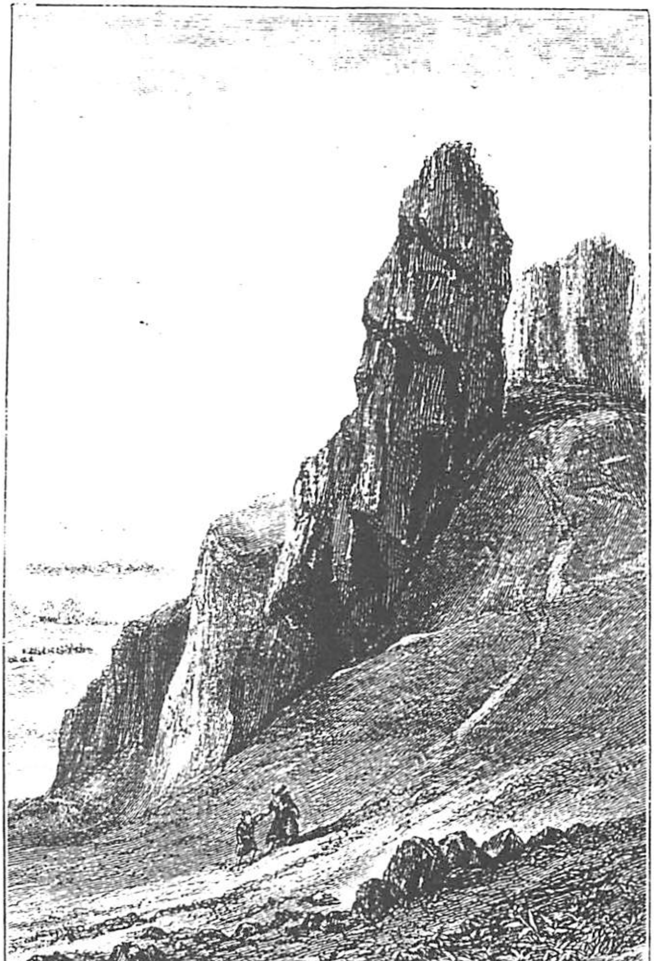

The Edinburgh Geologist

No. 18 Autumn 1985

Cover Illustration from: Edinburgh Past and Present
by J.B. Gillies
Edinburgh 1886

EDITORIAL

We would like to thank Helena Butler and Andrew McMillan for sustaining "The Edinburgh Geologist" for so many years – and we hope to keep it going for at least as long!

This issue catches up with the events of the spring and summer – MEGS 4, the long excursion to Kylesku, and Dr. Waterston's address on the day excursion to Arthur's Seat. It also reflects a new development in geological studies, with SCE Geology now offered at O grade and H grade in Scottish schools.

Contributors to this issue responded generously to our request for copy. Perhaps some members of the society might even like to volunteer material for the next issue.

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"IS ARTHUR'S SEAT OF VOLCANIC ORIGIN?"

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On 4th June 1835 the first field excursion of the Edinburgh Geological Society was held to discuss the question "Is Arthur's Seat of Volcanic Origin?". It was appropriate, therefore, that on 8th June 1985 the Society should again visit the Queen's Park to ponder anew the geological significance of these classic rock exposures which are associated with so many of the greatest names of geology. As we examined Hutton's Section and the Salisbury Crags we were again impressed by the anatomy of the teschenite sill, there so wonderfully displayed. The crystalline rock, the chilled margins, the baked contact sediments, the stoping and digestion of the upper sandstone beds, the disruption of the lower sandstones, the pattern of cooling joints, the stepping of the teschenite from horizon to horizon all evidenced the intrusion of a sill of molten magma into pre-existing sediments. On Arthur's Seat we saw again the succession of lava flows and ashes, the intrusive necks and the spectacular agglomerates. No wonder the founders of our Society concluded that Arthur's Seat was indeed volcanic. So obvious does this appear to us today that we might wonder why any geologist could have thought otherwise. But many distinguished geologists did think otherwise and, in fairness to them, we sat in the sunshine at Hutton's Section and tried to think ourselves back to geological understanding as it was at the end of the eighteenth century which led to that question posed at the first excursion.

The Plutonist theory of Hutton and the Neptunian theory of Werner were published within a year of one another and, although their supporters became involved in one of the best known geological arguments, the authors – so far as I know – were never in communication. Hutton's theory was laid before the Royal Society of Edinburgh in the spring of 1785 and his paper appeared in the *Transactions* of that Society in 1788 and afterwards, in extended form, in two volumes published in 1795. Werner's *Kurze Klassification und*

Beschreibung der verschiedenen Geburgsarten appeared as an article in 1786 in a volume of the *Abhandlungen der Böhmischen Gesselschaft der Wissenschaften* and as a separate volume in 1787. The merit of both theories was that they wove together many previous observations into frameworks of universal application which could be tested in field observations and thus geology as a science was born. In Fleming's words (1859, p. 3):

> These did not fail to excite a deep interest in the minds of those who were occupied with the study of geology, because many recondite subjects were brought prominently forward, and fearlessly discussed, while appeals were boldly made from the closet to the quarry – from the hall of the Royal Society to Salisbury Craigs and Arthur's Seat.

It is not necessary to elaborate the Huttonian theory to an Edinburgh readership (see for example in our own *Transactions* Tomkeieff 1948). The merits of Werner's work are less well appreciated here partly because it is so briefly stated in the original and of his reluctance to commit his thoughts to print and his consequent dependence upon his pupils of the Bergakademie at Freiberg to inform the world of his ideas, and partly because in Edinburgh since the time of Sir Archibald Geikie (Geikie 1897) we find it hard to see beyond the reputation of our own Dr. Hutton. However, since the publication of Ospovat's translation of Werner's *Short Classification* together with his excellent introduction and notes (A.M. Ospovat 1971) there is little excuse for this lack of understanding. In summary Ospovat recognises as the significance of Werner's work:

1. That in it clear definitions of rock types were given for the first time. Previously the same rock had been given many different names and communication was thus difficult. In the case of fine grained rocks, such as basalt and wacke, definition remained difficult until microscopy could be applied to petrography, at a much later date.

2. That it established petrography as an independent branch of the

geological sciences. Previously rocks had been incorporated in mineral classifications but the *Short Classification* was exclusively a classification of rocks.

> Despite the seemingly endless variety of rocks which compose the earth's crust, the make-up and composition of these rocks are determinable and definable and the number of different rocks is limited.

3. That it represents a history of the earth's crust. Werner worked out a system in which the relative age of the rocks is supplemented by the mineral content, internal structure and texture. His theory accounted for the possibility of the simultaneous formation of different kinds of rocks and the formation of similar rocks at different times.

In all of these ways Werner called for precision of description and laid a scientific foundation for our science. That part of Werner's theory which has not stood the test of time was his contention that all rocks were chemical or mechanical precipitates from a primaeval ocean with the exception of transported or derived rocks and modern volcanoes. Although belief in the primaeval ocean soon waned, the stratigraphical dimension which his theory had added to our understanding of rocks is nonetheless valuable. He recognised five major rock formations:

5. Volcanic rocks (present day and local)
4. Transported or derived rocks (of local origin)
3. The Flötz rocks – characterised by abundant fossil remains
2. The Transition rocks – characterised by marine fossils showing the beginnings of life.
1. The Primitive rocks – of crystalline character lacking fossils.

Werner was familiar with the rock succession in Saxony and his classification arose from that knowledge. His field experience of other districts, however, was limited and it was left to his pupils to apply his universal system to their own countries. One such was the Leith-born Robert Jameson who studied under Werner from 1800 to 1802 and succeeded John Walker as Professor of Natural History at Edinburgh University, a post which he held from 1804 until his death in 1854. Jameson had a powerful influence in the Neptunian cause in the early years of the nineteenth century writing the most detailed statement in English of Werner's system of rock classification (Jameson 1808, White 1976) and founding in Edinburgh the Wernerian Natural History Society in 1808 (Sweet 1967). Application by such men as Jameson of Werner's system to Scottish rocks resulted in the recognition of crystalline granites, gabbros and metamorphic rocks as Primitive while the Lower Palaeozoic greywackes, shales and cherts of what we would now call the Cambrian, Ordovician and Silurian were classed as "Transitional". The Old Red Sandstone on through to the Mesozoic was recognised as "Flötz" or secondary. In Scotland controversy centred particularly on whether Granite and Greenstone were igneous rocks (the plutonist view) or were they crystalline precipitates from the primaeval ocean (the neptunian view). The greenstone problem was especially relevant in Edinburgh where so many basalt and greenstone bodies occur, the evidence from which was used by protagonists of both theories.

So far as I can determine Jameson did not contest with the Plutonists on the Hutton Section (at least in print) but chose his own ground by describing quarries favourable to a Neptunian interpretation. He published a series of papers in the first volume of the *Edinburgh Philosophical Journal* setting out the Neptunian view of the origin of Granite, Quartz Rock, Greenstone, Wacke, Trap veins etc (Jameson 1819a, b, c). The last two of these papers are of interest since the field evidence is drawn from the Edinburgh area. In them he contends *inter alia*:

1. That the sandstone of Edinburgh is not an aggregate of broken pieces of quartz or of sand but is a rock formed by crystallisation. The local subordinate rocks – Shale, Clay Iron-Ore, Coal, Limestone and Greenstone are all, likewise, formed by crystallisation.

2. That the parallelism of the greenstone bed in the Lothian Street

Quarry with the thin layers of slate-clay resting upon and lying under them, is not reconcileable with the volcanic hypothesis – had the greenstone been forced into position an irregular junction would have been expected.

3. The alternation of beds of highly crystallised sandstone (indurated according to the Plutonists) with slate-clay, and the occurrence of unaltered slate-clay and marl in the most highly crystallised sandstone immediately over the greenstone, proves that cystallisation (hardening) is not produced by heat flowing from the greenstone otherwise the slate-clay would also have melted.

4. That the transition from greenstone into wacke, wacke into clay, clay into sandstone proves that the same agent must have presided at the formation of these different rocks, an explanation irreconcileable with the Volcanic, but in accord with the Neptunian hypothesis. Similarly the occurrence of diverse rock types interbedded on Calton Hill shows that they were of simultaneous formation and that if wacke and greenstone are true volcanic rocks then the sandstones, shales and ironstones with which they are associated must have been formed in the same manner – a position which cannot be maintained in conformity with any of the systems of volcanism.

5. Some veins are wide at the top and terminate below and thus must have been filled from the top and been formed at the same time as the rock in which they occur. Further evidence for the contemporaneity of veins with the beds in which they are found was adduced from veins of sandstone penetrating greenstone as well as vice-versa.

In Edinburgh the Neptunians maintained a stout rearguard action but such arguments have the character of special pleading in the face of the increasing weight of evidence which was being assembled by the Plutonists. It was probably before our Society's first excursion that Jameson recanted the Wernerian hypothesis at a meeting of the Royal Society of Edinburgh (Sweet 1976). The historical perspective suggests that the Huttonians were not entirely right nor the Wernerians entirely wrong. Earth science owes a great debt to both schools of thought.

Fleming, J. 1859 *The Lithology of Edinburgh*, Edinburgh, Kennedy, 102pp.

Geikie, A. 1897 *The Founders of Geology*, London, Macmillan, 297pp.

Jameson, R. 1808 *System of Mineralogy*, 3, Edinburgh, Blackwood, 368pp.

Jameson, R. 1819a On the Geognostical relations of Granite, Quartz-Rock, and Red Sandstone. *Edinb. Phil. Journ*, 1, 109-15.

Jameson, R. 1819b 1 Secondary Greenstone with Wacke not of Volcanic Origin. 2 Veins which connect Mineral Beds together not confined to Trap-rocks. 3 Trap Veins (Whin-dikes) probably of contemporaneous Formation with the trap-rocks which they traverse. *Ibid*. 138-47.

Jameson, R. 1819c Geognostical Description of the Neighbourhood of Edinburgh. *Ibid*. 352-63.

Ospovat, A.M. 1971 *Abraham Gottlob Werner – Short Classification and Description of the Various Rocks*. Translated with an introduction and notes. New York, Hafner, 194pp.

Sweet, J.M. 1967 The Wernerian Natural History Society of Edinburgh in *Freiberger Forschungshefte* C 223 Mineralogie – Lagerstättenlehre Abraham Gottlob Werner Gedenkschrift aus Anlass der Wiederkehr seines Todestages nach 150 Jahren am 30 Juni 1967. Leipzig.

Sweet, J.M. 1976 Introduction in White 1976 q.v. xii-xxiv.

Tomkeieff, S.I. 1948 James Hutton and the Philosophy of Geology *Trans. Edinb. Geol. Soc.* 14, 253-76.

White, G.W. 1976 *The Wernerian Theory of the Neptunian Origin of Rocks,* A Facsimile Reprint of *Elements of Geognosy*, 1808 by R. Jameson. New York, Hafner, 1 - xxiv, 368pp.

GEOLOGY IN SCOTTISH SCHOOLS

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I once heard an Englishman explain to his son 'Scotland's all rock'. For a country that is all rock Scotland has been remarkably short of Geology. Before the introduction of Ordinary Grade Geology schools could present candidates for O- and A-levels to exam boards outside Scotland. University prelims in Geology died out in 1971 when Scotland could muster only seven candidates who all took the exam in Aberdeen.

Early moves to get Geology into schools are not well documented. The first recorded approach to the Scottish Examination Board came in June 1967 when Renfrew County Council said that one of its schools was preparing pupils for G.C.E. O-level in Geology and there was an intention to present at A-level. Renfrew pointed out that this situation was probably not unique to them so it asked the Examination Board to consider offering a syllabus and examination in Geology. The desirability of introducing Geology was then discussed by the Examination Board on the one hand and the Scottish Education Department and the Consultative Committee on the Curriculum on the other. Subsequently, approval for the setting up of a Geology Panel was given by the Examination Board in February 1973. The Panel met for the first time in May 1973 and a proposed syllabus and examination in Ordinary Grade Geology were issued in August 1975. Following consideration of the comments from various bodies a revised syllabus was issued in March 1976 and the first examination in Ordinary Grade Geology was held in 1978. Following consultation with interested bodies by the Examination Board a Joint Working Party of the Board's Geology Panel and of the Scottish Central Committees on Science and on Social Subjects was set up in August 1980 to devise proposals for a syllabus and examination in Higher Grade Geology. Proposals were issued in June 1983 and the first exam was held in 1985.

Syllabuses

There was no prospect of a Higher Grade when the Ordinary Grade syllabus was made up. Partly because of this the Ordinary Grade syllabus covers a wide range of topics at a shallow depth. It is briefly as follows:

1.	The Earth in Space	The solar system, the origin of the Earth covered briefly.
2.	What Rocks are	Examination of rocks and simple rock classification.
3.	Minerals	Examination of minerals and mineral identification.
4.	Igneous Activity	Volcanoes, intrusions, classification of igneous rocks, thermal metamorphism
5.	Sedimentary Rocks	Formation and classification of sedimentary rocks.
6.	Earth Physics	Earthquakes, Earth structure, isostasy.
7.	Tectonics	Structural geology, maps, plate tectonics, regional metamorphism.
8.	Earth History	Fossils, principles of stratigraphy, an outline of British stratigraphy.
9.	Economic Aspects	Ores, fossil fuels, evaporites, engineering geology, water supply, the geological effects of man.

The Higher Grade syllabus demands a greater level of knowledge and understanding. It is made up of these sections:

1.	Minerals	Properties of minerals, crystal systems, chemical bonding, identification and classification of minerals.
2.	Igneous Processes	Crystallisation of igneous rocks, magma types, volcanoes, intrusive igneous rocks.
3.	Sedimentary Rocks	Formation and petrography of sedimentary

		rocks, sedimentary structures, environments of deposition.
4.	Earth Physics	Earthquakes, isotasy, the Earth's magnetic field, internal heat and structure.
5.	Tectonics and regional metamorphism	Structural geology, plate tectonics, regional metamorphism.
6.	Palaeontology	Use of fossils, palaeoecology, evolution.
7.	Stratigraphy	Principles of stratigraphy, radiometric dating, study of late Precambrian – early devonian or Devonian – Permian or Permian – Cretaceous.
8.	Economic Geology	Ores, fossil fuels, construction materials, methods of exploration.

Both syllabuses require a considerable amount of practical work. For example, in the Ordinary syllabus 'laboratory work is emphasised' and 'field studies are an essential part of the course'. In the Higher Grade field studies are equally or more essential and 'practical skills should include the use of the polarising microscope'.

Assessment

The Ordinary Grade examination paper (2½ hours) is in three sections. Section A (50% of total marks) consists of short questions which test knowledge, understanding, handling information and problem solving. Section B (15%) is a problem question based on maps, diagrams or photographs. In Section C (20%) the candidates answer two from six essays. Candidates must also submit a fieldwork log (15%) of about a thousand words which should contain a record of three field visits. Till 1982 logs were assessed by markers appointed by the Examination Board. However, in 1983 assessment became the responsibility of teachers. The logs are then moderated by the Board's examiners and, if necessary, marks are amended.

There are two examination papers at Higher Grade. Paper 1 (2½ hours) is worth 50% of the total marks. Section A (30%) consists of short questions while in Section B (20%) candidates answer two from five essays. Paper 2 (2 hours) is worth 30% of the total marks. It consists of practical problem questions such as map interpretation, drawing geological cross-sections, three-point problems and interpreting photographs. A fieldwork report of about two thousand words is worth the remaining 20% of total marks. The fieldwork reports are marked by teachers then moderated by the examiners. For Higher Grade 'candidates should spend a minimum of twelve hours in the field ... the report should be an independent, in-depth one and may concentrate on a particular theme or be made up of several discrete studies'. At the same time 'The geological value of particular localities and the consequent need for conservation should be emphasised. In this respect the use of geological hammers should be carefully controlled.'. A related point in conservation is made in the introduction to the Ordinary Grade syllabus.

The questions reproduced here all come from the 1985 examinations. Hopefully, they give an indication of the variety of questions used.

Candidate numbers and performance

Surprisingly, Geology is not the most popular of the school science subjects. In 1984, presentations in Ordinary Grade were Geology 406; Biology 25 128; Chemistry 27 515; and Physics 24 295. In 1985, 51 candidates were presented in Higher Geology. In 1984, 12 108 candidates sat Higher Biology; 15 500 sat Higher Chemistry; and 13 621 sat Higher Physics. Geology has a small but consistent following from colleges of further education. They have been presenting about 40 candidates a year in Ordinary Grade.

Table 1 shows presentations and pass rates since 1978. the 1985 figures are preliminary statistics so they are not strictly comparable with the results for other years. The table shows one or two interesting features. For instance, the number of fourth year candidates has remained consistently low. This may be because pupils were not

Table 1: S.C.E. Geology Presentations

Grade	Year	Total candidates	Male candidates	Fourth-year candidates	% of candidates gaining a pass
Ordinary	1978	263	205	52	67.4
Ordinary	1979	319	218	31	66.5
Ordinary	1980	339	224	70	62.3
Ordinary	1981	394	275	27	63.2
Ordinary	1982	407	279	24	65.8
Ordinary	1983	456	308	29	63.2
Ordinary	1984	406	281	45	62.3
Ordinary	1985*	360	250	53	60.1
Higher	1985*	51	39	–	58.5

* Preliminary statistics (do not include the results of appeals)

Table 2: Scottish Universities' minimum entry requirements.

University	S.C.E requirements	G.C.E. requirements
Edinburgh, Dept. of Geology	4 Highers at BBBC including Maths and 2 of Biology, Chemistry, Physics	3 A levels at CCC including two of Biology, Geology, Maths, Chemistry, Physics
St. Andrews, Faculty of Science	4 Highers at BBBB including two of Biology, Chemistry, Physics, Economics, Geography, Maths. (One of Chemistry, Physics or Maths is essential.)	3 A levels at BCC or CCC including two of Biology, Botany, Chemistry, Economics, Geography, Geology, Maths, Physics, Zoology. (One of chemistry, Physics or Maths is essential.)
Dundee, Faculty of Science	3 Highers at BBB in Biology, Chemistry, Geography, Maths Physics. or Higher Maths at A and 3 Highers at BBB including one of Biology, Chemistry, Geography, Physics.	2 A levels at CD in Maths, Biology, Botany, Chemistry, Geology, Physics, Statistics, Zoology.
Aberdeen, Faculty of Science	4 Highers at BBBB or 5 at BBBCC. One Higher should be in a science subject other than Maths.	2 A levels at BC or 3 at CCD. One A level should be in a science other than Maths.
Strathclyde, Depart. of Applied Geology	4 Highers at BBBB including Maths, Physics and Chemistry. English is the preferred fourth Higher.	A level Maths plus at least one of Physics, Chemistry, Physical Science
Glasgow, Faculty of Science	4 Highers at ABBB or 5 at BBBBB from Biology, Geology, Chemistry, Geography, Maths, Physics. At least one should be Chemistry, Maths, or Physics or/ Higher Maths at A plus 3 non-science Highers at BBB.	2 A levels at BB or 3 at BCC in Maths/ science. At least one A level should be in Chemistry, Maths or Physics or/ Maths at B an A level at B in a non-science subject.

Note: O Grade and O level requirements have been omitted. also, general entry requirments include English (to O Grade at least) and may include a foreign language at O Grade.

prepared to embark on a course which terminated in an Ordinary Grade certificate. Also, schools may have been reluctant to squeeze a new subject into an already crowded third-year curriculum.

The percentage of candidates who pass Ordinary Grade Geology tends to be in the low sixties. In 1984, other pass rates included Biology 56.4%; Chemistry 69.2%; and Physics 71.7%. The preliminary 1985 Higher Grade pass rate of 58.8% in Geology compares with the 1984 figures of other sciences as follows: Biology 61.3%; Chemistry 68.4%; and Physics 69.4%. The most likely conclusion that can be drawn from all this is that the best pupils tend to study Chemistry and Physics. It should be noted, however, that some candidates do very well in the Geology exams. Also, fieldwork logs and reports are frequently of a very high standard.

University entrance

Higher Grade Geology was recognised as a mathematics/science subject for entry to university by the Scottish Universities Council on Entrance in November 1983. However, this does not mean that it is welcomed by university geology departments. A look at minimum entry requirements (Table 2) shows some interesting features. For example, it is clear that aspiring geologists would be well advised to aim for good Higher Grade passes in Maths, Physics, Chemistry and English. Inspection of Biology and Geography syllabuses will show, however, that certain notable departments and faculties have no justification for preferring these subjects to Higher Grade Geology. University entrance requirements dictate the subject choice of many pupils. Would it be asking too much of Edinburgh, St. Andrews and Dundee to follow Glasgow and give us a mention?

Conclusions

It could be said that school Geology has been born into difficult times. As a result of the Munn and Dunning reports third and fourth year curricula and styles of assessment are being reformed. The

Candidates must not write in this margin

SECTION A

(All questions in this section are compulsory. Fifty marks are allocated to this section.)

Marks

1. (*a*) Complete Table Q 1 (*a*) to show the main minerals or materials present in some igneous rocks. You may choose any mineral or material once, more than once or not at all. The first one has been done for you.

Minerals or materials: glass, flint, pyrites, ash, quartz, calcite, feldspar, garnet, pyroxene.

Table Q1 (*a*)

Igneous rock	*Minerals or materials.* (Give only one or two items)
dolerite	feldspar and pyroxene
granite	
obsidian	
gabbro	
basalt	

(2)

(*b*) Complete Table Q1 (*b*) to show the properties of some minerals.

Table Q1 (*b*)

Name of mineral	*Colour*	*Cleavage*	*Hardness*	*Lustre*
malachite		good	$3\frac{1}{2}$–4	silky or dull
biotite	black		$2\frac{1}{2}$–3	glassy or pearly
talc	white	perfect		pearly
galena	grey	perfect	$2\frac{1}{2}$	

(2)

2. The volcanic cone shown in Figure Q2 (*a*) blew up to form the very large crater shown in Figure Q2 (*b*).

(*a*) What name is given to the very large crater?

.... (1)

(*b*) The volume of the ash cone in Figure Q2 (*a*) was 25 km^3. After the explosion, ash covered a land area of 200 km^2 to an average thickness of 50 m.

(i) What volume of ash (in km^3) had covered the land?

.... km^3 (1)

(ii) What happened to the ash which did not go up into the air during the explosion?

.... (1)

Marks

(*c*) During the eruption of Vesuvius in AD 79 ash rose straight up into the air. Why did most of the ash fall to the south-east side of the volcano?

.... (1)

(*d*) (i) Which type of volcanic rock is most commonly erupted at constructive plate margins?

.... (1)

(ii) Which type of volcanic rock is most commonly erupted at destructive plate margins?

.... (1)

Figure Q2 (*a*)

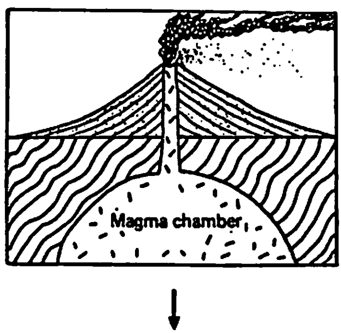
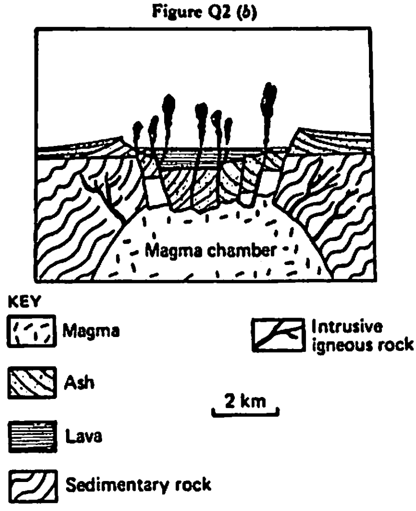


Figure Q2 (*b*)



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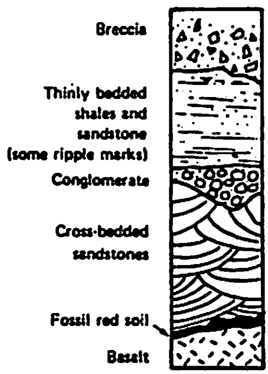
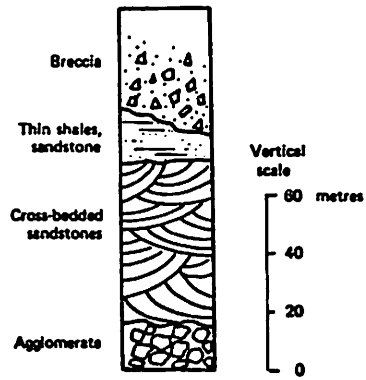
Marks

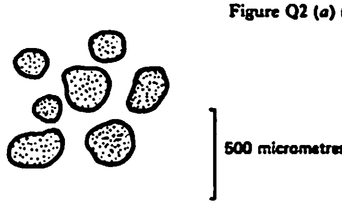
2. (*a*) Figures Q2 (*a*) (i) and Q2 (*a*) (ii) are sections from places 350 m apart. Figure Q2 (*a*) (iii) shows sand grains from the cross-bedded sandstone.





All sediments have a reddish colour

Figure Q2 (*a*) (i) Figure Q2 (*a*) (ii)



Microscopic view of sand grains from cross-bedded sandstones
Figure Q2 (*a*) (iii)

Describe as fully as possible the sequence of events and changes of conditions which occurred during the formation of both sets of rocks. Possible relationships between the two sections should be mentioned.

....

....

....

....

....

....

....

....

....

....

.... **(3)**

Marks

6.

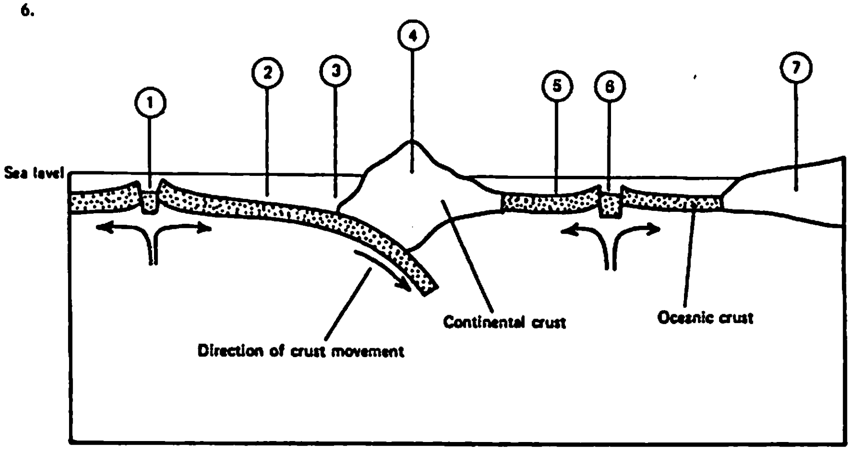


Figure Q6

Figure Q6 is a section through the crust of an imaginary planet called Thera. Reversals of Thera's magnetic field have taken place every 2 million years. The distance between mid-oceanic ridge ⑥ and continent ⑦ is 1000 km. 100 magnetic field reversals have been recorded in the oceanic crust between ⑥ and ⑦. Oceanic ridges ① and ⑥ are stationary.

(a) At which positions are large numbers of dykes likely to be forming?

.... (1)

(b) At which position are granite plutons likely to be forming?

.... (1)

(c) How fast are continents ④ and ⑦ moving apart?

.... cm per year (2)

(d) At position ① sea floor spreading is taking place at a rate of 1 cm a year to each side of the oceanic ridge. How wide is each magnetic reversal strip between ① and ②?

.... km (1)

(e) How fast is oceanic crust being subducted at position ③?

.... cm per year (1)

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(*b*) Figure Q1 (*b*) shows a thin section of rock type X, Figure Q1 (i).

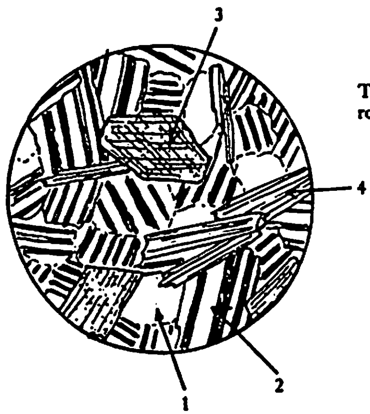

Figure Q1 (*b*)

(i) Identify minerals 1–4 by completing Table 1 (*b*).

Mineral Number	*Optical Properties*	*Name of Mineral*	*Percentage of Mineral in rock X*
1	Colourless in plane polarized light. No cleavage.		7
2	Colourless in plane polarized light. Twinning obvious in cross polarized light. Cleavage present.		60
3	Pale green in plane polarized light. Green to yellow in cross polarized light. Good cleavage.		18
4	Pale brown in plane polarized light. One very good cleavage.		15

Table 1 (*b*)

(4)

Candidates must not write in this margin

Marks

(ii) Rock X is most likely to be:

(*Underline the correct answer*)

A peridotite.

B diorite.

C gabbro.

D porhyritic basalt.

(1)

Candidates must not write in this margin

Marks

2.

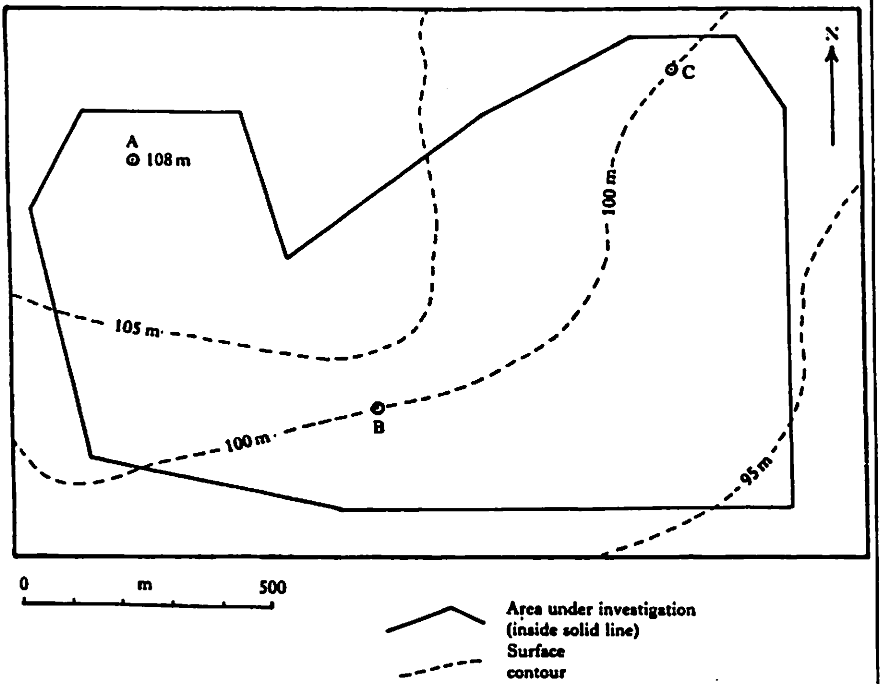

Figure Q2

The map Figure Q2 shows a coal mining area. Because of subsidence, mining has been abandoned at A (108 m above sea level). Trial bores have been sunk at B and C to test the extent of coal reserves. The following successions occur at A, B and C.

	Thickness (metres)		
	A	B	C
glacial drift	13	5	5
shale and siltstone	40	15	25
coal	2	2	2

Table Q2

(*a*) On the map Figure Q2 draw structure contours for the top of the coal seam. (Assume a uniform dip.) **(6)**

(*b*) On the map Figure Q2 mark with an "X" a point where coal should occur at the surface. **(2)**

(*c*) In Figure Q2 the area inside the solid line is being investigated for open cast mining. Work can only take place where the top of the coal seam is within 30 m of the surface. Lightly shade the part of the outlined area in which open cast mining would be possible. **(4)**

[Turn over

replacement of Ordinary Grade by Standard Grades has already begun and the first Standard Grade exams in Science, English, Maths and Social and Vocational Skills will be held in 1986. Standard Grade exams based on revised syllabuses are due to be introduced in Biology, Chemistry, Physics and Geography in 1989. Revised Higher Grade syllabuses will be developed to follow on from the new Standard Grade courses. The place of Geology in this scheme of things is uncertain. Hopefully, it will be redeveloped along the same lines as Biology, Chemistry and Physics.

In conclusion, it is hoped that those of you who have never been in a school before will now have some idea of what is going on. Finally, let me thank Mr. T.A. Forrester of the Scottish Examination Board who supplied a great deal of very useful information. The exam questions are reproduced by kind permission of the Director of the Board.

THE NATURAL HISTORY OF THE MINERAL KINGDOM

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Intimate and fruitful connections have always existed between academic geology and mineral exploitation. When mining engineer John Williams published 'The Natural History of the Mineral Kingdom' (Edinburgh, 2 vols) in 1789, he hoped that it would be used as a textbook on "principles of Mineralogy", enabling new courses to be taught in a subject which, apart from some "fossilology", had been unwisely "neglected in our public schools"

As manager of Gilmerton coal-mines in Midlothian, John drew upon forty years of experience of mining and mineral surveying. His factual accounts of mining were intercalated with detailed criticism of the theories of Count Buffon and Dr James Hutton, based primarily upon his view that a belief in erosion and orogeny "in a perpetual succession, forming world after world", led immediately to atheism. He could not accept "the wild and unnatural notion of the eternity of the world."

When James Miller produced an edited version of John's book in 1810, he explained that it had originally been "received, and still continues to be regarded, as a most valuable practical treatise on the Natural History of coal which has yet been offered to the public". In fact, it was also rather good on lead mining. James used the new edition as a vehicle for his own appendix giving "a more copious detail of geological facts than any other work." Fortunately he also researched a short biography of his predecessor.

John Williams had led a colourful life. The son of a Welsh miner and trained in his father's footsteps, he soon sought adventure as a mercenary in the Dutch army. He re-emerged as a mining superintendant at Leadhills, Lanarkshire, extracting silver from lead ore, but soon resigned and began searching for lead ore near Edinburgh on behalf of some landed proprietors. This was followed by an unsuccessful spell as coal tacksman (mine overseer) on Newhall estate, Carlops, on the extreme edge of the Midlothian coalfield, and an equally unsuccessful exploration for coal on Dunrobin estate in northern Scoland for the Earl of Moray.

At some point he served as mineral surveyor with the government Board of Annexed Estates, in the Highlands, before a settled period as manager of Gilmerton coalworks, where he had to contend with very steeply dipping (45°) 'Edge' coals that were marketed in Edinburgh. Shortly after completing the 'Mineral Kingdom', he published a geological survey from Mid Calder to Polkemmet (Edinburgh, 1793) for Sir W.A. Cunynghame of Livingstone, before travelling to Italy, where he died while exploring for coal and copper.

The 'Mineral Kingdom' commenced with coal mining, providing students with details of the "troubles" ("dykes", "slips", or faults) and strata encountered. John directed them to suitable sections for observation, along the Musselburgh coast, Esk rivers, Salisbury Crags, Water of Leith, and River Almond near Cramond Bridge. (The fashion remains unchanged.) Since limestone often alternated with coal seams, and sometimes formed the immediate roof to the coal, the subterranean lime quarries at Gilmerton were particularly recommended as "singular and extensive, and their magnificent appearance strikes the imagination with a pleasing awe and astonishment."

Students were warned of drainage problems caused by folded strata, particularly "sow's-backs," which "sometimes resemble long and large waves at sea". Fairly horizontal coal beds around Dalkeith developed these waves out towards Carrington. Of particular importance, to avoid simplistic errors, John stressed: "I have never yet found that the external figure of the ... (ground) surface governed the position or the bearing and declivity of the strata below."

He stoutly maintained that coalfields were entirely separate from each other, at a time when many coal-masters believed "that the coals and coal metals stretch away in under the mountains, and emerge again upon the other side." It was a common misconception that coal strata "keep their course in general in the line of bearing quite through the island, and perhaps round the globe." Instead, he demonstrated their outcrop pattern all round separate coal basins.

John attributed the induration of rocks to mineral deposition from solution, as observed when concretions formed in old mines. However, unlike Hutton, he preferred to regard basalts as sedimentary rocks, quite distinct from localised slags and lavas of clearly volcanic origin. Many basalts observed underground were conformable over large areas: "I would ask the Doctor how he is to lift the superincumbent strata to a sufficient and equal height from the strata below, for many miles extent ... until such a quantity of melted lava is poured in as will fill up all the extensive empty space." "There are several thick beds of ... (basalt) betwixt the different seams of coal at Borrowstouness, and one of them is the immediate roof of a coal seam." Thin coal also underlay "beautiful columnar basalts" at Hillhouse quarry, Linlithgow.

Half a century before James Young's mineral-oil distilleries produced red spent/shale bings in the Lothians, it is remarkable to find thin argillaceous coal 'blaes' containing carbon being specially burned for pale-red road 'metal' at Pitfirran in Fife.

John described the several varieties of coal as caking (bituminous), rock, stone (splent), cannel (parrot), culm (blind), and jet. Some laminated splent coals burned "with such a clear strong flame as to give a light equal to that of a number of candles, and the country people in many places use no other light in the winter nights." The evident vegetable origin of coal suggested "the greatest part of the antediluvian earth was covered with a tall and luxurious growth of timber". Coal tar, recently "extracted in such great quantity", consequently closely resembled that produced by wood-distillation.

Metallic ores occurred under quite different geological conditions, but John still believed the veins were water-deposits. The problems of following a thin rib or 'rake' (perpendicular vein) of ore through a 'twitch' (pinching-out) to reach the next "small nest", or wide "belly of ore", were illustrated by several examples: the 'old man' mineral 'gash' worked by York Building Co. at Strontian, the Llangunog 'slip' vein and Darenfawr lead 'rib' in Cardiganshire, and Telford's lead mines at Wanlockhead. "It is a pleasant and chearful sight to see a great number of miners, one before another in straight line, working upon stopes or steps, on a rib of solid ore, of two or three feet thick."

John provided a vivid account of exploration by 'hushing', a more effective technique than trial pits and trenches, for seeking 'float-ore' (placer deposits) and veins on vegetated hillsides. Small streams were first diverted to pond behind a dam built near the top of the slope. A 'gutter' was then prepared down the slope by removing a strip of vegetation and digging a trench two feet wide and 1½ feet deep. Water was released down this gutter many times, in increasing quantity. At first, workmen between whiles loosened the ground and moved aside large stones.

"When the gutter is worn deep enough to hold a strong hush or current of water, it will carry down an amazing quantity of stones and rubbish with such incredible force and violence, that it is impossible to describe or imagine without feeling it ... I have seen stones of several tons in weight, and as big as little huts, carried several hundred yards down a large hush gutter; and the water and stones of all sizes which the water carries down ... wears down, by the friction of the stones, a considerable depth of the superfices of the rock itself ... (revealing) all the veins, useful and curious stones, &c." Several 'hushes' of this type may still be seen in the Leadhills area.

The second volume of the 'Mineral Kingdom' is less satisfactory, propounding John's belief that "all the great hollows, gulphs, precipices and other irregularities" of the Earth were formed by strong tides during a universal deluge. Finally, in examining volcanoes as heat engines by analogy with James Watt's steam engine, he suggested they were powered by inflammable gases and compressed air.

In addition to his valuable description of mineral workings in Scotland, John Williams developed a great interest in the vitrified forts which he made a point of visiting during surveys of Highland areas "inaccessible to strangers". He connected them with the legendary kingdom of Fingal, and considered their partially fused stone walls to have been baked in trench-kilns before the introduction of lime cement. In his 'Letters from the Highlands' (Edinburgh, 1777) he claimed to have been the first to bring the existence of these interesting structures to the attention of the public.

International Report: MEGS 4, EUG 3

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No, it was not another football match at which visiting English fans rioted. In fact April 1985 saw the Fourth Meeting of the European Geological Societies and the third Meeting of the European Union of Geosciences. For many earth scientists, there was a choice to be made between the homely atmosphere of MEGS 4 in Edinburgh and the razzle dazzle of EUG 3 in Strasbourg. About 1000 people chose Strasbourg to hear over 600 talks covering 40 major geological topics. However I was one of over 150 people who attended the Edinburgh meeting (or couldn't afford the expense of Strasbourg?) where over 50 lectures were given covering six main themes embracing the "Evolution of the European Lithosphere". For some reason the Quaternary deposits of Europe were omitted from the content of this meeting to the disappointment of some attending members. Two of the session formed the 12th Meeting of the International Commission on the History of the Geological Sciences (INHIGEO), in the presence of its president Professor Gordon Craig, and were entitled "The Influence of Scientific Organisations on the Development of Geology".

The meeting was organised by our own Society with considerable assistance from the British Geological Survey, the Grant Institute of Geology, the Royal Scottish Museum and the Royal Society of Edinburgh. Financial backing was also provided by the British Petroleum Company, Robertson Research International, the Bank of Scotland and the Royal Society of London. The meeting marked a notable milestone in the lives of the Edinburgh Geological Society and the British Geological Survey, both celebrating their 150th Anniversaries. During the course of the meeting our president, Mr Butcher, admitted Ing. Hageman and Mr Glennie as Corresponding Fellows, and Professor Herries Davies and Sir Malcolm Brown as Honorary Fellows of the Edinburgh Geological Society.

Now that the dust has settled in the Appleton Tower the highlights of MEGS 4 are clear. The most important feature of the meeting was the friendly atmosphere generated, in part, by the excellent receptions held at the Royal Scottish Museum and at the British Geological Survey in Murchison House. It was the first time that MEGS delegates had been received by the host nation's Government and Mr John McKay, MP, the Scottish Minister for Health and Social Work, showed his understanding of the value of geology (at least to anglers) when he acknowledged that outcrops of limestone in streams were associated with bigger and better trout. Professor Luttig, replying in similar vein to the minister, also commented on the export of certain types of dust from Britain to Europe and the effect these had on living plants and animals. Mr McKay also noticed that the boundaries of Europe appeared to have been extended. In reading the list of delegates he was to meet, he had noticed that participants from USA, Brazil, China and Canada were included and that many had come from eastern Europe as well.

A different brand of humour was in evidence at the reception at Murchison House on the following night. The Hungarian delegates made presentations to the Survey and to the Society to mark their 150th Anniversaries. The links between Hungary and Scotland are strong because Robert Townson of Edinburgh produced the first geological map of Hungary around 1797. In any event, the Survey in England, represented by Sir K.C. Durham had received a medal and address from the Hungarians some years ago, and they now wished to make the same presentation to the Scottish office. In a piece of comedy worthy of Fawlty Towers, the Director of BGS prepared to receive the award from Dr Dudich only to be disregarded as Mr Hull of the Edinburgh office was called forward to accept the night's star prize!

I have already indicated the friendly nature of the meeting and I am sure that had we all gone to Strasbourg instead, we would not have had the same opportunities to meet and socialise with internationally well-known geologists such as Dr Paproth, Prof. Luttig, Dr Dottin, Prof. Ciric and Ing. Hageman to name just a few. The scientific programme was highlighted by excellent keynote addresses introducing each session although the content of some sessions was a little disjointed. The length of the session, and of each day's programme, was about right and did not requre the physical and mental stamina of a marathon runner to cope with the content. An interesting feature about the presentation of the lectures was the split between those profusely illustrated by photographs and those accompanied mainly by diagrams. It wasn't entirely an east-west divide either. My own choice of lectures which I will remember for some time to come were by Prof. Dewey (Lithosphere deformation mechanisms;, Dr Surlyk (Evolution of the Mesozoic and Tertiary Basins), Dr Hamilton (Charles Lapworth, his relationship with Sir A. Geikie etc) and Prof. Ellenberger (Le role des ingénieurs dans le dévelopement de la géologie Française au XVIIIe siècle). The reasons for remembering each I will leave obscure (c'est la guerre). My prize for the most interesting lecture would go to Dr Hamilton but that may reflect a personal bias towards the history of science (Alternative O Level examination pass in 1963!).

To all those who helped in organising MEGS 4, it was a job well done and it was a very successful meeting. They can also take consolation in the fact that unlike W. Ivison Macadam (Secretary of our Society in 1902) they were not shot (dead) by the servitor either at Surgeons Hall or indeed at the Appleton Tower. Whether at any time during the meeting our representatives felt like taking their revenge on today's university servitors is not recorded.

The meeting closed with minibuses taking 10 to 20 people each on field trips to the North West Highlands, Girvan-Ballantrae, Ardross (east Fife), Arthur's Seat and on a round of the classic geological sites in central Scotland.

The next meeting is in September 1987 in Dubrovnik (Yugoslavia) where not only will the architecture and general ambience of the city tempt delegates away from the conference floor, (at one time on the second day of our meeting only a quarter of the delegates were present), but also the fine hot weather, beautiful beaches and local exposures (not forgetting the rocks). By 1987, perhaps the meeting will be known as

MEGA 5 not MEGS 5. This is because not all eastern European countries have geological societies and thus representatives from these would prefer the title 'Meeting of European Geological Associations'. In deference to Nicoll and Pienkowski (1972) perhaps MEGS should be restricted to its proper use in relation to dinosaurs' eggs.

Reference

Nicoll H. and Pienkowski, J. 1972. *Meg's Eggs* pp. 29. Puffin Books.

INHIGEO SYMPOSIUM IN EDINBURGH

Cliff Nelson: United States Department of the Interior
Geological Survey, Reston, Virginia 22092

INHIGEO's XIIth Symposium, "The Influence of Scientific Organizations on the Development of Geology," formed part of the fourth meeting of European Geological Societies (MEGS 4) held at the University of Edinburgh during April 1985. Gordon Craig (Edinburgh) and Gordon Herries-Davies (Dublin) co-chaired the 14-paper symposium on April 11-12; Davies' keynote address analyzed British geological institutions as "functioning organic communities," evaluating their "evolution," "generic characteristics", "population sizes," and "environmental impacts." Martin Rudwick's (Cambridge) "The Geological Community in Early 19th Century Europe" looked at the geologists who attended and the topics they discussed at three meetings, held in 1835 as an example of the shape and composition of that community, and the degree of privacy and heterogeneity of their public debate. Rudwick urged that the history of geology be written to reflect the international activities of the science and not as chronicles of heroes or separate national enterprises. These papers and the symposium's contributions to the history of the national survey – including those by Directors Malcolm Brown, (BGS, Keyworth) and Martin Kürsten (BGR, Hannover) – geological societies in Europe, and geological controversies, will be published in the Royal Society of

Edinburgh's *Transactions*. MEGS 4 and INHIGEO participants were the guests of Her Majesty's Government at cordial evening receptions held at the Royal Scottish Museum, which displayed an exhibit and color brochure on "Geology Serves the Nation: 150 Years of the British Geological Survey," and the BGS' Murchison House, whose staff showed us some of the results of its past and ongoing work.

To mark its own sesquicentennial, the Edinburgh Geological Society and other organizations arranged for a facsimile reprint of the 1939 printing of the manuscript color geologic map of Scotland (1808) by Louis Necker (1786-1861). Necker, who had studied at the University of Edinburgh from 1806, used Thomas Kitchin's 1:800,000 scale map as a base. "The 'Explanation,' thought to be in Necker's own hand, shows that the young Swiss geologist skillfully steered a middle course between the Wernerian school of Jameson and the "Huttonians" – for example, Necker's map depicts both stratified and unstratified "Primitive" rocks. Copies of the facsimile of Necker's map are available for £2.50 (plus packing and postage) from the EGS' Publications Sales Officer, Kings Buildings Central Library, West Mains Road, Edinburgh, EH9 3JF. H.E. Wilson's single-volume history of the BGs will be printed by the Scottish Academic Press later in 1985.

For 20-plus historian-geologists who had attended the symposium, Craig, and his charming wife Mary, also arranged a 4-day excursion during April 12-15 to "Some Classical Geological Localities in Scotland," including several of the outcrops that Hutton visited in the 1780s to gather evidence of his *Theory of the Earth* (1795). The localities were chosen "to show Hutton's power of observation (aided and abetted by the artistic hand of John Clerk of Eldin) and demonstrate that the Earth indeed is a machine fired by heat." Referring at these sites to Hutton's and Playfair's descriptions, and to Clerk's drawings published in 1978, enabled us to see through their eyes vital evidence for the Huttonian Theory.

Minivans driven by Craig and Hugh Torrens (Keele) took us from Edinburgh across East Lothian to Siccar Point, on the Berwickshire coast east of Cockburnspath, where, in a striking setting, gently dipping Upper Old Red Sandstone overlies steeply tilted silurian graywackes and shales. The Siccar locality (1788) has been described as the most spectacular of the three unconformities by which Hutton demonstrated that the Earth's rocks were "the products of an essentially cyclical, oft-repeated process" and the place that made Playfair "grow giddy by looking so far into the abyss of time." A visit to Sligh Houses, one of Hutton's farms, preceded an excellent evening buffet at the RSE and a tour of its portraits, books, and manuscripts.

On the excursion's second day, Craig and Herries-Davies guided us around Arthur's Seat Volcano in Holyrood Park and discussed some of the key sites whose features showed Hutton the force and heat of the intrusive contacts between the Carboniferous basalt and sediments in the Salisbury Crags and nearby sections. The Crags gave us a fine view of the city northwest towards the glacial "crag and tail" that connects Edinburgh Castle and Holyrood Palace via the "Royal Mile." From Edinburgh, we drove north to Kinnordy House, Sir Charles Lyell's ancestral manor near Kirriemuir in Angus, where we were royally entertained at a buffet luncheon hosted by the present Right Honourable Lady Lyell before examining Lyell's library, some of his manuscripts, and several nearby localities he described in 1825.

From Forfar in Angus, we passed west and north on the third day across the Boundary Fault to Glen Prosen, in the Southern Highlands, where, in 1840, Buckland showed Lyell the moraines that temporarily convinced him that Agassiz's concept of continental glaciation was correct. Further west, we crossed the pass of Killiecrankie in Perthshire, where the Jacobite general "Bonnie Dundee" was killed in 1689, and drove up starkly beautiful Glen Tilt. Along this glen, we examined sites where, in 1785, Hutton and Clerk recorded the feature of granite and other intrusive rocks which cut well-bedded metasediments now known to be of Precambrian age. We ended the afternoon by touring Blair Castle, the ancestral home of the Murrays and Dukes of Atholl.

From Blair Atholl, we drove, partly by General Wade's Military

Road (built after "The '45"), south through Crieff to view the Carboniferous dolerite dike that Hutton also had studied in 1785. The last day of our tour continued along Hutton's and Clerk's route of that year to the section of Devonian and Carboniferous sediments and extrusive rocks in the Ochil Hills exposed along Glen Devon in the gorge at Rumbling Bridge and at the waterfall in Cauldron Linn. We returned to Edinburgh via Falkirk and Linlithgow, the latter the birthplace of Mary Queen of Scots.

The XIIIth INHIGEO Symposium, on topics in the history of stratigraphy and paleontology, will be held in Pisa, just before MEGS 5 at Dubrovnik in September 1987.

FOURTEEN DOWN: BOULBY'S DESERT WINDS TAKEN WITH A PINCH OF SALT

M.A.E. Browne
BGS

It was Monday afternoon, September 16th, the air temperature was 38 degrees Celsius and a hot, dry, sometimes suffocating, dust-laden wind was blowing. Could it be the sirocco in the Sahara or a simoom in the Arabian desert? Fourteen people from the Edinburgh Geological Society struggled on, the bitter taste of salt on their lips. It was rather dark and visibility often less than 30 m. Was this a bad dream caused by consuming too much alcohol in the hotel last night or had the climate of Whitby changed so much during our weekend field excursion. The reality was that we were walking along the return airway in the Boulby Potash Mine [NZ 760 180] almost 1200 m below ground. The Mine is situated just west of Staithes, within 2 km of the Yorkshire Coast, and is claimed to be the deepest in Britain. It is owned by Cleveland Potash Limited and is the only one working potash.

The factors which influenced the siting of the mine at Boulby (orebody apart) are the existence of shale bings associated with old mine workings in the Cleveland Ironstone Formation of the Lower Jurassic (environmentally damaged land available), access by road and rail (part of disused coast line easily relaid) and proximity of the sea for water supply and waste disposal. The sinking of the two 5.5 m diameter shafts began in 1968 and was completed in 1976, both to a depth of 1150 m. Initially the potash ore (sylvinite, a mixture of potassium and sodium chlorides) was extracted using a rectangular pattern of stoop and room working, the stoops 30 m square and the roads 6 m wide. Serious problems arose with this mining system as roadways always deteriorated rapidly because the ore is a weak material under load. The current practice (Stress Relief Mining) is to extract the ore in panels, 120 m apart, consisting of six parallel galleries advancing in chevron pattern with the outer tunnels ahead of the central roads. Each gallery is about 4 m high and 6 m wide and is separated from its neighbour by pillars 4 m across and 20 m long. The roof is strengthened by emplacement of 1.5 m long rock bolts about 1.5 m apart, held in with the assistance of resin. To advance the face, a 15 cm slot is undercut about 1 m above the floor to a horizontal depth of about 4 m to form a space into which the blasted material can fall. The shotholes are drilled horizontally to a depth of about 3.75 m and each blast yields about 200 tonnes of ore. In addition to blasting, the ore can be ripped by the many revolving teeth of the big heliminers. The outermost roads and their pillars are deliberately designed to be subject to the most pressure as mining takes place. These pillars, even with additional rock bolting, readily fracture and the roof fails. The pillars erode by necking in the classical manner with large triangular prisms of ore spalling off the walls. Thus the two outer roads are quickly crushed and closed but the inner roads remain intact in an artificially created area of low stress. Three laws of the mine in areas of sidewall rock bolting are (1) walk quickly, (2) if standing still, do not stand opposite a rock bolt and (3) if you are hit by an exploding rock bolt make sure it hits you in the back and that it came from the farthest wall! A fourth more general rule is that drivers of heliminers and other large pieces of moving equipment are nice fellows but can be a little dozy at times so when you are near them wear your lamp on your head where they can see it. Otherwise you will be squashed flat although they won't mean you any ill by it. A fifth law, especially for men, is always walk over moving cables and hoses by placing your front foot firmly on it or else you were warned!

Our journey over 1 km into the earth's crust was preceded by an informative lecture by Charles Mackenzie, the Mine Geologist, a Fellow of the Society, whose invitation to visit we had gratefully accepted. The mechanics of mining were also explained by John Theobald, the District Geologist, whose area of the mine we were to visit. By 4 pm, lightly clad, armed with lamps, helmets and self-rescue kit, we passed through the contraband checkpoint, handed in our dog tags and passed through several airlocks to reach the pithead. In two minutes we were whisked down to the bottom of the shaft passing through the Quaternary in four seconds (one way time, for the benefit of the geophysicist), Liassic and Rhaetic Shales (42 secs), Keuper Marl (71 secs), Bunter Sandstone (96 secs) and entered the Permian in 108 seconds. Like a descent in an aircraft, the change in atmospheric pressure following a drop of over 1 km caused discomfort to the ears but the extreme noise of compressed fresh air being forced round the cage near the botton of the shaft caused the first visible reaction from the mob. It is not clear whether the bachelor male (well under 21) or the married female Fellow (probably over 21) initiated the hand holding session, or what the reason was.

From the pit bottom we went to the lowest part of the mine (depth over 1200 m) which is within the mining barrier around the shafts. Here we examined the geological succession below the orebody and also a spectacular reverse fault (Woods 1979, figs 3 and 6). The lowest formation seen was the Upper Magnesian Limestone, possibly 25 m thick, which consisted of dark grey to black, bedded, fine-grained dolomite with some mudstone partings. The contact between the dolomites and the overlying Billingham Main anhydrite was sharp and generally flat. The anhydrites, 12 to 15 m thick, were mainly fine grained, pale to mid grey in colour and well-bedded. The anhydrites pass up into the overlying Boulby Halite Formation by interbedding.

The Boulby Halite, c. 50 m thick, consists of rhythmically repeated cycles (cm scale) of fine to very coarse grained halite and clayey halite with clay partings and patches. The halite is colourless to white if pure, red if stained by hematite and grey to black if dark clay is present. Lenses of recrystallised salt occur, sometimes 30 m thick and more than a metre long, and often are a beautiful pink colour. Where circulating waters have dissolved salt, the cavities have subsequently been filled by 'table pure' very coarsely crystalline colourless halite. These three formations form the third evaporitic cycle (EZ3) of the Permian Zechstein Sea.

John Theobald then took us to a newly started mining district. All the access roads are cut in the Boulby Halite at a horizon some distance below the orebody. After walking about a kilometre west of the pit bottom, the relationship between the bedded halite and the sylvinite orebody could be examined. The sylvinite (sylvite and halite) is not bedded and the fabric and structures observed in it are reminiscent of metamorphic textures (folded gneisses). The ore is probably secondary in origin and is believed to result from the chemical alteration of primary carnallite (potassium magnesium chloride) and upward migration and local concentration of the sylvite produced within the top part of the Boulby Halite. The overlying Boulby Grey Shale has been heavily brecciated and reconstituted by these processes, the shale commonly being found as small clots and patches within the Boulby Potash. Pure coarse grained sylvite is white and can be distinguished from halite by its very bitter taste (salt is sweet by comparison, but not if accidentally added to your coffee). The white variety forms augen crystals in an orange or pink matrix of sylvinite with clay clots. The gravity induced plastic flow fold and thrust structures associated with the orebody have been described by Talbot, Tully and Wood (1982). The thickness of this unit as a result is also variable from 1 m up to 20 m. A marker horizon used to locate the orebody when driving headings up from the main roads is a band of halite showing beautifully preserved desiccation polygons up to a metre across and two metres deep, the cracks being filled with clay or clayey halite. We saw them both in plan in the roof and in section in the wall of the mine. This horizon is about 6 m below the orebody. As the aim of the mining methods employed is to avoid roof troubles the overlying succession including the top 1.5 m of the orebody, Boulby Grey Shale and Carnallitic Marl, was not seen in the mine. The appearance of salt clay ('marl') in the roof is very bad news as roof conditions become uncontrollable.

Our overall impression of life in the headings was one of intense noise from the drilling equipment and lots of dust. The pervasive salt dust was clean, unlike a coal mine, but the large concentration of it in the mouth and nose is an experience not easily forgotten. We also learned the sixth rule of the mine – when looking at the highly stressed rocks in the outer roads of the chevron, never hammer the walls. Another impression was the foetid smell. The orebody contains small pockets of gas consisting mainly of nitrogen with methane, ethane, butane and pentane, the latter pair giving rise to the smell. The gas is released during drilling (we could hear the bangs) and blasting. If a large pocket is released during blasting, up to ten times the normal quantity of rock may be brought down, and of course that works wonders on the carefully designed shape of the pillars and the roof. When we left the working face we were glad of the iced water offered to us by the miners. "You must be mad coming down here on your holiday!" We learned that painters, decorators, graduates and a professor had left the dole queue to work down Boulby and that they were all members of T.G.W.U.

After visiting the sump to look at large snowflake crystals of salt precipitated out of the mine waters, we briefly sampled the delights of the return airways (which is where we came in) to see salt stalactites (salt straws) and stalagmites at least 1.5 m high and wide. The fancy shapes formed by the dripping brine are known locally as Boulby coral and you could see why. Where the cavity in the roof hereabouts went to was anyone's guess but if it ever linked up with the the brine-bearing Bunter Sandstone 200 m above, that really would be trouble.

So our visit to the largest sauna in Britain (effective working temperature 30°C) drew to a close. Retracing our way to the pit bottom we collected our samples from the various strategic points safe in the knowledge that as long as they weighed less than 2 tonnes we would be allowed to return to the world above and wouldn't have to pay for them. It didn't feel as though we had had three hours underground as we emerged at the surface to the fading day, a cup of tea (or three) and a presentation box of samples from the mine. Some began to wonder why they had bothered to bring up sackfulls of specimens!

Certainly it was a visit not to have been missed, even if the gap in succession between the Liassic mudstone of the Staithes shore section which we had seen on Saturday and the Permian evaporites in the mine was concealed behind the concrete lining of the shaft. The policy of Cleveland Potash Ltd is to limit the number of visitors (many are called but few are chosen) and no school parties are allowed (two lucky boys). Thank you Charles and John for a great trip.

P.S. Other facts : 2 million tonnes of raw potash ore (for fertiliser) and 250,000 tonnes of halite (for icy roads) are mined each year. The Billingham Anhydrite Mine is in the same part of the Permian succession but there is no salt in their sequence. Salt straws curve upwind because of increased evaporation on the wind side. The diameter of the circle circumscribed by the mined area around the shafts is 4 km and the northernmost workings are also a half km offshore and this will be raised to 3 in due course. The mine should still be working in the next century. Perhaps this wasn't a once in a lifetime experience. Next time we can travel underground to the far corners of the mine like the miners do – flat on your face on the conveyor belt. Tell me, how do you get off?

Further Reading

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ASSYNT REVISITED

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The Edinburgh Geological Society returned to the Assynt area for the 1985 long excursion. The weather deteriorated rapidly as we clinked (we had been forewarned about the lack of certain types of shops) our way towards the north west, and we thought that it was not going to come up to the usual, and now expected, standard. The chalets this year were in Unapool, to the south of Kylsku and arranged so that an excellent view of Quinag could be seen, across a side-arm of the loch, through the lounge windows. On arrival it was found that all the numbers of the houses had been changed; despite this nobody manage to gain extra rations (or lose them!) in the confusion. On the first evening Frank May gave a short talk on the proposed itinerary for the week, pointing out that we could do a great deal of the geology without actually having to go out, especially with the use of a good pair of binoculars.

The first day in the field dawned dry but rather cloudy. The party set off for Upper Badcall where the contacts of a Scourie dyke against the Lewisian were to be studied in detail; another dyke was traced across a shear zone and was seen to thin and be deflected. The sun was shining by the time the party set off after lunch for a hard, 4 km walk to look at the basic and ultrabasic rocks to the south of Loch Gorm. The route threaded its way among myriad lochs and lochans; one member of the party, not to be diverted from the directissima, waded one shallow stretch of water only to find himself on a peninsula with the prospect of either the original detour or getting even wetter; the detour won! Another stalwart had decided that a more energetic day was called for and, despite new boots, had conquered Quinag, or rather three-quarters of it. The evening's entertainment was a trilobite hunt in a small quarry just to the south of Inchnadamph where fossils were meant to be plentiful. One spine was found before the thoroughly chilled party had to take refuge in the Inchnadamph Hotel in order to thaw out, where they were met by those who had been a little tardy with the washing up, or (official version) were valiantly trying to reduce the various food mountains (and wine lakes?).

Monday, which turned out to be our warmest and sunniest day, was spent to the south of Loch Glencoul studying the Cambrian succession, its overlap across the Torridonian and Lewisian, and the Glencoul thrust plane. From a knoll near the road the geology of the area could be easily demonstrated; looking westwards towards Quinag it is possible to trace the unconformity between the brown Torridonian sandstone and the grey Lewisian gneiss from the foreground to 300m on Sail Garbh and 600m on Sail Ghorm, demonstrating the hilly nature of the ground on which the Torridonian was deposited; and to the north, across Loch Glencoul, the effect of thrusting is well displayed on Beinn Aird na Loch. After the 'binocular' geology the details of the Cambrian succession were examined below the Glencoul Thrust plane. After lunch and a short visit to the thrust plane the more energetic members continued to the Stack of Glencoul while the rest of the party returned to the buses and went, via Lochinver, to Achmelvich Bay to look at the Lewisian of the central 'Scourian' zone again. Some members were lured by the sun and sandy beach to try the first, and only, bathing of the trip. It turned out to be a quick dip! In the evening those members interested were invited to see some slides taken in Iceland the previous year by some members of the Society. A poster on Iceland was also circulated, by request, to all the chalets during the week.

Tuesday was spent near Clachtoll on the Stoer peninsual looking at the Stoer group of the Torridonian. The predominantly red, muddy sandstones also contained some elusive algal limestones, which once seen were found everywhere, and cupriferous nodules, which remained elusive. In the evening the whole party foregathered to mark the retirement of Wally Mykura from the B.G.S. and to express the wish that he could continue to attend E.G.S. excursions for many years to come. A desk set, a clock and a pair of book-ends in Skye Marble, donated by Don Shelley, were presented in the name of the Society to show the members' appreciation for all that Wally has done over the past years.

Wednesday was designated a day of rest! The party duly set off for Tarbet where it divided. The majority visited Handa Island, and the "Lewisian enthusiasts" (including those who did not fancy birdwatching or the boat trip – stories had been heard about the excitement of the landings!) headed north for Rubha Ruadh and the Laxford front. The geology was varied and extremely interesting, and included bands of brown weathering schists which are thought to be metasedimentary bands. Basic and ultrabasic rocks similar to those seen on the Loch Gorm traverse were also seen, together with a strongly foliated rock of granite composition. One metagabbro was particularly noticeable with large garnets up to 40 cms across! At one locality, a large and extremely interesting but complex Scourie dyke, the most profound saying of the week was heard that – "in some cases it is best just to walk away from the exposure and forget about it". The evening's entertainment consisted of a hilarious quiz arranged by one "house" on what we had seen (or should have seen) during the week. The result was unique in that the questionmaster finished up with –3 points for not knowing the correct answers to some of the questions set!

On Thursday the energetic set off to conquer Conival and Ben More Assynt, or in one case, to complete Quinag. The geological party looked at the Cambrian/Lewisian unconformity and the Cambro-

Ordovician succession up to the Eilean Dubh limestone in the road sections by Lochg Assynt. Lunch was taken at the Peach and Horne memorial before following the path along the north side of the Traligill river to see the thrusts, caves and disappearing rivers. The evening was free.

Friday was to be an easy day. The party set of for Durness, stopping briefly north of the Laxford front to let the birdwatchers have an opportunity of seeing the granite sheets that cut the gneiss. At Durness we looked at the remainder of the Cambro-Ordovician succession (as well as Primula Scotica in flower) at Balnakeil Bay. Dedication was severely tested in the afternoon as we experienced the first rain of the week which lasted the whole afternoon; despite the rain the section was found to be very interesting. The final stop (excluding the local tea shop where we dried out) was Smoo Cave.

In the evening the now traditional ceilidh took place. An innovation this year was a raffle – a brilliant idea for getting rid of the remaining (and unwanted) food mountains. Other contributions were enthusiastically received, especially the presentation of the "Strontian Hammer" to Frank May for "his immense contribution to the success of the excursion, including his clear explanations and unique humour", which was exemplified by his comment on the Scourie dyke that was quoted earlier. This year also saw the presentation of smart computer printed certificates (due to the foresight of David Moseley) for various nefarious reasons; unfortunately (in some cases) the recipients would prefer to forget the activities for which they were so honoured.

And so another long excursion had come to an end. Some chalets were spared the usual cleaning ritual, as 4 out of the 6 experienced power cuts just before we were due to leave – luckily after breakfast had been cooked otherwise an unforeseen egg and bacon mound might have materialised. During the journey south to Edinburgh the weather deteriorated until a state of continuous heavy rain was achieved – possibly related to the traditional weather expected for English Bank holidays.

Acknowledgement

Thanks are due to the the Catering Committee without whose mammoth efforts we would not have the annual mountains and lakes (which, incidentally, are always different) on which I have commented freely. We wouldn't like it any other way!

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STRANGE EARTH No. 3

by Bill Baird

Two large stacks of baled hay, some 15 feet apart, on a property in the Parish of Gnarkeet, near Lismore, Western Victoria were burnt to the ground on the 7th of March of 1961. The 325 tons of hay were mowed and stacked during a relatively hot dry period and contained only the normal grassland plants associated with meadow hay. The soil underlying the fields from which the hay was taken had a basaltic origin. Examination of the fire site revealed that 325 tons of hay had been converted into approximately 16 tons of silica glass. The reasons for the production of this "natural glass" are discussed by George Baker and Alfred A. Baker in Hay-Silica Glass from Gnarkeet, Western Victoria, Memoirs of the National Museum, Melbourne, Australia, 1963, No. 26, pp. 21-45.

THE TESTIMONY OF THE ROCKS – MAY 1985

by Bill Baird & Andrew McMillan

If only these rocks could speak, what tales they could tell!

1. "Hello, Moine! How's your Schist?"

2. "Oh, a bit micaceous, Jurassic. How are the Gryphae?"

1. "Fairly fossiliferous, Moine, fairly fossiliferous."

2. "Have you heard that the Edinburgh Geological Society are around again this spring?"

1. "Oh, no – I don't think I could stand them again, after what they did at Loch Aline."

2. "I know how you feel Jurassic. I mean, a girl likes a bit of attention but when that Frank May looks at me I just feel as though I haven't got a stitch on."

1. "I know, dear, they had their hands all over my corals at Applecross and I won't tell you where they poked their chisels."

2. "Well, thank goodness they're not coming here this year. They're up at Kylesku, doing unspeakable thinks to Lewisian, Torridonian and Cambrian."

1. Well Torridonian and Lewisian are fairly mature girls and not easily excited, but Cambrian is a bit too Palaeozoic."

2. "I know, dear, they were down at Cambrian on Monday night trying to get hold of her trilobites."

1. "Did they get any?"

2. "No! She managed to hide them all, but that little Sandy Robertson had his eyes on her vugs."

1. "I suppose they were examining the Glencoul Thrust?"

2. "Oh yes, dear – you can't have a little bit of family friction without them shoving their nose in."

1. "Has Bill Roberts got his big hammer?"

2. "Of course dear – and the worst think about that is you never know where it's going to fall."

1. "I suppose that Alec Mackie is there again?"

2. "Yes, you can't trifle with him. But he's getting very forward; a could of hundred years in the EGS and he's on first name terms with us."

1. "Their president Norman is still trying to flog that Necker map. If he keeps carrying on like this we'll fix him the way we did Necker."

1. "Do you think there is anything we could do to stop them coming back?"

2. "Apart from re-activating the Great Glen fault, I don't think there's a chance. They're a pretty rugged lot: you've got to Handa to them."

EDINBURGH GEOLOGICAL SOCIETY

Prices to Members of the Society

Macgregor and Phemister's Geological Excursion Guide to the ASSYNT DISTRICT OF SUTHERLAND, edited and revised by M.R.W. Johnson and I. Parsons. Fourth revision edition, 1979. Illustrations, four coloured and nine black and white maps. Price £1.33

ARDNAMURCHAN: a Guide to Geological Excursions by C.D. Gribble, E.M. Durrance and J.N. Walsh, and edited by C.D. Gribble, 1976. 132 pp, 16 black and white maps, etc. and a folded coloured geological map of the peninsula inserted in a pocket inside the back cover. Price £1.33. Extra copies of the coloured map are also available, both folded and flat for field and office or home use, and are laminated for durability. Price 40p.

DALRADIAN GUIDES, separately bound papers comprising an Introduction and description of the following areas: (1) Rosneath and S.E. Cowal, (2) Knapdale and North Kintyre, (3) Tayvallich, (4) Jura, (5) Lunga, Luing and Shuna, (6) Loch Awe, (7) Loch Leven. Reprinted from the Scottish Journal of Geology, Vol. 13, 1977, these papers are available either as a set of 8 at the price of £3.20 or individually at the price of 40p each.

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