THE EDINBURGH GEOLOGIST

The cover illustration of the Edinburgh volcano is taken from the Geological Museum booklet on Volcanoes with permission of the Director of the Institute of Geological Sciences and of Aerofilms Ltd.

MARCH 1977

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The idea of having an informal publication such as this was greeted with enthusiasm by many members of the Edinburgh Geological Society, both professional geologists and amateur members. Thanks to the help of Dr. Mykura, Dr. Clarkson and Mr. Butcher, this first issue is now in print.

I hope that the Edinburgh Geologist will serve at least three purposes -

- to provide the amateur members with articles written at an appropriate level by the professional geologist; also news of current geological research.
- to allow the amateur members to write about their own particular interests in geology either in articles or short notes on specific topics.
- to serve as a general information bulletin in which special meetings, exhibitions, publications and social events may be announced.

There is no point in setting a specific format at this stage, for the issues will vary depending on the material available, but I hope that a balance can be maintained between the different aspects of geology and also between amateur and professional contributions. Some features which I should like to see established are : book reviews, reviews of current geological research of general interest, and perhaps a section in which amateur members may pose questions for the 'experts' to answer.

The success of the Edinburgh Geologist will depend on the willingness of members to write for it. I am looking forward to receiving articles, notes, news or questions from members, and anyone who would like to discuss a potential topic is most welcome to 'phone or write to me. I would also like to hear from anyone who has ideas about how this magazine should evolve, or general suggestions as to what it should cover in future.

I hope you will enjoy reading the articles in this first issue.

EDITOR : Helena Butler,
49, West Savile Terrace,
Edinburgh. Tel. 667-3006.

ARDNAMURCHAN GUIDE

In the first three months since it appeared, the Ardnamurchan Guide has already sold well over 300 copies.

The 120 page guide is of a useful pocket size with a plastic laminated cover and rounded corners. In addition to 16 maps and diagrams, it has a folded plastic laminated colour geological map in a pocket at the back. This map is also available separately, flat or folded (50p. to members, 60p. to others).

Available from - Mr. I. Bunyan,
Publication Sales Officer,
c/o The Royal Scottish Museum,
Chambers Street,
Edinburgh EH1 1JF.

Cost - Guide - £1.33 (members - 1 copy only)
Map - 50 p. (members-specify flat or folded copy)

POSTAGE EXTRA

(A list of other publications available is included at the back)

DALRADIAN GUIDES

The second part of the Scottish Journal for 1977 is being devoted to the publication of a series of field guides to the South-West Highlands. There will be seven guides as well as an introductory article reviewing the geology of the area.

The South-West Highlands contain many classical sections through the Dalradian and as such have been the subject of a considerable amount of recent work. Nevertheless geologists visiting the area found it difficult to locate many of the more interesting exposures. It is hoped that the production of these guides, all of which were invited from recent research workers in the field, will remedy this situation and allow fellows and others visiting the area to enjoy the maximum amount of geology. The guides cover many famous sections, such as the north shore of Loch Leven from the Fort William slide eastwards through the Ballachulish rocks into the Moine, and a profile through the Loch Awe Syncline with its core of Upper Dalradian rocks. There are excursions to the Tayvallich Peninsula with the beautiful exposures of pillow lavas and to Roseneath, Cowal and North Kintyre where the Highland Border structures and lithologies can be seen. In addition, itineraries are given for Jura with its interesting sedimentary structures in the quartzite and also to the islands of Lunga, Luing and Shuna where an examination can be made of the sedimentary environment of the Middle Dalradian rocks.

Each guide contains travel information and a brief account of the local geology as well as the detailed list of localities. The standard is such that the guides should be useful to many geologists both as members of specialist groups or as interested amateurs.

In order to maximise the use of the guides, it is the intention of the Society that the guides should be available, at a reasonable cost, as offprints with a paper cover.

D. FETTES.

MURCHISON HOUSE

The Scottish Headquarters of the Institute of Geological Sciences are now established at Murchison House, at the north-western corner of the King's Buildings complex of the University of Edinburgh, some 300 yards west of the Grant Institute of Geology. The large five floor building was designed to bring together staff from several offices in Edinburgh and from Herstmonceux in Sussex. These staff comprise the Scottish Field Survey and Continental Shelf Units, and the Marine Geophysics, Global Seismology, and Geomagnetism Units. Sections of the Palaeontological and Petrographical departments and of the Mineral Assessment and Computer units are also accommodated. It will be seen that a very wide range of geological work is performed by the staff of Murchison House, including the entire government research effort for Great Britain in marine geophysics, global seismology and geomagnetism.

The Institute is a constituent body of the Natural Environment Research Council, funded by the Department of Education and Science and, increasingly, by certain other government departments on a customer-contractor basis, the Institute being paid for research carried out at the behest of these departments. It is the official national geological agency, incorporating the Geological Survey of Great Britain, founded in 1835, the Museum of Practical Geology in South Kensington, and the Overseas Geological Surveys.

The Geological Survey began working in Scotland in 1854 and was set up on a permanent basis, with the opening of its first office in Edinburgh, in 1867. The Director-General at that time was Sir Roderick Murchison, a most eminent figure in the world of geology and of geographical exploration, and it is appropriate that the first headquarters built for the Geological Survey in Scotland should bear his name. Sir Roderick was also responsible for the establishment in 1871 of a Chair in Geology in the University of Edinburgh, the first in Scotland.

Murchison House will be officially opened on 14th. June, 1977 by Professor Sir Frederick Stewart, Chairman of the Advisory Board for Research Councils, and present incumbent of the Regius Chair at Edinburgh. In association with this occasion the building will be open to visitors on the two succeeding days, when the work of all the resident units will be displayed and demonstrated. Fellows of the Edinburgh Geological Society may attend on these days, under the arrangements to be published later, or they may wish to take advantage of the 'private viewing' which is being organised for the evening of Wednesday 15th. June. Details of this visit will be made known in the excursion circular which will be distributed within the next few weeks. It will be an excellent opportunity, which is unlikely to be repeated for several years, to see the building and the extensive range of geological work performed in Scotland by the Institute, by far the largest organisation in the country for geological research and its application.

D.C.GREIG.

ALKALINE ROCKS

Alkaline rocks can claim justifiably to be the most exotic of all igneous rocks. Their essential characteristic is unusual richness in the alkalis, soda and potash, which are present in quantities greater than required to form the main rock-building minerals in normal igneous rocks - the feldspars. When enough alumina exists to combine with this alkali excess, minerals called feldspathoids, appear : sodalite, nepheline, lapis lazuli etc. With insufficient alumina, highly colourful silicates called riebeckite and aegirine occur. Under special conditions neither alumina nor silica is sufficient, and such conditions also generate an abundance of rare elements, both metals (uranium, copper, tin, zirconium etc.) and volatile non-metals (fluorine, chlorine, sulphur and phorphorus) - all of which are more concentrated in alkaline rocks than in almost any other rocks. The alkalis are able to combine with these to form hundreds of minerals.

Although alkaline rocks are relative rare (only a few percent of igneous rocks), they are easy to find. They abound in rift valleys (e.g. African/Rhine rifts, Oslo/St. Lawrence grabens, Midland Valley of Scotland) where they may build spectacular volcanoes - Kilimanjaro and Mount Kenya, (the highest mountains in Africa) are alkaline and so is Vesuvius.

Their unique rare element enrichment is of vital economic concern : the elements listed above are essential in the energy, pharmaceutical, electronics and television industries. Alkaline rocks also yield large quantities of major industrial minerals such as fluorspar (for steelmaking), corundum (abrasives) as well as important deposits of more common metals such as iron and titanium (aircraft and spacecraft manufacture). Perhaps their most crucial potential is as a source of phosphorus, for agriculture. As world supplies of guano (fossil phosphates) dwindle, the rich phosphatic soils above some alkaline masses may yield the necessary minerals, while massive phosphate ores are already being mined from alkaline rocks in the USSR.

Alkali rocks may be seen closer to home on the face of many city buildings. This particularly beautiful rock is larvikite - dark grey with brilliant blue irridescence - and is a type of nepheline syenite.

Nepheline syenites, one of the most abundant alkali rock-types, have a low melting point for an igneous rock (700°C) and are much in demand as industrial fluxes. As an alternative to felspars, they are also being used as a source of clay for china and porcelain.

Apart from insulating granules and radiation shields, one major use is as a source of alumina. Currently this comes from bauxite, which is a product of rocks weathered in a tropical climate. However, these deposits are being used up and nepheline syenites are a suitable alternative. They contain more alumina than any other igneous rock so their weathered remains are particularly rich in the mineral.

While most other igneous rocks are composed of silicate minerals, the alkaline rock <u>Carbonatite</u> has no silica and is like an igneous "limestone". Indeed there was a long argument as to whether carbonatites were merely remobilised limestones until, in 1960-61, the volcano Ol Doinyo Lengai in Northern Tanzania erupted carbonate lavas with a composition very similar to kitchen washing-soda (sodium carbonate). Unfortunately they were watersoluble and were destroyed by rain and subsequent eruptions before geologists had time to collect more than a few samples.

Ancient carbonatites are not quite so peculiar. They are calcium and magnesium rather than sodium carbonates, but many geologists now believe that ancient carbonatites did originally contain soda which was leached or lost. These elements may have contributed to the formation of the extensive soda-lakes in Rift Valleys which are of major economic and ecological significance. Carbonatites are mined today as a source of calcium in countries lacking ordinary limestones, but they contain prodigious reserves of important metals. The Oka carbonatite, Quebec, carries the world's largest niobium deposit and the Palaborwa carbonatite in South Africa has been yielding enormous quantities of low-grade copper ore. Recently there has been a search for carbonatites in Scotland after the discovery of a characteristic country-rock alteration called fenitisation. It has been found along the Great Glen but so far no carbonatites have been located.

Carbonatites may have a connection with kimberlites, the rocks from which diamonds are mined. Like kimberlites, they are generated very deep in the Earth, at depths of 100km or more. As carbonatites contain about 30% CO_2 , the magmas from which they crystallised must have been very gaseoues, and rising to the surface from such enormous depths they tend to release these gases with explosive violence. Although Ol Doinyo Lengai erupted its washing-soda lavas relatively quietly, the 6,000ft. cone of the volcano otherwise consists entirely of volcanic ash and debris from tremendously powerful eruptions in the past, while ancient carbonatites are commonly associated with large areas of shattered and brecciated country-rocks.

Such shattered rocks weather rather easily, and give rise to deep iron-rich (lateritic) soils overlying many carbonatites, in which their mineral riches are concentrated. Soils over Ugandan carbonatites are rich in phosphorus, over the Norwegian Fen area in iron, and others in manganese, uranium, etc.

Alkaline rocks as a whole, not only carry a greater variety of rocks and minerals than any other group, but also have an economic potential and interest far in excess of their relatively small abundance over the Earth. It is only a pity that in Britain we are so sadly lacking in them !

Further reading -

Allen, J.B. & Charlsey, T.J., 1968, - Nepheline Syenite and Phonolite. H.M.S.O.

Heinrich, E.W., 1966, - The Geology of Carbonatites. Rand McNally, Chicago.

Sorensen, H. (Editor), 1974, - The Alkaline Rocks, Wiley, New York.

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N.M.S. ROCK.

VIDLIN - SCOTLAND'S NEWEST COPPER DISCOVERY

In these days of sinking pounds and rising inflation news of 'home grown' natural resources is particularly welcome. We have, of course, become accustomed to a procession of new oil finds in the North Sea but this should not be allowed to obscure successes in other fields of exploration. During the past decade Scotland has also witnessed a significant upsurge in onshore mineral exploration notably in the field of base metals (e.g. copper, lead, zinc, nickel, molybdenum). This has been motivated principally by the rising cost of imported ores which in conjunction with more efficient mining techniques has resulted in some hitherto uneconomic deposits becoming attractive propositions. Further encouragement is provided by the government in the guise of the Mineral Exploration and Investment Grant Act by which companies undertaking exploration in the United Kingdom could, with certain provisos, recoup up to 35% of their costs.

In 1972 the government established a much closer link with active exploration when the Department of Industry contracted the Institute of Geological Sciences to undertake a reconnaissance search for base metals. In effect, an experienced team of field geologists, geochemists and geophysicists with back-up analytical services was required to locate new occurrences of base metals which, it was hoped, would subsequently attract mining companies. Because this Mineral Reconnaissance Programme appeared at a relatively late stage in Scotland's exploration history it was anticipated that it would be concerned mainly with deposits which were only marginally economic and consequently not immediately attractive to mining companies. Naturally this has meant that some projects have proved disappointing but recently the programme has received a welcome shot in the arm with the announcement of a favourable conclusion to work being carried out at Vidlin, 25 km north of Lerwick, Shetland.

This concerns a 'pyrite bed', discovered by an officer of the Geological Survey as long ago as 1930 but not followed up (largely because it was not of the vein type of mineralisation then being sought) until a research student working with Dr. D. Flinn of Liverpool University noted the additional presence of chalcopyrite and the latter drew the attention of IGS to this. This was significant, for in the intervening years several economically viable 'stratabound' type sulphide ore bodies have been discovered in Scandinavia within schists which, though probably of Silurian age, have nevertheless strong similarities with those of Shetland. Initial geochemical tests carried out by IGS were encouraging and in 1975 a combined geological - geochemical - geophysical investigation was mounted which culminated in the spring of last year in a drilling programme which located a stratabound ore body 500m long and up to 10m thick, with the mineralised samples containing up to 12% copper, 1.7% zinc and 0.23% lead.

When the report on the investigation was published the mineral rights were obtained by a mining company and the result of their continuing exploration will decide whether the deposit is economically viable. The residents of the Vidlin area have the satisfaction of knowing that should the deposit be worked it will be by mining and not by opencast. Despite the as yet unproven viability of Vidlin the discovery of Scandinavian type massive sulphides in Scottish Dalradian rocks has given a considerable boost to other investigations being carried out by IGS in the Grampian Highlands which have located similar 'pyrite beds' but none with sizeable base-metal contents. By analogy with Vidlin it is quite possible that sulphide deposits of economic proportions are present.

In passing, it is interesting to note that the Vidlin mineralisation has several unusual features which distinguish it from most other Scottish copper deposits. In particular it is a stratabound body of pyrrhotitic ore, whilst the majority of Scottish occurrences comprise pyrite vein deposits. However, the most significant aspect of the Vidlin deposit is its close association with amphibolites - almost certainly the first recorded example in Scotland of a stratabound base-metal deposit interbedded with metamorphosed basic volcanic rocks. Perhaps the only comparable Scottish deposits are those at Craignure and

Coille-Bhraghad on the west side of Loch Fyne though these lack the volcanic association and have relatively high nickel concentrations.

This note is published with the permission of the Department of Industry and the Director of the Institute of Geological Sciences.

C. G. SMITH,
Institute of Geological Sciences.

THE SOUTHERN UPLANDS

The Southern Upland Fault extends in an almost unbroken line from near Dunbar to Girvan, with only a small kink near Leadburn deflecting its course. South of the fault the high moorland and hill country of the Southern Uplands rises to a 2,000 ft. dissected plateau, but in the west where the granite masses of Criffell, Carsphairn and Cairnsmore lie, the land reaches an elevation not far short of 3,000 ft. Most of the rocks of the Southern Uplands are Greywackes and shales of Ordovician and Silurian age; they are intensely folded and faulted, and since they are overlain to the south and east by an unconformable cover of Devonian and Carboniferous sediments, this period of folding must have been near the end of the Silurian, or in earliest Devonian time. The Southern Uplands fault itself separates the Lower Palaeozoic greywackes from the gently folded Devonian and Carboniferous of the Midland Valley, and its latest movements must have post-dated the formation of the Upper Palaeozoic terrain. This fault, however, seems to have had a long history before then, and following an old line of weakness, probably first started moving in the Ordovician.

Several small Silurian inliers lie in a chain some miles to the north of the fault and in the Girvan area there is a large, intensively studied Ordovician exposure as well.

Most of the Southern Scottish area is of singular structural complexity and is now recognised as being critically important in European and indeed global geology. It seems to have been the site of a former ocean, contracting as it was squeezed in between two colliding continental plates. This radical hypothesis has emerged from the development of plate tectonics in the 1960's. But the application of plate theory to this region was only possible because of the detail accumulated through the work of many geologists over nearly 200 years. Hence we shall here be examining our current model of the Southern Uplands in a historical perspective.

Many geologists have contributed, many of them amateurs; Henderson and Brown, who first clarified the nature of the Silurian beds of the Pentland Hills; Begg of Glasgow, who described many of the faunas of the Girvan region; and Mrs. Gray of Girvan.

One has to look no further than James Hutton, at Siccar Point to see where it all began. He saw the beds of upturned greywacke lying vertically below the gently dipping sandstone and concluding that they were older by far, made it clear that the beds below the unconformity (Silurian) were from a distinct time period. Early work was slow, but by the 1860's the first maps of the Southern Uplands had been made by Howell and Giekie and others of the Geological Survey and the fossil graptolites common in the shales were being used successfully as stratigraphic markers. By this time the inliers north of the fault had been dated by trilobites and brachiopods though the precise horizons within the Ordovician and Silurian were not resolved for many years.

Just over 100 years ago, Charles Lapworth, an English geologist,came to settle in Scotland. He used to walk from Galashiels to a cottage at Birkhill at weekends, to map the surrounding hills and work out their stratigraphy and structure.

Near Birkhill cottage is the deep chasm of Dobbs Linn, which Lapworth used as his type succession. It was sufficiently complete for him to establish a sequence of zones based on the graptolite faunas which could then be used to map the whole region. The sequence of black shales which ranged from the lowermost Caradocian (Ordovician) through to the base of the Wenlock (Silurian) was full of graptolites. They were so numerous that this, coupled with the extreme thinness of the beds, immediately suggested a condensed sequence, deposited very slowly over a long period of time. In Girvan the equivalent succession of Ordovician and Silurian beds is over ten times as thick as at Dobb's Linn. The sediments at Girvan include limestones, sandstones, conglomerates and some highly fossiliferous mudstones containing mainly trilobites and brachiopods, but enough graptolites to enable a good correlation to be made with the graptolite shales. Quite clearly this succession represents near shore facies, with great quantities of sediment being deposited quickly, contrasting with the very slow sedimentation of the Moffat Series, in tranquil and probably deep water far away from shore.

This basic concept of Lapworth's gave evidence of the palaeogeography of Southern Scotland; a shoreline running more or less north north-east (approximately parallel to the present Southern Uplands fault). The conditions extended some distance to the north of the present fault, for most of the sediments in the Silurian inliers are shallow water marine in origin. To the south there lay a deeper water region, in which only the finest particles of the terrigenous sediment accumulated as graptolite bearing mud.

Noting the succession seemed to become younger on going south, three parallel belts were defined -

- a northern belt of Ordovician rocks (mainly cherts, basalts, greywackes and shales).
- a central belt of Llandovery rocks, generally greywackes and shales with occasional inliers of Ordovician such as are exposed at Dobb's Linn.
- a southern belt, well exposed in Kirkcudbrightshire. Here there are greywackes, shales and some peculiar red beds, the Hawick Rocks, which are still a bit of a mystery in terms of age and environment of deposition.

Although this succession seemed to young southwards on graptolite evidence, the beds mainly dipped northwards, and all the sedimentary structures showed a northerly dip. Lapworth and his followers, Peach and Horne invoked isoclinal (concertina type) folding as an explanation.

Within the last two decades, however, the idea of an isoclinal fold as the dominant structural control has been largely abandoned in favour of strike faults. Such faults, running NNE, parallel both with the strike of the beds, and the line of the Southern Uplands Fault are hard to detect, except where the stratigraphic control is good or where continuous coastal exposures allow them to be seen in the cliffs, as in Berwickshire. It is not surprising that they were missed but most recent mapping has shown their undoubted presence, and it is now held that these are the most important control and that though isoclines do occur they are not necessarily significant. If one imagines a series of northwardly canted folds of large amplitude, with their southern limbs cut out by large strike faults, so that the succession is repeated, and if the line joining the uppermost tips of the folds (faltenspiegel) is tilted to the south, then we have a model which accounts for the southward younging of the beds, yet at the same time allows for the dominantly northward dips (Fig 1).

This then is the model borne out by recent evidence, and it is one which must imply a great amount of crustal shortening with intense NNW-SSE compression, a feature recognised by Lapworth, even if his model needed modification.

But there were two unresolved problems. The first was the nature of the sedimentary environment, and most particularly how the superabundant greywackes had been deposited. Secondly, the place of the "Southern Uplands Geosyncline" as it came to be called, in terms of global tectonics.

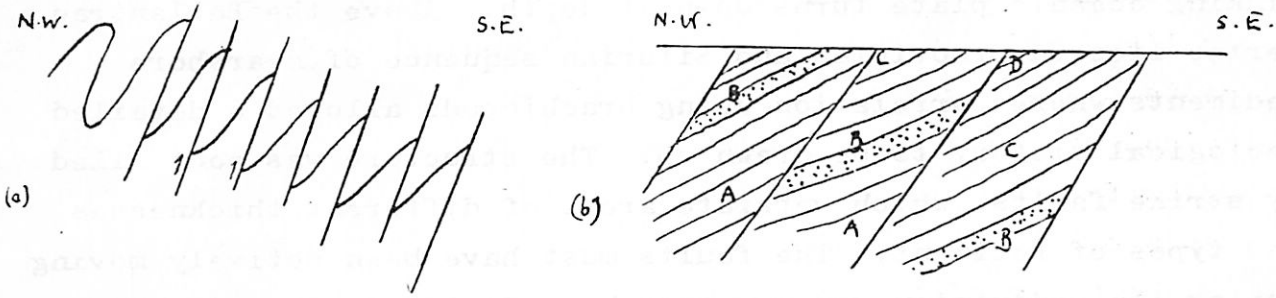
In the early 1960's it was recognised that most greywackes (unsorted sediments of heterogeneous components) are deposited from currents of suspended sediment which flows under gravity, down the continental slope. The flow may be triggered by an earthquake; or the collected sediment at the top of the slope may simply become unstable and start to move very fast, leaving characteristic scrape-marks of shells and vortices in the soft sediment below. However,the 'turbidity current' as this flow is called eventually slows down and the sediment that has been carried is deposited, heaviest grains first, filling and preserving the carved surface of the bed below. Each turbidite flow is deposited rapidly, but there may be a long period of quiescence before more sediment comes down.

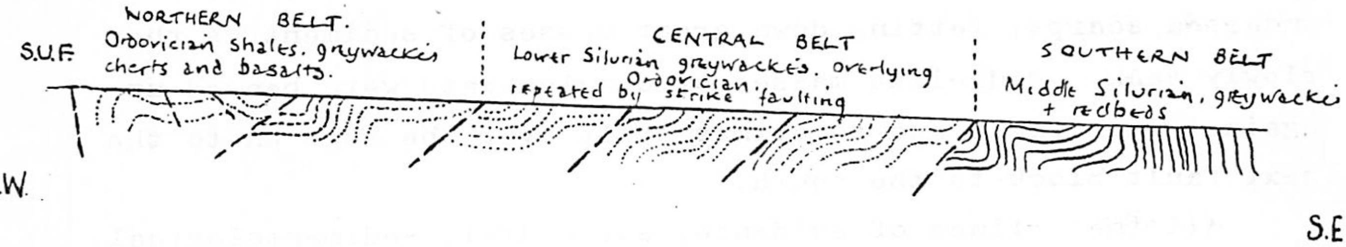
During the Ordovician and Silurian a shoreline lay to the north of a continental shelf in the southern part of the Midland Valley. South of this again there was a continental slope, upon which the accumulation of successive turbidity currents led to the formation of giant submarine fans. In the Ordovician of the northern belt there are other sediments besides greywackes and shale; namely red and black cherts (some containing silicious microfossils - radiolarians) and also limestone boulders thought to come from atolls surrounding volcanic islands. Brachiopods and tribolites are also abundant in a few places in mud flows which slumped into deep water.

Perhaps the most telling area of all is the Girvan region. Here great thicknesses of sediment accumulated during the Ordovician just south of a shoreline.

At Girvan the basement is formed by the Ballantrae Volcanics, a very complex series of dominantly igneous rocks, with pillow lavas, serpentinites and cherts, as well as some unusual metamorphic rock types: glaucophane schists and eclogites. There is reason to believe that the pillow lavas and cherts and serpentinites

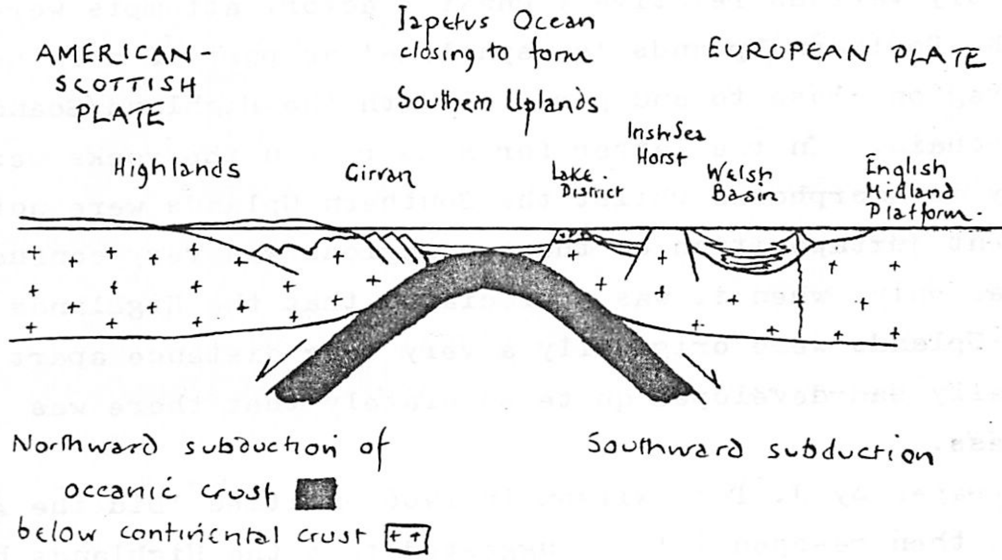
Fig 1. Diagrams showing how a succession which dips northwards can be repeated by strike faults so as to appear to young southwards (a) being a model (b) a rock sequence.





(c) Schematic section across the Southern Uplands from the Southern Uplands Fault to the Solway Firth, showing strike faults and fold patterns. (based on Walton, 1963)

Fig 2



Section across British Isles. approx N-S. in late Ordovician times

(after Williams, 1976)

were formed at depth on an ocean floor, while the metamorphics are produced by partial melting at a consuming plate margin, where a sinking oceanic plate turns down at depth. Above the Ballantrae Series lies an Ordovician and Silurian sequence of nearshore sediments where correlation using brachiopods allowed a detailed geological history to be drawn up. The structure was controlled by strike faults, which separate areas of different thicknesses and types of sediment. The faults must have been actively moving during the Ordovician and may even have formed southward-facing undersea scarps, letting down great masses of sediment as they slowly sank. Wedgelike masses of conglomerate were banked up against each fault and sometimes spilt over the edge on to the next fault block to the south.

All these lines of evidence, structural, sedimentological, stratigraphical have been used to infer the history of the Southern Uplands — a region of sedimentation extending from shoreline to deep water, subsequently deformed by intense compression. But where does this fit in terms of global tectonics ? And what lay to the south ? Before the advent of plate theory various relatively unsatisfactory attempts were made to see the Southern Uplands 'geosyncline' as part of a rather complex region close to and parallel with the Highland/Scandinavian mountain chain. In the latter for some reason the rocks were intensely metamorphosed whilst the Southern Uplands were not. The present juxtaposition of the two regions was very confusing, and it was only when it was appreciated that the Highlands and Southern Uplands were originally a very long distance apart and geologically had developed quite separately that there was hope of progress.

The paper by J. Tuzo Wilson in 1966 entitled 'Did the Atlantic close and then re-open ? ' , suggested that the Highlands had once been part of North America, whilst the Southern Uplands were possibly a sutural zone along which opposing continental masses had collided. The Highlands had remained 'stuck' to Europe whilst the new split down the joined continents occurred, though not quite in the same place - this being the Atlantic ocean.

The sutural theory was the start of a new and deeper understanding which took into consideration not only Scotland, but Scandinavia on the one hand and Newfoundland on the other, where there was a similar sequence of events.

A picture now emerging of the region is as follows - the Proto-Atlantic Ocean (or Iapetus Ocean as it is better called) separated two bordering lands, perhaps several hundreds or even thousands of miles apart. In the early Ordovician each opposing continental shelf was so far apart that it carried its own faunas, quite unlike those of the other shelf. The gap slowly closed. By the Upper Ordovician, the plates approached close enough for the faunas to have largely mixed, a process which was complete by the earliest Silurian. At Caradocian times, the two continental masses lay on either side of an oceanic region. The Scottish plate was bordered on its southern edge by a continental slope with its turbidite fans, and there was possibly also a series of volcanoes in an island arc. Greywackes eventually filled the trench at the foot of the slope and spilled out over the oceanic plate. The southern plate, with the Lower Palaeozoics of England and Wales accumulating, may also have had its northerly string of island arcs, though the location of the volcanic islands is unclear. The suture along which the two plates finally collided lay south of the Girvan region, probably under the Solway Firth. It was this collision of the two plates which was responsible for the intense compression of the sediments of the Southern Uplands which had originally lain in the Southern Uplands trench, between the two approaching shelves of the 'American' and 'European' continents. A model for the two plates shortly before final collision is shown in Fig.2; here one sees the antiform structure of the oceanic plate with its two subduction zones slipping down underneath the northern Scottish region and the Lake district respectively.*

It would hardly be expected that the approaching continental margins would be parallel, and indeed there is now good evidence that continental collision was oblique, having taken place in different areas at different times along the whole Caledonian front from Newfoundland to Scandinavia. The process of collision and associated crumpling and faulting seemed to have been more or less complete by later Silurian time, but perhaps the initiation of the Great Glen Fault in the Lower Devonian could be a later effect of the same compression. The two plates were then completely welded along the Southern Uplands, and from then on the Scottish landscape we know today began its development with the downfaulting of the Midland Valley and the beginnings of Devonian and Carboniferous sedimentation.

In conclusion, it should be emphasised that the exciting developments of the last few years as yet give only a model.

There is still a lot of controversy and much remains unsolved, but it is at least a working basis for further study.

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* The step faults carefully documented by Williams seem to be associated with the downdragging of the continental margin by the descending oceanic plate.

E.N.K. CLARKSON.

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* The Hutton Postcard has sold out but is being reprinted.