshot of this study is that any contamination of stream waters from this site is highly localised

Soil contaminated by As was restricted to an area around the mine entrance. Given the low population of sheep in the area and the infrequent visits of tourists the levels were unlikely to create a major problem.

The mine shafts were fenced and marked so present no problem, spoil heaps are all at an angle of repose of between 30 to 35° which is suitable for the size and angularity of the constituent material.

In summary the Carrock Fell Mine Site appears to present a generally low risk to human health and the environment. The only potentially serious issue is the build up of waters in the mine adit and their sudden discharge.

Dr Dearlove then turned to the topic of landfill sites and risk assessment. In England and Wales there are an estimated 5000 old and operational landfill sites

The main hazards from landfill sites are:

Landfill gases – mainly methane (which is explosive in air) and carbon dioxide (which is an asphyxiant) (both are also greenhouse gases). The main risk comes from this migration offsite. Many sites flare gas to reduce odours, but this polluting activity also wastes energy. Inefficient partial combustion can generate gases more noxious or harmful than the original CH_4 and CO_2.

Leachate – Leachate is generally a brown, sweet smelling liquid derived from leaching material from the waste mass as water passes through it. It has a high organics content and a wide variety of metals, sometimes at very high concentrations (such as Hg, Cd, Pb & Zn & Cu, Fe, Cr, Ni, As, Sn etc) and non-metals such as ammonia, chloride, sulphide/sulphate, nitrite/nitrate as well as a variety of microbes.

Key hazards come from discharge into surface streams and to groundwater. This can reduce water quality – high levels or organics in leachate can consume all the oxygen in the water by chemical reactions and suffocate the fish. It can have an impact on water quality in terms of chemical and micobial quality. It is generally only if drinking water is affected that remedial action is undertaken on landfill leachate plumes

In recent years steps have been taken to reduce the risks from landfill sites. Landfill liners, sheets of high density Polyethylene (HDPE for short), can be installed prior to infilling – these can control gas and leachate migration but are prone to leakage. In many modern sites credit is taken for the effective operation of this Engineered barrier in the risk assessment.

Dr Dearlove described LandSim – A probabilistic landfill simulation risk assessment tool. The tool is aimed primarily at groundwater contaminants risk assessment and tries to simulate a wide variety of chemical and biological processes within a landfill and in the ground beneath a site. There are a number of input components including site geometry, the leachate inventory, the engineered barrier and aquifer characteristics.

Unfortunately LandSim doesn't have a biosphere or target component – its outputs are endpoint concentrations in groundwater, which may be compared with legislative targets. It is only really a scoping study tool – the groundwater flow path calculations it uses are extremely simplistic.

If more detailed assessment is required a groundwater modelling package such as MODFLOW would be used. This requires more data to set up the model (which requires more Site Investigation expense) and more computer time to run its simulations.

Dr Dearlove closed his lecture by indicating that the future for risk assessment was as a means of providing objective and informed decisions about hazards which affect human health and the environment.

GEOMORPHOLOGY IN THE LAST MILLENIUM: A NORTHERN ENGLAND PERSPECTIVE

A lecture by Dr Jeff Warburton, University of Durham
on 10 November 1999
at Queen Elizabeth's Grammar School, Penrith

Dr Warburton opened his lecture with a slide of Durham Cathedral, where the foundation stone was laid in 1093 AD, and asked the question 'what has happened to the geomorphology of Northern England in the last 1,000 years?' i.e. in the period since the start of the construction of the cathedral.

Dr Warburton reviewed the very recent portion of the geological timescale – the Flandrian stage extends from 10,000 years BP (before present) to the present time, the Late Flandrian starting 5,000 years BP. Within the last 1,000 years the 'Little Optimum' (1100 - 800 years BP) and the 'Little Ice Age' (400 – 200 years BP) are the most significant climatic features recognised.

Three questions were posed

- How much of the present landscape can we attribute to processes that have occurred in the last 1,000 years?
- Why is there so little documented evidence? is it
  - because there has not been much change
  - the changes are not known or dated
  - the changes are not preserved
- What is the relative importance of natural and human changes over the last 1,000 years

Dr Warburton indicated that he would attempt to provide some answers to these questions by concentrating on two areas, the North Pennines and Northern Lake District. These two areas are very different geomorphologically. For example, comparison of catchments showed that the Lake District was much steeper and had greater relief. The use of sediment budget models was explained and their value in determining rates of upland erosion, but it was recognised that few measurements were available. However, it was clear that the bed load yields were much higher in the Lake District due to the greater topographic relief.

Dr Warburton addressed the questions posed via a number of topics, these are considered below.

Vegetation Change

A pollen diagram of sediments from Coniston Water was presented. Over the last 1000 years this showed marked changes in vegetation, with a decline in Alder and Hazel, fluctuation in Birch, and an increase in species such as Pine and Oak. It was noted that most of the landscape had been cleared by 1,000 BP. Final tree clearance was generally followed by sheep grazing, introduced by Norse invaders and later on, Cistercian monasteries, and this has continued throughout the Millennium. The consequent erosion of the land by sheep is clearly evident in the Lake District but the overall significance is open to some debate.

Analogues for such changes can be found on a local scale. Current tree felling in Upper Weardale has the effect of loosening soil, increasing erosion (and the sediment yield) which results in high levels of suspended sediment entering local reservoirs. Pulses of sediment in the reservoirs can be shown to be associated with phases of tree felling.

The creation of drainage channels in moorland areas to improve land quality has also caused increased land erosion and has produced 'gripped' catchments – areas of increased sediment production in drained areas.

Erosion

Recreational erosion of paths, notably in some areas of the Lake District, is a relatively recent phenomenon, with millions of pounds being spent each year on footpath repair. Erosion has a significant effect on land use and vegetation change.

Peat erosion is a particular feature of the moorland areas of northern England. In the Moss Flats area of the Moor House Nature Reserve, peat erosion is being monitored by the use of troughs collecting eroded material and with vertical pins placed in the peat to measure the depth of erosion. Despite pessemistic predictions in the 1950's time lapse photographs of Moor House between 1957 and 1998 indicate that the situation is getting better, with the peat repairing itself. Other time lapse photos confirm that the situation is improving, with increasing re-vegetation with time. In contrast, in the south Pennines, there has been accelerated peat erosion since 1700, which is related to burning of vegetation and atmospheric pollution.

Slope Stability

A number of examples of slope stability were shown, including Bannerdale and Iron Crag, the latter with a clearly visible alluvial fan at the base. A trench through the sediment in the alluvial fan had identified the presence of buried soils, these had yet to be dated to establish the soil chronology. It was apparent that mining activity appears to cut across the fan, indicating that at least some of the fan predates the mining activity. A further example of Raise Beck on Dunmail Raise was described. Here the beck had been diverted into Thirlmere at the time of construction of the dam, but during the floods of 1995 it re-diverted back into the Grasmere valley in spectacular fashion, closing the A591 by dumping a large volume of cobble to boulder size rock material on the road.

Examples of peat slides in the northern Pennines were reviewed. It was readily apparent that storm events do produce dramatic changes but that the landscape does recover with time. At Harthope up to 38,500 m3 of peat was removed from an area 550m long and 70m wide in February 1995. However the area of the Stainmore peat slide of 1930, which was of a similar size is not readily visible now. Over a period of 60-70 years peat slides are masked out by re-vegetation. No peat slides which occurred before the start of this century, are seen, but this is presumably because of repair rather than the fact that they did not occur. Sorted stone stripes on High Pike were also mentioned (see the account of the field trip elsewhere in this edition of the Proceedings). These may have been re-activated during the 'Little Ice Age' but appear to be quite stable features.

Mining

The impact of mining on the geomorphology of northern England is significant. For example in the Nenthead area 'hushes' can be very extensive and the same is the case in the Lake District e.g. hushes and adits at Rampsgill in the Caldbeck Fells.

River Channels

The impact of river channels was illustrated using the example of Swinhope Burn and the Greenly Hills moraine. The Greenly Hills moraine is a large glacial raft that was pushed across Weardale blocking Swinhope overtime. Swinhope Burn is the stream that has cut through it. The evolution of the Swinhope Burn channel can be established through the use of old Ordnance Survey maps. In 1815 the burn is seen as highly meandering, in 1844 it is mapped as very straight (there were several large floods at this time and extensive mining activity), but by 1856 it is seen to have reverted back to its meandering course, with a very stable meandering pattern from 1856 to the present.

Summary

Dr Warburton presented a table summarising an approximate chronology of landscape change in the last Millennium (Figure 1). It was emphasised that a lot of landscape change at the beginning of the Millennium was the result of clearances.

In conclusion Dr Warburton made the following points

- Cause and effect are related by a coincidence in timing, but there is not always a strict deterministic link
- Climate in the 'Little Ice Age' was only 0.6°C cooler, with 7% less precipitation but greater storminess. This period was important from a landscape point of view because of the increase in storminess, not necessarily the cooler climate
- Upland geomorphology is characterised by local responses, greater storminess leads to greater frequency of local responses – local evidence doesn't always represent a regional signal
- There is a bias to recent geomorphological change, older trends that are defined rely on historical records and radiocarbon dating
- Over the last Millennium regional geomorphological changes have been moderate, with increasing complexity towards the present

Dr Warburton was warmly thanked by Dr Alan Smith who was deputising for the President. Special mention was made of the impressive aerial photographs that were used during the lecture.

(Dr Warburton's work on the geomorphology the North Pennines has been assisted by a Millennium Award from the Royal Society and British Association Grant Scheme)

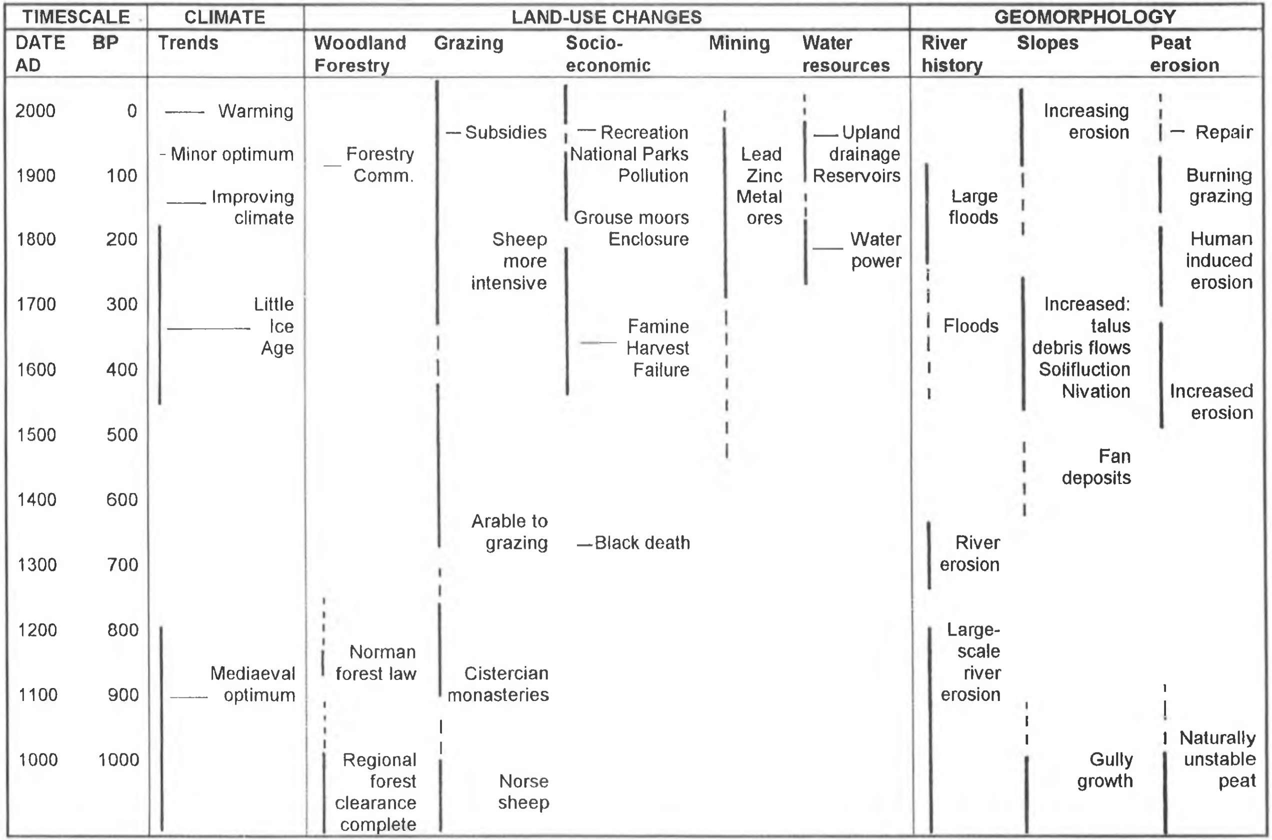

Figure 1. Approximate chronology of landscape change in the uplands of Northern England in the last Millennium

MEMBER'S EVENING

held at The Friends Meeting House, Elliot Park, Keswick
on 8 December 1999

The member's evening consisted of the opportunity to review a number of exhibits brought along by members of the Society and two short lectures given by members of the Society.

The first lecture, by Angela Marchant was on the Ries meteorite crater. This crater some 20km in diameter, is located in southern Germany in the middle of a triangle defined by Stuttgart, Munich and Nuremburg and was formed by the impact of large meteorite about 14.8 million years ago. Thought to have come from the asteroid belt, the meteorite had an estimated diameter of 800 – 1200m and hit the earth with an estimated impact velocity of between 20 and 60 kilometres per second! The energy release is estimated to be equivalent to fifty 100megaton bombs exploding simultaneously. The consequence of this was the destruction of all living things within a 500km radius.

The meteorite pierced through the Jurassic and Triassic sedimentary rocks and penetrated nearly 1 km deep into the crystalline basement. Immediately before impact and during penetration moldavites (tektites) were expelled. These were natural glass droplets that were jetted out with such force that large amount of these, associated with the Ries event can be found today in Czechoslvakia.

0.2 seconds after the impact a pressure of several million kilobars, and temperatures of over 10 000°C had been reached in the impact centre. The meteorite and adjacent rocks, having been compressed into less than a quarter of their original volume, vapourised explosively. The energy from the shock wave dissipated rapidly, but the legacy is observable in 6 identifiable phases of shock wave metamorphism.

After less that 2 seconds the main ejection phase began with material being expelled in a funnel-shaped ejecta-front. They were strewn over an area of 2500km2, reaching thicknesses of over 100m. It is possible that large Jurassic limestone megablocks may have been transported by roll and glide mechanisms. The ejected material was subsequently covered by suevite which also remained in the 8km diameter primary crater. (Suevite consists of melted crystalline basement, some dust and a small proportion of sedimentary rocks and was formed from the gas and molten rock resulting from the impact).

The primary crater became almost completely filled with rock material which 'sprung back' after the shock wave pressure had lost its force. Sinking around the primary crater rim extended the crater to its present day diameter of approximately 24km. An inner ring of elevated crystalline rock was also formed. The crater hollow was then filled by water forming a lake which had an area of up to 400km^2. Subsequent uplift drained the lake to form the landscape that is seen today. The area was visited by the Apollo 14 astronauts to familiarise them with the characteristics of meteorite crater rocks.

The second lecture by Mervyn Dodd, reviewed his recent visit around Iceland. The route followed was along and close to the Ring Road. The first area visited was the spreading ridge between Keflavik Airport and Reykjavik, an area of recently erupted lavas currently registering earth tremors at Richter Sale 4. The areas south-east of the capital were using geothermal water, both for hot water, swimming pools and space heating, including greenhouses. One surprise was swimming in the Blue Lagoon, cooling water from a geothermal power station. More dramatic was the line of 60m high waterfalls south of the small Myrdalskokull icecap, where harder lavas cap softer conglomerates and volcanic ash. The largest waterfalls, particularly the huge volume Dettifoss, were further north and were mainly due to the final ice melt after the Devensian glaciation.

The route crossed the bleak quicksand-like Skeidarsandur, the outwash sand and gravel flooded by the 1996 jokulhaup, which followed the subglacial eruption of Grimsvotn. A little further east was Jokulsarlon, a 60m deep lagoon with small icebergs, between a glacier snout and the sea.

The Lake Myvatn area, on the spreading ridge north of the transform fault was the geological highlight. It was approached through a hot spring area, noisy, like team whistles, with sulphurous smells and vivid green and yellow suphur salts. Around the lake were fancifully shaped lava pillars formed in fresh water, an extinct cinder and ash volcano, Hverfjall, and the maare of Viti, Jules Verne's entrance to the underworld. A large amount of magmatic differentiation, from tholeiitic basalt to rhyolite, was seen in 15 year old exposures on the fission eruption area of Krafla.

The Geysir area, south of the transform fault, was a less impressive hot spring area. The performances, every 3-5 minutes of Strokkir, with their 20m high fountain of water were interesting, a small replacement for the 60m fountains of long retired Geysir. The nearby Pingvellir rift valley, part of the spreading ridge, with its extensional faults and fissures and pahoehoe lavas was a major structure, much larger than expected.

The final flourish was a visit to Heimaey, affected by part of the 1975 eruption in the Westmann Islands. One third of the town had been lost in the eruption (now under lava), but it was heartening to see the present-day return to normal life and prosperous fishing, and to an amazingly luxuriant flower garden on 25 year old lava.

FROM LAURUSSIA WITH LOVE......A TALE OF ANCIENT COLD WARS

A lecture by Dr Nick Riley (BGS, Keyworth)
on 26 January 2000
at The Kirkgate Centre, Kirkgate, Cockermouth

Dr Riley introduced his lecture by indicating that it would focus on climatic change, primarily in the Carboniferous, and emphasized that the past provided vital clues for interpreting current and predicting future variation in climatic conditions.

At the end of the Carboniferous, 300 million years ago, there were 2 super continents, Laurussia and Gondwana. What is now North America and Russia were both parts of Laurussia – the Atlantic Ocean did not exist. Various items of fossil evidence were put forward to confirm this palaeogeographic model. Tracks produced by large millipedes (probably one of the main predators in Early Carboniferous forests) were found in Newfoundland and Arran, and examples of the animal itself were found in nodules in the soapstone bed (Coal Measures) at Padiham, Lancashire. Identical species of freshwater bivalves have been found in rocks in the Grand Canyon and in southern Scandinavia (Oslo Graben).

During the Carboniferous there were rapid sea level changes mainly due to marked climate changes without any artificial man made 'greenhouse gas' effects.

One of the most significant of these sea level changes took place at the Tournaisian/Visean boundary. Palaeontological evidence indicates a significant time gap at this level (with examples provided from Clitheroe, the Moscow Basin, the US and China), with soil horizons and solution surfaces (sink holes) on a palaeokarst surface. All the evidence points to a very rapid 160m fall in sea level. There is currently no explanation for this specific event, it was not ice cap governed, since there were no ice caps at this time, but it is obviously a global feature. One result of this event is that river systems formed on the Russian Platform following the drop in sea level and these are now of great interest to oil companies. Significant oil accumulations have also been found in North America associated with this sea level fall.

During the late Visean (Asbian) and throughout the rest of the Carboniferous and early Permian, rapid and frequent sea level changes were brought about by glacioeustasy. There is also clear evidence for sea level changes in the Visean and Namurian marine cycles in the north of England. These cycles are asymmetric with rapid catastrophic marine flooding. In pericratonic areas such as around the Lake District such cycles have large stratigraphic gaps marked by erosion, fluvial deposits or prolonged soil formation. In deeper water sections further south (Craven Basin) an asymmetric cyclicity of brackish siltstones and turbidites (equivalent to the fluvial Millstone Grit sandstones elsewhere) to deep water sequences is observed. This is clearly seen on natural gamma ray logs from boreholes, where deeper marine sediments (marine bands), equivalent to periods of high sea level, are readily identifiable by their high Uranium content.

Dr Riley then turned to sea-level changes in the recent past. The measurement of isotope variation in growth bands of corals and from other sources provide an indication of seawater temperature and the presence of ice caps can then be inferred. These sources can be combined to produce an accurate picture of sea level change over the last 20,000 years. At the end of the last glaciation sea level was 110m below present. At 14,000 years bp sea level rose from –90 to –70m in 500 years, at 11,500 years bp it rose from –55 to –35m in less than 1000 years with another rise at 7,500 years bp. Current sea levels were reached some 5,000years ago. It may well be that one of these relatively recent events is the one responsible for the biblical story of Noah's flood, since it is thought that the sudden flooding of the Black Sea, through the breaching of the Bosphorus, was associated with one such event.

Examples of the very significant (and almost instantaneous in geological terms) sea level rises were provided from Vietnam, where sugar loaf karsts had been flooded within the last 8,000 years (Halong Bay) to form spectacular island scenery. In Australia, where, with sea levels 60m lower than the present, the Gulf of Carpentaria was all land, with ancient river valleys having been identified beneath recent marine sediments.

A further indicator of climate change in the Carboniferous is the change in the morphology and reproductive strategy of brachiopods, where clear changes in internal structure are apparent across the mid-Carboniferous boundary (coinciding with glacial maximum). These changes are considered to be a response to the onset of much colder conditions associated with an ice age. By using fossils, isotope data and radiometric ages a very good correlation can be achieved between flooding events in the Upper Carboniferous in the UK and the US. There are however more marine flooding cycles identified in the US than in the UK, this is attributed to the fact that the UK was further away from the open sea than the Appalachian area of the US.

Dr Riley concluded that there were very marked climate changes during the Carboniferous and that there is really nothing unusual about rapid climate change. In response to questions he indicated that he felt that the current speculation about accelerated climate change should be taken very seriously, noting that if natural changes are alarming, then the additional impact of man made influences will only serve to accelerate this. He pointed out that 80% of the world's agricultural supplies are on coastal zones and that areas of high population density are similarly located (e.g. Bangladesh). His view was that the biosphere would cope (since it has done on many occasions in the past), but not the human socio-political-economic system, and that agreements such as that from Kyoto (hold CO_2 emissions at 1990 levels) will not have any significant effect – the only way forward is for a wholesale change in human lifestyle to reduce global warming.

SHORT LECTURES FOLLOWING THE AGM

On 23 February 2000
at The Kirkgate Centre, Kirkgate, Cockermouth

Due to the unavailability of the programmed speaker 3 members of the Society presented 'Lecturettes' on the following topics:

David Kelly	Permo-Triassic Brockrams in Cumbria
Tom Shipp	Glacier Surges in Spitzbergen
Margaret Bennett	Californian Geology

RECORD OF ANNUAL GENERAL MEETINGS, ANNUAL DINNERS AND OBITUARY NOTICES

The Record of Annual General Meetings, Annual Dinners and Obituary Notices has been held over to the next volume of the proceedings

OFFICERS AND COUNCIL.

Officers and Council elected for 1999 and 2000 are listed below.

OFFICERS ELECTED FOR	1999	2000
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In addition F. Cockersole, T. Shipp, I Gray and K. Bond past Presidents of the Society are ex-officio members of Council.

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