

The Edinburgh Geologist

Benjamin
Neeve
Peach



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EDITORIAL

'We take the first step in geological knowledge when we recognise the fact, as who does not, that the solid lands upon which we live are undergoing certain modifications by natural operations.' So wrote James Geikie in the introduction to his Outlines of Geology. As geologists living in a country of temperate climate, intermediate latitude and relative crustal stability we seldom have the opportunity to witness dramatic natural events, whether atmospheric or lithospheric. So when things go bump in the night as they did on 26 December 1979, not owing to an excess of Christmas pudding but to crustal adjustment it is hardly surprising that British humanity is stirred, if only briefly, out of its actual (4 am) and societal lethargy. A glance at the IGS Visitor's Book at Murchison House for instance would indicate that the media at least found the event worthy of journalistic appraisal.

This 7th edition of the Edinburgh Geologist reminds us that we too should take an interest in active as well as passive natural phenomena. Articles on either will be welcomed by the Editors for the November 1980 issue. Contributions (which should reach us by the first week in October) need not necessarily be earth-shaking.

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CAPTION COMPETITION (November 1979)

The Editors are pleased to announce that the winner of last edition's Caption Competition is Dr P Stone who contrived this entry:-

"OK Paddy, so it works, but how are you going to get it inside the lunar module?"

BENJAMIN NEEVE PEACH 1842 - 1926

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There can be few names in the history of Scottish geology better known than that of Ben Peach, whose classic work in the Geological Survey of Scotland from 1862 to 1905 laid the foundations for so much of our present understanding of the geological structure of this country.

Ben Peach was not a Scot by birth or ancestry but was born of an East Anglian family living in Gorran Haven, a small fishing village in Cornwall. His father, Charles Peach served as an officer in the Coastguard Service and was also a distinguished amateur naturalist and geologist, with a wide circle of friends, both scientific and literary. Young Ben was therefore introduced to geology at an early age and he and his brothers often accompanied their father on his geological excursions. When Charles Peach was promoted to Peterhead, Aberdeenshire in 1849 the boy's interests and knowledge was extended greatly for he learned not only about the local rocks but also about marine life and sea birds.

A further promotion took the family to Wick in Caithness. In 1854 Peach senior paid a visit to Durness on the north coast of Sutherland to "receive a wreck" and there he noticed poorly preserved fossils in the local limestone. He duly informed Sir Roderick Murchison, then Director of the Geological Survey of Great Britain and the discovery reawoke general interest in the north-west Highlands, more especially when a subsequent visit in 1857 yielded better specimens thought at the time to be of Ordovician age. Murchison felt so indebted to his friend that he undertook to send Ben to the Royal School of Mines when the young man reached the age of seventeen. Among Ben's new teachers were the renowned glaciologist and structural geologist Ramsey and Darwin's champion Thomas Huxley. Three years later in 1862 Ben, who had distinguished himself as "an able student", graduated and was appointed by Murchison to his newly formed Geological Survey of Scotland, as their fourth member of staff.

Ben Peach's first work for the Survey involved identifying Carboniferous fossils from Fife and surveying coalfields. From there he moved to Old Red Sandstone formations and then on to the complex Ordovician and Silurian rocks of the Southern Uplands of Scotland. In the latter work he was joined, five years after his first appointment, by John Horne, with whom his name is now

inseparably linked as a result of their outstanding work together on the Southern Uplands and the Northwest Highlands of Scotland. A large number of maps and the two huge memoirs of 1899 and 1907 were the result of this collaboration, together with several articles published in the learned journals of the day. This remarkable partnership lasted throughout the whole of their lives and they were known to their colleagues as Castor and Pollux, the Heavenly Twins.

Peach and Horne who worked together for forty years, first went to the Northwest Highlands, the scene of their most famous work, in 1883. Peach was then forty years old. They were sent by Archibald Geikie to resolve a long standing controversy about the structure of the area. Murchison had believed that the fossiliferous Cambro-Ordovician Durness limestone passed conformably upwards into the "Eastern" schists of which a large part of the Northern Highlands are formed. Nicol (inventor of the Nicol prism) was the main exponent of the opposition and pointed out that the metamorphosed schists must be older than the unmetamorphosed limestones and that the junction was a steep fault. Since it could easily be demonstrated in the field that the junction is sub-horizontal, Murchison's views were accepted in toto. In 1883 both Calloway and Lapworth suggested a low angle tectonic thrust and this idea was now being given serious consideration by Geikie. It was during their first season of field mapping in the Durness-Eriboll region that Peach recorded the true situation. Instead of the simple conformity which Murchison had suggested there were gigantic structures of a kind never before encountered in the British Isles. The Eastern (Moine) Schists had been thrust westwards by a series of large-scale low-angled faults over the unmoved foreland rocks of ancient Lewisian gneiss and their cover of Late Precambrian Torridonian sandstone and Cambro-Ordovician limestones. During this process a series of smaller faults (imbricate structures) had been produced en echelon in the underlying foreland and cover rocks. The thrust zone was eventually traced in the field from Eriboll to Skye. These well exposed structures now seem easily recognisable but it was perhaps the most spectacular discovery of all time in British geology and by 1884 Murchison's views on the succession had to be abandoned in view of the rapidly accumulating evidence against them. This was done rather reluctantly on Peach's part as he felt a debt of gratitude to Murchison and greatly respected the old man.

While the Highland work was still going on Peach and Horne resumed their work on the Southern Uplands in 1888. In 1878 and subsequent years,

Lapworth had shown that the original survey of the Ordovician and Silurian was unsatisfactory. Peach and Horne began their revision with the Moffat sheet (16) and the Loch Doon sheet (8), which had been surveyed but not published. These sheets were then issued in 1889 and 1893. Thereafter, at odd times during the autumn and spring seasons, when work was impossible on their Highland ground, they gradually extended their search and made exhaustive examination of most of the important field exposures, adding notes and lines to the original six-inch maps. Peach made himself an authority on the palaeontology, in particular, the graptolites and identified them with precision and accuracy. He also drew up the cross-sections with which the great Memoir of 1899 is illustrated. Horne, meanwhile, wrote the text and the work on the petrology of the igneous rocks was done by J J E Teall. Though produced under less than ideal conditions the Memoir stood for fifty years before any of its ideas were challenged: surely a great tribute to the men who produced it.

Peach retired from the Geological Survey in September 1905 after a period of forty-three years service. His retirement gave him time to pursue at his leisure a line of research that had always fascinated him since his early days with Huxley at the Royal School of Mines - the technical description and illustration of fossils and in particular, the Scottish Carboniferous crustaceans. As a man of sympathy for all living things, he found their dead remains a source of endless fascination. At various horizons in the Scottish Carboniferous there occur sporadically, isolated but very well preserved faunas of "shrimps", probably of fresh-water origin. Throughout the 1880's and 90's collections of these crustaceans had accumulated and Peach being Acting Palaeontologist for the Survey, became custodian of "these treasures" as he called them. Several detailed papers emerged, culminating in his Monograph of 1908, with page after page of technical description and twenty plates executed with his usual artistic flair. This fine monograph was Peach's last major work yet he remained as enthusiastic as ever with all aspects of geology until the end of his days. Greenly, who visited him six months before his death in 1926, tells how Peach, then a sick old man, became so excited about the opportunity to discuss geological theories with his visitor that the grim-faced landlady had to eject poor Greenly while Peach's voice, still declaiming geology, pursued them down the stairs!

There is still yet another facet to the genius of Ben Peach. He was a very good artist in the romantic Victorian manner. His field notebooks and the backs of his field maps are covered with monochrome paintings in brush

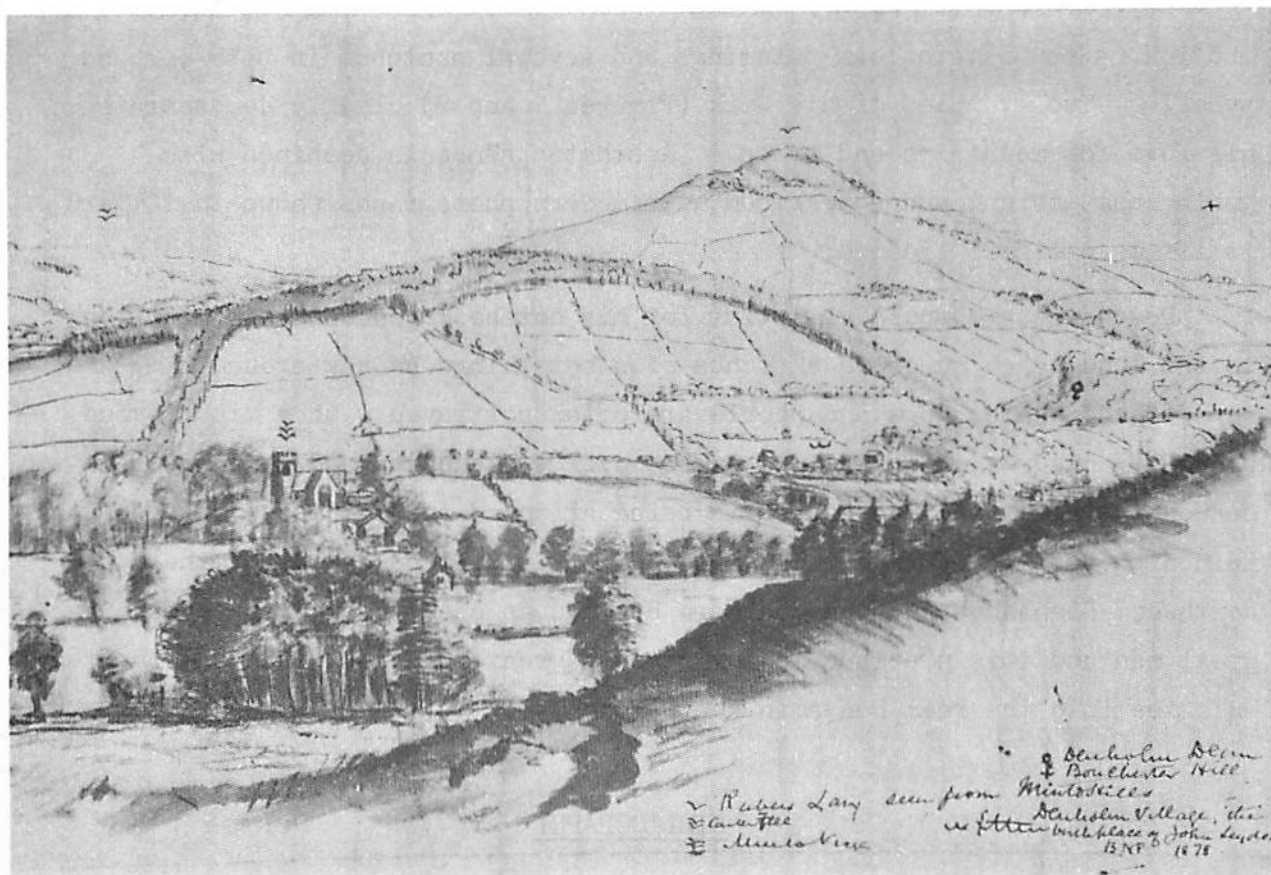


Fig 1 Rubers Law from Minto Hills, Roxburgh



Fig 2 Southern Uplands

and ink, a few watercolour paintings and several sketches in both pen and pencil. Two examples of his work (Figures 1 and 2) clearly demonstrate his love for mountains and trees. Aesthetic sense is combined with geological insight and comparison with modern photographs shows that there is little artistic licence.

Peach was a compulsive artist for his notebooks contain, in addition to the landscapes numerous sketches of other things he saw around him, and cows, sheep, cats, dogs and people are often portrayed with a mischievous sense of humour. His drawings number over two hundred and an exhibition concentrating on the landscapes is being arranged in Murchison House for the Edinburgh Festival Fringe in August 1980. It will be a tour of the Northwest Highlands and the Southern Uplands as seen through the eyes of a great man and this precious legacy gives a greater insight than all the many eulogies into the real Benjamin Neeve Peach.

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THE 1979 ROYAL AIR FORCE EXPEDITION TO ANDØYA, NORTHERN NORWAY

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The main purpose of this scientific expedition to Andøya in Arctic Norway (Figure 1) was research into bird behaviour and accordingly three of the total of eleven places were occupied by ornithologists. However, in order to obtain an all round view of the island's natural history the party also included a geologist, botanist and anthropologist together with a back up group of mountaineers and photographers from the RAF.

As the geologist with the expedition I was fully aware that at present the most interesting rocks in Andøya are those of Mesozoic age, described by Dalland (1975) which occur between Ramsaa and Skarstein on the east coast. In fact my main occupation was to collect specimens from the Mesozoic rocks to form a reference collection in the Geology Department of the Royal Scottish Museum. It is hoped that the collection will help research workers making comparisons with similar material from north-east Scotland.

However, during my stay I hoped to cover large areas of the island and to see as much of the general geology as possible. I started in the area of our base camp at Skogstad, just south of Prestvatn. This is an area of open, low moorland with extensive beds of peat. Several pits were dug to examine soil profiles and samples were taken. The peat varied immensely in thickness from place to place, having formed on an irregular terrain of glacial debris which had been deposited during the last ice age. Locally the peat was up to 10 feet thick and of good quality. Old workings showed that it had been used extensively in the past. At present, only small amounts are being dug, but as the price of other fuels rise, it may well be that residents will turn once again to this local resource for purposes of heating. On a much larger scale, there is currently a proposal by a commercial company to remove considerable quantities of peat for horticultural purposes in the Ramsaa area, where trials have already commenced.

Moving further afield I examined the corrie below Vitten where a most unusual barrier retains the small lake of Prestedalsvatn. At first I thought that this natural dam was some kind of moraine, but in such a position it seemed most unlikely. Only later did I realise that perhaps there had been a great rockfall from the cliffs of Vitten while the corrie was still occupied by the remnant of a corrie glacier. If so, the large rocks would have tumbled down over the steeply sloping ice to pile up at the opening from the corrie. (c.f. Sissons, 1976).

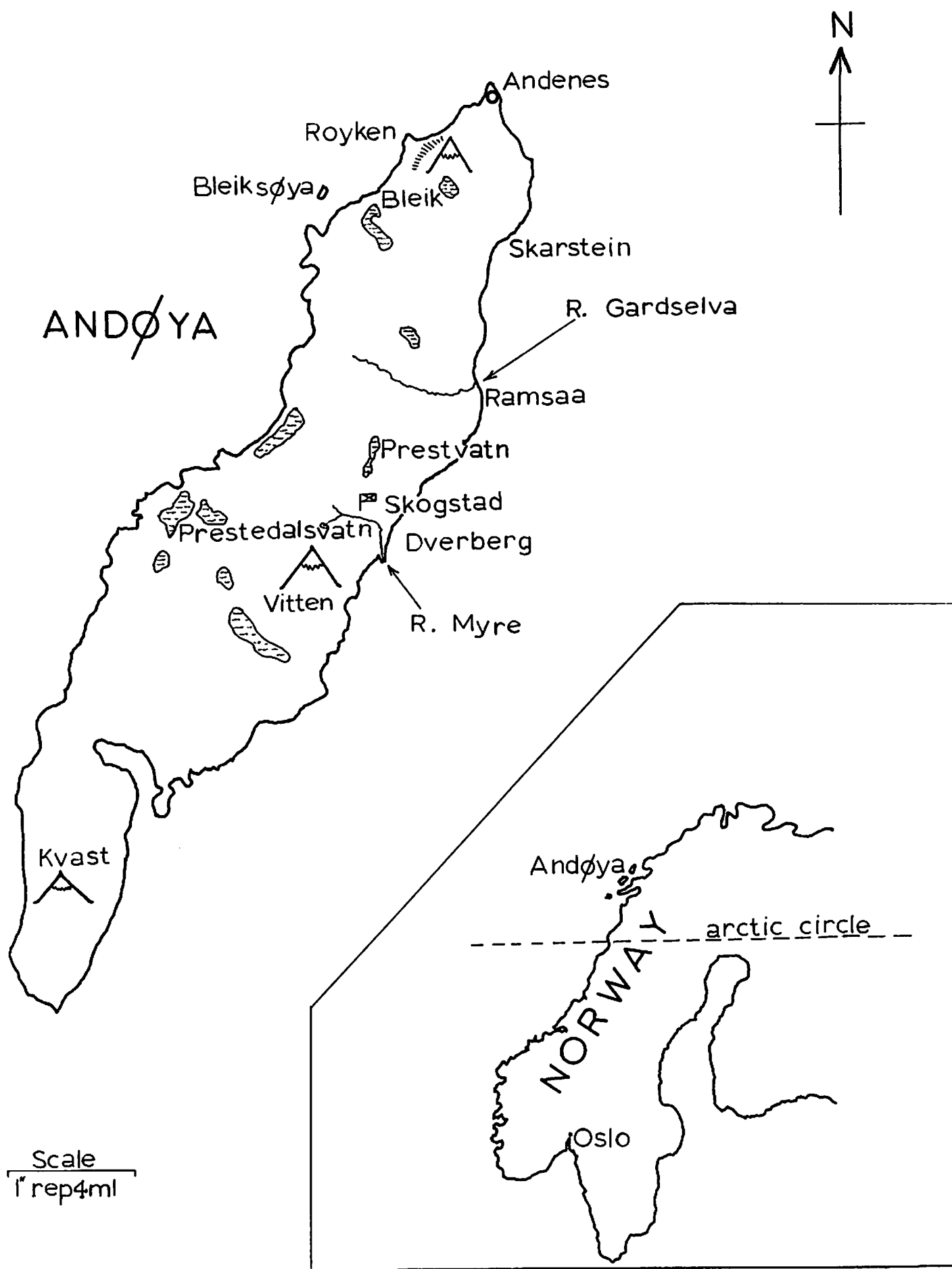


Figure 1. Location of Andøya

On a small cliff to the north-east of Prestedalsvatn by the Myre river there was a beautiful indication of the link between geology and botany in the form of a very fine group of the Alpine Butterwort Pinguicula alpina growing on a metamorphosed limestone.

A full-day excursion was made to the Ramsaa area to look for fossils in the Jurassic rocks. Members of the party were lucky enough to find many fossils such as belemnites, bivalves of various types and fossil wood. A selection of the best specimens was taken for incorporation in the collections of the Geology Department at the Royal Scottish Museum. In addition a large and fine specimen of a Pectinoid bivalve was transported to the local Polar Museum in the main town of Andenes. Unfortunately although we searched diligently we failed to find any worthwhile ammonites such as those which are so well described in Birkelund et al (1978). Many thanks are due to Mr Elling Solstrand who not only showed the expedition members where to collect, and gave them permission to do so, but also extended the hospitality of his home to them.

Recent exploration work in the form of drilling for oil and gas has taken place in the Mesozoic rocks of the Ramsaa area, and during the Second World War the Germans began development of an open cast site by the River Gardselva. Some publications (eg Tourist Guides) and local opinion suggest that this was a trial pit for coal, but I believe that the rock extracted was oil shale. During the latter half of the war Germany was in desperate need of oil and a certain quantity of the shale may have been shipped back for extraction tests. Whether workable quantities of oil or gas are present in the rocks of this area is uncertain but it is true that as prices continue to rise smaller and smaller reserves become viable propositions.

A day in the north-west of the island was spent examining the cliffs of Royken above the road from Bleik to Andenes. Here the basal complex of granite and gneiss was well exposed with very fine sections of folding and veining visible. Several rocks and a specimen of biotite were obtained from this area. Samples brought back by three members of the party from the nearby island of Bleiksøya indicated it to be geologically similar in nature to cliffs of the main island.

Going south to climb the highest mountain on the island I was fortunate enough to find in the high corries of Kvast one corrie which contained snow in the Firm state, that is, in a compact form, intermediate between snow and ice, which is created during the transformation of accumulating snow into

glacier ice. I also began to notice that generally corries were orientated to the northern half of the quadrant. South and south westerly facing slopes, although showing the effects of an overall glacial scouring were relatively free from the pock marks of corries. Sissons (1967) reports a similar but more precise orientation for corries in Scotland. Frost features on the mountains of Andøya were surprisingly few, being restricted to lobes of debris and rock fragments, which create the impression of a far quicker fluid movement down the slope than their imperceptibly slow creeping progress justifies (c.f. Ball and Goodier, 1970).

Towards the end of our stay on Andøya I examined the Cambro-Silurian sedimentary rocks between Dverberg Harbour and Dverberg Kirk (see Høltedahl, 1960), where a fine array of metamorphosed sediments are well exposed on the beach. In Dverberg Harbour the mineral tremolite was collected from a pod in a beautiful pink and white 'sugar' marble. Farther north near Dverberg Kirk, an amphibolite inclusion appears in a similar marble and here a most exciting discovery of iron pyrites and "chalcopyrites" was made. In recent years tests have been carried out on these particular pyrite-rich beds, with the object of establishing whether there are workable reserves of mineral ore in the area. To date (1979) no ore extraction has taken place, possibly because the "chalcopyrite" which has a perfectly standard appearance in a hand specimen, contains no copper when tested by X ray analysis and is therefore much less valuable as a metal ore.

Although I only spent a brief period on Andøya I saw much of interest and, thanks to the help and kindness of the people of the island, I was able to collect some useful specimens. Some of these will be prepared and registered into the fine collections of the Royal Scottish Museum where they will be permanently available for future research workers who wish to examine the geological fabric of Andøya.

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ETNA VOLCANO

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Introduction

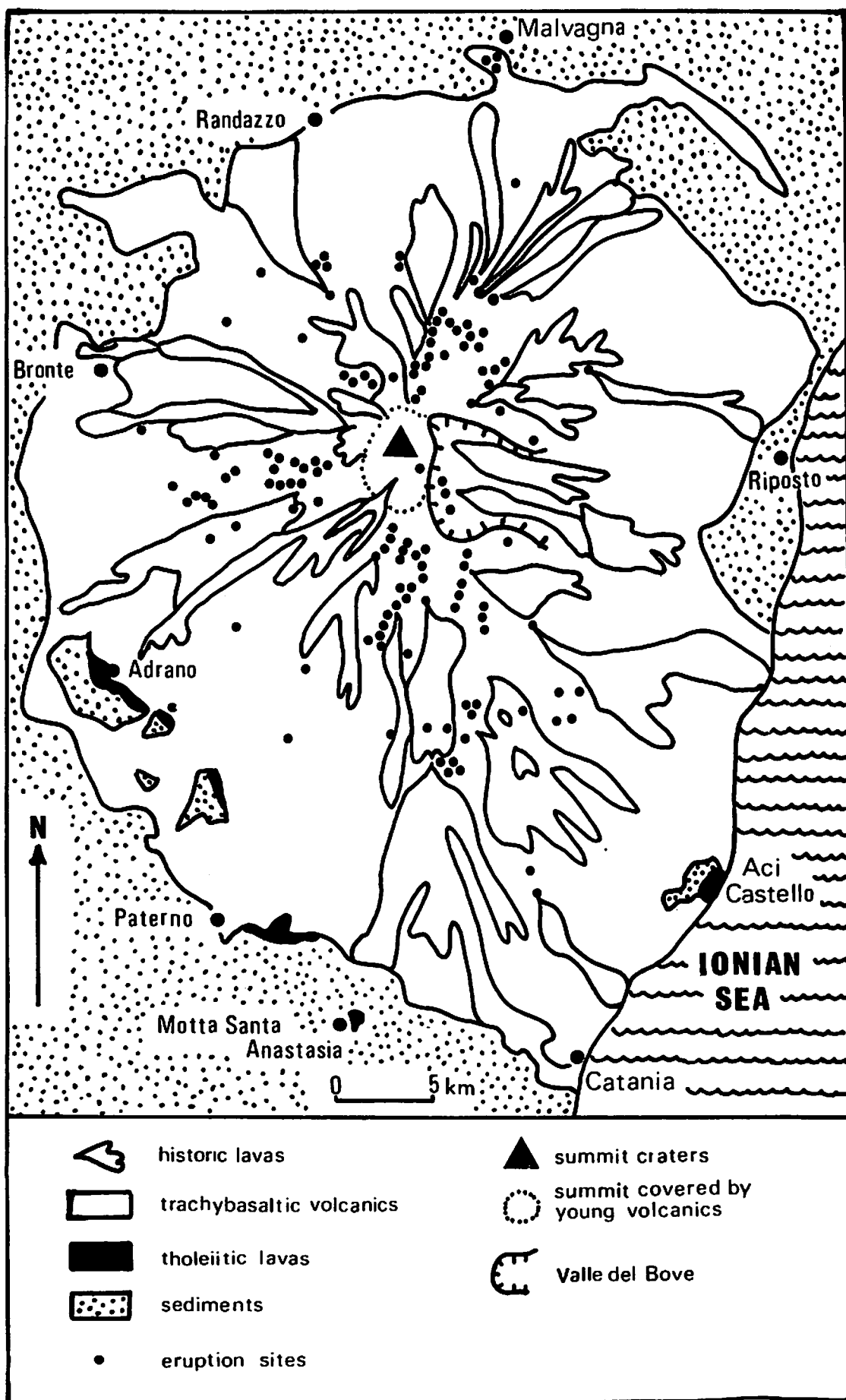
With the development of the tourist industry in Sicily over the last few years access to Mount Etna, the largest active volcano in Europe, has become relatively easy. This article is intended as an introduction to the geology and volcanology of Etna for those who have the opportunity to visit this fascinating volcano.

Etna is one of the few volcanoes in the world that is almost continuously active. Nearly 3300 m in height and covering an area of about 1300 km², the volcano dominates the landscape of eastern Sicily.

Situated in the centre of the ancient world, Etna has received attention from an early stage. The Greek poet Pindar, referred to an eruption in 475 B.C. and Thucydides records that during the Peloponnesian Wars in 425 B.C., lava caused a great deal of damage in the environs of Catania. Virgil, in the Aeneid, gives a vivid description of the volcano. Modern geological study of the volcano was initiated in the 19th century by Lyell and Von Walterhausen. The classic work of Lyell (1872) contains many astute observations concerning volcanic structure. Recent accounts of the geology are provided by Guest and Skelhorn (1973) and Pichler (1970).

Volcanic Activity

In historic times Etna has displayed two main types of activity (Wadge et al 1975), persistent activity and periodic eruptions. Persistent activity usually occurs in the summit area and lava is produced at a low rate over a



Sketch map of Etna volcano

long period of time. In periodic eruptions, however, lava is issued at a high rate for a short time, generally of less than three months duration, this lava being emitted from vents on the flanks of the volcano. Many of these flank eruption sites are situated on fissures that radiate from the summit region. This pattern of small scale summit eruptions, persistent activity, punctuated by larger flank eruptions approximately every six years, periodic eruptions, suggests that magma enters the volcanic system at a constant rate and can be stored within a high level magma reservoir for a few years (Wadge 1977).

Over the last ten years Etna has displayed a wide variety of styles of eruptive activity. In mid-1971 there was a major flank eruption which lasted about two months (Guest and Skelhorn 1973). Activity started in the summit region and subsequently lavas were erupted at progressively lower levels on the flanks of the mountain along a fissure trending in a north-easterly direction. The eruption lasted 69 days with the last lavas being erupted from a vent 5 km from the summit at an altitude of 1700 m. After the 1971 eruption, no further lava was emitted for over two years until January 1974 when there was a small eruption on the western slopes of the volcano. Towards the end of 1974 there was a resumption of activity in the summit region with explosive activity from the North East crater and gentle effusion of lavas. Throughout 1975, 1976 and 1977 there was persistent activity in the summit region, generally associated with the North East crater. In the spring of 1978 there was another major eruption, with lava being emitted at a high rate from a fissure developed to the south-east of the summit cone. The lavas from this eruption flowed over the western wall of the Valle del Bove. There was another period of activity from this fissure in the late summer of 1978.

In August 1979 there was a resumption of activity associated with this south-east fissure. This 1979 eruption, though it lasted only six days, was one of the most explosive eruptions of Etna in recent years. Lava flows threatened the village of Fornazzo, which was evacuated by the authorities, and ash-fall temporarily closed Catania Airport.

On September 12th, a month after the end of the eruption, when the volcano was quiescent and there were about 150 tourists in the summit area there was a sudden, violent explosion from the Bocca Nuova, one of the summit craters. Nine tourists were killed and several others injured by debris from the 30 second blast. No fresh magmatic material was thrown out by the

explosion and it appears that there was no obvious warning that could have been detected without the use of instruments. To the best of the author's knowledge, these were the first deaths to result from volcanic activity on Etna for over a 100 years. This tragedy highlights the potential hazards posed by any active volcano.

Volcanic Structure

Etna is a composite volcano with a shape somewhere between that of a shield volcano and a stratovolcano. One of the most distinctive morphological features of Etna is the number of parasitic cones, over 200, on the flanks of the volcano. These cinder cones are not random in their distribution but are located in distinct belts, see Figure, indeed many of these parasitic vents are situated on fissure lines. It is considered that the distribution of these cones is controlled by structures in the subvolcanic basement.

When viewed from the south west it can be readily seen that the profile of Etna is asymmetric. This is because Etna is in fact constructed of at least three central volcanoes of differing age which partly overlap one another, with Mongibello being the name given to the currently active cone (Rittmann 1973). Near the summit of Mongibello there are several annular kinks which contour round the flanks of the volcano. These are interpreted as the rims of old calderas that have been subsequently infilled with lava (J E Guest, personal communication). If this is correct, it indicates that Etna has enjoyed in the past much more violent activity than has been witnessed in recent years.

On the eastern flanks of the volcano there is a major horse-shoe shaped depression up to 1000 m deep and 6 km in diameter, the Valle del Bove. The Valle del Bove exposes part of the interior of Etna and thus provides much useful information on the subvolcanic structure and consequently on the evolution of the volcano. Many ideas have been put forward concerning the origin of the Valle del Bove, including glacial activity, volcanic explosion and also volcanic collapse. As yet the origin is uncertain and represents a major topic of current research.

Volcanic History and Petrology

The volcanic rocks of Etna belong to three different magma groups: the basal tholeiitic basalts, the alkali olivine basalts and the trachybasaltic series. These three magma groups show distinct $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (Carter and

Civetta 1977), suggesting derivation from different source regions within a heterogeneous mantle. The three magma groups are also distinct in their stratigraphic position and petrology.

1. Basal Tholeiitic Basalts

The oldest exposed volcanics of Etna belong to this group, they have not been directly dated but Cristofolini (1973), on the basis of their field association with Sicilian clays, suggests that they are mid to late Pleistocene in age. These tholeiitic volcanics are only exposed round the southern periphery of the volcano. At Aci Castello, in the east, pillow lavas of tholeiitic basalt occur associated with marine sediments indicating eruption in a submarine environment. Near Adrano in the west, however, the tholeiitic basalts are subaerial and show many of the characteristics of 'flood basalts' and are thought to have resulted from effusive fissure eruptions (Rittmann 1973).

These tholeiitic basalts contain abundant small phenocrysts of olivine with a groundmass comprising intergrowths of plagioclase and pyroxenes (including some low calcium pyroxenes) with titanomagnetite and ilmenite. Geochemically, they show a limited but distinct variation from olivine normative through to quartz normative. The chemical variation cannot be readily explained in terms of crystal fractionation and probably results from melting processes in the source region. These basal tholeiitic basalts represent only about 1% of the volcanic products of Etna. For an alternative approach see Tanguy (1978).

2. Alkali Olivine Basalts

The alkali olivine basalts are very limited in abundance, cropping out in an ancient eroded cone at Paterno, with possibly some related rocks occurring in the Piedemonte region on the north east flank of the volcano. These alkali olivine basalts were erupted at an early stage in the evolution of the volcano; basalt from the Paterno cone has been dated as 210000 B.P. by radiometric techniques (Condomines and Tanguy 1976).

These basalts contain up to 13% by volume of forsteritic olivine (Fo_{86}). The olivine is rich in Ni, around 1800 ppm (cf 850 ppm for olivine phenocrysts from a basic member of the trachybasaltic series). These olivines must have crystallized from a rather basic melt, or possibly represent partially reequilibrated mantle derived xenocrysts.

3. Trachybasaltic Series

The trachybasaltic series comprise a mildly alkaline suite of volcanics ranging in composition from hawaiite through mugearite to benmoreite

(Duncan 1978). These volcanics are much younger in age than either the basal tholeiitic basalts or the alkali olivine basalts. Condomines and Tanguy (1976) have dated one of the oldest trachybasaltic flows as 95000 B.P. On the basis of rate of lava output and volumetric considerations, Wadge et al (1975) suggest that the trachybasaltic activity could have started around 60000 B.P.

These trachybasaltic volcanics are volumetrically dominant, comprising over 98% by volume of the volcanic products of Etna and make up the edifice of the volcano. All the mildly alkaline volcanics have been placed in this petrological group: however, further work may show this to be an oversimplification.

The trachybasaltic lava flows generally have an 'aa' or 'slabby' morphology. Hawaiite and basic mugearite lava flows are erupted from cinder cones or spatter cones, whereas flows of mugearite and benmoreite are generally associated with volcanic domes. Near Adrano, pyroclastic flow deposits composed largely of pumiceous benmoreitic fragments occur and it is thought that these deposits resulted from explosive eruptions involving caldera collapse in the summit region of the volcano (Kieffer 1973, Duncan 1976).

The lavas are generally porphyritic with phenocrysts of plagioclase, augite and olivine. In their chemistry they show continuous variation from hawaiite to benmoreite. The trend is somewhat unusual in being from Ne-normative in the hawaiites to Hy-normative in the mugearites. The chemical variation can be largely accounted for by moderate to low pressure crystal fractionation, involving mineral phases that are present as phenocrysts, from a parental magma of hawaiite composition (Duncan 1978). Crystal fractionation, however, cannot readily account for the variation in Na and some other mechanism, therefore, must be operative for the removal of Na from the magma. Etna being continuously active is very much an open system and it is suggested that Na and possibly other fugitive elements are removed from the magma as volatile phases.

It would appear that there is a fairly steady input of hawaiite magma from the mantle into the volcanic system. Generally this magma undergoes limited differentiation with eruption of lavas ranging from hawaiite to basic mugearite in composition. Periodically in the history of the volcano, however, the magma is able to undergo more extensive differentiation with eruption of mugearites and benmoreites. This may be due to a cessation in the supply of parental magma leading to a temporary halt in activity. This is followed by explosive eruptions with possibly caldera collapse and the

emission of more evolved lavas and pyroclast flows. After this period of explosive activity, partial melting reverts to normal with the resumption of a steady supply of parental magma and eruption of hawaiites and basic mugearites.

Interesting Localities

This is not intended as an inclusive guide to Etna but merely to indicate some places of volcanic interest that lie off the tourist routes. After the deaths of the tourists in September, 1979, and until the safety aspects are reviewed, it would be premature to consider the summit craters in this account. The tragedy demonstrates that even during a period of relative inactivity the summit area can be a very dangerous place.

A trip round the western flanks of the volcano passes through some interesting scenery well away from the tourist resorts on the coast. This journey can be carried out using the narrow-gauge railway, ferrovia, that skirts round the volcano from Catania through Adrano, Bronte and Randazzo to Riposto on the coast.

Travelling west from Catania, at Motta Santa Anastasia there is an interesting plug of tholeiitic basalt surmounted by a Norman castle and cathedral. Further to the west in Paterno, another Norman castle is situated on an ancient eroded cone of alkali olivine basalt. Adrano, again with the inevitable Norman castle, is built on the tholeiite basalt terrace (Chester and Duncan 1980) and commands a spectacular view over the Simeto valley. Northwards from Adrano the altitude rises, the climate becomes more pleasant, the scenery more wild and the Sicilians more Sicilian. This is one of the cinder cone belts and upslope the flanks of the volcano are studded in old parasitic cones attractively situated in the forestry commission land. At Bronte, noted for its connection with Admiral Nelson, the 19th century lava flow which partly engulfed the town can be seen. Randazzo stands on a platform of lava overlooking the upper reaches of the Alcantara river. Randazzo is rather a gloomy city famous for its buildings of historic interest. On moving down the Alcantara valley towards the coast a distinctive eccentric cone can be seen below the town of Malvagna. Near Francavilla, the Alcantara flows through a narrow gorge of lava exposing a spectacular development of fan-columnar jointing.

Two other localities of note are firstly Aci Castello where there is a fine outcrop of pillow lavas visible on the shore and secondly at Pomiciaro, off the Zafferana - Rifugio Sapienza road, where there is a lookout point with an impressive view over the Valle del Bove.

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REVIEW

Geology for Civil Engineers by A C McLean and C D Gribble
George Allen & Unwin 1979 310 pages Hardback £11.00, Paperback £5.95

Of the string of four titles in the Earth Sciences which Allen and Unwin have newly presented this past summer, a text on the application of geology is especially to be welcomed. Written by two members of the Geological Society of Glasgow and based largely on their experiences in Glasgow in teaching geology to civil engineering students, the book also includes some Scottish case histories in which the authors have been personally involved.

The authors are at pains to point out that their book is essentially an introduction to geology for civil engineers, and is thus conceived as an alternative to the well-established text by Dr F G H Blyth, revised by Dr M H De Freitas, rather than be a treatment of engineering geology as such. It is claimed that much of purely geological interest, but little engineering relevance, has been left out. Even so, though well presented, there is still a lot for the budding engineer to wade through. For instance, one can question the inclusion of an account of overstep and overlap (pp. 140-142), a source of perennial confusion to students of geology, let alone engineers. More seriously, if the book really is for civil engineers, might not the ordering of the material present have been different? It seems to the present reviewer not a good idea, after the admirable introductory chapter, to plunge straight into all the gory scientific details of rocks and minerals. The book does have some very good chapters, for instance, that dealing with sub-surface (ground) water, though the highly important topic of the disposal of wastes merits rather fuller treatment than it gets.

As well as a number of appendices dealing with specific topics, the book includes some case histories, notably the new Strome Road and the Kishorn Dock excavation, both in Wester Ross, the Clubbiedean Dam near Edinburgh and the proposed Channel Tunnel. Many more case histories, at the expense of some other sections, could have been included with profit, since engineers, being practical people, presumably learn largely by experience. It is to be hoped that a future edition of McLean and Gribble's book will include, as one case history, the story of the British Rail Penmanshiel Tunnel.

Norman E Butcher

THE RECENT CARLISLE AREA EARTHQUAKES

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It is likely that some readers of this note will have experienced the Boxing Day 1979 earthquake at first hand since it was felt throughout the Central Belt of Scotland as well as in Northern England, the North East counties of Ireland and the Isle of Man (Fig 1). This brief article is intended to present the facts of the Carlisle area earthquakes of which the shock of the 26 December is the largest to date.

For a number of years IGS has been expanding its network of seismic stations to give a higher station density for the UK land area. As a result of this policy the larger Carlisle earthquakes were successfully recorded by 13 IGS stations. In addition data from a number of stations operated by other agencies in the British Isles was made available for analysis of these shocks (Fig 2). Within a few days of the main earthquake occurring, Cambridge University's Department of Geodesy and Geophysics and IGS deployed small networks around the epicentre of the main shock to enable high quality locations and fault plane solutions of the aftershocks to be made.

A number of felt reports of the main event and several of the aftershocks were received and to supplement these data questionnaire forms were placed in selected newspapers to ensure uniform reporting of the degree of shaking experienced throughout the felt area.

The instrumental data has been used to give locations and focal depths for the events of the Carlisle series (Fig 3). In addition magnitudes were computed (Table 1). The hypocentres were determined using a Geiger-based location technique (Geiger, 1910). Simply this procedure involves using the arrival times of the seismic waves at the recording stations and comparing them with arrival times computed from a given position (assumed epicentre) at a given time, (assumed origin time) and a velocity model

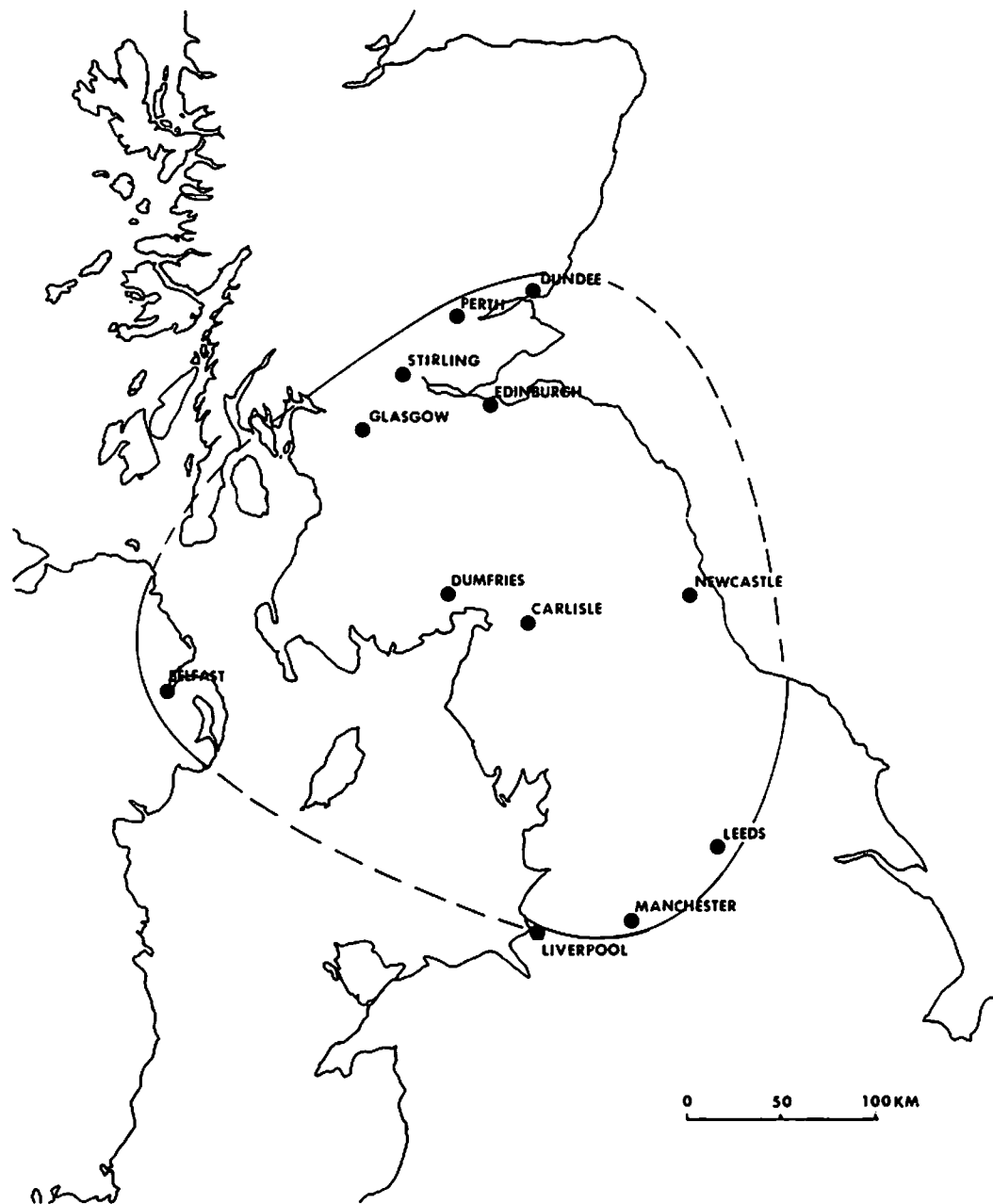


Fig 1 Sketch map of the disturbed area of the Carlisle earthquake of 26 December 1979.

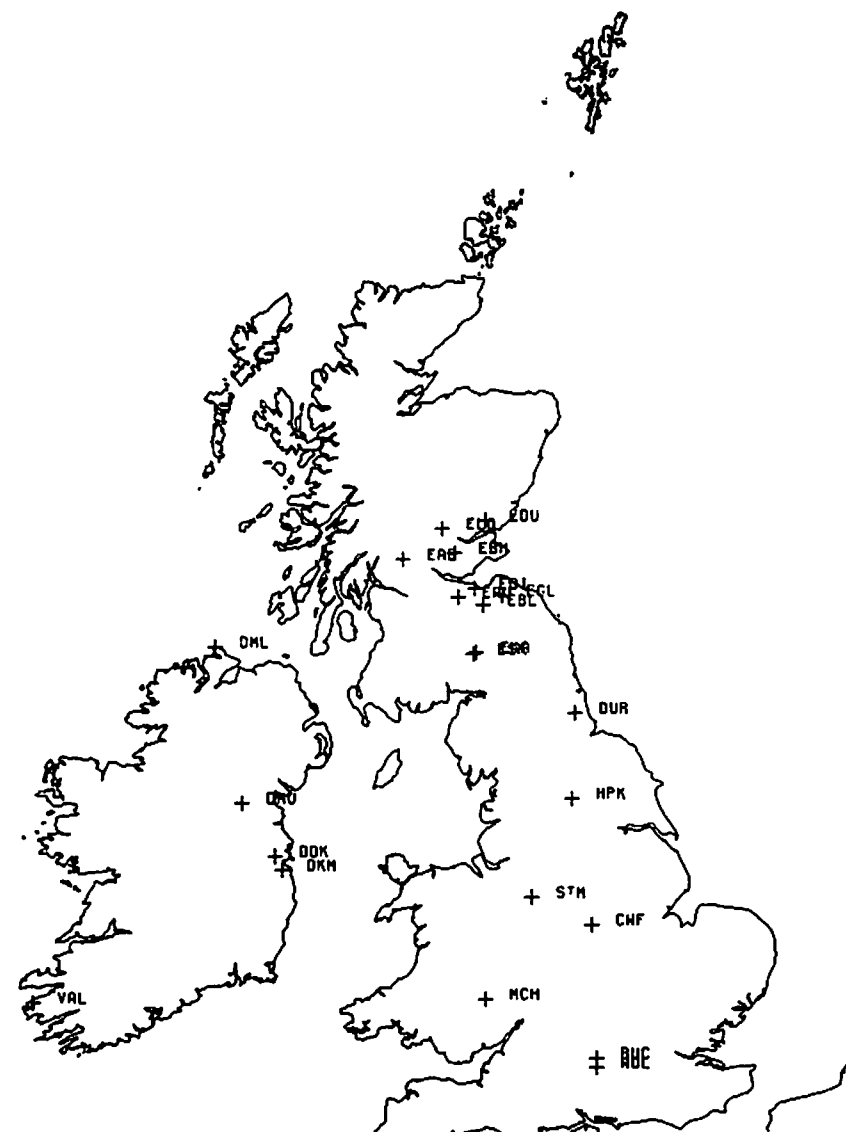


Fig 2 Seismograph stations which recorded the Carlisle earthquake of 26 December 1979. Stations EAB, ELO, EDU, EBN, EBI, EAU, EBL and ECL make up the principal recording network of IGS. LOWNET (Crampin et al, 1970). ESK, HPK, STM, CNF and MCH are also operated by IGS.

of the earth's crust. The difference between the observed and the computed arrival times for each station is minimised using a least squares method. This procedure is executed at a number of depths and the solution giving smallest residuals is the one adopted.

The method depends on a very accurate knowledge of crustal structure in the epicentral area and it is a fortunate coincidence that the Carlisle series occurred close to the site of a timed explosion fired in 1973. This event has been located using the same method used on the earthquakes and a likely location error of about 3 kilometres to the north west was found. By using more sophisticated location methods more exact solutions will be found in due course.

The magnitude values given are Richter Local Magnitudes (Richter, 1958). They give a rough idea of relative size of the earthquakes, a difference of 1 unit in magnitude corresponding to a factor of about 30 times in energy release. The main shock's magnitude is $M_L = 5.2$ and it was preceded by 4 smaller foreshocks and followed by a number of aftershocks, the largest of which occurred on 1 January 1980 with a magnitude, $M_L = 4.1$. This pattern of activity is broadly similar to the sequences observed for earthquake series in other parts of the world (Bath, 1979).

Prior to the event of 26 December 1979, the largest shock known to have affected this area took place on August 11 1786 (Davison, 1924). It was centred about 18 miles southwest of Carlisle and had a maximum intensity of about 7 on the Davison scale (Davison 1924). This earthquake was felt in Glasgow, Edinburgh, Berwick, Leeds, Manchester and Liverpool. A chimney was thrown down at Whitehaven, at Egremont several chimneys fell and there was damage to the quay at Workington. A small aftershock occurred on July 6 1787. The next recorded event to affect this area was on July 9 1901 (Davison, 1902). It was centred about 7 miles SSW of Carlisle and reached intensity 5 on the Davison scale. This shock was felt as far as Eskdalemuir, where IGS now has a seismological observatory.

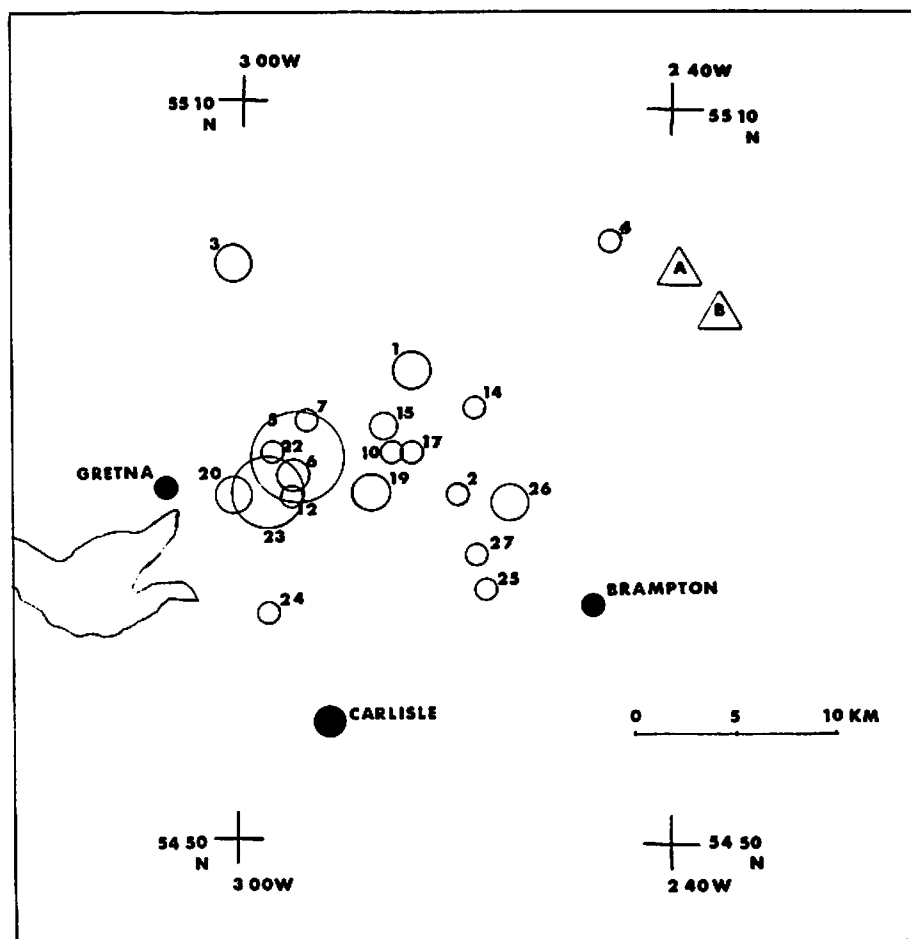


Fig 3 Epicentres of the Carlisle earthquakes. Epicentres are indicated by open circles, whose diameter is approximately proportional to magnitude. Numbers correspond to those given in table 1. B is the true position of the 1973 timed explosion. A is the location obtained by the same location technique as was applied to the earthquakes. Epicentres marked with an * in Table 1 are not shown.

TABLE 1

No	Date	Origin Time	Latitude North (degrees)	Longitude West (degrees)	Depth km	Magnitude ML
1	09.10.79	01 ^h 29 ^m 20 ^s .6	55.05	2.87	2	2.2
2	17.10.79	18 55 42.3	55.00	2.84	2	1.1
3	17.10.79	20 57 28.9	55.10	3.01	2	2.0
4	12.11.79	13 31 38.2	55.11	2.72	2	1.6
5	26.12.79	03 57 07.8	55.01	2.97	11	5.2
6	26.12.79	04 00 14.7	55.00	2.97	4	2.1
7	26.12.79	04 04 53.0	55.03	2.96	-	1.6
8	26.12.79	04 08 02.9	54.55	2.60	3	1.0*
9	26.12.79	04 12 00.0	55.08	2.86	-	1.5*
10	26.12.79	04 16 49.3	55.01	2.89	9	1.7
11	26.12.79	04 17 35.5	55.21	2.77	3	1.3*
12	26.12.79	04 59 18.9	55.00	2.97	2	1.9
13	26.12.79	05 26 35.3	55.28	2.83	-	0.9*
14	26.12.79	05 44 22.7	55.03	2.83	3	1.4
15	26.12.79	10 02 49.1	55.03	2.90	3	1.3
16	26.12.79	14 53 10.7	54.80	3.04	-	1.0*
17	26.12.79	17 38 01.6	55.01	2.87	5	1.7
18	27.12.79	05 39 21.8	55.07	2.92	-	1.3*
19	27.12.79	17 23 28.4	55.00	2.91	3	2.6
20	27.12.79	23 05 24.9	54.99	3.01	3	2.6
21	30.12.79	10 40 09.2	54.95	2.98	-	1.2*
22	31.12.79	11 24 55.3	55.01	2.98	1	1.7
23	01.01.80	05 05 47.2	55.00	2.99	3	4.1
24	01.01.80	05 43 59.1	54.94	2.98	5	1.6
25	03.01.80	01 59 54.1	54.95	2.82	6	1.0
26	03.01.80	02 35 47.3	54.99	2.80	3	2.0
27	08.01.80	06 10 59.0	54.97	2.82	6	1.6

Hypocentral solutions for the Carlisle Earthquakes between 9 October 1979 and 8 January 1979. Less reliable solutions are marked with an asterisk.

and was followed by at least three felt aftershocks within 48 hours of the main event.

Caution should be exercised in placing a tectonic interpretation on the data presented here as certainly better solutions for the recent shocks will be obtained and also fault plane solutions together with other parameters such as stress drop and seismic moment will become available in due course. Even more caution should be exercised with the pre-instrumental reports, ie pre-1900, as rough intensity maps based on relatively small numbers of observations can lead to large errors in location of earthquakes. IGS will continue to operate the Carlisle network and analysis of its data together with other UK station records will continue. Processing of the questionnaire based macroseismic survey also is underway and accurate intensity maps for the main shock and principal aftershock of the Carlisle series will be drawn. These maps together with the instrumental data will enable a re-evaluation of the pre-instrumental record of seismic activity in this area to be made as, prior to about 1900 no instrumental observations of any UK earthquakes exist.

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