PROCEEDINGS OF

THE GEOLOGICAL SOCIETY

OF GLASGOW

Session 148 **2005 – 06**

SESSION 148 (2005 – 2006)

SESSION 148 (2005– 2006)

Members of Council

President	Dr Chris J. Burton
Vice Presidents	Dr Colin J. R. Braithwaite
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Proceedings Editor	Miss Margaret Donnelly
Publicity	Dr Neil D.L.Clark (web)
	Dr R. A. Painter (meetings etc)
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	Mr David McCulloch (Residential)
Strathclyde RIGS Chairperson	Dr Brendan Hamill
Strathclyde RIGS Secretary	vacant
Rockwatch Representative	vacant
Junior Member	Ms R. Farthing/ Ms L. Munro
Journal Editors	Dr Colin J.R. Braithwaite
	Dr R.M. Ellam
Ordinary Members	Miss Karen Baillie
	Mrs N.G. Hornibrook
	Mrs Rosemary McCusker,
	Dr A.W. Owen.
	vacancy
	vacancy
Auditors	Dr Ben Browne
	Miss Sally Rowan

MEMBERSHIP

	At end 148 30 Sep., 2006	At end 147 30 Sep., 2005
Honorary Members	5	5
Ordinary Members	300	302
Associate Members	67	58
Junior Members	23	18
TOTAL Members	395	383
New Members	23	
Memberships Closed	10	

Ordinary Membership has remained fairly static, with solid growth in the numbers of Associate and Junior Members leading to an overall growth in total membership of 3%. The Memberships Closed category rolls up resignations and terminations due to non payment of subscriptions.

R. A. Painter

LIBRARY

The library continues to provide a wide range of publications to a relatively small group of borrowers (19). Borrowers in general use the library to support their extramural or fieldwork activities, the majority of borrowings being guides to region or local areas (16), followed by introductory works (4) and more specialist volumes. Clearly, members require local and regional guides as their first priority, and plans are in hand to augment and refresh the already extensive collection. This will include the imminent reshelving of the BGS collection of regional and sheet memoirs, hitherto almost inaccessibly shelved in the staff room.

The periodical collection has outgrown its storage and is in the process of being reorganized to remove dead runs to storage, allowing current publications more display room.

Chris J. Burton

SCOTTISH JOURNAL OF GEOLOGY

The Journal is the joint property and financial responsibility of the Edinburgh Geological Society and the Geological Society of Glasgow. The Societies share any surpluses or deficits in equal proportions and own the copyright of articles published with the Editorial Board acting on their behalf. The intention is to publish one volume of the journal each calendar year, generally comprising two parts. By agreement drawn up on 18th October 1991, the Journal is published by the Geological Society Publishing House (GSPH).

The present accounts cover the calendar year 2005 during which Volume 41 was published. The volume size was maintained at the target of 192 pages, less 5 pages (not charged) filled by GSPH advertisements. The agreement with the GSPH is for a flat-rate charge per page, £145.50 for volume 41 giving a publication cost of £27,208, an increase of £232 on volume 40. In this period the number of Trade subscriptions decreased by 5.6% from 156 to 152. This compares with a 1.3% decrease for 2004. The Journal remained on-line during 2005 but no charges were paid as it emerged that the charge of £1,061 paid in November 2004 had been for 2005.

There was a deficit on the publication of volume 41 of £7,122, compared with £8,149 for volume 40. The subvention from each Society was maintained at £4,500 to cover the full deficit and leave a working balance in the Journal's bank account. The reserves of the Journal account at the year end rose from £764 to £2,642. For volume 42 (2006) the agreed increase in Trade subscription rate is again in line with the page rate charged by GSPH so the effect of this change should be neutral. The number of papers received remained reasonably high during 2005, allowing publication of a full volume of 192 pages. Prospects for 2006 are good and volume 42 is also likely to be 192 pages. As a result, a deficit of £8,500 to £9,000 is anticipated that will be made up by subventions from the Edinburgh and Glasgow Societies. The two Societies increased their rates of membership with effect from October 2005 to fund these costs as well as increases in their own running expenses. The accounts carry no liability with respect to taxation.

During the year the editorial Board was served by Dr CJR Braithwaite (University of Glasgow), Convenor; Dr RW Duck (University of Dundee); Dr R Ellam (SUERC, Glasgow); Dr D Gould, Treasurer (Edinburgh); Mr K Hitchen (British Geological Survey, Edinburgh); Dr S Miller (National Museums of Scotland); Dr ER Phillips (British Geological Survey, Edinburgh); Dr S Rigby (University of Edinburgh); Ms S Oberst (GSPH Production Editor). The Secretary, Dr RF Cheeney was unable to perform his duties during 2003-4, due to illness, but resumed office in January 2005.

C.J.R. Braithwaite and R. Ellam

PUBLICATIONS

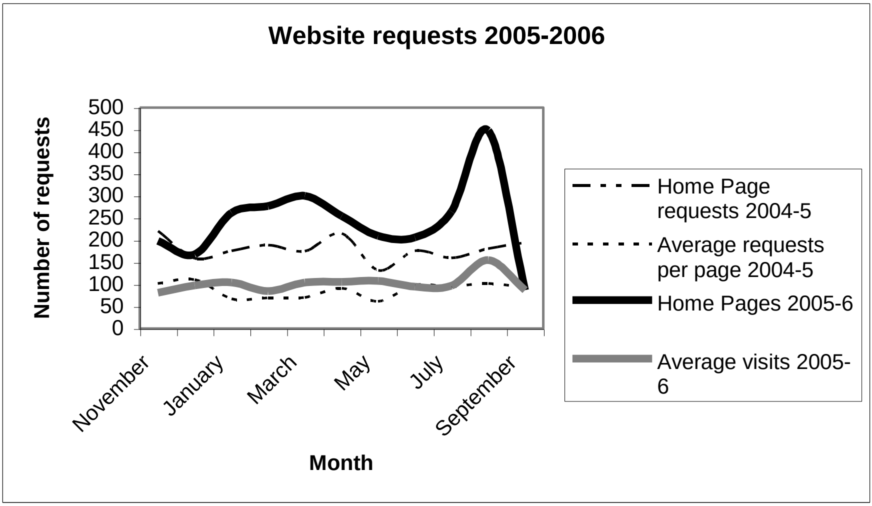
The year showed a surplus of £308 on a turnover of £1526. This takes into account our pricing structure which gives members reduced prices on many titles. These prices apply generally to students in Adult & Continuing Education classes, from whom we recruit many of our new members. We also supply our own library with recently published books. In all, some 65 titles and maps are stocked, a range only found at such as BGS. The expenses of running the operation (mainly postage) were 2.9% of turnover. Mention must be made of the Department's lecturing staff who promote our stock among the students.

Roy Smart

WEBSITE

Over the last year the website home page have been requested an average of over 243 times per month, becoming the most requested single page used as a gateway to the rest of the website. This is 30% more than last year which averaged 188 per month. It is also a record number of requests for this website. The next most popular pages are the publications pages with over 850 requests over 9 months (not including the Lesmahagow trip of 2002 which had several thousand requests over the year for some

reason), excursion (about 80 requests per month) and lectures pages (with about 60 requests per month). The two outstanding months for requests in 2004 (3,048 requests recorded) were not repeated this year, although there was a substantial increase in requests immediately prior to the Scottish Geology Festival in September. Some improvements to the pages have been undertaken throughout the year, and news items have been added occasionally. The server crashed in October, so no figures are currently available for that month. There may also have been a few problems in September that would account for the drop in requests during that month. During the server crash, the website reverted to an earlier version that had the previous year's information on excursions and lectures, but this was rectified as soon as the server was operational again. The peak months for requests are during the spring and August. Comments and suggestions for the web pages are always welcome, but the content is reliant on information being provided by members.
http://www.geologyglasgow.org.uk/.



Neil D.L. Clark

STRATHCLYDE RIGS GROUP

The group has been working on the designation of Campsie Glen during most of 2006 and a leaflet is now nearing completion. Membership stands at 17 with regular meetings having been held throughout the year. Our first RIGS site at Ardmore Point has generated much interest, and take-up of the information leaflets, first produced in September 2005, has been such that we are now requiring a reprint to restock our outlets. Several other sites are being looked at and one of our next objectives will be the non SSSI section of the Highland Boundary Fault Zone at Balmaha. Loch Lomond & Trossachs National Park Authority have been approached as have East Dunbartonshire Council with regard to Campsie Glen. The list of potential sites stands at 18.

SNH facilitated a review which began in autumn 2004 of Local Nature Conservation Sites. This refers to non-statutory sites, selected at local level for biodiversity and/or geodiversity features. UKRIGS, RIGS groups and the British Geological Survey have argued for some time that geodiversity audits and action plans should be prepared at local level in Scotland, and that RIGS should be identified and managed in this context.

Unfortunately none of our members were available to represent our group at the UKRIGS AGM at Dudley in the West Midlands in September. Dr Brendan Hamill stood down as Chairman of the group in May due to business commitments.

Stuart Fairley

TREASURER

<u>Income and Expenditure Account for Year Ended 30th September 2006</u>

(Scottish Charity Number SCOO7013)

Income			**2004 - 05**
Subscriptions received	£ 6539.54		
Deduct paid in advance	120.00		
		£6419.54	£5728.16
Investment Income:			
Dividends	571.76		485.51
National Savings	1870.89	2442.65	1331.74
Tax refunds (Gift Aid)		1075.46	813.15
Conoco Philips prize		233.00	-
Net surplus from publication sales		308.13	554.94
Excursions		129.40	(62.62)
Float refund		19.75	
Donations		nil	100.00
		£10,627.93	

Expenditure		
Scottish Journal of Geology	4500.00	4500.00
Meetings	1864.50	1603.50
Proceedings publication	1998.27	nil
Billets, programmes, postage, telephone, stationery etc	1227.82	1169.59
Sponsorship grants	2150.00	1000.00
Library	851.15	574.46
Insurance	520.00	520.00
Conoco Philips Scottish Geol. Societies' prizes	300.00	400.00
Mull Guide survey	260.27	-
RIGS	40.20	305.00
Hunterian 2007 fund	250.00	250.00
T N George Celebrity Lecture	20.00	150.50

Society's web site		00.00	55.17
Geology Festival		00.00	50.88
Affiliation fee		32.00	31.00
AGM – Expenditure	84.00		
– Income	49.50	34.50	21.00
		14048.71	
Less deficit for year		3420.78	
		£10627.93	

Publication Sales Account For Year Ended 30th September 2006

Gross Sales	£ 1501.83	
Deduct Expenses	45.60	£ 1456.23
Stock at 30/09/05	£ 10761.15	
Add Purchases	1154.65	
Publications available for sale	11915.80	
Deduct stock at 30/09/06	10767.70	
Cost of publications sold	1148.10	£ 1148.10
Net surplus on sale of publications		£ 308.13

Balance Sheet as at 30th September 2006

Assets			**2004 – 05**
Debtors for publications at 30/9/06		£30.00	£ 55.00
Cash in hand:			
Publications Sales Officer		32.62	
Cash at Bank:			
Royal Bank of Scotland Account	£ 4171.88		
National Savings Investment Account	39594.42	43766.30	45163.41
National Savings Income Bond		12000.00	
Investments at Cost		1025.70	
Stock of Publication		10767.70	10761.15
		£ 67622.32	

Liabilities			
Subscriptions in advance		120.00	74.00
Uncashed cheques		877.20	11107.20
Monies due by Society		2055.71	273.79
T.N.George Fund		379.80	399.80
Hunterian 2007 fund		1000.00	750.00
Accumulated fund at 30/09/05	66610.39		
Add surplus for year	3420.78	63189.61	
		£ 67622.32	

We have compared these statements with the books and records presented to us and find them to agree.
We have verified the investment certificates and bank balances held by the Society at the 30th September 2006

Honorary Auditor	**Ben H Browne**
Honorary Auditor	**Sally Rowan**
Honorary Treasurer	**Mervyn H Aiken**

MEETINGS

Mike Baillie from Queen's University, Belfast opened the meetings of Session 148 with a talk on the use of tree ring dating to elucidate historical events such as Black Death and tsunamis. In November, the retiring President of our sister Society in Edinburgh, Doug Fettes, gave a masterly exposition of the geology of the Outer Hebrides and its relations to scenery and topography. On the evening of the AGM, instead of the usual 'light entertainment', we had talks from Iain Allison on his expedition to Svalbard and from Alan Owen on biodiversity in the Ordovician i.e. more on trilobites!
Ed Stephens of St Andrews gave the first lecture of 2006, examining the roles of minerals as essential nutrients, but also as hazards, especially to the lungs. Rod Brown, recently appointed Professor of Earth Sciences at the University of Glasgow, spoke to us in February on the African superswell or why southern Africa is raised by about a kilometer. Still in Africa, Tony Waltham from Geophotos transported us to the amazing Afar Triangle – a triple junction of divergent plate boundaries – whose remarkable scenery gave the backdrop to the equally amazing fur bikini worn by Raquel Welch in the film "One Million Years BC" filmed at this location! Edinburgh igneous petrologist, Brian Upton, delighted us with highlights from his recent book on "Volcanoes and the Making of Scotland". The session's meetings closed with Members' Night which had a packed programme of contributions, both short talks and displays.

Jim M. Morrison

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Thursday 13th October 2005
Dr Mike Baillie, Queen's University, Belfast

TREE-RINGS HINT AT THE UNUSUAL NATURE OF SOME PAST EVENTS

Having access to precisely dated tree-ring records, which work best with multiple chronologies and extend back through the Holocene (10,000 years), can allow re-interpretation of normally dismissed ancient tales and myths. These dates suggest that history is catastrophic, and not always as recounted. For example, there are global tree-ring downturns around the times of the two greatest plagues in the last two millennia; this raises questions about the environmental effects in the run up to the plague of Justinian (542 AD) and the Black Death (1348 AD). What mechanisms

were involved? Can geological and extra terrestrial effects be separated? Why are some records accepted by historians while others ignored?
At 540 AD, a growth downturn in tree-rings appears in Irish oak, Finnish pine, and in Germany and America; a temperature anomaly can be traced from Fennoscandia to Northern Siberia. There is the Maya hiatus, famines from Ireland to China, and the so-called ‘Dim Sun of Dry Fog’. In 1994, the ‘540 event’ was recognised all over the world – and this was the time of the Justinian plague.
Greenland ice cores contain no acid for the years 536 – 545 AD so the event was not a volcano. Other factors point to comet(s) or extraterrestrial event(s) around 539, 540, and 541 AD. Edward Gibbon wrote ‘the atmosphere was corrupted’ between 542 and 594 AD. British and Irish mythology describe a Celtic ‘sky god’, with tales of terrible events in the heavens. Cassiodarus stopped writing in 538 AD, Maletus wrote only 21 lines between 533 – 9 AD while Zachariah’s 9 volumes ended in 536 AD – volume 10 is missing. Intriguingly, the ‘History of the Popes’ (1750) records that ‘nothing happened worthy of notice’ during this period, perhaps denying that something had taken place?
King Arthur reputedly died in 542, 539, 537 AD or… and his death is associated with dramatic signs in the sky. Or is he just a story – a Celtic deity linked to other deities, stretching far back in time? The close appearance of comets such as Donati (1858) can be spectacular. We watched comet Schumacher/Levy slam into Jupiter in 1994, and know the result of the Tunguska ‘comet’. Several ancient writers record dramatic events: Roger of Wendover wrote about ‘battles in the air’; in Gaul, 541 AD, there was a comet so vast that the whole sky seemed to be on fire, with drops of blood falling. Could this refer to real blood dropped, in other words – great mortality?
We find that the two highest ammonia (NH_3) values from the GRIP ice core occur in 539 AD (45 ppb) and 1014 AD (35 ppb). Was the biomass burning? Could energy from a comet have split the nitrogen molecules in the air, making them available for combination with hydrogen from organic matter?
Our lecturer enthralled us with possible explanations for unexplained catastrophes in history – as ever, there were in the end, more questions than answers!

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Thursday 17th November 2005
Dr Doug Fettes, British Geological Survey, Edinburgh

THE OUTER HEBRIDES – THE FOUNDATION OF SCOTLAND

The atmospheric Outer Hebrides are a fragment of the great North Atlantic craton against which the Caledonides and other mountain belts were formed. This island chain, 210 – 230 km long, is composed almost entirely of Lewisian rock, a basement gneiss made up of a vast range of intrusives and sediments. These were accumulated, deformed and recrystallised over 1500 million years: a time span which covers more than half the history of Britain and which witnessed the formation and break-up of at least three supercontinents. This extensive story is reflected in the island scenery and topography that are full of contrasts and dramatic features. Fifty percent of the history of the Lewisian occurred between 2900 – 1500 Ma. Later episodes featured

the Outer Hebrides Thrust Zone, and the Stornoway Beds of the Permo – Triassic. Lewisian geology is quite variable: the Uig and Harris hills display a typical Lewisian topography of interlacing lakes and hills while the imposing hills of South Harris have a rather complicated geology.
The west coast cliffs with their stacks show the rocks in 3D outcrop as at Loch Roag and Bernera. The Outer Hebrides Thrust Zone and its deformation features affect the east coast of the islands; the thrust runs as a spine of hills, its scarp face typically on the west side, from Lewis through North Uist and Benbecula to the sandy machair of South Uist. The islands continue southwards as a diminishing archipelago.
The earliest rocks are the Archaean supercrustal sequence of metasediments dated at 3100 – 2900 Ma and associated with banded basic rocks, followed by the protoliths of a grey gneiss (e.g. at Caradale on Uist) indicating a main intrusive phase ~ 2800 Ma. The Scourian metamorphic event occurred around 2700 – 2600 Ma and late intrusions of dioritic dykes cut through the Scourian gneiss. A granite pegmatite has been dated to 2500 Ma while on Barra a younger basic dyke cuts a strongly folded diorite dyke. Most of the basic Scourie dykes were intruded around 2400 Ma, and a later group around 2000 Ma – part of a global event seen in Canada, Russia and Scandinavia. At mid crustal levels the rock melted and recrystallised into metamorphic mineralogy, ubiquitous throughout the islands. Around 1880 Ma, South Harris was in an island arc setting – today it comprises three zones: the Leverburgh Belt of metasediments deposited in an accretionary prism, the Central Igneous Complex of mainly meta-anorthosite and metatonalite with a peak metamorphic date of ~ 1870 Ma, and the Langavat Belt (2400 – 1700 Ma) of metasediments derived from grey gneiss. The northern Ness Complex is of juvenile Proterozoic metasedimentary and metavolcanic rocks (1860 Ma). Laxfordian deformation occurred ~ 1800 – 1650 Ma, and affected the whole of the Outer Hebrides; the late granite vein complex dates to 1675 Ma. The earliest movement of the Outer Hebrides Thrust is believed to be ~ 1650 Ma, because the granite was still soft.
Our speaker concluded his fascinating lecture with the prospect of future discoveries. The story of the Outer Hebrides is not yet complete: recent research suggests that at least four different terranes, with individual histories, came together in their construction. We eagerly await the next episode in the tale of these amazing islands!

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Thursday 8th December 2005

ANNUAL GENERAL MEETING

Thanks were expressed to retiring members of Council: Assistant Librarian – Bill Bodie, who has recently resigned, Membership Secretary – Charles Leslie, Ordinary member – Philip Close, and Auditor – Dorothea Blake, as well as to Meetings Secretary – Jim Morrison, and Publicity Officer – Robin Painter who will stand again, for their contribution to the work of the Society over the past three years.
The Society elected two Honorary Members at the end of last Session: Mr William Taylor of Comrie and Dr Ted Tremlett formerly of the Department of Geology, University of Glasgow, and now based in Knutsford.

The business of the AGM was followed by two short illustrated talks before our annual Christmas social including wine, soft drinks and nibbles.

Dr Iain Allison, University of Glasgow

78^0 North: An Expedition to Svalbard

Dr Allison recounted his five and a half week expedition on Spitzbergen, the largest of the Svalbard island group, in July/August, 2005, organised by BSES, a charity based in the offices of the Royal Geographical Society, London, which has been providing 'science with adventure' expeditions since 1932. Seventy-six people took part, and Dr Allison was the science leader in the Structural Geology 'fire' – a group of 12 young explorers (YEs). Each fire also had a mountaineering leader to ensure that everyone had the necessary safety training. The other fires were Glaciology, Palaeobiology, Botany and Physiology. Svalbard is about 78ºN, and 800 km from the North Pole. Geologically, it lies just to the east of the mid-Atlantic ridge, here a transform fault, and comprises three terranes which were offshore Greenland before coming together about 400 Ma. Carboniferous to Tertiary strata cover the basement metamorphic rocks. During the Tertiary opening of the northernmost Atlantic the islands underwent strike-slip movement and contraction in the fault zone; this gave rise to a fold and thrust belt along the western seaboard. Basecamp, opposite to the 40 metre vertical face of the Tunabreen glacier and adjacent to the smooth gentle gradient of Von Postbreen, was located 70 km east of the main town and was reached by hired boat. Unlike many glaciers here, Tunabreen has had a recent surge and the ice front extends further into the fjord than shown on modern maps. Gunshot-like cracks were heard continually as it moved and rumbled while large pieces calved off into the fjord. Dr Allison's fire travelled in two zodiacs some 20 km west of basecamp to the west of Svalbard's largest river. Mosquitoes below about 100 m forced their camp up to a corrie at about 350 m. However, some of the other wildlife was much more attractive – small arctic foxes scampered around the camp showing little fear, and there were spectacular lichens, green mosses and wild flowers, but little grass. The ptarmigan is the only bird to stay all year round; the barnacle geese overwinter on Islay and around the Solway Firth. The project was to examine fault movement in the Permian to Cretaceous rocks (mainly shales with various types of concretions) which had one steep normal fault and one flat-lying normal fault. Sections were logged below and above the flat-lying fault. Using published work for comparison, it was found that some 570 metres of stratigraphy were missing. Only some 420 metres of displacement could be due to the steep fault so it was inferred that the low angle normal fault had cut down sequence as it propagated from west to east from the fold and thrust belt. (Like the Moine Thrust Belt, there are low-angle normal faults which formed late when the mountain belt was collapsing). Some of the expedition spent a further 10 days in Oscar II Land, north of Isfjord, walking over glaciers with crampons and usually roped together because of crevasses. Nearby was a major outcrop of Svalbard's national mineral – pure white anhydrite. Svalbard has about 3000 people – and 3000 polar bears; some old paw prints were seen by the shore! Coal was mined in the Tertiary and Carboniferous rocks, and the framework of the now-abandoned conveyor system can be seen around the main town. Tourism is more important nowadays. Our speaker enthralled us with tales of midnight daylight, climbing mountains and magnificent slides of this beautiful landscape.

Dr Alan Owen, University of Glasgow

The Ups and Downs of Biodiversity During the Ordovician

Dr Owen entertained us with a fascinating and often humourous account of the wide variety of life in the Ordovician, and, referring to a previous lecture, commented that his talk could be renamed 'One Really Useful Thing to do with Trilobites'. 'Memoirs of a Trilobite' by Richard Fortey provides a detailed description of the great Ordovician Biodiversity Event which affected bryozoans, brachiopods and all marine life. Our speaker described many of the huge variety of features which evolved, including the numerous forms of trilobite eyes, the biggest of which is now in the Manitoba Museum. Diversity of life increased enormously in the earlier part of the Period before falling to a dramatic low at its end, and the start of the Silurian. Trilobites in Avalonia came from both local areas, and also elsewhere, and from low latitudes, indicating that the continents were now closer together and that oceans were shrinking. The 'End Ordovician Extinction Event', in which 86% of all species disappeared, may be linked to a major glaciation centred on North Africa. However, life finds a way; there are survival routes and one important 'Lazarus taxon' has been identified from Norway

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Thursday 8th January 2006

Dr Ed Stephens, University of St Andrews

MINERALS AND HUMAN HEALTH: THE GOOD, THE BAD AND THE UGLY

Minerals provide many of the essential nutrients for healthy life. A close link can be demonstrated between local geology and the mineralogical/chemical composition of many products we consume. Minerals may also be hazardous, and their toxicity usually involves mineralogy. Many have become so because of some anthropological disturbance or technological application, as many asbestosis-suffering Clydeside shipyard workers can painfully testify.

<u>Biominerals</u> are intrinsically involved in life forms, and living cells are micro environments. Some minerals which grow in green plants are good: calcium and phosphorus (for bones) and small amounts of zinc, copper, selenium. Most are inert but some are harmful. A deficiency of calcium can lead to osteoporosis, whilst too much can create kidney stones (calcium oxalate minerals)

Our respiratory systems can inhale very tiny particles, < 10 μm, into the air sacs; carcinogens, and macrophages such as asbestos, are also problematical.

<u>Asbestos</u>, a general term applied to several fibrous minerals, includes chrysotile (fibrous serpentine), sheet silicates, and amphiboles which are double chained. These are linked to asbestosis and mesothelioma, from which Steve McQueen, once a marine and famous for his love of racing cars, suffered. Crocidolite, or blue asbestos,

a silicate of sodium and iron, is more hazardous and was used mainly in the UK. Talc is also found associated with asbestos.

Silica. Silicosis and lung cancer are hazards of mine working and sand blasting. The silica particles are < 5 μm. In the Hawks Nest Tunnel Disaster 1930 – 32, a total of 5000 people died: 3000 in the blast, but 1500 of lung disease in the following two to three years. The volcano Montserrat is a silicosis time-bomb: 10 – 20% of its output was cristobalite, a high-temperature polymorph of silica. There are several different types of quartz – when freshly ground it forms reactive free radicals; but older quartz can be dangerous too.

Smoking. Apart from the well recognised danger of carcinogens, this has additional hazards. 8% of the ash is composed of minerals, including calcite and talc in the paper, while from 1952 – 57, 30% of the filter was crocidolite. Tobacco is radioactive: the hairy leaf of the plant traps minerals so that it contains 4 – 15% thorium, an α-particle emitter, found in the rare-earth phosphate monazite. All these minerals thermally decompose to toxins.

Our lecturer presented an informative picture of the importance of minerals in the human diet, and the rather worrying need for caution in some aspects of life style.

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Thursday 9th February 2006

Professor Roderick Brown, University of Glasgow

RAISING SOUTHERN AFRICA: THE EFFECT OF COUPLING BETWEEN EARTH'S DEEP MANTLE PROCESSES AND SURFACE TOPOGRAPHY?

The average height of southern Africa is anomalously elevated (> 900 m) – a phenomenon often referred to as the African Superswell. Surrounded on three sides by mid-ocean ridges, it is the largest non-orogenous region of elevated topography in the world. While different models have been proposed to explain the Superswell, each suggests that it was formed at different times and at different rates. Much is known about its deep lithosphere (~ 200 km). From here, kimberlite pipes scavenge carbon to form diamonds. Two types of kimberlite pipes are recognised: a one-off, diamondiferous type, about 90 Ma, and another, about 130 Ma, associated with the break up of Gondwana. The first type occurs in the central part of South Africa, where the Archaean crust is ~ 2.6 Ga. The diamonds are eroded into the Orange River, which cuts a 90 metre gorge through this crust, and are carried to its mouth. Billions of £s end up on the beach on the west coast; De Beers annexed the area and proceeded to 'hoover it all up'. Garnets, olivine and kyanite, i.e. small bits of mantle, are encased inside some of these diamonds, and these have been dated to the Archaean and Early Proterozoic. The surface heat flow is very low in this craton and seismic waves travelling fast through the top 100 km show that it is cold. This layer extends to 400 km – it is old, cold and thick, and should be tectonically inert. However, recent studies have identified a region beneath southern Africa of hot, upward flowing mantle which originates at the core-mantle boundary – the largest seismic-thermal mantle anomaly of its kind on Earth. It is a superplume whose head spreads out in a ponded plane because the overlying crust acts like a blanket or tarpaulin. Some scientists now believe that this active flow is pushing the Earth's surface upwards from below and is the cause of the unusually high elevation of southern Africa.

The area consists mainly of Pan African schists ~ 450 Ma with Tertiary sandstones on top. Using a known 1 km uplift along the east coast in Pliocene/Pleistocene times, and the dynamic topography uplift prediction of about 500 m, geomorphologists have estimated a rate of elevation of ~ 40 m/Ma. However, ~126 Ma, the anomaly lay under the Africa/Mediterranean/India region. As the continents drifted apart, East Africa moved over it. Boreholes (3 km) through Gondwana 'sags' in South Africa show cooling at ~100 Ma, and that there was a plume 'spike' around 100 – 90 Ma, and not in the Pleistocene. A huge amount of sediment was deposited on both the east and west coasts at this time and an erosion rate (very fast) can be calculated.

Two dating methods made use of calcium apatite. This contains uranium thereby providing U-Pb radiometric ages; Apatite Fission Track Ages were also obtained (long tracks indicate cold temperatures while short tracks indicate hot).

This fascinating talk explored some ideas about how southern Africa acquired its unusually high elevation, and discussed how they might be tested in a quantitative manner using new data, new analytical methods and new modelling techniques.

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Thursday 9th March 2006
Tony Waltham, Geophotos

AFAR TRIANGLE – EXTENSION TECTONICS AND VOLCANISM IN EAST AFRICA

Where the African Rift Valley meets the Red Sea, a triple junction of divergent plate boundaries has constructed the Afar Triangle, now occupied by parts of Ethiopia and Djibouti. The barren terrain, with virtually no rainfall and average summer temperatures of 50^0C, displays some fine features of divergence tectonics and volcanism filling the gap. Active rift valleys enclose the Lake Assal depression, the Ardoukoba volcano and the Lake Abhe basin with its myriad tufa towers. Djibouti lies in the main rift valley together with older (~10 Ma) and younger Holocene lavas. A land of extremes, Djibouti is poor and squalid but there is loads of gold at weddings! Faulting and rifting features abound, much fresher than those in Scotland, with tilting, rotation, stepped faults and grabens filled with hundreds of metres of sediment accumulation. There are large silt and salt flats, layers of flood basalts with 800m deep canyons, and small volcanic cones in the rifts, seas and lakes. The numerous travertine towers of the Lake Abhe basin were deposited under water but are now exposed up to 60 m high, each sitting on top of a spring on a fissure. The River Awash flows into Lake Abhe and there is 'bookshelf' faulting. Grabens accommodate ~ 20% of the crustal splitting while volcanic activity accommodates ~ 80%. To the north, the Danakil Depression (a microplate) lies up to 120 m below sea level. Within it, Lake Assal is the second lowest point on Earth. There is a massive input of ground water which rapidly evaporates leaving huge deposits of gypsum and salt (mined by local people on a large scale). All around are grabens within grabens and fresh fault scarps. There are, however, relatively few dykes as the area is too high up in volcanic pile. South of the lake lies the basaltic Erte Ale volcano, which built up in the middle of the depression and contains a small active lava lake. Lava lakes are very temporary features, the surface expression of dyke activity and controlled by the thermal balance. Satellite imaging showed that the lava lake disappeared and then returned in September 2005.

Our speaker gave a fascinating and humorous account of his journey to find and see this lava lake, with tales of arduous treks, awful hotels and nights in the desert under the stars – a minor epic indeed!

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Thursday 13th April 2006
Professor Brian Upton, University of Edinburgh

VOLCANOES AND THE MAKING OF SCOTLAND

Scotland is particularly well endowed with evidence of a volcanic past, perhaps more so than any other place on Earth. The area has been drifting north, from a position about 30^0 S in the Devonian, to the equator at about 340 Ma, to its present 55^0 N today. The palaeogeography earlier than the late Silurian is speculative because the components of Scotland had not yet come together.

Tertiary Volcanics, the youngest suite at 59 – 50 Ma, occur in the Hebrides, Skye, Mull and Arran; their peaks are the eroded plugs of shield volcanoes which were associated with crustal extension as the Atlantic Ocean began to form. Magma moved upwards in a series of vertical conduits, extending to northern England and Wales. Many did not reach the surface and, with subsequent erosion, now appear as dykes, mostly only a few metres wide. More energetic ones did extrude, ejecting curtains of incandescent magma to form low angle lava piles and a series of fissures and cones similar to those of southwest Iceland, but with important differences. The warm, wet climate rapidly eroded the lava producing oxidised lateritic soils in the heavily forested land, and hydrothermal action produced steam vents and hot springs. The very fluid lavas spread over subsiding ground: they seldom reached much above sea level, even though considerable thicknesses (~ 1 km) developed, as seen in the Ardmeanach peninsula of western Mull (The Wilderness) where there is evidence for a rich flora, and subsequent land uplift has exposed the pile. The layer boundaries have been emphasised by ‘recent’ glacier action. While most of the fissure eruptions took place over about 3 million years, the time between flows could have been thousands of years. As the linear fissure eruptions decreased, smaller conduits combined to feed major volcanoes. Multiple cone sheets developed, and rings of more silicic rocks formed as continental crustal rhyolites were incorporated.

Major faults, developed during the assembly of the British Isles, provided conduits for magma during Carboniferous Volcanism, 360 – 290 Ma.; the earliest, ~ 350 Ma, formed scattered outcrops from the Solway Firth to Melrose, creating a landscape like that of mid Madagascar. A few million years later, lava flowed from vents such as Edinburgh Castle Rock and Arthur’s Seat; the Clyde Plateau Lavas erupted from fissures, vents (Dumgoyne, Dumfoyne etc) and from central volcanoes in the

Campsies, and in the Kilpatrick, Gargunnock, Renfrewshire and Ayrshire hills. Just as in the Palaeocene, there was overall subsidence allowing the accumulation of thick (~ 1 km) lava sequences forming regular parallel terraces. During the Carboniferous, the Midland Valley was mostly high and dry, but at times nearby seas transgressed westwards; a close facies of marine sediments and basaltic lavas occur around the Bathgate Hills. Lakes formed when rivers were damned by lava, pyroclastic debris and landslides, as at Ardtun, and East Kirkton Quarry (NS 990689), Bathgate Hills (important palaeoecological sites). The latter has a sediment sequence of ashes, muds and 'coaly' material formed in lacustrine conditions – hostile to life due to an accumulation of toxins and sulphur gases. Fossilised animals may have been fleeing the frequent forest fires; they include fossil tetrapods: salamander-like animals whose features are between those of typical amphibians and ancestral reptilians. The fossil 'Lizzie' (discovered by amateur fossil hunter, Stan Wood) was bought by Stuttgart Museum, much to the dismay of local museums, but more examples have since been found. About 300 Ma the Midland Valley had a climate similar to that of the Niger or Amazon deltas today. Volcanoes erupted through thick sequences of wet sediments whose water flashed to steam, giving rise to large, relatively low-walled craters, as around Stranraer and at Heads of Ayr. Tuff rings with clasts of basalt and country rock were very rapidly invaded by the vegetation.

In the Upper Silurian/Lower Devonian, 420 – 400 Ma, at a time 'shortly' after all the pieces of Britain had come together (closure of the Iapetus Ocean), more silicic volcanic rocks were formed (Andes model) above the descending slab of oceanic crust. These produced the Leadhills, Pentlands and Sidlaws, and also the Lorn Plateau Lavas and more siliceous components in Glen Etive, Glen Coe and Ben Nevis which may have underlain surface volcanoes, possibly similar to those of Yellowstone Park. Along the margins of the Midland Valley and around the great Glen Fault vast quantities of sand, gravel and boulder beds (near Oban, with many volcanic pebbles) accumulated from the rapid erosion of these volcanic superstructures.

Somewhat sparse evidence of Ordovician volcanism (500 – 420 Ma) occurs along the Highland Boundary and Southern Upland Fault Zones. Most of this was submarine, forming rounded 'pillow' lavas as at Dounans Point, Ballantrae and on the northern edges of the Southern Uplands, south of Edinburgh, while some were emergent. They were produced under very complicated palaeogeographical situations, perhaps similar to those between Australia and Indonesia today, and were formed during various phases of destruction of oceanic crust as Iapetus closed.

Between 650 – 595 Ma, massive, mainly submarine, eruptions occurred in Argyllshire, e.g. Tayvallich Volcanics, indicating the opening of Iapetus, while, ~ 870 Ma, north of the Great Glen Fault, there is evidence of major volcanism. Dated to ~ 1200 Ma, locally derived volcanic clasts are found in the Torridonian of the Stoer peninsula. These may be from the 'feather edge' of the East Greenland volcanic field. At around 2400 – 1800 Ma, there is evidence for abundant volcanism along the NW seaboard of the Lewisian in the Scourie Dyke swarm, now exposed on the surface but crystallised at depths of some 10 – 15 km. This formed in a continental setting and could have easily reached the surface of what is now gneiss to produce flood basalts, being of basic/ultrabasic composition.

Finally, pre 2800 Ma, in the NW Highlands, there are ‘stripey’ gneisses, with bulk chemistry similar to andesites, typically found near the subduction zone on a destructive margin today, indicating active plate tectonics 3000 Ma. These gneisses may have been lavas, andesitic ashes or, most probably, sediments derived from these, incorporated with crustal rocks during an ancient orogeny.
There is a constant recycling so that today’s volcanoes are bringing up yesterday’s rocks, formed from the sediments of earlier eroded volcanoes.

“Sediment is to igneous rocks what sawdust is to wood”

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Thursday 11th May 2006

MEMBERS’ NIGHT

We acknowledge with thanks the contribution of our members noted below to the success of this evening.

Short talks

Lochaber Geopark and the application to the European Geopark Network
Mr Jim Blair, Lochaber Geopark Association

The Lochaber Geopark has now been established as part of the European Geopark Network, recognised globally by Unesco, and with member countries France, Greece, Germany and Spain. Following the Northwest Highlands, it is the second Geopark in the UK. A fascinating description of its complex and varied geology was delivered, and a number of attractive and colourful leaflets distributed.

Loch Ness Monster and Elephants Dr Neil Clark, Hunterian Museum

This was a humourous and entertaining account of the possible origins of this phenomenon/legend/myth, with a small green plastic version as demonstration. The monster was first seen by St Columba in 565 AD, whereas, more credibly, in 1661 a 3.5 m sturgeon was caught in the loch! Peak sightings occurred in the 1930’s, when the A82 opened, but the famous photograph from this period has since been acknowledged as a hoax. In 2003 some Plesiosaur bones were found on the lochside adding to the debate. Our speaker’s favoured theory, rather tongue in cheek, is that it is an elephant from a travelling circus swimming across the loch!

Library of the Geological Society Mrs Seonaid Leishman, Assistant Librarian

The Earth Sciences Library which houses the bulk of the Society’s collection is open to members. A timetable for access is posted on the door or members may telephone the Earth Sciences’ Secretary on 0141 330 5436. On Meetings’ nights, the Assistant Librarian is in attendance from 7.00 pm until 7.30 pm. Members should note that the library contains many general geological texts – it is not just for the professionals or specialists – as well as an extensive range of field guides which cover the whole of the UK and many overseas destinations. These may all be borrowed by members. In

addition the journal collection is available in room 510 of the Gregory Building where current issues and back numbers of a wide range of journals are housed, from the all-embracing Nature and Science to the very specialized as well as more general periodicals such as Geology Today. The old and rare books that the Society possesses are now in the Special Collections of the University Library. These are mainly 19th Century books and like all the collection may be consulted though not borrowed.
Our speaker delivered a light-hearted and entertaining account of her own experiences using the Library, and of finding within it the answers to many geological queries.

"Cuttlefish Rock of Silver Glen" Dr Brendan Hamill

In the foothils of the Ochils, to the north of Alva and close to the Ochil Fault, near a quartz dolerite intrusion and the old silver mine, there is a strange cataclastic rock known as Cuttlefish Rock. It is a sandstone of mainly quartz, but when examined under the microscope, the quartz contains numerous lines, and is similar to the shattered quartz found near to impact craters. The same rock occurs at four sites within the network of the Ochil Fault, and Dr Hamill intriguingly suggested that it could indeed mark the presence of a meteor impact site.

Durness Group Mr Rob Raine

Our speaker, currently studying for a PhD at University of Birmingham, is carrying out new research on the Durness Group of NW Scotland. He presented some of his recent findings on the details and formation of this Group, and on the organisms found within it.

Displays

Chris Burton	Fossils from Trearne Quarry
Charles Leslie	Photos of Excursions – Summer 2005
Margaret Donnelly	Photos of Excursions – Summer 2005
Brendan Hamill	Slide of section from Silver Glen sandstone
Bill Lamb	Photos, memorabilia etc of NASA at the Kennedy Space Centre, Vietnam War memorial etc
John McNeill (recipient of a Society grant)	Minerals of Alkali Igneous Gardar Province of SW Greenland

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The average attendance at lectures, excluding the AGM, was 84, and was slightly down on that for Session 147. Ways are continually being sought to broaden the attraction of the Society and to advertise its events to wider audiences.

EXCURSIONS

Saturday Excursions Report

These went well although attendance was down by 30%. This was partly due to the application form not being in the members' hands early enough. The arrangements for the May excursion were very last minute. Buses were only used on three excursions to reduce overall costs, and a slight profit was made overall. This session's excursions were:

6th May	Corrieburn and Garrell Burn, Kelvin Valley – Dr Jim Morrison and Dr Chris Burton
3rd June	The Wandel Burn – Dr Alan Owen
15th July	Joint excursion with EGS to St Monans – Martin Lee & Maxine Akhurst
28th July	Friday visit to the BGS Core Store at Gilmerton – Barry Hepworth
19th August	Innellan – Dr Geoff Tanner

Carolyn Mills

Residential field excursions

Once again the annual programme included two residential field trips. The excursion in June led by Dr Simon Cuthbert consisted of a geotraverse across the Moine succession including an examination of the eclogites of Glenelg. Disappointingly, only 13 members booked on the trip but this small group size actually allowed us to concentrate on some of the finer detail of the structural geology. In September Dr Steve Cribb led a party of 22 members to Assynt and Wester Ross. It was good to welcome some new faces on this residential excursion. An unusual aspect of the excursion was a boat trip on Loch Glencoul to view the thrust planes in the coastal sections. The 2006 residential excursion programme will be remembered for the unusually good weather which accompanied it; the pure blue skies and crystal clear views in Assynt were especially noteworthy. Thanks are due to both Simon and Steve for their expert tuition and endless patience.

David McCul1och

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GARRELL BURN AND CORRIEBURN: 6 May 2006
Leaders : Dr Jim Morrison & Dr Chris Burton
Report by : *Robin Painter* Participants : 10

The excursion was in two parts. In the morning, starting at Allenfaulds Farm above Kilsyth, ascending north towards the Campsie fault, we viewed the rocks of the Inverclyde Group of the Lower Carboniferous where they are exposed by the gorges of the Garrell Burn. In the afternoon, further west and ascending towards the Campsie fault from Burnhead Farm above Queenzieburn, we viewed the subsequent Lower Carboniferous rock succession starting within the Strathclyde Group up into the Limestone Coal Formation of the Clackmannan Group.

In the morning in the lowest part of the Garrell Burn we saw exposures of crevasse splay sandstone deposits interbedded with some thin organic shaley layers, characteristic of plant growth on the splays within cycles of repeat marine indurations. Ascending the line of the burn in the third gorge we reached an exposure of the Kinnesswood Formation which lies at the bottom of the Inverclyde Group near the base of the Lower Carboniferous. (Rifting of the Midland Valley and the resulting faulting has produced a series of east-west trending faults which throw southwards, so that in this area, ascending across the faults is a transit from exposures of a younger formation into those of an older one.) In a hollow above the second gorge we observed an exposed flood plain deposit, a limestone coal exposure, mudstones and another crevasse splay sandstone. Fossil rootlets were visible in the sandstone overhang of the gorge face.

At the Corrieburn location, in the afternoon, we saw the younger part of the Lower Carboniferous sequence which overlies the Inverclyde Group visited in the Garrell Burn. We ascended from Burnhead Farm, crossing the Cairnbog Fault to the Corrieburn where we observed the Kirkwood Formation, exposed there with red horizons from volcanic detritus of the Campsie lavas. The Corrieburn Limestones, at a younger level in this succession, are exposed at the site of old quarries running up the hillside. Brachiopods are observable in the upper sections of this limestone.

The most visually striking feature of this site is the 20 m black cliff of shale on the eastern side of the valley which overlies the Blackhall Limestones. The base of the cliff forms the Neilson Shell Bed, though on the day we failed to find the bivalves, brachiopods, and gastropod fossils that can be found there. However ironstone concretions are very numerous in the lower, accessible section of this shaley cliff.

A day that was a comprehensive tour of the Lower Carboniferous succession of the Midland Valley, and one that, at the higher elevations, brought home to some of us the scale of the faulting in the formation of the Valley, and the influence this has on coming to an understanding of the succession.

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WANDEL BURN : 3 June 2006.
Leader : Dr Alan Owen.
Report by : *Bob Diamond* Participants : 15

On a glorious day we journeyed to Wandel Burn, just south of Abington, and explored some of the classic fossil-bearing sites that had enabled Drs Euan Clarkson and Alan Owen to work out the rock sequence in this part of the Southern Uplands. This seems to be a series of red biogenic cherts, followed by black oceanic shales, followed by psammites.

The first location we went to was Hawkwood Burn. Here we found an outcrop containing red chert. Within the chert were minute (*ca* 1 mm) white blobs which were the remnants of the radiolarians which had formed the silica from which the chert was derived. These radiolarians were deep water organisms with beautiful basketlike silica skeletons. When they died and sank to the bottom, their skeletons formed a silica ‘gel’ which lithified into chert. This then was the first piece of evidence that we were dealing with an oceanic environment. As well as the foraminifera, Alan had found conodonts. Both the conodonts and the radiolarians were linked biostratigraphically with Laurentia and Baltica. So far so good, in confirming the conventional Southern Upland formation story.

However, in true Glasgow Geological Society excursion tradition the certainties began to crumble at the next location a few hundred metres up the burn. Here we found an outcrop of hyaloclastic lava. This rock consisted of shattered clasts of basalt which appeared to have exploded in deep water when the lava had been extruded into the seawater. The clasts were poorly sorted and in a mudstone matrix. It seems that these rocks had been produced in similar benthic conditions to pillow lavas, but because of differing chemistry and conditions they had explosively shattered. Oh, and by the way, the basalt geochemistry seemed to indicate an intraplate origin, not the expected plate margin. At this point Alan dropped the little gem that the rare earth chemistry of the cherts seemed to indicate a depositional environment in deep water on the continental margin. All of a sudden our oceanic crust had become continental, still a deep water environment, but not the traditional story.

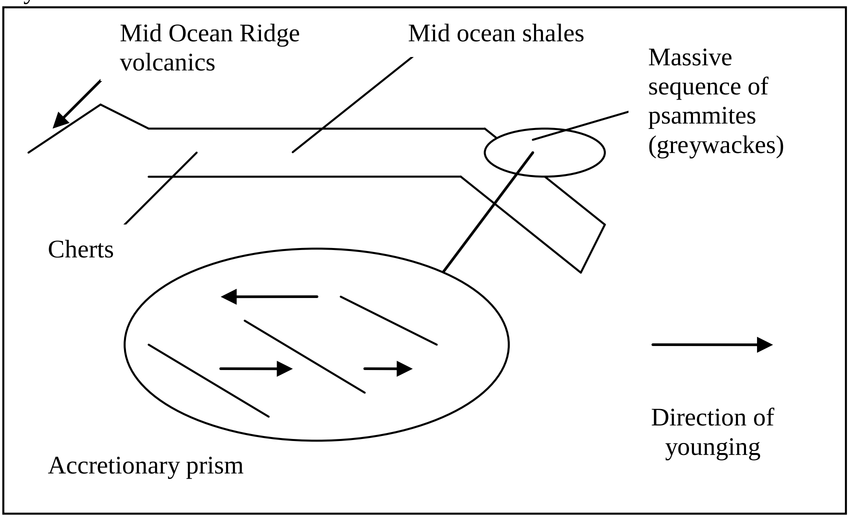

Fig 1 Schematic diagram of traditional depositional sequence in Southern Uplands

Undaunted we moved on to another outcrop (whose location escapes me) where we came across a much more shaley outcrop. The conventional view is that these rocks were deposited as the result of very fine airborne dust settling over the ocean and slowly sinking to the bottom. However, Howard Armstrong (University of Durham) thinks that they are the distal part of a turbidite sequence deposited in a deep basin.

Thankfully our fossil hunting came up with a lovely specimen of a *Diplograptid* (two rows of thecae along a single stipe). Alan thinks it may belong in the genus *Lasiograptus*, a species of which, *L. costatus Lapworth*, has been described from similar levels elsewhere in the Southern Uplands. Moving on we came to

Wallace's Cast where we found an outcrop of some shelly fossils. These had links with Girvan and Pomeroy (in Northern Ireland).

Finally we challenged Alan to say what he really thought was happening in this part of the Southern Uplands. He believes that the Midland Valley and Southern Upland crust is the same 'microplate', and that the Southern Uplands are a thrust zone formed when the Iapetus Ocean was closing obliquely.

All in all we had a challenging day both in terms of terranes and terrain, but thoroughly enjoyed a good sunny day out.

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GLENSHIEL : 23 – 26 June 2006
Leader : Dr Simon Cuthbert
Report by : *David McCulloch, Margaret Donnelly* Participants : 9

<u>Friday 23 June</u>

Our small party of nine members gathered together at the House of Bruar before heading off with Dr Cuthbert to our first stop only a few miles away, just south of Clunes Lodge (NN 782670). The old A9 runs right beside the River Garry and we gathered beside the fast-flowing river where Simon gave us an introduction to the regional geology using a map spread across a convenient boulder. Luckily it was a warm, calm, sunny day so the map didn't get blown away as so often happens.

Simon explained that over the weekend we would be following a geotraverse across the Moine succession which lies between the Great Glen Fault and the Moine Thrust. So why were we starting our journey beside the River Garry so far east of the Great Glen? Simon pointed out that the Grampian block between the Great Glen Fault and the Highland Boundary Fault consists mainly of the well-known Dalradian succession (Appin, Argyll and Southern Highland groups). However in the northwest sector of the Grampian block there is a suite of rocks formerly considered to be part of the Moine but now considered to be the oldest part of the Dalradian Supergroup, called the 'Grampian Moine'. This group, very different lithologically to the main Dalradian succession, is further broken down into the older Central Highland Division (migmatites) lying beneath the younger Grampian Division. Granites and gabbros can be dated to provide relative ages for the metamorphic rocks.

The Grampian Moine is mainly psammitic (sandy) and contrasts with the Moine succession west of the Great Glen which has a higher pelite content. Simon described the three components of the Moine succession: the Morar Division is at the base, separated by the Sgurr Beag Slide from the overlying Sgurr Beag Nappe comprising the Glenfinnan Division and the younger Loch Eil Division. We discussed the theories which attempt to explain the relationship between the Moine succession west of the Great Glen and the 'Grampian Moine' to the east. Some researchers argue that these are part of separate terranes. However this is still a subject shrouded in controversy, partly due to arguments over the interpretation of dates obtained from the rocks. Simon rounded off his overview by mentioning that the late Precambrian metamorphic event in the Moine seems very localised and the only other place it appears is in Peru.

After this reference to distant Latin America we began examining the Grampian Division psammites and semi-pelites beside the River Garry. The bedded, steeply dipping metamorphic rocks were cut by a pink lamprophyre dyke containing xenoliths. The chilled margins were particularly noticeable because the dark, finely-grained margin contrasted sharply with the country rock and graded into the core dyke material. Lamprophyre is a potassium-rich rock and we could see feldspar (mainly orthoclase), hornblende, biotite and some olivine. The dyke was undeformed so clearly post-dated the metamorphism and provided a latest date for that deformation.

We gathered round a beautiful example of a highly-folded quartz vein snaking through perfectly linear micaceous foliation. The vein represents the original bedding which has been folded, and the resulting axial planar cleavage which developed in the mica was seen to be perpendicular to the nose of the folds and almost parallel to the limbs of the folds. Simon used this exposure to explain how the relationship between bedding and cleavage can infer the nature of the regional folding. Here, in common with other parts of the southern edge of the Grampian Mountains, the sequence is upside down.

Further downstream near the gorge we found large-scale folding, a metre or two across. A new cleavage was starting to develop inside the nose of the folds. Simon described how compression of a fold initiates shearing and results in folds with short and long arms. On opposite sides of the fold the small rucks take on an ‘S’ or ‘Z’ shape.

After that intense introduction to Moine geology we had lunch beside the attractive river and then drove north to Strath Mashie and parked near Spey Dam below Dun da Lamh (NN 583929). We walked along the forest track on the south side of the hill in very light drizzle which soon stopped although the midges were out in force. Beside the track we found a quartz vein which had been ‘necked’ to form a shape reminiscent of links sausage, hence the French term ‘boudinage’. Compression perpendicular to the vein had caused extension parallel to it. Whilst the surrounding mica had stretched and flattened uniformly, the quartz had begun to break into pods creating the distinctive shape.

Further on we came across an exposure with a mixture of light and dark components indicating that we were in the Central Highland Division where the rocks have been migmatised. This division forms the base of the whole Dalradian sequence and partial melting has taken place at depth. The source rock is a biotite-rich metamorphic mudstone and forms the dark layers. The lighter-coloured layers are granitic melt comprising feldspar and quartz. Migmatites are therefore partly metamorphic, partly igneous. Pressures of (7 – 9) kbars can result in the formation of kyanite and sillimanite as well as garnets. The granitic content (about 30% melt) has been deformed when molten into folds to create an oddly fluid-like structure. The quartz formed long rod-like structures due to being ductile when melting under pressure.

We climbed steeply up to the saddle of the ridge (NN 580928) and took a short, rough walk over to a small crag where we saw garnets surrounded by a white collar. This indicates that they had given off their grossular content during retrograde metamorphism. The rock had been eclogite or high pressure granulite buried to a depth of (35 – 40) km before rebounding and is now a garnet amphibolite lens within the migmatites. The mineral content included hornblende and plagioclase, but also two unusual pyroxenes, diopside and omphacite. Eclogite is apparently able to preserve its geological history in a way which is usually masked in other rocks.

We walked east up to the ruined iron-age fort on Dun da Lamh, apparently built about 500 BC. According to an information board 5000 tons of rock were brought in from elsewhere to build the massive structure. The view south encompassed Ben Alder and Beinn Bheoil, remote high mountains normally hidden from view by lower hills. Simon used the elevated viewpoint to describe how the 'Glen Banchor high' (the migmatites) was a horst and the Grampian Group sediments were laid down in a half-graben on the northwest side. The boundary zone is marked by mylonites indicating intense shearing along the Grampian Slide. Apparently rocks can be buried and then rebound so rapidly that it can all take place within the error of the dating methods, around 2 – 10 Ma.

We then headed off by car into increasingly heavy rain to our hotels in Dornie where we met up with the four remaining members of our party.

<u>Saturday 24 June</u>

We began the day on the shores of Loch Cluanie (NN 124104) looking at the youngest rocks of the Moine succession, the Loch Eil Division. Isoclinal folds in the equigranular psammite indicated ductile deformation. The rock was intruded by quartz and granite veins. The granite may have come from the nearby pluton or it may be the result of migmatisation within the rock.

A nearby laminated unit contained cross-bedding indicating that the laminations are bedding, not foliation. An array of tension gashes cutting across the main fabric contained granitic material. The diffuse boundaries suggest they were formed by in-situ partial melting rather than injection of fluid. A pod of dark material was interpreted as a basic igneous intrusion which had been metamorphosed to amphibolite. Veins of trondjhemite were found in the pod indicating partial melting. Microdiorite was seen lying between the pod and the country rock. The sequence was therefore interpreted as basalt intruding into sediments, the whole rock then being metamorphosed before the onset of partial melting and subsequent injection of microdiorite related to subduction.

Driving east we stopped at another loch-side location (NN 177104). Simon pointed out the change in the shape of the hills around here. To the east, the shallow-dipping strata result in flat-topped hills but to the west the hills become more pointed in shape due to the more steeply-dipping strata. The change occurs along the 'Loch Quoich Line' where the younger Loch Eil Division gives way to the underlying Glenfinnan and Morar Divisions, brought to the surface by the steep angle of their dip. We wandered down to the shore and even the most unperceptive visitors could not fail to notice the massive crystals which looked just like sugar cubes embedded all over the rock surface. These were large orthoclases but the rock also contained abundant plagioclase and quartz along with some hornblende and biotite but no muscovite. It is in fact similar to the Shap granite and is more properly called a monzogranite or adamellite. It is post-tectonic and has been dated to 425 Ma.

We drove east and followed a narrow side road to Ceannacroc Lodge. We had a brief look at the paintings for sale in the artist's studio before heading off to the river and we sat on the rocks mid-stream to have our lunch. This was a really idyllic spot in the sunny weather. We noticed that the river was flowing over gently-dipping slabs of rock comprised of light and dark strata. The light-coloured layers were streaked with long, dark minerals giving the rock a very distinctive appearance. The dark minerals were blade-shaped biotites and the light minerals were strung-out feldspars. The whole rock was formed by the ductile deformation of a granitoid igneous body and is known as the West Highland Granite Gneiss. This was described to us as an 'LS tectonite', that is a rock formed by deformation where the main fabric is formed by Lineation (stretching) but also some Schistosity (flattening). The Moine sediments had been subjected to partial melting then intrusion of basic dykes (hence the dark amphibolite strata parallel to the foliation in the gneiss) before the whole lot was deformed and metamorphosed. The West Highland Granite Gneiss has been dated to 870 Ma. This means that the Moine sediments must be older than 870 Ma, but younger than the last Lewisian deformation which occurred around 1000 Ma. At this point we considered the origin of the partial melting. One theory is that there was a late Precambrian orogeny involving compression. Another theory is that there was deep burial in a tensional environment with later deformation. In northeast Scotland the Moine is seen to be undeformed before the Caledonian orogeny and this would tend to support the second theory.

Our brains suitably sore, we headed back west to a road cutting in Glen Shiel (NN 026124). The ribbed appearance of the steeply dipping flaggy rock is due to interbedding of pelites and psammites and is typical of the Glenfinnan division. The steep dips west of the Loch Quoich Line are due to late D3 folding, probably of Caledonian age. Slickensides indicated movement along faults.

Our leader crosses the burn! (*Charles Leslie*)

We drove to our final stop of the day and climbed uphill a short distance to a small waterfall (NN 008137) where we saw two rocks interlayered with each other. One was a white marble with green serpentine, the other an ultramafic black hornblende schist. This is a Lewisianoid inlier at the base of the Sgurr Beag Nappe. Mylonites nearby marked the lowest part of the Glenfinnan division above the Sgurr Beag Slide.

We then crossed the road and walked down to the River Shiel (NN 006134). Overnight rain had made the river quite high and fast-flowing but nevertheless our intrepid leader took his boots and socks off and waded across. Curiously, no-one followed him. From the far bank Simon proceeded to shout over the noise of the river and pointed to the Sgurr Beag Slide which cuts across the river. The Slide is the junction of the Morar Division / Moine Nappe (grey psammites) with the overlying Glenfinnan Division / Sgurr Beag Nappe (flaggy augen gneiss). Although the Slide was once a site of movement it has since been folded by D3 deformation. The augen are sheared-out migmatised leucosomes.

<u>Sun 25 June 2006</u>

We woke to a beautiful day with loads of blue sky, glorious sunshine and only a few 'erratic' clouds. Eilean Donan Castle was the classic calendar picture with the loch and mountains as backdrop. We stopped first at an outcrop of Lewisian rock (NG 883259) beside the Visitors' Centre of the castle, where our leader gave us an overview of today's geology. The term 'Lewisian' 'should now be dropped' as it is a 'bucket term', for all Lewisian rocks. Recent research (Friend & Kinney) has identified at least four 'terranes' or blocks in the Outer Isles and a similar number in the Foreland of NW Scotland. However, linking them together has proved difficult. Here at the mouth of Loch Duich, the rocks are like Lewisian (Lewisianoid) but are not exactly the same as in the Foreland. We are in the Glenelg/Attadale Inlier, the biggest Lewisian inlier east of the Moine Thrust, in the basement of the Moine Nappe. This western belt of the inlier has not suffered as much late (Caledonian) deformation as the eastern belt, and so is a window into earlier events such as the Grenville Orogeny. The area has younger sediment cover (Moine) on top of basement (Lewisian inlier) – pairs of 'sediment cover over basement' are common to mountain belts and the contact is often blurred. This basement has many deformations, and zircons from it provide several dates. Later today we will see the Ratagain complex.

The Western Lewisian belt is made up of orthogneisses (metamorphic igneous rocks) with numerous metabasic amphibolites, granulites, and eclogites which preserve the early Lewisian mineral assemblages of garnet, pyroxene etc. The Eastern Lewisian belt contains high grade metasediments such as forsterite marbles, mica schists and iron formations (high pressure quartz iron oxide indicating that Archaean atmospheric oxygen had increased), and eulysite – a peridotite with granular texture containing iron/manganese-rich fayalite, clinopyroxene, garnet and magnetite. This is a high pressure/high temperature metamorphic rock. The best analogy is the Loch Maree Group at Gairloch, but correlation is uncertain. This belt also has orthogneisses and swarms of eclogite (jadeite – clinopyroxene/garnet). There are no eclogites in the Foreland – they did not form, it seems, during the Archaean as the mantle was too hot. The rocks here have a late Grenville overprint (southeast of the Great Glen Fault and in the Rhinns of Islay the Grenville rocks are juvenile).

The Western and Eastern Lewisian belts are separated by the Deformation Belt, the Barnshill Shear Zone. Most of the shear sense is extensional because normal movement occurred after the thrust. The Lewisian was thrust over itself (imbricated), trapping some Moine rocks. The Eastern Lewisian was further east originally, but was sliced and carried nearer to the Western Lewisian

Beside the castle, the basic gneisses of the Western Lewisian have mafic/ultra mafic amphibolite pods, streaky plagioclase and pinkish layers of highly deformed granitic and granodioritic (trondhjemite) pegmatites. They contain omphacite, a high density pyroxene typical of eclogite, but the rock as a whole has retrograded to almandine (Fe/Al end-member of the garnet group) amphibolite facies. The rock is migmatitic as a result of partial melting, and fine grained because high temperatures drove water off quickly. We then walked south-eastwards along the A87, examining the road cuts on the north side which contained xenolithic basalt dykes and discordant foliation.

On the northeast side of a road cut, ~ 600 m southeast of the castle (NG 886255), were garnet granulites and mylonites – very platy rocks, exhibiting high strain, with many folds whose axes were perpendicular to the lineations and which had been drawn out to form sheath folds. The shear direction was to the NW and there had been folding, flattening and refolding, but this was probably all one deformation event. A hard basic pod could be seen with softer sediments folded around it. We were close to the kms-thick Barnshill Shear Zone. Attempts to establish the age of this deformation (Grenville, Neoproterozoic, Caledonian?) are being made using U-Pb. On the opposite side of the road was a big white, folded pegmatite and a dark basic body of amphibolite facies with streaky plagioclase, hornblende and late faults. There were also garnet granulites with blue quartz (blue because it contains rutile, titanium oxide), some of which had regressed to the adjacent amphibolite facies because of the addition of water. On the loch side, there was a hornblende garnet granulite, with augite and plagioclase – probably once a gabbro formed at the bottom of the crust (35-40 km, 800^0 C, 10 kbars). Cracks and sheets of epidote evidenced water penetration, altering the material it contacted. The water had produced a melt (hence the streaky plagioclase) and the granulite had regressed to amphibolite, but the amount of water was limited, the melt could not escape and so some granulite remained beside amphibolite. Without garnet the rock is less stiff, and this allows shearing. The minerals here are Archaean; the deformation could be Laxfordian or Grenvillian.

(As an added gem, our leader pointed out that here, in this corner of Scotland, we are among the oldest and youngest igneous rocks, oldest eclogites, youngest sediments, oldest metamorphic and oldest sedimentary rocks in the UK!!! Pick your answers from the following – Cuillin, Torridonian, glacial deposits and Lewisian (meta) igneous, metamorphics, eclogites!!!)

We drove on to a road cut opposite the car park at the An Leth Allt burn (NG 905232). We had passed the Shear Zone and were now in the Eastern Lewisian Belt: a mixture of orthogneisses and metasediments, some rich in manganese. There was a schist, originally a pelite and quite rusty at the top, with distinctly <u>purple</u> garnet, kyanite and two micas. There had been retrogression: muscovite + garnet produces biotite. A surprising date of 670 Ma has been obtained (U-Pb) but this was using titanite and so is in fact the closure temperature, when the rock reached this level in the crust. However, a date of 1515 ± 104 Ma was obtained by Miller & others (1963) from eclogite found nearby (subsequently buried in the road construction). There were also marbles, calc silicates, and very highly sheared hornblende gneisses. The rock contained relict pods of eclogite and pyroxenite with omphacite, phengites (pale green muscovites with high silicon and iron), garnets very rich in calcium and magnesium, and kyanite; all indicate high pressures up to eclogite facies, surprising for metasediments. However, the rock has undergone extensive deformation and retrogression: a large asymmetric fold of a deformed white pegmatite, thickened in the nose, stretched and flattened in the limb, displayed the strain pattern, and there were folded, boudinaged pegmatites and many elongated leucosomes (quartz pods). Shearing and vergence was to the northwest, with lineations into the cliff; the Moine (hanging wall) had slid back down and the Lewisian (footwall) had risen. These rocks resemble diamond-bearing kimberlites found in Norway, Lapland and mined in Russia (crustal depth 84 km, 700^0 C, when quartz converts to coesite, normally found only in impact craters).

Panorama from Ratagan Viewpoint. (*Charles Leslie*)

We continued round the southeast end of Loch Duich and up to the viewpoint (NG 905199) on the road to Glenelg, where we had lunch, looking out over the loch to the Five Sisters of Kintail. Stunningly beautiful!! The Strathconon Fault cuts along the end of the loch, giving it the appearance of an elephant's foot, and the Sgurr Beag Slide, Nappe and Moine Nappe are laid out in the landscape. We were in the Ratagain complex, a very pink/red quartz monzonite (< 20% quartz, alkali feldspar = plagioclase), quite potassium rich, and close to quartz syenite. There is also appinite which is basic/dioritic. We were close to the lid of the pluton as roof pendants of Moine rocks can be identified. The intrusion is ~ 430 Ma, similar to those of Ballachulish and Rannoch moor, and post tectonic. Around Fort William, the big igneous intrusions are associated with faults; here the Ratagain Complex is surrounded by Moine rocks, but may have been initiated along the Strathconon Fault. The magmas have a strong mantle signature, but some have a high water content and show crustal influence, like Loch Borralan. However, there is more potassium here than in the south indicating deeper subduction. It is thought that subduction in the south had stopped, but that the slab had broken off and continued to sink.

We drove on towards Glenelg, parking at the road junction (NG 821199), and set off up the hill looking for eclogite!! At the Dun (NG 822208) near Allt Mor Ghalltair, there is a series of amphibolite, granulite and eclogite facies rocks. The latter contain beads of gem garnet surrounded by diopside pyroxene and interleaved with albite ('fingerprinting'): the eclogite had come up so fast that the high temperature was not lost, i.e. adiabatic decompression. Its omphacite then decomposed to produce jadeite and diopside – a very dense packing of the atoms. This rock was probably originally a basalt sill which had metamorphosed and subsequently degraded. We set off in search of better eclogite – across the hill and up to the western ridge of Cruachan Eilgeach (NG 842217)!!

Party examining eclogite above Dun at NH 822208. (*Charles Leslie*)

The area around Loch Duich is the only place in the UK where eclogite is found; at 1082 Ma it was long thought to be the oldest in the world, first described by Teall in 1898. However, the Sandaig Bay eclogite is 1750 Ma! The same rocks occur in Sudbury, Norway and Sweden, and all are of Grenvillian age. The streaky eclogite on this ridge has retrograded, and has quartz veins. The eclogite went down cool into the crust, and then warmed up just like baked Alaska! If it is warmed up enough, it retrogrades to granulite and so the eclogite is lost. This rock also occurs in Tanzania – eclogites from Kimberley are called 'travellers of the mantle'. As amphibolite converts to eclogite, water is released through the mantle, which melts – the melting point of eclogite, when stable at high pressure, is higher. (Other planets may not have water and so no eclogite…..). Higher in the crust, adakites (felsic, sodium-rich magmas, produced today by partial melting of the descending ocean slab) are formed, erupting as dacites, as would this sample if it had escaped. Carrying our few precious specimens of eclogite, we trekked (exhausted!!) the long way back to the cars.

Mon 26 June 2006

On another glorious morning, we drove along the A890 (Auchtertyre to Stromeferry) to Hangman's Bridge on the old road (NG 856298). In the stream bed, the Moine Thrust plane was exposed: pinkish platy Morar Group rocks of the Moine over mylonised Lewisian rocks (phyllonites, with a Grenville overprint), and a thin clay gouge between. Below is the Balmacara Nappe (its thrust outcrops to the west), and under this, the Kishorn Nappe. Kink folds and brecciated rocks showed that brittle deformation had followed ductile: the rocks had slipped over each other like a pack of cards in a vice. Some of our enthusiastic party paddled into the stream for a closer look, but soon we were all driven off by the hordes of midges!!!!!

We returned south towards Auchtertyre, stopping at a road cut (NG 853285). Here was pale green, shiny, platy, altered ultra basic rock. It was originally peridotite, pyroxene rich and very aluminous, with olivine, enstatite and spinel (green or purplish with lots of chromium). It now contained talc, chlorite and tremolite with some actinolite – fibrous amphiboles, pale bluish/greenish end members of the solid solution series Mg, Ca hydrosilicate (tremolite), Fe, Ca hydrosilicate (actinolite). Addition of sodium or aluminium gives rise to the hornblende series, while removal of calcium produces the asbestos minerals. Low stress and high water content had created large needle crystals of the amphiboles, which were weathering out like huge nails, and a strong fabric, so that the rock had survived the thrusting. At Glenelg the garnet peridotite came from mantle asthenosphere, or was meta igneous peridotite such as metamorphosed Scourie Dykes (2,000 Ma) – olivine rich and from very high temperature mantle (750^0C, 21 kbar, 80 km); but here, north of Loch Duich, there are crustal segments from under continental high pressure, attached to lumps of mantle. In Norway, garnet-peridotite solid solution rocks from pressures of (40 – 60) kbars are found. Most ultra mafic rocks in the Lewisian are igneous, not thrust-related; they are bits of mantle like today's Cuillin. Then we find these rocks. The talc is water-rich – where did the water come from???

We drove back south and then east to Balmacara Bay. In this area, Torridonian rocks lie within the Kishorn Nappe, forming an eastward closing, upward-facing syncline under the Moine and Balmacara Thrusts. The latter is a branch line, meeting the Moine Thrust at two points (so isolating a pocket) and closing off downwards. It produced the mylonite at the previous location. Normally in the Moine Thrust Zone, the Moine is the lowest (youngest) thrust but here it is the highest and so there seems to be out of sequence thrusting. Did this mylonisation occur later? The Moine Thrust cuts Ordovician sediments and so is younger than these. The syenites of Loch Borralan are ~ 430 Ma and are syntectonic; therefore the last movement on the Moine Thrust was ~ (430 – 420) Ma.

The Scandian Orogeny (late Silurian) is clearer in Norway (which has similar thrusts), Greenland, and in the deformation/metamorphism of the NE Moines in Scotland. This was the last event in the Caledonian Orogeny and marked the final closing together of Baltica, Avalonia and Laurentia. (In NE Greenland, a Carboniferous orogeny occurred ~ 360 Ma, with eclogite facies, but the reason for this is unknown.) Then extensional basins started to form, with reversal of fault movements (back-sliding). Off the north Scottish coast there are extensional faults forming Devonian basins, such as Lake Orcadia, and exhumation brought up old rocks in 'orogenic collapse' – like blancmange on a hot plate!!!! Kink folds can be seen as evidence of this in the Torridonian at Balmacara.

Party members at Balmacara. (*Charles Leslie*)

We set off along the shore towards Ard Point (NG 818263), over Torridonian rocks of the Sleat Group, within the Kishorn nappe. The Sleat Group was deposited in an earlier small basin inside the later large Torridonian basin. These rocks were quite strongly deformed, with lineations, folding, faulting and fractures indicating early ductile folding, some metamorphism and later brittle deformation. Detailed study has shown them to be upside down i.e. we were in the inverted limb of the Lochalsh Syncline. Towards Ard Point the dip became much steeper, and the once flaggy rocks finer, platy and more fissile. Then came the contact with Lewisian gneiss – green lustrous, satin rocks containing chlorite (from hornblende) and flattened orthoclase (phyllosilicates), most of which had changed to muscovite. This was a phyllite, here a tectonite, converted by tectonics not burial, and was of green schist facies, the lowest metamorphic grade on the trip. There were fairly thick highly folded pegmatites, much shattering, and evidence for two deformations. Some of our party scrambled the short distance up the steep cliff to see the thrust plane – fabulous!! – where 3-5 metres of gouge and breccia with mylonite fragments separated Torridonian sandstone below from mylonised Lewisian gneiss above – a crush zone stretching for 10 miles. The thrust plane makes a low angle with the mylonised sandstones, but the foliation in the hanging wall is vertical and so its angle with the thrust plane is large.

We returned to the village for lunch, and thanked our leader enthusiastically for an extremely fascinating, informative, enlightening and enjoyable weekend.

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ST MONANS, FIFE : 15 July 2006
Joint excursion with Edinburgh Geological Society
Leaders : Martin Lee and Maxine Akhurst
Report by : *Margaret Greene*

The Edinburgh contingent arrived first at the car park in St Monans by bus; a short time later most of the Glasgow contingent turned up in cars, except for a couple from the nearby campsite. The sun was blazing down as we were led off through St Monans and along part of the Fife Coastal Path to the start of the excursion. This was at a point on the beach just below the dovecot east of Newark Castle.

At the first location our leaders invited us to look closely at the rocks. At this section the Upper Ardross Limestone dips at a 50 degree angle to the east. Here the white bedded sandstone was interspersed with mudstone and ironstone, with limestone weathering to dolomite and cutting through this was a volcanic intrusion containing large chunks of sandstone. This is one of the volcanic necks or vents which can readily be seen along the Fife shoreline from Lundin Links to St Monans and at some inland locations. These necks tend to be funnel shaped and the sedimentary rocks around them tend to be inclined inwards at angles of 45-80 degrees. The formation of the neck is quite explosive in nature with volcanic magma coming from the depths as dykes along fissures. When water gains entry the mixture becomes explosive and the surrounding countryside rocks are penetrated and brecciated. The vent deposits postdate the sediments and are dated at approx 285 Ma at the end Carboniferous/early Permian. At this first locality we observed huge blocks of sandstone, some measuring many metres across, within the volcanic debris.

Carrying on east along the beach we observed acutely angled sediments with fossil ripple marks made by waves in a shallow marine environment. Our leaders instructed us to form a line along a prominent structure on the beach; once we were all in position you could see the outline of a plunging anticline, within which is another small neck called Davie's Rock. Further on we came to the large St Monan's neck. Here were some fine grained vent deposits with a number of structures evident within the bedding layers. Evidence of the slumping of the tuffs can be seen with 'horst and graben' structures and there are also small 'lapilli' within the volcanic ash, evidence of the pyroclastic nature of the event. This vent is intruded by later basaltic dykes.

Lunch was enjoyed in glorious sunshine on a small grassy park next to St Monan's harbour and as we watched, the sea came in and the local children took to the water – as did one of our number! After lunch we had a long look at the section of rock to the west of the harbour which was a succession of deltaic deposits. As our leaders explained, during the Carboniferous this area was a large delta such as you find in the present day Mississippi Delta – with weather similar to that which we were at present enjoying. There was evidence of successive incursions of the sea leading to ripple marks and marine fossils, mainly the ubiquitous crinoid ossicles. There was bioturbation, plant debris, and coarse sand fining upwards; in fact a really close study of this area could take a day in itself.

We then crossed to the other side of the harbour where there is a spectacular syncline of Mid Kinniny Limestone plunging out towards the sea. Closer inshore near the path could be seen more of the Mid Kinniny Limestone with the spectacular fan shaped trace fossil called *Zoophycus*. Martin explained that although trace fossils are named, in many cases the creature that made this trace is unknown. Further along, there is a thin example of a deltaic cycle, with wave ripples followed by *Stigmaria* roots, followed by coal, followed by evidence of a further marine excursion.

Following the path past the now disused outdoor swimming pool, we came to a number of shallow impressions in the grassy raised beach. These are the remains of late 18th Century salt pans which are overlooked by a small windmill which was used for pumping seawater into these saltpans. A row of stone buildings once stood here and, with coal from the neighbouring area providing the fuel for the heating, the water was distilled leaving only the salt. It would take approximately 32 tons of sea water to produce 1 ton of salt. It was hot dirty work. The windmill is open for visitors and there are display boards on the site explaining the extraction process.

The excursion finished at this point and after a vote of thanks from Cliff Porteous of EGS, we all made our way to the Mayview Hotel for high tea. Seonaid Leishman from GSG gave a further vote of thanks before our meal to all those who organised the transport and the excursion and booked the hotel. There were 45 of us for the meal which was served with great efficiency and very welcome after a day at the seaside.

References –

1. Fife RIGS group have produced a simple leaflet on the geology of St Monans starting at the harbour and travelling east past the windmill, called Fossils and Folds.
2. The Geology of East Fife: Forsyth and Chisholm published by HMSO.

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BGS CORE STORE, EDINBURGH : Friday 28 July 2006
Leader : Dr Barry Hepworth
Report by : *Marion Ballantyne* Participants 13

The weather was fine as we travelled through to Edinburgh and we had a clear view of the Devonian lavas of the Pentland hills. On our arrival at the Core Store we could see Arthur's Seat clearly with the Salisbury Crags in prominence, a sill of Devonian age. We were met by our leader Barry who showed us round the store where the stacks of cores were placed from floor to ceiling. The taking of cores began in the 1960's as studies began by the oil industry in the Central and North Sea. We were given a presentation on the position of the Oil Field where cores of Jurassic and Cretaceous rocks had been taken.

A mid Jurassic thermal dome developed over the axis of the Central Viking Graben. This was the result of a mantle hot spot of early Jurassic age producing lavas. The oil field is situated in the Northern half of the 3-armed system of the Viking Graben. Among other effects of the domal uplift were the mid-Jurassic products of erosion that were transported to the north. These became the reservoirs of the important oil fields of the Shetland Basin; gas is also a product of these reservoirs. The Brent oil field is positioned on the East Shetland Basin. For oil and gas to form certain conditions are necessary: an abundance of algae, bacteria, plant debris and muds which must be buried to a great depth, and reach a temperature of 100 – 150 degrees centigrade. At this point the kerogen in the source rock decomposes to produce oil and gas. Oil is rarely found in its original site of formation but migrates along carriers to a structural or lithological trap. Small samples (core cuttings) had been taken from each core to determining their permeability.

Rows of cores were laid out in sections giving us a chance to examine the sediment structures. Various rock cycles appeared showing shoreline and shore face profiles with the existence of anoxic environs. Tidal systems and deep storm wave basins were in evidence showing clouded formations and also the smooth facies of less turbulent deposits. From rootlets to forams the core held many interesting features. We discovered belemnites in the Jurassic core, and *Skolithos*, an 'ichnoguild of trace fossils characterized by vertical or steeply inclined burrows' with thick knobbly walls. These age from the Permian to the present day and are associated with arthropods. The microfossils were strongly in evidence within the Cretaceous core, and in some parts were highly compressed and became distinctly marble-like. A small piece of hydrocarbon, light in weight, with the distinct smell of bitumen, was also found within the core,

Gillian Hornibrook thanked our leader warmly for an extremely interesting and informative day, with which we all enthusiastically concurred.

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THE HIGHLAND BOUNDARY OPHIOLITE AND DALRADIAN ROCKS OF COWAL : 19 August 2006
Leader : Dr. Geoff Tanner
Report by : *Charles Leslie* Participants : 23

Following a dire weather forecast, the main party of 17 left Glasgow with full wet weather gear. After 5 more were picked up en route, the forecast rain hit us on our way down Loch Eck. However, by the time we reached Innellan the rain had stopped, and warm sunshine prevailed for the rest of the day. At Innellan, the party was joined by Dr. Grace Page, an Honorary Member of the Society, visiting the area on vacation.

On the foreshore, East of Toward, on the Cowal Peninsula, Dalradian rocks of the Bullrock Greywacke Formation were examined and were found to be 'right way up' with cleavage planes at a lower angle than the bedding. This is consistent with their being on the top limb of a nappe structure – the Tay Nappe which can be traced across the breadth of Scotland. Some beds have finer material representing a channel fill of gouges cut by high energy turbidity flows off a continental shelf. At one point, a black rock with imbricated sandstone blocks and no evidence of sorting was identified as a mud clast breccia (debrite), produced as a mud flow dumped its load as a single unit. On the seaward edge of the Dalradian rocks partial melting of the rocks has resulted in the formation of small granitoid bodies, with evidence of mylonisation. Skirting the edge of these altered Dalradian rocks is a suite of completely different ultrabasic rocks, peridotite, and its derivatives, serpentinite and harzburgite, but these were examined in more detail near Innellan Pier. They form part of the ophiolite of the Highland Boundary Complex which rests between the Dalradian rocks of the NW and the Old Red Sandstone rocks to the SE of the Highland Boundary Fault.

It was suggested, by our leader, that the ophiolite was formed as a hot slab of ocean floor, not far from a spreading ridge, was obducted on to the Dalradian rocks, causing them to suffer contact metamorphism, as evidenced by the partial melting and the presence of the mineral stilpnomelane in the granitoids in the Dalradian rocks. Mylonisation, normally associated with thrusting, could have been caused by the movement of the obducting slab.

The ophiolite is largely obscured by a cover of Old Red Sandstone but neither has suffered deformation so must postdate the Tay Nappe and major Dalradian folding, but only just, since recent studies of orogenies worldwide suggest these activities can be of short (few million years) duration. This implies that the ophiolite, and Highland Boundary Complex to which it belongs, sits unconformably on the folded Dalradian rocks and was not remotely formed on an exotic terrane brought into contact by strike-slip movement along the Highland Boundary Fault.

We eagerly await the outcome of the debate when this suggestion, with its associated field data is tested against other explanations of the sequence of events which brought together the Dalradian, Highland Boundary Complex and younger Old Red Sandstone cover rocks to their present positions.

Dr. Tanner was thanked for carefully leading of us through the 'simple' identification of rock types and structures to the complexity of constructing a possible sequence of events from what was observed in the field.

UORS on Ophiolite in contact with Dalradian. (*Charles Leslie*)

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ASSYNT AND WESTER ROSS : Thursday 14 – Monday 18 September 2006
Leader : Dr Steven Cribb
Report by : *Bob Diamond, Chris Henderson, Colin McFadyen* Participants : 23

Thurs 14 September 2006

We travelled by coach from Glasgow to our hotel in Ullapool.

Fri 15 September 2006

We set out on a beautiful sunny morning in the footsteps of Roderick Impey Murchison and Peach & Horne (those inveterate surveyors), to explore some of the classic areas of the Moine Thrust.

The first site was Knockan Crags where there is an excellent SNH Visitors' Centre. Here the Moine rests on top of the Cambrian succession. This allowed Murchison to 'read this' as a straightforward succession, as opposed to Nicol's view that there was an unconformity which showed evidence of thrusting. The low angle of the contact could easily be interpreted as a bedding plane. Unfortunately, as so often happens, arguments are won by influence and power, not necessarily reason, and Nicol lost.

We stopped at the Inchnadamph Hotel for coffee and a look at the hotel register which has the names of the luminaries (including Murchison, Peach and Horne) who attended the 1912 British Association Aberdeen meeting excursion to the newly surveyed Assynt area. We eventually decided not to break into song over "La chanson du Moine Thrust" written by Maurice Lugeon, another of the excursion notables. We did however visit the nearby monument to Peach and Horne. Deserving of better signposting and recognition we thought.

An excellent display of the beds at Knockan Crags *(Bob Diamond)*

Clachtoll and Stoer. In the afternoon (after an excellent stop at the Lochinver larder for pies) we moved down the succession to look at the Lewisian gneiss and the Torridonian sandstone on top of it. At A'chlach Thuill beach we saw the division between the pink/grey foliated gneiss (some 2800 Ma) and the Stoer Group sandstone (some 1000 Ma), the lowest of the Torridonian sandstone groups. At Lochinver beach we came across a breccia and other indicators of alluvial fans arising from desert outwash. Further along the shore it was possible to see sedimentary features such as cross-bedding. Incredible that such features have survived over so many millennia. Finally at Stac Fada we looked at a volcanic mudflow made up of tuffs. We returned to Ullapool weary but happy, and full of admiration for the likes of Peach & Horne

Much of the detail of the geology which we saw has been omitted since there are two excellent internet sites:

http://www.earth.ox.ac.uk/~oesis/nws/nws-home.html

http://earth.leeds.ac.uk/mtb/

which give much of the detail of the area. There are also an excellent series of leaflets covering the area, as well as the more academic guides.

Saturday 16 September 2006

Another fine day in prospect as we headed north to the first location at Skiag Bridge. This was a brief stop (NC244235) to examine a good exposure of the Pipe Rock. This is the upper section of the Cambrian Quartzite, which is pink in colour with "pipes" running vertically through the rock. The top layers show rounded bumps a few millimetres across and the vertical faces show stripes. The pipes are thought to be fossil burrows, formed by worms sifting through the sand.

Fucoid Beds at the Waterline: Moine Thrust under the Stac and to the left of Skyline. (*Charles Leslie*)

Loch Glencoul and the Thrust. (*Charles Leslie*)

The next location was a viewpoint (NC352212) above Loch Glencoul, which gave a fine overall view of the Glencoul Thrust. We then joined the "Statesman" for a cruise on the loch and a closer look at the geology. The boat is an excellent way to see the geology and the skipper was well used to taking parties of geologists to the best vantage points. As we cruised up the loch we could see the Stack of Glencoul at the Eastern end of the loch. The Stack is composed of mylonite, a rock formed by intense deformation during earth movements, in this case the Moine Thrust. The Thrust lies below the top of the Stack. It is possible to walk up the hill but we did not have enough time, and were willing to take Steve's word for it! On the northern shore of the loch are prominent cliffs of Cambrian Quartzite sloping down to the water. These rocks lie unconformably on the Lewisian Gneiss. There is no outcrop of the Torridonian Sandstone present and it is assumed to have been eroded before deposition of the quartzite. Above the quartzite, a grassy slope dips towards the loch and a rocky, hummocky outcrop above is composed of Lewisian Gneiss. The line of the Glencoul Thrust lies at the top of the grassy slope with the Lewisian Gneiss above it. The small islands in the loch where it becomes Loch Beag are a popular spot for basking seals. The first one was composed of quartzite and the next one of gneiss. It was possible to project the line of the Glencoul Thrust reaching the water between the islands. On the southern shore the Glencoul Thrust runs through the cliffs below the Lewisian Gneiss and above Durness Limestone which in turn is underlain by a cliff of Fucoid Beds, marked by a line of trees. Near the water's edge the familiar quartzite could be seen. The boat returned to Kylesku where we had lunch overlooking the loch.

<u>The Bone Caves</u>. This walk took us up the valley of the Allt nan Uamh to a series of caves where the bones of reindeer, wolves, bears and humans have been found. The famous geologists Peach and Horne had examined these caves in 1889 and found some pieces of bone. Another well-known geologist, JE Cree, and his colleagues excavated the caves in 1926 and found many more bone fragments. The rock in the valley is mainly limestone and the river appears as a spring from the ground underneath a limestone crag. In heavy rain conditions another river bed appears but in the summer only a tumble of loose boulders shows where the river runs. The climb up to the caves is steep but not too long. The caves were quite shallow and some were interconnected. Originally the cave system was much larger, but over thousands of years the valley has deepened leaving only these remnants. We all enjoyed the exploration and the walk down was very pleasant in the sunshine.

<u>Trilobite Quarry.</u> A short distance along the A837 we stopped at a small quarry where trilobite fossils had previously been found. We all enjoy a fossil hunt and some small specimens of *Olenellus* species were found. As usual however a whole specimen was not to be seen and we had to be content with some rather insignificant examples. Peach and Horne had been here first!

<u>Sunday 17 September 2006</u>

A day of two halves – a morning of experiencing by bus the regional geology and an afternoon undertaking a mapping project putting into practice experience gained over the previous few days. It was also a day in which numerous highlights of hard structural geology were punctuated by stunning geomorphological features. The weather was not particularly sunny but for the most part it was pleasant and did not hamper the day's activities.

A walk over a vertiginous suspension bridge and midges were to be contended with at the NTS property of Corrieshalloch Gorge in Loch Broom glaciated trough. The gorge is a classic example of a gorge cut by the erosive power of glacial meltwater streams. It is notable for its length and depth and shows particularly well the effects of geological controls on gorge formation with the stepped profile and slot shape of the gorge due to the horizontal foliation and well jointed nature of the Moine schist into which it is cut. The glacial melt waters cut the gorge during and immediately following several glacial episodes, with waters running at pressure under glacial ice when the valley was filled by glaciers. The River Droma that flows through the gorge alludes to previous more powerful incarnations, particularly where it forms the Falls of Measach.

There was a brief stop at the head of Little Loch Broom in the Moine Thrust Zone to gain an appreciation of the regional geology, with reference to the geological map. Within view was the frost shattered Torridonian sandstone ridge of An Teallach. The scenic Ardessie Waterfalls were observed after passing Dundonnell before a stop at a viewpoint in the Torrridonian landscape at the end of Little Loch Broom. From there the Scoraig peninsula was observed, important for having the youngest beds of the Torridonian occurring at the top of the Torridon Group, at the end of the peninsula at Cailleach Head. Dating to around 850 Ma, the Cailleach Head Formation is important for illustrating a sequence of cyclothems formed as deltas prograded into a freshwater lake. Microfossils in the shales are the first Precambrian fossils described in Britain.

There was a stop at a road cut on the hillside above the south end, at Gruinard Bay, which offered superb views of raised beaches that backed the present shore and of the Lewisian hills behind. In the distance the river-deposited Torridonian sandstones formed the spectacular mountain backdrop. Surely one of the most exciting geological views in Scotland. The road cut provided an excellent exposure of the grey polydeformed Lewisian gneisses. Good examples of deformed amphibolite masses and folds could be seen and there was time for a spot of mineral identification. Members gained further insight into the complexity of the Lewisian and with the benefit of modern road cuts that offered superb 3D exposure were able to appreciate and marvel at the work of Janet Watson and John Sutton who in the 1950's made major advances in elucidating the evolution of this high grade gneiss terrane without the benefit of such exposures.

At Loch Ewe, the line of the NW-SE trending Loch Maree Fault, a prominent feature of the landscape, and various features of recent historical interest associated with the Second World War were pointed out on the way to lunch at the NTS property of Inverewe Gardens at Poolewe.

After lunch the journey continued through Gairloch with a drive along Loch Maree. There was a brief stop at the Beinne Eighe National Nature Reserve to marvel at the unconformity between the Lewisian and Torridonian, where the river-deposited sandstone that forms Slioch can be seen infilling a broad deep valley in the Lewisian gneiss. Of all the interpretive panels experienced by the society on the excursion the one interpreting the story of an ancient landscape carved into Lewisian gneiss and drowned by sand around 1000 million years ago was deemed to be the best. Most of the afternoon was enjoyably occupied by a mapping exercise to determine the nearby geology of Glen Logan. Members participated enthusiastically, scaling hillsides and coping with vegetated river banks, with one particularly brave member and the leader getting very wet feet, all in a concerted effort to identify outcrops of rock. Quartzite, Pipe Rock, Fucoid Beds, Durness Limestone, Lewisian and Torridonian were all encountered – mapping their positions enabled the completion, by the end of the afternoon, of a simple map illustrating a section of the Moine Thrust Zone in the area. The exercise provided a useful insight into the fieldwork undertaken by Peach, Horne and others who mapped this area in the late 19th and early 20th Centuries.

The last stop before the return to Ullapool was to view the outstanding examples of glaciofluvial outwash and delta terraces at Achnasheen, formed by meltwater deposition in an ice-dammed lake. The lake was dammed by glaciers in Strath Bran and adjacent valleys. Formed about 11,000 – 10,000 years ago during the last glacial cold snap known as the Loch Lomond stadial, at the end of the Ice Age, the terraces are a classic example of their kind, important for studies of sedimentation in a glacial lake environment.

In the evening, back at the hotel, Dr Cribb was thanked enthusiastically for providing such a fascinating, entertaining and varied weekend, with several 'firsts' for most of us.

Opposite Slioch, our leader explains the geology. (*Colin McFadyen*)

GENERAL INFORMATION

Scottish Geological Societies-ConocoPhillips Awards.
These were awarded to pupils from Westhill Academy Westhill, Aberdeenshire; Ellon Academy, Ellon, Aberdeenshire; The Royal High School Edinburgh and Perth High School, Perth.

North West Highlands Geopark.
Officially launched on the 12th September 2005, the NW Highlands Geopark is Scotland's first, and is an exciting initiative in Earth Science education, interpretation and conservation. The Park includes the area north from Ben More Coigach to the north coast and from the western seaboard inland to the Moine Thrust. A Geopark officer has been appointed: Dr Isobel MacPhail who can be contacted via the website – www.northwest-highlands-geopark.org.uk.

Scottish Festival of Geology. 1st to 30th September 2006. www.scottishgeology.com. This is now an annual event, but is no longer funded by SNH so a formal partnership of universities, museums, societies and individuals to publish booklets of events etc. was needed.
Our Society held an Open Day with the following programme of events:
Saturday 9th September
Open House in Earth Sciences, Gregory Building, Lilybank Gardens, University of Glasgow, 10.00 am – 4.00 pm.

1. Displays of rocks, minerals and fossils. (Level 1 Lab). (Dr Burton)
2. What is Granite? – Interactive exercise for all ages (Level 2 Lab). (Dr Burton)
3. Scottish Dinosaurs – an exhibit of the first vertebrate animal to walk on land, *Pederpes* from Dumbarton (Level 1 Lab). (Dr Clark).
4. Making rock thin sections (Level 2 Lab). (Mervyn Aiken/Sally Rowan)
5. Tour of Building Stones on the Campus – 11.00 am and 2.00 pm. (Dr Burton)
6. Tour of polished rock slabs (Floor 4) – 12 noon and 3.00 pm. (Dr Burton)
7. Short talks (15 – 20 minutes) on topical geological subjects – 11.30 am, 12.30 pm, 2.30 pm, 3.30 pm.
8. Bookstall (Level 2 Lab) – all day (Roy Smart).

In addition there were numerous free copies of 'Down to Earth', together with samples of granite for Item 2.
Sunday 10th September, 11.00 am
The Strathclyde RIGS Group arranged a guided walk up Campsie Glen to trial their latest leaflet – an interpretative account of this area. After lunch, some participants continued up to the abandoned quarry in basalt lavas near the Crow Road car park – in the Glen these lavas are now inaccessible for safety reasons.

Scottish Fossil Code.
Society members have been involved in drafting the new code which will be available for public consultation shortly. Details will appear on the website www.scottishgeology.com. The code aims to encourage responsible collecting and to

promote interest in palaeontology and the appreciation of Scotland's rich heritage of fossils.

Expedition Funding.

The Society awarded a sum of £500 to help fund a trip by Dr Neil Clark to Shell, Wyoming and Washington DC, in order to study Middle Jurassic dinosaur footprints and to compare them with those found in Scotland. We look forward to a 'Society Lecture' on the outcome of the trip.

Local Geodiversity Action Plans (LGAPs).

The West Lothian Geodiversity Framework is nearing completion and will be Scotland's first LGAP. The project has involved West Lothian Council, Scottish Natural Heritage and Lothian and Borders RIGS who have conducted an audit of geodiversity of the area. The geological aspects are related to their local or national context and their relevance to biodiversity, soil conservation and other protection designations. The audit will then inform sustainable planning and development and the interpretation of the area's geological heritage.

OBITUARY

With regret, we record the death of

Dr James Dixon Lawson. 1922 -2005.

Jim Lawson died on Christmas Day 2005 at his holiday home on the Island of Seil, his death drawing to a close a long, distinguished and productive career in geology, during which he achieved an international reputation in the fields of stratigraphy and Silurian geology.

Jim was a well-known and committed member of the Glasgow Geological Society, joining in 1962, and taking part in the full range of society activities, including stints on the Council, as an excursion leader to a variety of locations and as an editor of the Scottish Journal of Geology.

A Manchester man, he had, during his schooldays in the 1930s, begun to enjoy the British countryside in the Peak District and the Lake District, an enjoyment that never left him. He commenced his undergraduate geological studies at Manchester University, his studies being interrupted by army service during World War II. During his service he was posted to the Orkney Islands where he first encountered the Old Red Sandstone in particular and Scottish geology in general. Returning to his studies at Manchester in 1946 he had completed his degree by 1948, at which juncture he was appointed to an Assistant Lectureship and began his long association with the Welsh Borders and the Silurian System, commencing, under the supervision of Dr. S. H. Straw, a study of the May Hill inlier in Gloucestershire. This study opened up the detailed use of fossils in subdividing the Silurian succession in the Welsh Borders.

Following this, Jim took up a research fellowship at the University of Birmingham and, with a base closer to his research area, set up, with his fellow Silurian workers Charles Holland and Vic Walmsley, the Ludlow Research Group, a group that revolutionized Silurian stratigraphy and led to a stream of key papers in which the whole of the Welsh Borderland Silurian – the type area for the Ludlow Series – was thoroughly explored, culminating in the Ludlow monograph of 1963. The group's emphasis on the vital importance of linking faunas and lithologies, and its definition of boundary stratotypes for the new stages that were set up, set the standard for the modern stratigraphical studies that were emerging at that time.

During this period, Jim suffered the setback of a car crash, which took time to recover from. Once recovered he resumed his work and, with Dennis White, wrote the chapter on the Standard Ludlow Series in *A Global Standard for the Silurian System*. Jim's interest in, and encyclopaedic knowledge of, Silurian faunas, led to a fruitful collaboration with Art Boucot of the University of Oregon and the development of a clear understanding of Silurian fossil communities and their ecological setting. A later phase of his work (1967) came when he tackled the difficult Aymestry area, linking his previous Ludlow and May Hill work. A GA guide to the Welsh Borders was one outcome of this link.

Jim came to Glasgow in 1962, joining the Department of Geology led by Professor T. N. George, retiring in 1984. During his long period as Lecturer and then Senior Lecturer he explored the geology of Scotland, notably that of the Girvan area, where he led student field groups, teaching the importance of precise and careful stratigraphical work to generations of undergraduates. Jim continued and further developed his research in Glasgow, becoming deeply involved in work on graptolites and the establishment of the International Stratotype for the Ordovician – Silurian boundary at Dob's Linn, work that naturally led to undergraduate field excursions with a strong emphasis on graptolite biostratigraphy! Jim's interest in, and work on, the Ordovician – Silurian boundary took him to some extraordinary places to view other contenders for the stratotype, including an expedition to far eastern Siberia, camping in the taiga, with other experts and a host of Russian support staff, complete, as he noted, with large supplies of vodka!

Jim's appetite for work continued long after his retirement and, as a Senior Honorary Research fellow of Glasgow University he was still fighting for the retention of the Dob's Linn section as the International Stratotype into his eighties.

Jim met and married Judith early on in his Glasgow days and together they took up hill-walking and wider travel, not only in Scotland, but throughout the world. "Collecting" islands was one of their specialities. Aside from his other talents, Jim was a fine, and published, poet, not something that he talked about, but important nevertheless, and all part of the clear and concise English of all his publications.

Chris Burton

Front cover photograph – Memorial raised to Ben Peach and John Horne in 1930, with Loch Assynt and Quinag, NW Highlands. *(Margaret Donnelly)*

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