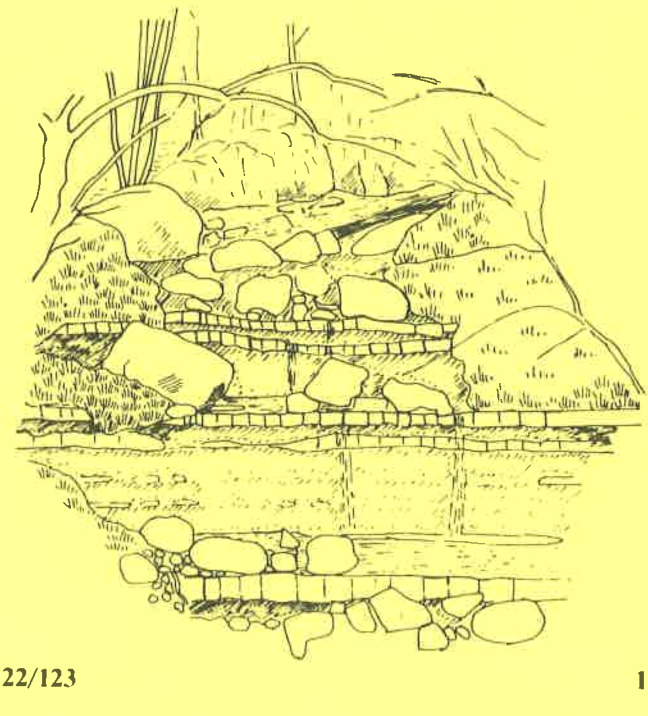
PROCEEDINGS OF THE GEOLOGICAL SOCIETY OF GLASGOW



Sessions 122/123

1980/1981

SESSION 122

MEMBERSHIP

The Membership of the Society for Session 122 was as follows:

Honorary Life Members	4
Life Members	3
Ordinary Members	394
Associate Members	19
Junior Members	16

Thirty new members joined the Society and 26 were deleted.

J. R. Thomson

LIBRARY REPORT

During the session 26 members used the library and made 198 loans between them, a slight increase on last session. Numerous other members consulted volumes but did not borrow them. Ten new books have been added to the stock, together with a number of booklets. A dominant subject among these purchases has been the geological guide, with guides to the geology of Rhum, the Bass Rock, the Cheviots and County Durham being notable. For the rest the choice attempts to reflect members' interests, with dinosaurs, the origin of species, field photography, volcanoes and sediments figuring largely. However the librarian is by no means omniscient and would welcome members' recommendations for the purchase of books likely to be of interest to the Society at large.

The latest volumes of the Society's periodicals have now been bound and are on the shelves together with newly received exchange journals. The financial aspects of these and other transactions will be found on the Society's Balance Sheet for the session.

There has been a welcome rise in the number of members wishing to use the University Library, although regrettably a minority have encountered difficulties in doing so. All such problems should be referred to the Society's librarian who will smooth pathways wherever necessary. It might be emphasized here that members of the Society are entitled to join the University Library on presentation of their membership cards at the main desk there, and to use the considerable resources of the library without any charge being made, a bargain that few others share!

C. J. Burton

NEW BOOKS IN THE SOCIETY'S LIBRARY

Once again I've surveyed the flow of literature entering the library and attempted to pick out those books which seem likely to best satisfy the multifarious interests of members. The choice ranges in content from the introductory to the advanced and from the innocuous to the violently controversial and in space from Scotland to almost everywhere else.

Firstly guidebooks, a smaller crop than last year, but including a **Field Guide to the Permian Rocks of the Dumfries and Lochmaben Basins** by **M. E. Brookfield** which, if you can't afford Death Valley, will give a clear locally based picture of desert features past and present. A little further afield **D. A. Robson's Geology of North East England,** although not strictly an excursion guide, provides a mass of information on all aspects of the geology of the Border region straying often into southern Scotland. For those who like to combine railways and geology then **"Through the Window: a guide to the geology and scenery, as seen from the train on the journey from Paddington to Oxford"**, by **"D.A.B."** delightfully recreates the lost and whimsical world of Victorian railway geology. In a more serious vein are the excellent guides produced by the Geological Survey of Ireland. Guide series number 2, the **Caledonian and Pre-Caledonian Rocks of South-East Ireland** by **P. M. Brück et al** sets out a series of excursions covering large areas of south-east Ireland from Dublin to Tipperary, while number 3, **A Traverse in the North-Western Irish Caledonides** by **T. B. Anderson et al** takes the traveller from Drogheda to Donegal and through much of the Irish Dalradian. A rather less demanding guide is **Michal Dooley** and **John Feehans' Exploring North-Eastern Slieve Bloom,** a look at flora, fauna and geology in County Laois.

Once back from the field there are numerous informative and absorbing books to be sampled. For the mineralogist there is a most remarkable book from the Geological Survey of Canada, **R. W. Boyle's The Geochemistry of Gold and its deposits.** Don't be discouraged by the title — this is a book both for dipping into and for deeper study, it contains an almost endless flow of information on the history of gold working, gold and its minerals, how to find it and even the distribution of gold in plants and animals — June Bugs being worth their weight in the element! Rocks in general and the minerals that make them are treated clearly and simply by **R. V. Dietrich** and **B. J. Skinner** in **Rocks and Rock Minerals,** a very agreeable introduction to petrology, while the broader view is taken by **J. T. Wilson** and others in **Continents Adrift and Continents Aground,** a collection of Scientific American articles which explore the beginnings and development of Plate Tectonic Theory.

Of late the palaeontological world has been in a state of civil war over the interpretation of the processes through which evolution takes place, and among the latest dispatches from the battlefront we have the British Museum's **Dinosaurs and their living relatives,** a finely illustrated guide to one way of looking at relationships. For a more balanced and yet, paradoxically, a more controversial view of the latest thinking on evolution there is **Steven Stanley's Macroevolution: Pattern and Process.** You may not agree with him but I do urge you to read him. For a more general introduction to palaeontology and one which combines readability with much fascinating information there is **The Natural History of Fossils** by **Chris Paul,** who treats fossils as much more than objects in stone. A more specialist look is provided by **Patricia Bergquist's Sponges,** a very thorough review of the ancient and modern members of that strange group.

Finally, a look back to the origins of all British Natural History societies, including geological ones, is given in **David Elliston Allen's The Naturalist in Britain: A Social History.** He doesn't mention us, but this unfortunate omission apart, he does most interestingly illuminate our Georgian and Victorian predecessors' attitudes to the natural world and the climate within which our society came into being.

C. J. Burton

REPORT OF THE EDITORIAL BOARD

Publication of Volume 16 part 1 was delayed by over three months due to a printer's dispute. Parts 2 and 3 were combined into one issue, thereby saving the Societies several hundred pounds, but was also published late due to the backlog of printing work after the strike. Part 4 was, however, issued in October, earlier than in any previous year. Editing of papers for 1981 is well in hand, and we may publish another combined issue late in 1981. There was no review paper in Vol. 16, because two prospective authors withdrew their offers early in the year. Our policy of encouraging shorter papers is now resulting in more papers per part, and the range of interests covered by papers submitted remains satisfactorily broad, although "hard rock" topics are currently somewhat under-represented. The continuing rise in printing costs will prevent us from publishing more than 330-340 pages per Volume for the foreseeable future.

D. K. Smythe

PUBLICATION SALES

The sale of publications has enjoyed another financially successful year. The Glasgow guide continues to sell well, although sales of the Arran guide decreased markedly, probably in response to last years high sales and should not be a cause for concern at present. Any shortfall in income caused by the Arran guide was more than matched by the highly successful sale of parts of the Transactions to Members, (thanks to all involved). Nearly half the Societies stock was sold, thereby greatly reducing the storage problem!

Income has also been maintained by sales to Extra-mural classes (organisers please note!); to the joint meeting of the Geological Society of London and the Volcanic Studies Group in May, and to students in the Department of Geology, for buying among other things 165 copies of the Manchester Museum Stratigraphic Column.

The last session also saw the arrival of the Societies latest publication "Geological Howlers", of which some 300 copies have already been dispatched prior to the start of the advertising campaign. Anyone willing to sell copies at Geological meetings or when visiting geological institutions please contact me.

Finally, my thanks to the many people who have helped in selling books at various times and places throughout the year.

C. J. Farrow

OBITUARY NOTICES

Noel N. Lunt, F.C.A. The Society suffered a great loss during the session on the death of its Honorary Treasurer, Noel Lunt. Although he had been a member for a relatively short time, having joined in 1975, and had served as treasurer for less than three years, his business acumen and professional skill in accounting provided the Society with invaluable insight into its financial position. Noel's accounting expertise continued a family tradition begun by his grandfather who was a founder member of the Institute of Chartered Accountants in England. Although originally intent on working in the family business in Manchester the intervention of the

Second World War found him engaged by the Ministry of Supply as a contract investigator and it was this that brought him to Scotland on a visit to Scottish Cables Ltd., in Renfrew. The management of Scottish Cables were so impressed that after the War they offered him the post of Accountant and over the following years he served in various capacities at home and in the company's subsidiary in Pietermaritzburg in South Africa, latterly being Commercial Director at Renfrew.

On retiral Noel and his wife Anthea took up again an interest in natural history which they had first pursued in pre-war days when they lived in Manchester and paid frequent visits to the Lake District. It was through their attendance at University Extra-Mural classes that they renewed their study of geology and came to join the Society.

Despite serious illness Noel maintained his meticulous stewardship of the Society's financial resources. He is survived by his wife, son and daughter.

J. G. MacDonald

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William John McCallien, D.Sc., F.R.S.E., joined the Society in 1924. A native of Tarbert, Argyll, he died at Helensburgh on the 19th January 1981 at the age of 79.

The son of an artist, Mac first matriculated as an undergraduate in the University of Glasgow in 1919. There he soon fell under the spell of Professor J. W. Gregory who, despite his small stature and sometimes indistinct delivery, proved a fascinating lecturer to Mac who along with about 400 other students packed into a theatre in the East Quadrangle to hear him. He was so "absolutely riveted" by Gregory's lectures that all thoughts of a career in any subject other than geology were rapidly abandoned and from then on he pursued his study and research with a singlemindedness which is reflected in the prolific output of papers which appeared in later years.

Mac's early research was centred largely on his home ground in Kintyre and South Knapdale. Soon after graduating with B.Sc. Honours in 1923 he was reading a paper to the Society on the Geology of the Tarbert District and it was for his extensive research in Kintyre that he received his D.Sc. from the University of Glasgow in 1930. Later his interests broadened to include studies of the Central Highlands and Ulster, particularly Co. Donegal. At this time also he was associated with Sir Edward Bailey who became Professor of Geology at Glasgow in 1929. The success of their collaboration, which is reflected in the output of papers in the Transactions of the Royal Society of Edinburgh, was probably in some measure due to the fact that Mac was one of the few geologists who could match Bailey's famous stamina in fieldwork. While he was a member of the staff of the Department of Geology at Glasgow University he served as an office bearer in the Society in several capacities including that of Secretary. He received the Neil Prize of the Royal Society of Edinburgh for 1939-41.

During the Second World War Mac volunteered for service in the Royal Air Force but his hopes of working as a "back room boy" in photo reconnaissance were dashed when on Bailey's recommendation he was sent to Turkey by the British Government. However he soon got over his disappointment when he found that there were structural problems to be solved in Anatolia. Within a month of arriving he had mastered sufficient of the language to begin lecturing in Turkish at the University of Ankara and during the following six years he travelled widely noting not only the contrasts but points of comparison that could be made between the geology of this unfamiliar ground and that of his native Scotland. In addition to his responsibility as professor at Ankara Mac was later appointed to the Chair of Geology at Istanbul and published several papers in Turkish on areas bordering the Bosphorus and the Black Sea. His observations of Anatolian greywackes, spilitic lavas and serpentine led to further collaboration with Sir Edward Bailey with whom he published joint papers on structural studies in Turkey, the Apennines and, nearer home, at Ballantrae.

In 1949 Professor McCallien was appointed to the newly created Chair of Geology at the University College of the Gold Coast. Arriving in Accra in early 1950 he was faced with the task of building up a department from scratch and this he set about with his customary enthusiasm. One of his principal aims, particularly after independence, was to train native Ghanaians to take over the running of the Department and by the time he retired in 1965 he had created what was regarded by many as the best geology department in Africa. While in West Africa Mac took the opportunity to travel widely in Senegal, Nigeria, The Gambia and further north. He always laid stress on field work often to the surprise of some of his African colleagues who had thought that academics should confine their activities to the college precinct.

After retiral Professor McCallien returned to Scotland and in 1970 revisited Glasgow to talk to the Society on Ghanaian rock structures. The following year he was elected an Honorary Life Member in recognition of his services to geology and the Society. In addition to his numerous papers he is rememberd for his books on the "Geology of Glasgow and district" and "Scottish Gem Stones". A bibliography of his publications has been deposited with the Society Librarian and in the University of Glasgow Archives.

J. G. MacDonald

LECTURES 1980-81 (SESSION 123)

The first lecture of the session was given by **Dr M. R. Coward** (University of Leeds) on **"Himalayan Tectonics"**. He described recent discoveries in the Karakorum Range of the Himalayas of North Pakistan of a Cretaceous island arc, up to 150 km wide and more than 400 km long, which occupies an elongate mini-plate caught between the collided Asian and Indian plates. The rocks are standing steeply on end and thus, for the first time, provide a complete, intact and continuous section through the entire continental crust. He then described the sequence from north to south and indicated future areas of research.

In November **Dr C. W. A. Browitt** (I.G.S. Edinburgh) gave a lecture on **"British Earthquakes"**. He described authenticated earthquakes from the historical past, with emphasis on those recorded at Colchester, the Dogger Bank and Inverness. He also discussed more recent ones of the last decade, including that of Boxing Day 1979 near Carlisle, pointing out that earthquakes are not of rare occurrence in the Carlisle area, one being recorded about every generation or so. He later discussed possible causes of earthquakes in the British Isles and finished by hoping that improved observations in the future would help in solving some of the problems.

After the A.G.M. in December there was a slide quiz between a "Hard" rock team with Dr C. D. Gribble, Dr P. R. Thomas and Dr M. J. Russell and a "Soft" rock team with Dr J. D. Lawson, Dr G. E. Bowes and Dr W. D. I. Rolfe who had a convincing win over their hard rock rivals. Andrew Burton won the individual prize of a book token. The very successful evening was rounded off by a wine and cheese party.

At the January meeting **Dr T. D. Ford** (University of Leicester) presented a lecture on **"Precambrian Fossils"**. He gave a review of the different types of fossil now known from Precambrian rocks in many parts of the World, and ranging back to the earliest Precambrian times. The fossils include microscopic unicellular algae, filamentous algae, and clusters of both, perhaps representing the early stages of evolution towards larger organisms. The structures believed to be formed by algal assemblages and known as stromatolites were described and their use as stratigraphic indicators within the Precambrian were discussed. He also reviewed megascopic "algal" cysts such as *Chuaria* and other problematica and ended with a survey of metazoan fossils found in late Precambrian rocks.

The February members night included the following short talks:

Geology and the Ordnance Trigonometrial Survey 1814-1821, **Mr D. A. Cumming.**

Non-graptolitic faunas and facies of Dob's Linn, **Mr H. Williams.**

Chrome minerals of Outokumpu, N. Karelia, Finland, **Mr A. Park.**

Origin of English geodes and celestite deposits, **Mr J. Jocelyn.**

Underwater marine life in British Columbia, **Dr G. Farrow.**

The following exhibits were on display:

Sedimentology in the Dalradian, **Mr A. Barraclough.**

Colour as a tool for the correlation of Scottish Red Beds, **Mr G. Blackburn.**

Ropy lava and pahoehoe from the Carboniferous of the Kilpatrick Hills, **Dr B. J. Bluck.**

Excursion guides from the Society's Library, **Dr C. J. Burton.**

Chrome minerals of Outokumpu, N. Karelia, Finland, **Mr A. Park.**

Crayfish and other crustaceans from the Lower Greensand of the Isle of Wight, **Mr M. Simpson.**

Diagenetic flattening of graptolites: an example in experimental palaeontology, **Mr H. Williams, Miss K. McManus, Mr I. Murray, Dr J. K. Ingham.**

Recent acquisitions by the Hunterian Museum.

In March Professor **Xavier Le Pichon** (Academie de Paris) gave the Celebrity Lecture (see report below, p. 00), while **Dr D. H. Tarling** (Newcastle University) gave a lecture on **"The evolution of the Earth's crust"**. Dr Tarling outlined the main features of the development of the Earth's crust.

In order to consider models for its evolution, possible mechanisms for present day plate tectonics were examined to determine their relevance to Precambrian times. A series of models for the possible evolution of the Earth was then presented as a basis for further discussion of some of the intriguing problems posed by the Precambrian geology of the Earth's crust.

The final lecture of the year was given by **Dr B. J. Bluck** (University of Glasgow) on **"The Ballantrae Complex".** The pillow lavas and the associated sediments of a section of shore near Ballantrae were described in detail and the environment of formation was discussed.

CELEBRITY LECTURE 1981

Professor **Xavier Le Pichon** presented a most elegant lecture in which he emphasised the processes associated with crustal extension in global tectonics.

Much of his evidence came from the eastern Mediterranean where he was able to demonstrate that the marked crustal thinning in the Aegean area, inside the Hellenic Arc, originated from extension due to subduction in the southern Mediterranean. He expanded this theme by citing further evidence from seismic surveys carried out in the Bay of Biscay. Here, numerous large scale, seaward dipping, normal faults are associated with both continental thinning at the edge of the European Plate and the formation of oceanic crust.

Such evidence was used to devise a generalised model for crustal parting based on extension tectonics.

P.R.T.

PERSONALIA

Dr B. J. Bluck has been awarded a Moiety of the Lyell Fund for 1981 by the Geological Society of London and has also been elected a Fellow of the Royal Society of Edinburgh.

EXCURSIONS 1980 (SESSION 122 — continued from previous issue)

Quaternary of the Glasgow Area (Leader: Dr J. Rose) 27th-28th September 1980)

by Tony Stevens

Jim Rose provided an excellent handout to follow the detail of the excursions and for subsequent study. The weather on both days was sunny and warm.

On Saturday 18 members visited the Clyde coast and the Gareloch. An easy climb to the vantage point of Carman Muir started the excursions. Here members visualised the passage of Highland ice streams moving from west to east, the crag and tail of Dumbarton Rock, and the deepened channels of the Leven and the Clyde formed in glacial times. The glacial story started to unravel at the Geilston Burn in Cardross where an excellent section of the Wilderness Till is exposed — macro and micro fabric analyses reveal the NW to SE direction of ice flow. A second exposure introduced the Clyde Beds, silts containing shelly fauna. At Ardmore members were puzzled by the problematical cliff, which enigmatically encircles the promontory. Evidence points to a Lateglacial age for its formation. At Rhu promontory, a morainic ridge, erosion produces ever changing exposures of glaciofluvial sands, all overlain by Flandrian beach deposits. Further up the Gareloch at Glen Fruin Head, bright green vegetation indicated the terminal moraine of the Loch Lomond Re-Advance, which being unleached contains good soil nutrients. Over the hill in Glen Fruin itself, a proglacial lake was postulated with the valley sides formed of soliflucted deposits, all produced in a periglacial environment.

On Sunday 18 members visited inland features associated with the Loch Lomond Re-Advance. The same patches of bright green vegetation were traced across part of the Cameron Muir indicating a further part of the Loch Lomond Re-Advance terminal moraine. This moraine was followed across the Muir and it plunged down and across the impressively deep and wide Carnock gorge, formed during glacial retreat times, by very large meltwater discharges. On Cameron Muir there were the lateral meltwater channels characteristic of the Loch Lomond Re-Advance. After lunch the classic readvance exposure at Pirniehall was visited. Here two tills, the Wilderness Till and the Gartocharn Till, separated by lake deposits indicate a readvance of the ice, though 100 years ago when it was first discovered its full significance was barely appreciated. At Gartness by the River Endrick, Jim Rose exposed exquisite varves, arguably the best in Scotland. Over the hill, on the morainic ridge, the to and fro of the ice margin had produced a deformation facies. The excursions were concluded with a visit to Flandrian beach deposits near Gartocharn on Loch Lomondside, where the sea flipped in and out again 5000 years ago.

The weekend was generally acclaimed to be of excellent interest by the members attending. Miss Brock, in her vote of thanks, said she was most grateful to the many kindly hands that had helped her over the two days so that she could hear such a magnificent local story and all revealed so clearly at last.

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EXCURSIONS 1981 (SESSION 123)

Gatehouse of Fleet Pluton (Leader: Dr J. A. Weir)

by N. MacGregor

The first meeting of the Excursion session started dramatically with hail, snow and a force 9 gale on the day prior to us visiting the south of Scotland. A large number had shown interest in this trip but due to the adverse weather conditions only 10 stalwarts arrived at Clatteringshaws dam on the 25th April. (We also lost 2 members in a snow drift.) Road conditions did improve somewhat however, and we were rewarded by an exceptional, contrasting cold day, which had the beauty of a white wonderland, with the clarity of clear summer hues in excess.

Our first geological encounters were by the roadside cuttings and we were able to view the contact of the Gateside Granite with the highly hornfelsed Silurian greywackes. At the next location however, we had to locate the flatlying contact of pale granite with the much darker Moffat Shales and the Craignell Greywackes from a distance. Pitons, crampons, ropes and ice axes could well have been the order of the day for this section.

At Talnotry the road follows a major fault, i.e. the Talnotry Thrust. Wedges of crust were upthrust in a SW succession and continuously degraded, the resulting sediments being deposited in an oceanic trench to the south east. Several imbricated slices and steep reverse faults which bound them were also exposed.

As the Pibble mine was inaccessible lunch was enjoyed in brilliant sunshine in the secluded Blackcraig Quarry where the variety of copper-lead-zinc assemblage minerals was only surpassed by the surprising diversity of the surrounding trees.

The last locality involved most of us getting slightly dampish, trying to find the metamorphosed garnetiferous greywackes at the Moneypool Burn, east of Creetown, which were buried under virgin snow. However we were rewarded and were able to see the difference between this and the granites at locality one.

As this pluton is a very complex structure we were only able to view the more basic aspects. I feel that a long weekend would have been more appropriate to view this fascinating and most interesting area.

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Misty Law Complex (Leader: Dr D Stephenson, I.G.S.)
by Margaret Connel

Around 30 members gathered in good weather in the car park of Muirshiel Country Park for the second excursion of the session on the 9th of May. After an introduction to the history of geological mapping in the area and an outline of the main topographical features on view, Dr Stephenson led the party up the Rough Burn to examine the faulted contact between the trachyte of the Misty Law Complex and the basalt (mugearite) of the surrounding area; thin veins of baryte in the trachyte were noted in the burn section. In the past, excavation further up the burn has shown the surrounding mugearite to be resting on trachyte with a thin basaltic tuff in between and this supports the view that the Misty Law Complex is a conical volcanic pile of trachytic and rhyolitic lava flows extruded during the Lower Carboniferous, within a sequence of more basic lavas.

After some more ascent, lunch was eaten by the upper Maich Water where a clay fault gouge was seen. Fortified by lunch, the party walked over fairly rough ground to two spectacular waterfalls — Murchan Spout formed by a Tertiary dolerite dyke and a nearby fault and Garnock Spout formed by faulting and trachytic dykes. The River Garnock was followed upstream and a relatively large vein of barytes was seen in the trachyte as well as several thin veins.

Approaching the summit of Misty Law from the west, fresh porphyritic dolerite sill-like formations were seen at Totterie Law; the summit of Misty Law itself is a trachybasalt which may be a remnant capping rather than a plug.

Having completed a short steep descent from the summit, the party were rewarded by some very good convolute flow-banded rhyolite. The excursion ended with a fording of the River Calder when those wearing Wellingtons (as recommended) had a distinct advantage!

The East Lothian Excursion (Leaders: Dr B. J. Bluck and Dr J. G. MacDonald) 23rd-26th May 1981
by Robert A. Hill

About 20 members met on Saturday morning in the car park near the castle at Dunbar. After booking into the Battleblent Hotel we ate our lunches in the lounge while handouts were distributed. After lunch we visited Catcraig where the Carboniferous Limestone was examined. The fossiliferous limestones included abundant *Lithostrotion* species (spaghetti and macaroni rocks), large solitary corals and trace fossils presumably from feeding movements. Later that afternoon we visited Pease Bay and the sedimentary structures in the Upper Old Red Sandstones to the East of the bay were lucidly explained by Dr Bluck. Mud-cracks, burrow trace fossils and fish scales were also found. We returned to the hotel for a fine meal after which some members investigated the local Belhaven beers.

On Sunday, after a brief stop in Dunbar for lunch supplies, we set out for Siccar Point where the more adventurous members descended the steep grassy slope to see Hutton's unconformity. A breccia of greywacke fragments and sandstones of Old Red Sandstone age lie unconformably on steeply dipping Llandovery age greywakes and shales. On returning to the vehicles we again visited Pease Bay, this time to see the Western end of the bay where the succession from Upper Old Red Sandstone to the base of the Carboniferous provided examples of slump structures, cementstones and plant fragments. The day was rounded off by a trip to Coldingham Bay where the agglomerates, tuffs and the intriguing Silurian greywackes were briefly examined.

The final day began with a more detailed survey of the greywackes at Coldingham before an energetic walk to Fast Castle to observe the large fold structures of the Silurian rocks. More impressive folds were found to the north of Burnmouth on an even more exhausting ramble. The talents of our leaders combined to make this an inspiring and memorable excursion.

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Wanlockhead Museum and Lead Mine (Leader: Mr Downs-Rose)
by J. McK. Allan

The showerproof clothing recommended in the excursion was certainly needed during this outing on the 6th June. The wet weather did not dampen the enthusiasm of the members visiting the museum, library, lead mine and other sites of interest in industrial archaeology along the Visitor Walkway.

In the museum our guide explained, with the aid of a relief map of the district, the position of the mineral veins which run roughly parallel in a NNW direction. The exhibits in this small museum were many and varied including mining artifacts of the 17th, 18th, 19th and 20th centuries as well as examples of minerals obtained in the mines. The large collection of books in the miners' library, covering all sorts of subjects, bears witness to the insatiable inquiring minds of these hard working men. Downhill from the library we started along the Walkway and stopped at the Loch Nell mine. After donning the hard hats provided we entered the mine and could see at once the steep dip of the country rock. Some distance along the level we saw in dim candle light an impressive scene made up of life size models representing two 18th century miners at work at the rock face. The guide left us in no doubt about the risks and heavy manual labour involved in mining in those bygone days.

Further along the Walkway we saw the water-operated beam pumping engine. Before the introduction of the Watt steam engine to this district in the latter half of the 18th century, the miners depended mainly on water-driven prime movers for the pumping of mine water. Without water power (e.g. during a drought) the mining of ore was much restricted. Continuing along the Walkway we arrived at the recently excavated site of the smelting mill where the operation of the smelting hearths was fully explained to us. After having thanked our guide for this very interesting tour we proceeded to forage the nearby mine tips for the many different types of minerals to be found there. It is understood that a large number of people visited Wanlockhead last year and no doubt the village will succeed in attracting many more this year.

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North Fife (Leader: M. A. E. Brown)
by Alex. M. Hall

The Society members had an interesting day out on 27th June, led by Mr M. A. E. Brown of the I.G.S., who had mapped the area of our visit, between 1967 and 1974. We left Glasgow by bus at 9.30 a.m., and picked up our leader on the M90 at the Kinross interchange. Our group now totalled about 30 people ranging from five years old up to — to spare some blushes — beyond retiral age. We were told that the day would be a "Cook's" tour of North Fife (and its mineral resources) and Thomas Cook could not have organised it better. We started off by driving through the beautiful Glen Farg and the bus dropped us off at Ayton Quarry (NO 167 153), just West of Abernethy. Although not a working quarry we discovered it was now housing bee skeps and decided it would be safer to investigate the intrusion of quartz feldspar porphyry at a higher level. We continued up a forestry track (the bees having been replaced by a plague of flies) which took us along an andesite lava flow. Then followed a climb to the top of Castle Law (NO 184 154), where we had a picnic lunch. Although the forecast had not been promising it turned out to be a beautiful day with excellent visibility over the lush Strathearn valley with Schiehallion and the Cairngorms beyond. We walked down to Abernethy where the bus picked us up and took us to Clatchard Quarry (NO 244 178) at Newburgh. The quarry proved to be andesite, similar to the rock type previously seen, badly faulted, making quarrying difficult. Geikie in his survey suggested this was a thin lava flow, but Mr Brown inclined to the view that it was part of a large lava pool extending over to Wormit. There was some mineralisation along fault lines, especially malachite. One unusual feature of the quarry was its air of organisation; even the tipper lorries were parked with martial precision.

Our tour of North Fife continued with a visit to Cults Hill Quarry (NO 337 084) where we examined the strata above the local equivalent of the Hurlet Limestone of Renfrewshire. Unfortunately it was not our day and few fossils were found. We then were shown the entrance to the nearby mine in the Charleston Station Limestone. In recent years this was the only operating Scottish Limestone mine, the output being used for agricultural use and also, by the Coal Board, as limestone dust to counteract firedamp. Due to fault boundaries, it will soon run out and the company have opened another mine.

Continuing the scenic minor roads we reached Langside Quarry (NO 345 037) near Kennoway. This quarry, within the vent of a volcano, showed clearly the columnar jointing of the basalt and the agglomerate within the neck.

This concluded an excellent day and we returned to Glasgow about 9 p.m. Before reaching the centre we dropped off one of our number. The driver asked her if she had "all her rocks". A voice from the back — fortunately out of earshot of the member — said he should have asked if she had "all her marbles". Sometimes drooked after a geological excursion, many of us have asked ourselves a similar question. But the weather and geology on this outing made us appreciate the enjoyment of it.

FIELD GUIDE TO THE QUATERNARY GEOLOGY OF THE SOUTH-EASTERN PART OF THE LOCH LOMOND BASIN

by J. Rose (Birkbeck College, University of London)

CONTENTS

ABSTRACT

This report summarises the history and relevance of the south-eastern part of the Loch Lomond basin to the establishment of the Loch Lomond Stadial as the last glacial episode in the British Isles. It outlines the Quaternary stratigraphy of the region and gives a brief summary of the local changes in the physical environment since the main Devensian glacial episode. It concludes with detailed descriptions of the field evidence upon which the Loch Lomond Readvance and the history of glaciation, periglaciation, river development and sea-level changes are based.

(A) INTRODUCTION

The short, severe, climatic deterioration that occurred in north-western Europe between 11,000 and 10,000 B.P. is known formally as the Loch Lomond Stadial. It follows a climatic amelioration that is known formally as the Windemere Interstadial (about 13,000-11,000 B.P., Coope and

Pennington, 1977) and followed by the Flandrian Interglacial. The Loch Lomond Stadial represents a period of time when polar waters shifted southwards in the North Atlantic (Ruddiman *et al.*, 1977), permafrost was common in much of northern Britain (Rose, 1975; Watson, 1977) and glaciers formed and expanded in the highland regions of the British Isles and north-western Europe (Lowe *et al.*, 1980). This glacial episode was named the Loch Lomond Readvance by Dr J. B. Simpson (while an officer of the Geological Survey [Institute of Geological Sciences]), as a result of detailed fieldwork in the Forth valley and around the southern shore of Loch Lomond (Simpson, 1928a, 1928b, 1933).

The importance of the event was emphasised by Charlesworth (1955), who designated it Stage M in his review of the "Lateglacial History of the Highlands and Islands of Scotland", but it was Donner (1957), using pollen analysis and standard stratigraphic techniques, who placed it in a wider Quaternary stratigraphy and proposed that the glacial epsiode occurred during Younger *Dryas* Time, which was subsequently dated to 10,800-10,300 ^{14}C yrs B.P. Around Loch Lomond this age was supplied by a radiocarbon date from derived marine shell fragments from the moraine ridge at Drumbeg (Sissons, 1967) and within Scotland as a whole a vast body of work, summarised by Gray and Lowe (1977) and Lowe and Gray (1980), has clearly established the Loch Lomond glacial episode as a roughly synchronous event within the time span 11,000-10,000 ^{14}C yrs B.P. Recently, the episode has been named the Loch Lomond Advance (Sissons, 1977, 1979) on the assumption that ice was absent from Scotland between the main Devensian Glaciation and the Loch Lomond stadial. This is an unfortunate case where the absence of evidence is used as evidence of absence and there is as yet no reason to revise stratigraphic

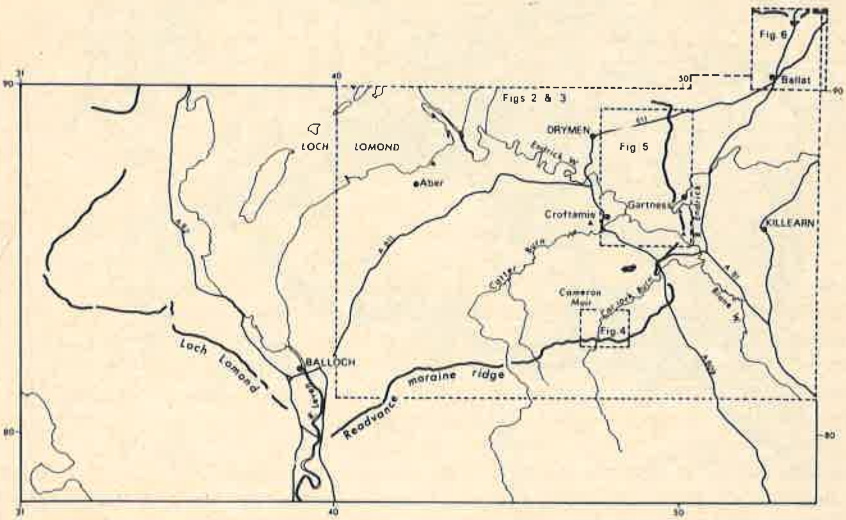


Fig. 1: The Loch Lomond area and the location of sites and maps referred to in text. Scale and orientation are indicated by National Grid co-ordinates.

terms and abandon Simpson's original designation. This field guide is designed to give an outline of the evidence for the Loch Lomond readvance in the type area defined by Simpson and to provide a local study of the glacial, shoreline, lake, and river processes that occured in the area over the last 14,000 years.

(b) QUATERNARY STRATIGRAPHY AND LOCAL PATTERNS OF LANDSCAPE CHANGE

The landforms in the area and the stratigraphic sequence are given in Figure 1, and Table 1, which also includes an interpretation of the contemporary environmental characteristics.

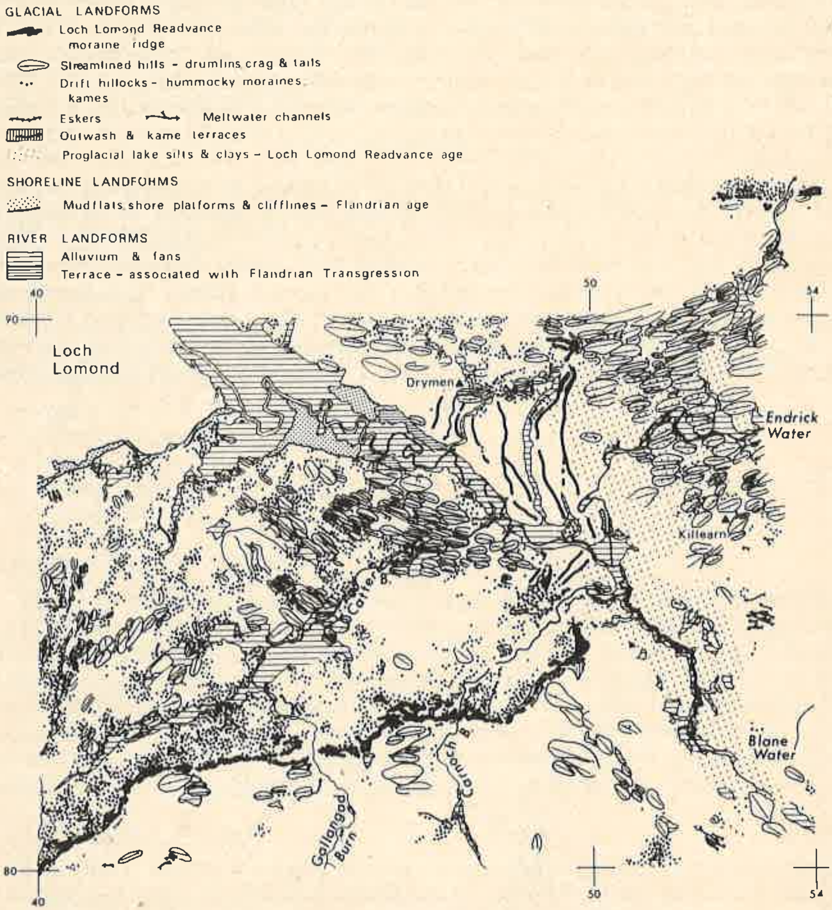


Fig. 2: Geomorphological map of the southeastern part of Loch Lomond basin. The scale and orientation are indicated by National Grid co-ordinates.

For the south-eastern part of the Loch Lomond basin the rapidly changing environments are summarised below and in Figures 3 a-f.

Table 1: Summary of glacial and shoreline events in the region around Loch Lomond and the Clyde Estuary.

Flandrian Interglacial	Beach sediments, shoreline landforms and associated river deposits and terraces.	(b) Raised beaches PG 1-4. Synchronous marine limit inside Loch Lomond Readvance moraine, at about 14m O.D. Marine incursion into Loch Lomond between 6,900-5,450 yrs B.P. Associated deltas in Endrick and Fruin valleys. (a) Relatively low sea-level
10,000 B.P.		
Loch Lomond Readvance	Blane Valley laminated silts and clays	(a) Proglacial lake silts and clays in Endrick/Blane valleys with drainage into N. Sea via Firth of Forth.
	Rhu glacifluvial sands and gravels	(b) Glacifluvial gravels of Loch Lomond Readvance. Associated moraine ridges, eskers, kames, outwash terraces and deltas. (b) Relatively low sea level < 2.3m at Rhu.
	Gartocharn Till	(a) Loch Lomond Readvance till. Often deformation facies. Usually shelly, derived from glacially reworked Clyde Beds. Associated with radiating piedmont lobe of Loch Lomond glacier and valley lobe of Gareloch glacier. Streamlined hills and drumlins formed.
	Main Lateglacial Shoreline	(a) Massive shore platform and rock-cut cliff associated with relatively low sea-level — about 10m at Ardmore.
c. 11,000 B.P.		
Windermere Interstadial	Clyde Beds	(b) Size-laminated or homogeneous estuarine silts, associated with falling sea-level and synchronous shorelines. Rich arctic-boreal marine fauna between 12,700-11,500 yrs B.P. (a) Colour-laminated facies associated with glacial discharge into Clyde estuary. Westward decreasing metachronous marine limit. Initial marine incursion through Lochwinnoch Gap.
c. 12,800 B.P.		
	Gartness gravel, sands and laminated clay	(a) Proglacial lake sediments in Endrick valley — dammed by westward retreating margin of Main Devensian ice.
Main Devensian Glaciation	Wilderness Till	(c) Westward retreat across region and down Clyde estuary. (b) Marine facies formed in Clyde from floating ice margin. (a) NW-SE glacier movement across Dunbartonshire hills and Clyde Estuary. W-E movement across S side of Loch Lomond. Origin of main drumlin field.
?		
?	Helensburgh Till	(a) NE-SW glacier movement across Clyde region from Loch Lomond.

(i) Main Devensian Glaciation

The lithology and fabric of the Wilderness Till, drumlin orientation, and meltwater channel trends (Figure 2) all indicate that during the latter stages of the main Devensian glaciation the regional ice sheet moved west-east across Dumbarton Muir and the south side of Loch Lomond as far as the Campsie Fells where the basal flow was diverted north-eastwards across the Clyde/Forth watershed around Ballat and south-eastwards along the Blane Valley. The drumlins indicate that the zone of basal ice divergence was around Killearn (Figure 3a). The landforms and sediments suggest that the ice remained active during deglaciation and the Gartness laminated clays indicate that temporary proglacial lakes were held up by the ice margin in Blane and Endrick valleys (Figure 3b) (Price, 1975).

(ii) Windermere Interstadial

The presence of Clyde Beds in the Endrick and Blane valleys indicates that the sea drowned the lowlands after deglaciation (Figure 3c). Relationships between ice-wastage and sea-level, established elsewhere in the Clyde estuary (Rose, 1975) show that the marine limit was reached during ice wastage, and that throughout the period of the Windermere Interstadial sea-level fell progressively due to net uplift of the land caused by isostatic rebound.

(iii) Loch Lomond Readvance

The fall of sea-level during the Windermere Interstadial continued during the Loch Lomond Stadial until the formation of the Main Lateglacial shoreline which is well represented along the south side of Loch Lomond by a cliff and shore platform cut across Old Red Sandstone bedrock and Wilderness Till and occasionally buried by Gartocharn Till (Figure 3d). The size of this shoreline landform is attributed to extreme shoreline activity caused by storminess and periglacial processes during the Loch Lomond Stadial (Sissons, 1974).

The readvance of glacier ice into the region is indicated by the Gartocharn Till, which is characterised by marine shell fragments and foraminifera derived from the Clyde Beds, a radiating pattern of drumlins and meltwater channels, and a dense, but irregular, pattern of till hillocks (Figure 2). The limit of the readvance is indicated by a lithologically and morphologically complex, but very well developed moraine ridge (Figure 2). Ice flow across the area was east and south-eastward as part of the piedmont lobe of the Loch Lomond valley glacier (Figure 3e). The presence of this glacier body across the lower part of the Endrick Valley meant that once again a proglacial lake was formed beyond the glacier margin. This time the lake level was controlled by an overflow channel at Ballat (Figure 2) where the drainage of the region was temporarily diverted into the Forth Valley. The Blane Valley laminated silts were laid down as bottom sediments during the formation of this lake. Deglaciation of the Loch Lomond readvance glacier was accompanied by the formation of additional moraine ridges in the Endrick Valley (some of which are of deltaic origin), eskers, kames and meltwater channels in the Cameron Muir and Cattermuir regions, and an ubiquitous scatter of till hillocks. The Blane Valley proglacial lake survived at least until ice wastage east of Drymen. Throughout the Loch Lomond Stadial periglacial processes were effective, as witnessed by ice-wedge development at Old Kilpatrick (Rose,

Fig. 3: Patterns of landscape change around the southeastern part of the Loch Lomond basin. Scale and orientation are indicated by National Grid co-ordinates.

(a) Glacier movement and the formation of Wilderness Till during later stages of the main Devensian ice sheet, about 15,000 yrs B.P.

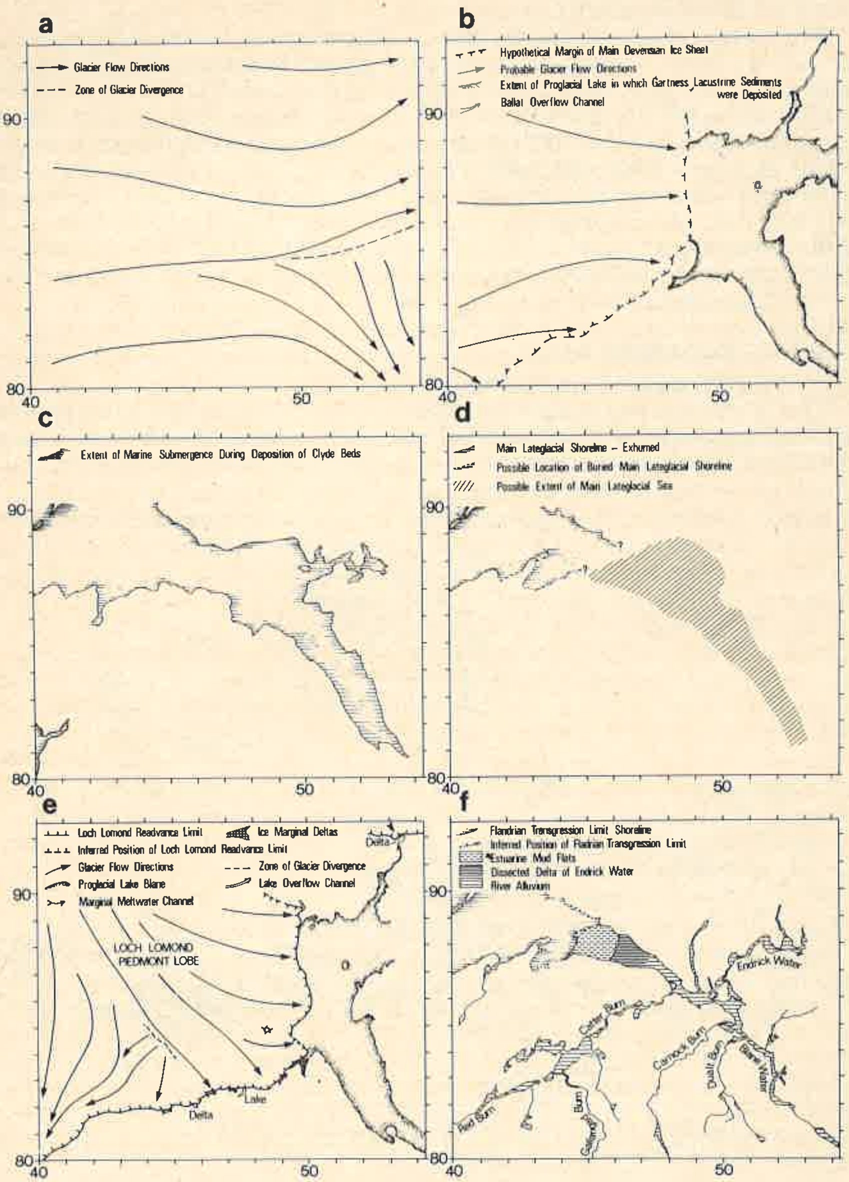
(b) Glacier marginal position and proglacial lake development with the formation of the Gartness lacustrine sediments during the wastage of the main Devensian ice sheet, about 13,000 yrsB.P.

(c) Maximum extent of marine submergence during formation of Clyde Beds about 12,700 ^{14}C yrs B.P.

(d) Position of Main Lateglacial shoreline about 11,000 ^{14}C yrs B.P.

(e) Glacier marginal position and proglacial lake development at the maximum of Loch Lomond Readvance. This phase is associated with the deposition of the Gartocharn Till and the Blane Valley silts. About 10,500 ^{14} yrs B.P.

(f) Maximum extent of marine submergence in Loch Lomond during the Flandrian Interglacial between 6,900 and 5,450 ^{14}C Yrs B.P. This phase is associated with the formation of the Endrick raised delta.



1975) and extensive gelifluction and pro-talus rampart development in the Fruin valley region. In the South East corner of the Loch Lomond basin, the hillside slopes beyond the readvance limit are extensively modified by gelifluction.

(iv) Flandrian Interglacial

Most changes in the region during the period of the Flandrian Interglacial are due to rivers re-modelling the glacial landscape and changes of sea-level leading to shifts in the position of the shoreline. Between about 10,500 and 6,900 ^{14}C yrs B.P., Loch Lomond was a freshwater lake with a level controlled by the drift barrier in the Vale of Leven (Dickson *et al.*, 1978). Between 6,900 and 5,450 ^{14}C yrs B.P. the sea re-entered the Loch Lomond basin, rose to a maximum level of about 12 m O.D., exhumed much of the Main Lateglacial shoreline, and led to the formation of a delta at the mouth of the Endrick. The subsequent relative fall of sea-level due to continued isostatic rebound has resulted in the formation of marine raised shoreline and deltas in the area.

(C) SITE DESCRIPTIONS

(i) Carnock Burn at Cameron Muir

The landforms and sediments at this locality illustrate the behaviour of ice and meltwater in a region where the Loch Lomond Readvance moved up-hill across Cameron Muir across the path of the Carnock Burn.

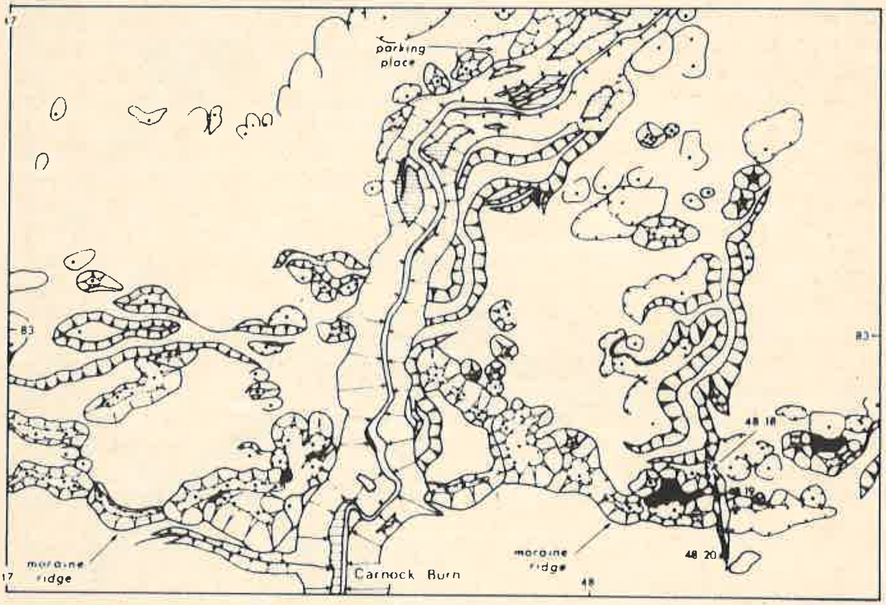


Fig. 4: Geomorphological map of the area of Cameron Muir around Carnock Burn showing the form of the Loch Lomond Readvance moraine and associated landforms. Scale and orientation are indicated by National Grid co-ordinates. Key is given on Figure 6.

This locality can be studied by walking from a parking site at NS 478 834 southwest to the moraine ridge at NS 4710 8272, then eastwards along the moraine ridge to a series of till exposures (NS 482 826), crossing the

Carnock Burn at NS 4761 8268. It is then possible to return to the car park by walking north-northeastwards across the muir and recrossing the Carnock Burn at NS 4777 8338.

The moraine ridge extends east-west in the area as a clearly defined feature about 5-7m high and around 40m wide at the base. Generally, it is a single feature but in the western part of this locality it comprises separate ridges. At the Carnock Burn, it descends into the valley where it locally causes a diversion in the river (NS 4761 8268). Exposures in the feature at sites 48.18 and 48.19 (Figure 4) show that it is composed of a dark reddish brown sandy till (2.5 YR 3/4) with occasional flow banding. Analysis of the orientation of elongate pebbles from this deposit at these sites show that they are arranged parallel with the ridge crest. It is suggested that the moraine ridge was formed by material pushed-up at the glacier margin combined with material that had slumped from the glacier surface. There is little evidence for meltwater playing a part in its development. The macrofabric represents material rolling into a final position of rest. This type of moraine ridge is typical of the Loch Lomond Readvance wherever the ice moved across a hillside slope away from the main drainage routes.

South of the moraine ridge, in the area not overridden by the Loch Lomond Readvance the relief is characterized by a subdued form, in marked contrast to the sharp features formed by the readvance. In particular, till hillocks are rare, and those which do exist (NS 482 826) are low and merge with the regional hillslope. This difference is attributed to accelerated slope movement in the periglacial environment (gelifluction) during the time of the Loch Lomond Readvance. This is supported by the downslope dip of elongate particles at site 48.20 (Figure 4). Analysis of the drumlins and meltwater channels in this area (Figure 2) indicates that ice movement was west-east, virtually at right angles to the movement of the ice during the readvance.

North of the moraine ridge the landscape is characterised by an irregular scatter of till hillocks, thick bodies of till and a large number of small meltwater channels. The till hillocks (often known as hummocky moraine) appear to have been formed by debris being concentrated in depressions on the glacier surface, then let-down onto the land during final ice wastage.

Till is thickest along the line of the Carnock Burn where it infills a rock-cut valley. The contrast either side of the moraine ridge is striking. To the south, the valley is relatively broad, the floodplain is continuous and the valley sides are composed of Old Red Sandstone. To the north the base of the valley is no wider than the stream and till outcrops extensively. In this part also there are terraces where lateral erosion has accompanied sedimentation, and frequent sites where drift filled valleys survive so that the present stream is located in a bedrock gorge (NS 4759 8270 to 4764 8275 and NS 4773 8328 to 4778 8337). This distribution implies that the body of sediment is of Loch Lomond Readvance age and that a much larger valley was formed between the main Devensian ice sheet and the Loch Lomond Readvance than between the latter event and the present time. This can only be explained if the Carnock Burn was used as a major meltwater channel during the wastage of the main Devensian ice.

The meltwater channels associated with the Loch Lomond Readvance form an assemblage that slopes from the west and south towards the north and east. Those in the west indicate meltwater drainage across the route of the present Carnock Burn, where they appear to join a set of channels running sub-parallel with this stream. Together, this group of channels appears to reflect temporary drainage routes until they became fixed along the lowest line of the land where the drainage survived to the present day. The meltwater channels in the east of the area are similar, but are of additional interest in that there are small hills of sand and gravel at their lower ends probably formed of material that was eroded from, or transported through, the channel. The western and eastern channels are located at a position on the hillside without a subaerial catchment and appear therefore to have been eroded by meltwater draining from the ice. The channels just east of Carnock Burn appear to have taken runoff from the Carnock catchment where it was obstructed by the ice blocking the valley. Because of the elevation of these channels some 25m above the valley bottom there must have been a small lake beyond the ice margin but no additional evidence has been found to support this. All these channels reflect subglacial drainage routes towards the lower snout of the Loch Lomond glacier in the area between Knockinhaglish Hill and Craighat (Figure 1) and ultimately proglacial Lake Blane.

(ii) Croftamie (NS 4727 8618)

This site provides evidence for two glacial episodes separated by non-glacial conditions. As long ago as 1858 the Royal Physical Society of Edinburgh included a report by James Macfarlane which described 2.1m (7ft) of blue clay overlain by up to 4.3m (14ft) of stiff till. Marine shells and a reindeer antler collected from the junction between, or close to, the blue clay and underlying Old Red Sandstone gave the site particular significance and it was used as evidence for a former marine submergence. Its importance was reviewed by Archibald Geikie in his paper "On the phenomena of the glacial drift of Scotland" (1863, pp 70-71), and considered in its regional context by Jack (1876), who suggested, in addition, that the upper till contained broken and striated fragments of marine shells (p 16) and considered that the site provided evidence for an interglacial, followed by a marine submergence and an advance of the glacier from the Loch Lomond basin (p 16). With the use of the abandoned railway line at Croftamie, for the water pipeline from Loch Lomond, this site has been re-excavated and elements of the stratigraphy once more can be observed.

The site is located just east of the railway bridge near Pirniehall on the road between Croftamie and Kilmaronoch Church. The section is on the north side of the cutting and is located just below the crest-line of a drumlin formed during the Loch Lomond Readvance. The surface elevation is 37m and the elevation of the base of the blue clay is about 30m. The stratigraphy is given in Table 2.

At the site the Wilderness Till has a high proportion of locally derived clasts with a relatively angular shape suggesting local entrainment and genesis as a deformation till. The felted organic detritus contains pollen grains (J. J. Lowe, pers. comm.) which reflect an environment dominated

Table 2: Sedimentary properties of Pleistocene deposits at Croftamie.

Lithology	Thickness	Moist Colour	Particle Size Distribution				Lithological Properties		
							8-32mm		500-64μm
			% G.	% S.	% Z.	% C.	% Highland	% ORS	Forams n/kg
Gartocharn Till	up to 5m	5 YR 4/3	24.7	24.1	36.3	14.9	4.4*1	94.7	552
Blane Valley Laminated Silts	up to 0.4m	7.5 YR 4/3	0.0	2.1	35.0	62.9	—	—	17
Felted Organic Detritus	up to 0.01m		—	—	—	—	—	—	
Wilderness Till	up to 1.5m	2.5 YR 3/4	60.9	20.0	15.8	3.3	0.0*2	100.0	0
Old Red Sandstone									

*1 Marine shells also comprise some of the erratic suite in the fraction smaller than 8mm.
*2 Rocks from the Highland province are included in the erratic suite in the fraction smaller than 8mm.

by grasses and small herbs with a small representation of *Artemisia, Valeriana,* and *Selaginella.* The assemblage is typically Devensian Late-glacial and may possibly indicate the effects of frost disturbed ground. The laminated clay has a diatactic structure (Sauramo, 1923) indicating deposition in freshwater, most probably, in view of the size range, as annual rhythmites (varves). The sediment is truncated, but if this is the case at least 50 years are represented. The marine foraminifera in the deposit are considered to be derived from the Clyde Beds. The Gartocharn Till is the material of which the drumlins in the region are formed. It contains a macrofabric with a northwest-southeast trend roughly parallel with the drumlins. The foraminifera and high silt component reflect the entrainment of Clyde Beds during the formation of this till. The position of the till indicates that there is no possibility of post-formational emplacement (Dickson *et al.*, 1976).

The main Devensian glaciation is indicated by the Wilderness Till and consisted of a southeast-northwest direction of ice movement in the area. Following deglaciation the land was colonised predominantly by grasses and herbs and the detritus from these was washed into a depression where they were preserved, along with the reindeer antler. These were then buried by laminated clays that were deposited on the base of the proglacial lake that formed as the Loch Lomond ice dammed the Endrick Valley. The significance of the marine shells recorded by Macfarlane is difficult to ascertain because there is no marine deposit at present exposed with which they can be associated. It is most probable that they reflect the Clyde Beds as they are typical of the fauna and are within the province and height-range of the deposit. Finally, the Loch Lomond Readvance overrode the site and deposited the Gartocharn Till, and the drumlin bedform landscape. The absence of Blane Valley silts from above the Till in the region indicates that the ice dam across the Endrick had ceased to be effective by the time this area was finally deglacierized.

(iii) Gartness

A series of sections are exposed in the region of Gartness where the Endrick Water cuts into (site 48.6, NS 498 864) and through (site 48.240, NS 4998 8594) the Loch Lomond Readvance moraine ridge (48.6 and 48.240, Figure 5). The sections provide evidence for the main Devensian glaciation followed by proglacial lake sedimentation; marine submergence with the deposition of Clyde Beds, and finally the Loch Lomond glacier readvance and associated proglacial lake development. The site also provides evidence for subaqueous moraine ridge formation and the changing courses of the river Endrick.

The stratigraphy recorded at these sites will be considered in chronological order. The sedimentary properties of the lithological units are given in Table 3, and additional information about the site is given in Jardine (1980, pp 44-49). It should be noted that the sediments on the ice proximal side of the moraine ridge (west) are glacitectonically disturbed, whereas those on the distal side are unmodified.

Table 3: Sedimentary properties of Pleistocene deposits at Gartness.

Lithology	Thickness	Moist Colour[1]	Particle Size Distribution[2]				Lithological Properties			
							8-32mm			500-64μm
			% G.	% S.	% Z.	% C.	% Highland	%ORS	%Volcanic	Forams n/kg
Gartocharn Till[3]	> 15m	5 YR 3/2	6.6	18.4	57.8	17.2	21.6	76.0	0.6	276.9
Gartness Sands	up to 0.4m	—	0.5	99.1	0.4	0.0	—	—	—	—
Wilderness Till	up to 3m	— 5 YR 3/3	31.8	26.7	33.8	7.7	6.0	93.0	1.0	0

[1] Munsell colour

[2] Percentage gravel, sand, silt and clay are grouped according to $\rhd -1\Phi$, -1Φ to $+4\Phi$, $+4\Phi$ to $+9\Phi$ and $\lhd +9\Phi$ size ranges respectively.

[3] Mean of two samples.

Wilderness Till forms the basal deposit outcropping on the river bank at the distal side of the moraine ridge (NS 4993 8650). It is a stiff, reddish brown till with well-developed glacially shaped clasts (Boulton, 1978) and a southwest-northeast preferred orientation. This sediment forms the drumlins which are well developed east of the moraine ridge, and was deposited by the main Devensian ice which moved northeastwards across the region towards the Forth Valley.

The surface of the Wilderness Till is eroded and covered by a scatter of stones, followed by a well sorted sand and finely laminated clays. These sediments are taken to represent fresh water lake deposits beginning with a lag facies produced by erosion of the till, followed by a shallow water sand and terminating with a relatively deep-water suspension fraction. The precise sorting and the high clay fraction of the laminations is typical of annual rhythmites (diatactic varves; Sauramo, 1923), while the valley configuration is such that a lake could only have been formed by an ice dam. Over 100 individual rhythms have been counted. The Gartness Gravels, Sands and Laminated Clays are considered, therefore, to have formed in a period of at least 100 years in a proglacial lake during the westward retreat of the margin of the main Devensian ice sheet.

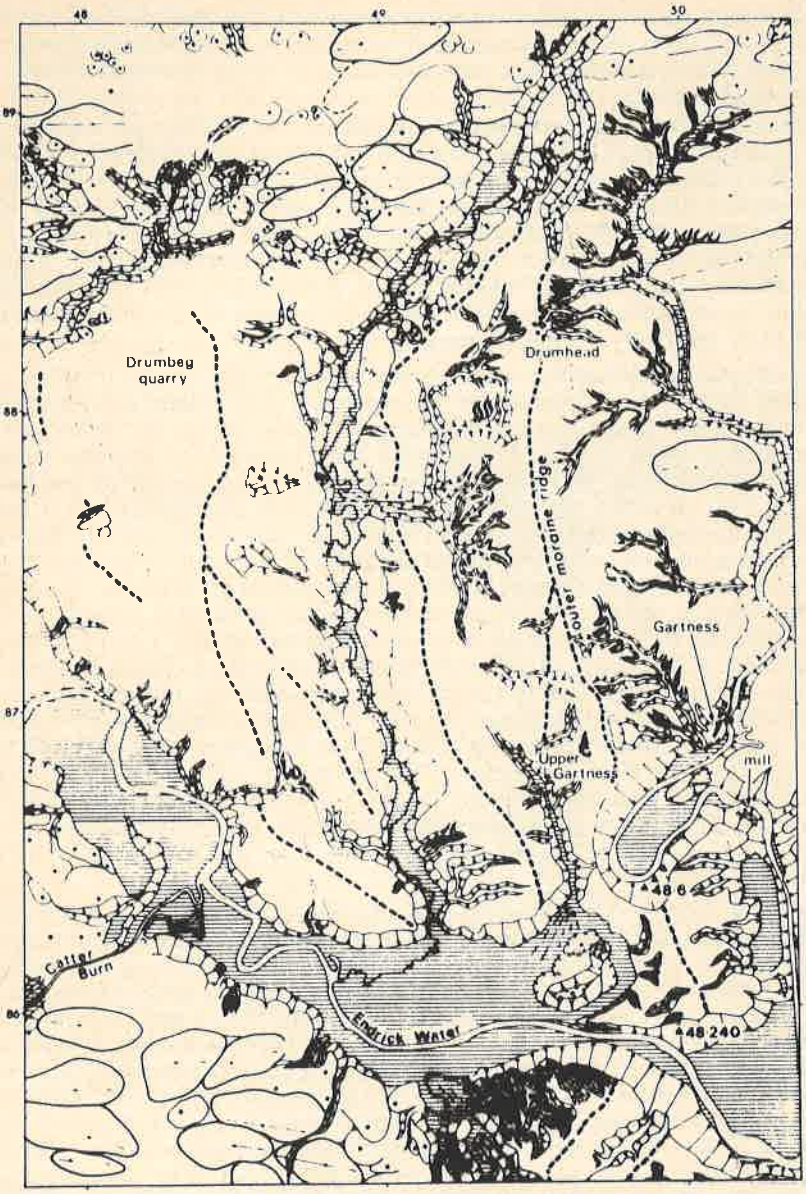


Fig. 5: Geomorphological map of the Gartness area showing the subaqueous moraine ridges, small dry gullies that dissect the ridge and the valley of the Endrick. North of Drumhead the moraine ridge was formed in a terrestrial environment. Scale and orientation are indicated by National Grid co-ordinates. Key is given on Figure 6.

The Gartness laminated clays are overlain by Clyde Beds, which consist of pink and grey silt laminations with a marine microfauna. They represent the marine incursion into the Loch Lomond basin during the Windermere Interstadial.

The Clyde Beds change from an undeformed to a deformed state from the distal to the proximal side of the moraine ridge. At the proximal side, they are sufficiently mixed with glacifluvial sand and gravel to be called a deformation till facies of the Gartocharn Formation. As such it typifies this sedimentary unit with a high silt fraction and a large foraminifera content, and reflects the action of the Loch Lomond Readvance ice which entrained Clyde Beds as it moved across the lower parts of the region. Within the moraine ridge the Gartocharn Till is associated with a radiating pattern of relatively small drumlins.

The Blane Valley laminated silts form the uppermost sedimentary unit in the area. East of the moraine ridge this material forms extensive terraces in the Endrick and Blane Valleys and drapes the drumlins on the valley sides up to an elevation of 65m. It forms the main body of the moraine ridge itself in the region of the Endrick valley bottom and has a consistent elevation of 65m. West of the moraine ridge it is less continuous but is still extensive in undissected depressions. This unit consists of pink and brown silt laminations, but in the region of the proximal side of the moraine ridge it becomes coarser with frequent clasts and abundant evidence of shearing. On the basis of these sedimentary properties and altitudinal distribution it is considered to have formed in a lake dammed by the Loch Lomond Readvance glacier, with the greatest thickness deposited closest to the ice margin. The sediment west of the moraine ridge indicates that the lake survived after the ice had retreated from its limit at Gartness, but the upper elevation of 65m indicates that at all stages the lake level was controlled by the spillway at Ballat (see below). No shorelines have been discovered associated with this lake despite the vast body of suspended sediment deposited. The source of the suspended sediment appears to be reworked Clyde Beds, washed out of the Loch Lomond basin and the lower Endrick Valley.

Between Finnich (NS 497 854) and Drumhead (NS 496 825) where the Loch Lomond Readvance moraine ridge is composed of Blane Valley silts it formed in a subaqueous location. The effects of the oscillating ice margin on the proximal side can clearly be seen by interdigitating sheared and non-sheared units. Above 65m the ice margin grounded and the moraine ridge changes its form to a gravel ridge, where there is a ready source of sand and gravel as at Drumhead, or to a till ridge such as on the hillside as at Upper Blairmore (NS 496 894). With the retreat from the moraine at Gartness a succession of five further ridges were constructed across the Endrick Valley. These have similar composition and also appear to have been formed in a subaqueous position, a fact supported by partial burial beneath the Blane Valley silts and the deltaic origin of a segment of moraine ridge at Drumbeg (NS 483 880). Each ridge is considered to represent a standstill in the margin of the Loch Lomond glacier in a region of rapid sedimentation. When the ice finally retreated from the westernmost ridge the lake drained across the area at the lowest elevation and the Endrick re-established a route to Loch Lomond.

The conspicuous meander of the Endrick is located along the line of the sub-drift valley just north of the rockhead valley side which is exposed at Gartness Mill (NS 502 866) (this is the origin of the waterfall at this location), and along the river either side of Gartness Bridge. The development of the meander reflects the relative ease of erosion into the unconsolidated deposits and it will not be very long, in the geological time-scale, before the Endrick completely breaches the moraine ridge. As the river level is some 13m higher on the east side of the moraine than the west, permanent diversion will occur and the section from Gartness Mill to the junction with the Blane will be abandoned.

(iv) Ballat/Stoneyacre (NS 527 907-NS 537 923)

This site was not included in the field excursion. It is included here because it completes the evidence for the development of Lake Blane.

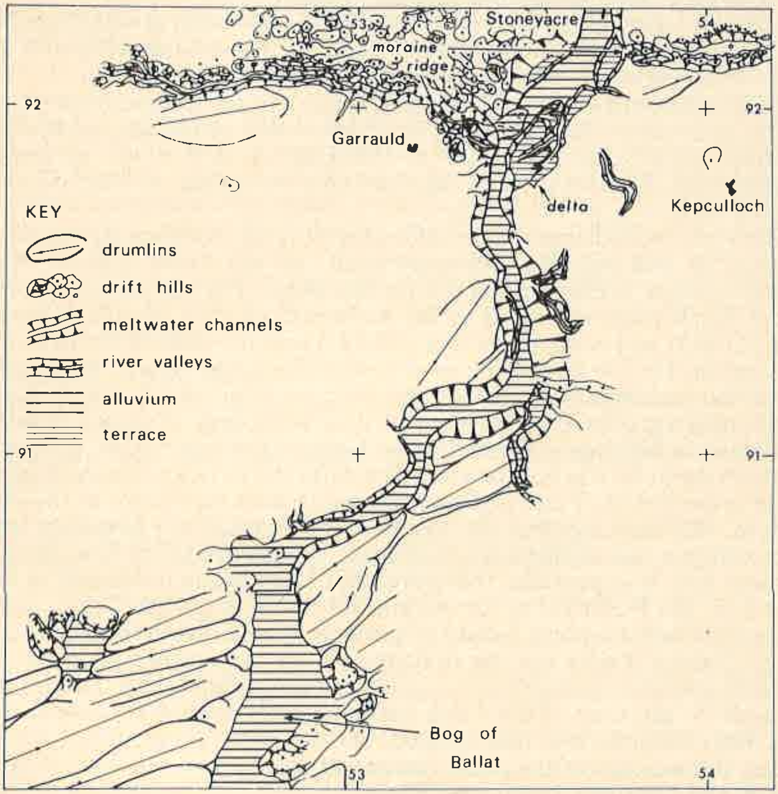


Fig. 6: Geomorphological map of the Ballat-Stoneyacre area showing the meltwater channel and delta related to the drainage of the proglacial Lake Blane. The map also shows a section of the moraine ridge formed by the Forth valley glacier during the Loch Lomond stadial. Scale and orientation are indicated by National Grid co-ordinates.

The area between Ballat and Stoneyacre is the lowest part of the Endrick/Forth watershed. It is underlain by red-brown Wilderness Till with occasional outcrops of Old Red Sandstone. The relief consists of southwest-northeast trending drumlins formed by the main Devensian ice sheet with occasional till hillocks in the intervening depressions. A meltwater channel follows the lowest lie of the land from Ballat to Stoneyacre, and within this channel, just east of Garrauld (NS 535 919) a delta is developed, composed of at least 4m of sand and gravel (Figure 6). The meltwater channel originates on the Endrick side of the watershed at a peat filled depression known as the Bog of Ballat (NS 5290), crosses the watershed, with a channel elevation of about 64m, then slopes northwards into the Forth Valley. This channel is considered to have formed as an overflow from Lake Blane during the Loch Lomond Readvance for the following reasons:

(i) it is located at the lowest col beyond the Loch Lomond Readvance moraine ridge across the Endrick Valley;

(ii) the elevation of the col coincides with the elevation at which the Loch Lomond Readvance moraine ridge at Drumhead (NS 496 825) changes from a subaqueous to a subaerial origin;

(iii) the sediments deposited in Lake Blane do not exceed 65m.

This meltwater channel provides evidence that at the time of the Loch Lomond Readvance the water of the Endrick and Blane catchments drained into the Forth Valley and not into the Clyde, as they do at the present time.

The meltwater channel and delta also provide evidence by which it is possible to establish the contemporaneity of the Loch Lomond Readvance ice lobes in the Forth and Endrick valleys. The lateral moraine ridge of the Forth valley dissected by the meltwater channel between Garrauld (NS 533 919) and Stoneyacre (NS 538 921) and the delta is located in the channel on the ice-distal side of this moraine ridge. These relationships mean that meltwater first eroded the moraine ridge and flowed under the Forth valley glacier. The ice then formed something of a dam causing a small lake to build up in the meltwater channel just beyond the ice margin, in which the delta was constructed. The delta shows two surfaces separated by an erosional bluff and is dissected on the west side down to the valley bottom. This indicates that the lake formed two relatively persistent levels, after which it was drained and meltwater re-established its flow along the channel bed. It is possible, therefore, that Lake Blane continued in existence after the Forth Valley ice margin had begun to retreat. Only when the glacier in Loch Lomond ceased to provide an effective barrier across the lower Endrick Valley did the drainage of this area return to the Clyde.

Although the interpretation given above relates, on stratigraphic grounds, to the time of the Loch Lomond Readvance it is likely that the meltwater channel was first formed, for the same geographical reasons, during the wastage of the main Devensian ice sheet at the time of formation of the Gartness Laminated Clays.

(v) Aber

This is a convenient site to examine the form of the raised shore platform and cliffline that are so well developed along the south shore of Loch Lomond. There are also exposures of Clyde Beds (NS 4268 8772). Access can be obtained through the Loch Lomond National Nature Reserve (NS 4272 8774) via the private road to Gartochraggan.

The relief in the area is small till hillocks overlying Old Red Sandstone sandstones and marls, and the contemporary alluvial plain of the Endrick delta. The present shoreline of Loch Lomond in the area has a notch with an elevation of 9.3m O.D. and consists of a cliff up to 4m high cut into the glacial landscape composed of Clyde Beds overlain by Gartocharn Till (NS 4255 8769), and a small cliff up to 0.4m high east of NS 4265 8770 cut into a raised shore platform underlain by Clyde Beds and sandstone. This raised shore platform is up to 40m wide and is associated with a rock-cut cliff up to 6m high with a notch at a mean duration of 11.9m O.D.

Taken by itself, this evidence indicates a marine incursion during which the Clyde Beds were deposited followed by a period of effective shoreline activity and the erosion of the raised rock-cut platform and cliff. The place of these events in the marine and lacustrine history of Loch Lomond can only be deduced from elsewhere (Dickson *et al.,* 1978). In summary, the Clyde Beds represent the deposits of the high Lateglacial sea-level following the main Devensian deglaciation, and the raised shoreline originated as the Main Lateglacial shoreline sometime before the ice of the Loch Lomond Readvance overrode the area. The story is complicated by the fact that this rock-cut cliffline was re-excavated by the sea when the Flandrian transgression invaded Loch Lomond between 6,900 and 5,450 ^{14}C years B.P. It was at this time that the fossil-raised delta of the Endrick around Kilmaronoch (Figure 3h) was formed. The present level of the Loch, to which the present alluvium and delta of the Endrick are related is controlled by the barrier of drift in Loch Lomond aided by the Leven Barrage at Balloch.

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THE LATE ORDOVICIAN LADY BURN STARFISH BEDS OF GIRVAN

by D. A. T. Harper

Exquisitely preserved and profuse shelly faunas have been known for close on a century from sandstones east of South Threave on the south bank of the Lady Burn, NS 250 038 (Fig. 1b). These rocks, the Lady Burn Starfish Beds, occur near the summit of the Drummuck Group in the Craighead inlier, north of the Girvan Valley. Over the years extensive collections from these horizons have featured in many detailed studies of Ordovician fossils. But in recent years these unusual beds have been hidden beneath rubble and soil. During a recent reassessment of the late Ordovician Upper Ardmillan brachiopods by the author, a number of exceptionally fossiliferous sandstone units were located, by mechanical digging at the type locality for the Starfish Beds. This report documents the excavations for these beds and records details of the currently exposed locality. The help of Dr J. K. Ingham throughout this and the broader aspects of the study was invaluable and is gratefully acknowledged; Professor A. D. Wright gave much advice during the research. All the author's research collections will be housed in the Hunterian Museum, University of Glasgow, in due course.

Some controversy still exists concerning the environmental setting of the Lady Burn Starfish Beds. It is fairly certain that the middle and upper Ordovician rocks of the Girvan district were deposited on the slopes of an unstable submarine fan on the south-edge of the North American Plate (Ingham 1978); to the south lay the Iapetus Ocean and an active subduction trench (McKerrow *et al.* 1977). The majority of the benthonic faunas e.g. the brachiopods (Harper 1979) have been subjected to, often considerable, downslope transport. However Goldring and Stephenson (1972), in

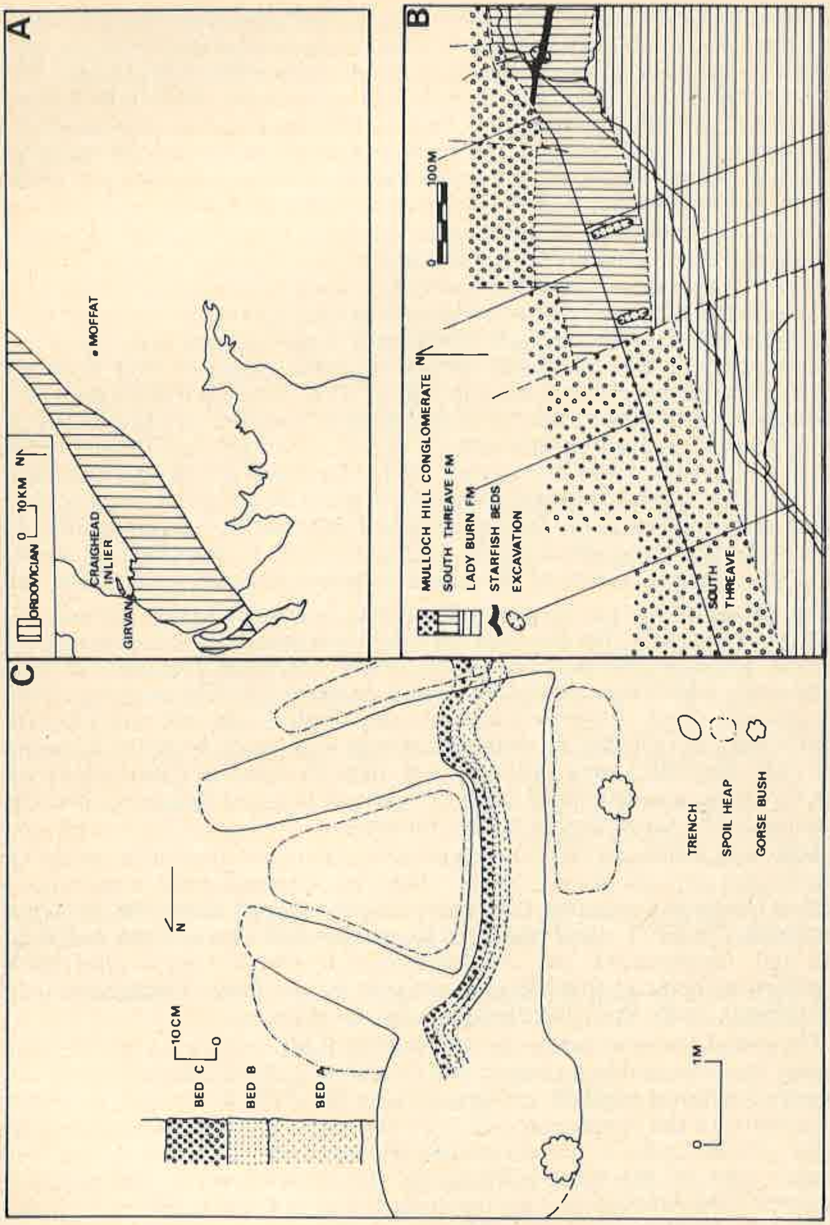

Fig. 1a: Location map of the Craighead inlier; Ordovician inliers of the Central Belt and granites of the Southern Uplands are omitted.

a recent study of certain "Starfish beds", concluded that the abundance and excellence of preservation of the faunas were due to their rapid entombment in a turbulent, shallow water environment. But there is no strong evidence to deny that burial occurred during sudden downslope movement of both sediment and faunas. This mode of formation is more consistent with the presence of shelf and slope faunas in the beds, the nature of the rocks above and below and the presumed geological setting of the middle and upper Ordovician succession at Girvan.

Professor Lapworth in his classic account of the Girvan succession mentioned the occurrence of a fossiliferous, highly calcerous, hard, greenish-grey sandstone bed a few inches thick, immediately beneath the poorly fossiliferous soft, blue mudstones at the head of the Lady Burn. He reported that the fossiliferous sandstones were located principally in a quarry but it is by no means certain from his narrative that Lapworth encountered these rocks *in situ* (op. cit., p. 619). This is partly supported by correspondence in the archives of the British Museum of Natural History brought to the author's attention by Mr R. P. Tripp. In a letter to Professor Lapworth, dated November 1898, Mrs Gray stated that the family had found a Starfish bed with beautifully preserved fossils; in reply, Lapworth confirmed that his best specimens from this horizon were obtained from walls in the neighbourhood of Quarrel Hill. Understandably he was most interested to learn of the exact location of the family's find. Miss Alice Gray in written comments on this correspondence, dated 1938, expressed the view that the Gray family's bed and that of Lapworth were not the same. In this part of the succession there are a number of sandstone units which were probably locally quarried for field boundary walls; the present study, however, suggests that both Lapworth and the Gray family were in fact dealing with sandstones and fossils from the same bed but that the latter was probably the first to discover the bed *in situ*. Nevertheless, exceptionally large collections resulted from the relentless activity of the Gray family at this locality.

Although Lamont (1935) is responsible for the definitive study of the Drummuck Group, it was Begg (1946) who documented a number of further fossiliferous units at the classic locality. Begg's classification, which comprises "beds" 1, 1a, 2 and 3, neglects the thickness of each individual unit and, furthermore, one is uncertain as to whether he is referring to fossiliferous beds or fossiliferous horizons within beds. Therefore during the present study this classification was not pursued.

The initial attempts to locate the Starfish Beds at the type locality were largely unsuccessful but a number of fossiliferous horizons uncovered with a pick and shovel yielded well-preserved and relatively complete trilobite specimens. In the summer of 1977 two trenches, dug perpendicular to the strike of the beds, were excavated by mechanical digger in the field directly east of the farm buildings at South Threave; it was hoped to encounter the Starfish and similar beds lower in the succession here. But although a number of new fossiliferous localities were established (see Fig. 1b) and certain stratigraphical problems solved, no exceptionally fossiliferous strata were found.

The following year Mr Hyslop of Lendalfoot agreed to try and drive his JCB across the western part of Quarrel Hill from Farden to the Starfish Beds locality; this site is virtually inaccessible to motor vehicles. A trench was first dug at the depression marking the original locality; two further trenches were then dug perpendicular to the strike of the beds (Fig. 1b). Three fossiliferous sandstone beds were located *in situ* within a sequence of locally fossiliferous mudstones and siltstones. The lowest of the sandstone beds (see Fig. 1c, Bed A) is very fossiliferous with abundant representatives of the brachiopods, trilobites, echinoderms and molluscs particularly concentrated in the top part of the bed. The middle sandstone is less fossiliferous although inarticulate brachiopods are not uncommon. Bed C is not quite as rich in fossils as Bed A but is nonetheless characterised by abundant shelly faunas. The lowest bed is assumed to correspond to the original Starfish Bed; the lithologies and faunas are virtually identical to those in museum collections. Preliminary studies on the overall faunal compositions of each bed suggest that they may have been deposited under slightly different conditions with sediment and animals entrained from adjacent sites on the sea floor.

Apart from the abundance of fossils, particularly in Beds A and C, the excellence of preservation of the faunas is quite unusual. Much of the fossil material is complete; brachiopods are often found conjoined and trilobites articulated. Breakage and abrasion of the material is negligible. Lenses of shell debris and commonly small disarticulated specimens occur throughout both the sandstone beds and surrounding mudstones and siltstones; orientated graptolites also occur, particularly at horizons in Bed C.

The age of these beds is late Rawtheyan (Ingham 1978); this assessment is based upon the rich trilobite fauna known from this locality. At present, British and Irish Ashgill trilobites are better documented than the other elements of late Ordovician faunas and this is reflected to some extent in their widespread stratigraphical use. But although certain aspects of this fauna have been recently redescribed, the trilobites as a whole are in need of revision. Similarly the mollusc, echinoderm and hyolith faunas would benefit from a reassessment in more modern terms whilst a significant vertebrate fauna has been recently recorded from Bed A (Harper 1979a). The brachiopods form the subject of a forthcoming monograph by the author.

The abundance and diversity of the faunas of the Starfish Beds together with the unequal distribution of information on the fossil groups represented make a succinct and unbiased summary of the faunal composition of the locality difficult; brachiopods and trilobites, however, numerically dominate the faunas. The plectambonitacean *Eochonetes advena* (Reed) and the orthids *Plaesiomys porcata* (M'Coy) *and Schizophorella aff fallax* (M'Coy) are particularly common whilst *Nicolella asteroidea* (Reed), *Glyptorthis speciosa* (Reed), *Salopina drummuckensis* (Reed), *Sampo ruralis* (Reed), *Sowerbyella thraivensis* (Reed), *Strophomena valens* (Reed), *Leptaena rugosa* (Dalman) and *Cyclospira girvanensis* (Reed) are fairly well represented. Trilobites are particularly abundant; representatives of the calymenids, cheirurids, proetids and raphiophorids are important constituents of the fauna while the trinucleids *Tretaspis sortita* (Reed) and *Cryptolithus praeterita* (Reed) are quite common. Graptolites are represented by species of *Orthograptus* at a few horizons. Gastropods, particularly bellerophontaceans occur throughout the section and may locally dominate the very rich shelly fauna.

Although the classic locality lies in the grounds of Farden Farm, it is on the edge of rough pasture and is sufficiently remote to allow collecting without causing inconvenience to the farm, providing due consideration is exercised. Access is through South Threave Farm (see fig. 1b) and Mr Andrew is happy to grant permission to individuals and small groups to walk up the Lady Burn to the locality. The site is a protected areas of scientific interest and should therefore not be damaged. Excellent specimens may be obtained from the extensive spoil heaps around the trenches. The staff of the Hunterian Museum will gladly assist with identification of material, but both part and counterpart of each specimen must be collected if possible.

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THE COMPOSITE INTRUSIONS OF BENNAN, ARRAN; A FURTHER NOTE.

by A. Herriot

In the Proceedings of the Society for Sessions 111 and 112 information additional to that contained in the Arran Memoir of 1928 regarding the Bennan intrusions, was given by the writer.* The possibility that a feeder to these bodies could be traced was put forward. At that time, the quartz-dolerite body shown on the official geological map in the Kilmory Water north-west of Torr Dubh Beag had not been examined by the writer. This omission has since been rectified. An interesting section was found in the stream on and near a small island (Grid Ref. NR 980 236). Here, a short distance downstream of the island and in the vicinity of an old footbridge, a rather dark granophyric dolerite with numerous xenocrysts of quartz and plagioclase and scarce basaltic xenoliths, occurs. This is followed upstream, and just below the island, by a 3 metre band of igneous breccia composed of angular blocks and fragments of dolerite, with xenocrysts and xenoliths, in a matrix of light-weathering acid rock. Next comes 9 metres of highly xenocrystic dolerite, then 6 metres of igneous breccia which has, on its eastern side, a sharp contact, striking 160°, against 1.5 metres of quartz-feldspar-porphyry. Light-coloured porphyry with xenoliths follows, merging into xenocrystic dolerite at the upstream end of the island. The relatively light colour of the dolerites here and farther upstream, is due to the almost complete replacement of pyroxene by carbonate. The attitude of this banded complex is essentially vertical, with NNW-SSE strike.

Upstream of the island, pale dolerite with xenoliths and xenocrysts, gives way gradually to more normal dark dolerite, which often bears xenoliths, seen around 150 metres from the island. Further upstream pale dolerite comes on again. The attitude of these rocks has not been made out.

Reference to the geological map shows that the banded complex here described strikes towards the composite 'dyke' south of Torr Dubh Beag. Both are vertical, but the former lacks the symmetry of the latter. Nevertheless, it seems not unlikely that these bodies connect beneath the main porphyry as a continuation of the feeder postulated in 1972.

The small body which lies between the Kilmory Water and the porphyry south-west of Auchareoch is composed of analcime-olivine-gabbro, and not quartz-dolerite as shown on the official map. It, together with the Torran Gaothar sill (the NNE-SSW intrusion lying between Torr a' Bheannean and Torr Dubh Beag) are possibly detached portions of the big Auchareoch intrusion of analcime-olivine-gabbro.

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