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The main object of the Association is to advance the teaching of geology in the United Kingdom.

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Membership of the Association is open to practising teachers of geology and allied sciences in schools, colleges or universities, and to persons actively interested in education in geology.

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General correspondence, requests for membership, etc. should be addressed to the Secretary (Mr. Anthony J. Dunk, College of St. Mark and St. John, Kings Road, London, S.W.10) and subscriptions to the Treasurer (Mr. John Myers, 148, Hempstalls Lane, Newcastle, Staffordshire).

Material for the Journal and for the Association's Newsletter, as well as enquiries regarding publication, should be sent to the Editor (Mr. Denis Hart, 2, Cray Avenue, Ashtead, Surrey).
### Geology

*Journal of The Association of Teachers of Geology*

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CARDIFF
EDITORIAL

The greater part of the contents of volume 3 of Geology is based on the lectures and demonstrations given at the third Annual Conference, at Sheffield in 1970. The contributions by Professor Samuel Tolansky and Mr. William Hall are based in part on previous publications and due acknowledgment is made below; those by Dr. John Phillips and Mr. Emlyn Evans and the Presidential Address are slightly enlarged versions of the original presentations, and those by Dr. H. J. Peake and Mr. Stephen Hannath are almost verbatim reports.

The remaining item in the main body of the Journal is contributed by Dr. George Black of the Geology and Physiography Section (originally the Geological Section) of the Nature Conservancy. It contains statistics based on surveys carried out in 1965-66 and in 1968-69. Many members will remember the exhibits illustrating the results of the surveys which were displayed at the Second Annual Conference, at Sheffield in 1969.

As in previous issues, a number of items have been included which describe or define geology. It is proposed to include such items in future numbers and members are invited to help by sending in appropriate quotations for consideration by the Editor.

During the year a determined effort was made to persuade booksellers in many of the towns and cities of the United Kingdom which are of importance to geology and are regularly visited by teachers and students to advertise the Journal. Unfortunately, the effort was not very successful, as can be seen in the pages of advertisements. A similar effort will be made in preparation for the next issue of the journal and if anyone is prepared to help in this matter, or in helping to persuade advertisers in general, the Editor would be grateful.

Acknowledgments

Acknowledgments are due to: The Robertson Research Company of Llanrthos, Llandudno for a donation of £100 towards the cost of printing this issue of the Journal; Edward Roberts Limited, Cardiff, for printing the journal at very short notice; the Editor of Endeavour for permission to copy the article by Professor Tolansky which appeared in the September 1970 issue of that Journal; the Institute of Physics and the Physical Society, for permission to reproduce parts of a manuscript by Mr. Hall; to the Staff of the Geology Department, National Museum of Wales, under Dr. D. A. Bassett's guidance, and to Mr. Gordon Margetts, for collecting, editing and refereeing the material in this issue, and for seeing it through the press; and finally to the advertiser for their support.

EDITOR
GLASS SPHERULES IN THE LUNAR DUST

Samuel Tolansky

The Association's Distinguished Guest at the Annual Conference 1970, was Samuel Tolansky, F.R.S., Professor of Physics at the Royal Holloway College of the University of London. The accompanying paper, which is a slightly modified version of one that appeared in the September 1970 issue of Endeavour and which summarizes the lecture given at Sheffield, is a report on the author's investigation of dust samples, using a specially developed interferometric technique. Hypotheses are advanced to account for the presence and the abundance of the spherules but further support for such conjectures must await the outcome of future Moon landings.

INTRODUCTION

FROM a consideration of some of the surface properties of australite tektites, the author predicted at a meeting at the Royal Society in London in February 1969, that the surface of the Moon was likely to be covered with enormous numbers of small glass spheres or 'marbles'. This prediction was reiterated in a subsequent note describing some interferometric studies on australite tektites in the British Museum (Tolansky, 1969). When in due course, through the courtesy of the United States National Aeronautics and Space Administration (NASA) we received in September 1969 two small samples of the lunar dust 'fines' retrieved by the Apollo 11 astronauts, we indeed found in our 5 grams of fines more than two hundred glassy spheres and related objects large enough to be extracted by tweezers. Besides these we also observed an enormous number of much smaller spheres, decreasing in size as far as the limit of resolution of a good quality 4 mm microscope objective. These small objects are exceedingly numerous, a large number being visible even on a smear on the microscope slide.

On 5 January 1970 a conference was held at Houston, Texas, where all the several hundred investigators engaged on studying retrieved lunar material submitted preliminary reports on their findings. Several independent research groups reported finding small spheres of glass. Different observers were in close agreement about sizes, chemical constitution, refractive indices, densities, and other properties. The author is the only contributor who has exploited interferometry to advantage in the examination of these objects, and this approach forms the substance of the present brief report.

An interferometric study had been decided upon before Apollo 11 set out, since the existence and retrieval of lunar glassy spheres was confidently anticipated and it was recognized that these might be small, according to accident of retrieval. The author prepared well in advance by developing and testing interferometric techniques for an extremely wide range of sizes of small glass spheres. To do so, a considerable range of 'ballotini' was obtained, these being the small glass spheres made commercially for such purposes as chemical filter beds. They are produced by directing a hot blast flame on to thin glass rod and fibre and are obtainable in very small sizes. When the lunar dust arrived we were in the position of being able to obtain easily and quickly interferograms on objects as small as 10 μ in diameter or even less.

NASA allocated to us two separate samples, each of 5 g. Sample A, true fines, was pre-sieved through a 1 mm sieve before receipt and thus contained particles ranging in size from 1 mm to sub-microscopic. Sample B was material in the nominal size range of 10—1 mm, but an appreciable quantity of finer dust grains was included. It is of interest to note that while we were able to extract over 200 objects from the fine material of sample A, in sample B we found only 12 small spherical objects and these were comparable in size to those in A. They had no doubt found their way in through the appreciable amount of fine dust unavoidably coating the larger pieces of B.
The present article is concerned almost entirely with the findings from sample A. The glassy spherical and allied objects described below were extracted with tweezers. Extraction presented considerable difficulty and required many hundreds of hours of sorting under a microscope. This was due in part to the tenacious way the dust covered and hid objects, apparently because it easily acquires electrostatic charge even through mere stirring by a sorting needle. Moreover, we found that quite a large proportion of the objects and some of the dust itself is magnetic. This caused complications until we resorted to a degausser of the simple kind used for tape-recording machines. In this connection we may note that I. Adler and colleagues (1970), using electron micro-probe techniques on their recovered spherules, report that quite a number of them contain small inclusions of free iron, a finding confirmed by other workers (Frondel, et al, 1970; McKay, et al, 1970; Keil, et al., 1970).

A further constraint had been voluntarily imposed by the original terms of reference agreed with NASA, for we had categorically stated in advance that all our studies were to be non-destructive, so that the received samples, after optical and X-ray examination, could be returned intact when required. Since we felt it essential not to deviate from this condition, there have been many self-imposed restrictions on operations. Thus we denied ourselves the advantages of flotation methods of extraction and immersion methods for refractive index determination. Nor could ultrasonic dust-cleaning techniques be used since these might have shattered strained objects. In any event, at the NASA conference many other investigators reported chemical analyses, refractive index measurements, and so on. These separate data were so consistent that we have no hesitation in accepting them as applicable to our sample, which in any case comes from the same immediate lunar location as that of the others; indeed all of us had quite small aliquots from the same bulk of fines.

SPHERULES

At best, in sample A, the largest extractable objects could not exceed 1 mm in diameter and spherules up to this size were in fact found. Several distinctive varieties have been extracted, some of which are shown in Fig. 1. the largest object shown having a diameter of 0.75 mm. Many of the spherules are translucent, of a red brown or amber colour, a few are pale green and transparent, whilst a big proportion are dark grey, with a metallic lustre and are effectively opaque. One small spherule, shown in colour in the original 

\textit{Endeavour} article, highly magnified (x 3000), is of a deep sapphire blue, slightly flecked with red and with a little fine amber dust still attached to it. At high magnifications we have also seen in the total sample numerous tiny deep blue spheres, which, in view of their small thickness must have inherently strong coloration. Many of 3\,\mu m and smaller size have been observed.

Many of the glass spherules reveal either internal vacuoles or near-surface blow holes. The objects are not thin shells, for apart from small local vacuoles they are solid and glassy. In this respect they differ from the well known very small thin pseudo-spherical shells found in the fly ash from furnace chimneys, which in any case are much smaller than our own extracted objects.

An appreciable fraction of the objects have one or more tail-like attachments (Fig. 2). This seems quite clearly to be sintered mother dust which is strongly adherent and can hardly be scraped off at all. It is reasonable to conjecture that such glassy objects have at some time been high-speed projectiles which on landing and impacting on the grey dust surface, have sintered on to themselves the ragged tails. Tails are quite frequent.

That many of the extracted objects have been projectiles is indicated by other features. Firstly, some are broken, but more significant is the common appearance of impact micro-craters of the kind shown in Fig 3. At the centre of each such crater is usually a small solid (crystalline?) piece of rock, often of the same colour as the spherule itself. It is quite certain that this has struck the spherule and embedded itself in the glass. Surrounding the foreign object is a shallow shatter region, sometimes with a raised lip. Interferometric evidence for projectile impact by spherules will be given later. At this juncture it is well to remember that on the Moon, in the absence of an atmosphere, any ejected even quite small objects will fall under lunar gravity with the same impacting velocity as any ejected large rocks. A floating cloud of slow-falling particles is impossible on the atmosphere-free surface of the Moon.

Some forty objects (Fig. 4) found were probably in most cases originally glass spherules, which, however, through some mechanism have acquired a very ragged coating of hardened dust. An impression is gained of hot glassy objects that have rolled in hot lunar dust, for in a number of instances the coating is incomplete and underlying smooth glassy regions can be seen. There are occasional completely opaque non-specular rough spheres, two of which appear in Fig. 5. Included in this picture are two pieces of irregular glass, of which there are many
pieces. Such glass spatters could well have arisen through ground impact by globules larger than those which become spherules. Indeed one might well argue that rate of cooling and associated time of flight are such that only small spherules could survive. If initially both large and small drops of liquid glass formed, the cooling rate being less in the larger objects, it could well be that they were still soft enough on arrival to spatter out into the shapes and sizes observed.

There is another feature of Moon rock samples that lends powerful support to this projectile theory. Many of the larger rocks retrieved from the lunar surface are pitted with glass-lined depressions, perhaps 2 mm across, but not much bigger. They give the strong impression that the rock surfaces have been 'shot-blasted' with glass spherules of up to 2 mm diameter, that is, struck by a shower of glass projectiles of limited size.

GLASS CYLINDERS

An unexpected finding was the presence of a fair number of hemispherically-ended shiny glass cylinders, some of which are shown in Fig. 6, the largest being 0.8 mm long. Besides the intact objects, ten fragmented cylinders were recovered, each split half-way across. Cylinders of both translucent amber colour and of grey metallic opaque lustre occur. The surfaces are variously highly specular or slightly dust-coated. In some instances there was an unresolved fine structure revealing itself in coloured diffraction effects. Some cylinders possess a sintered tail and are magnetic and quite erratic in their mutual attractions and repulsions so that a group on a slide were controllable only when demagnetized. It is doubtless of real significance that these objects exhibited magnetic effects when brought near together, before they had been exposed to the strong field of a hand magnet. It is unlikely that the Earth's field induced any polarity, since a powerful hand magnet closely applied was needed to move the objects on the microscope slide.

It is interesting that a number of spherules and cylinders disintegrated into fine powder when picked up with tweezers. Their behaviour was very reminiscent of the historical 'Rupert's Drops'. Any object that disintegrated in this way must undoubtedly have been very severely strained. Examination of the more transparent of our cylinders between crossed polarizers did in fact reveal some strain birefringence, even in perfectly shaped specimens.

Apart from the cylinders extracted by hand, examination of dust smears at a magnification of ×800 revealed numerous very small spherically-ended cylinders, most of them amber-coloured.

INTERFEROGRAMS OF SPHERULES

A large proportion of the specular objects, both spherical and cylindrical, have been examined interferometrically. Each object was placed upon a pre-selected smooth thin glass cover slip which acted as reference flat, and this was then examined at at least ×500 magnification with a 4 mm objective, chosen to fulfil optical conditions for securing accurately collimated, parallel, incident, light. Both green mercury-light and white-light illumination were variously exploited. White-light supplementary examination, from the fringe pattern obtained, decides in cases of doubt whether a topographic feature seen is a hill or a dale. Illumination conditions when viewing the smaller objects were very critical.

Some of the spheres gave astonishingly well-defined Newton's ring interference fringes of which Figs. 7 and 8 are quite typical. There is much to be learnt from such fringe patterns (obtained with green mercury light). Thus the fine definition shows that the specularity is high. From the very good contrast between the light and dark rings it follows that the refractive index in these cases closely approximates to that of the glass cover-slip (1.55). It is of interest to note here that C. Frondel and his colleagues (1970) report that the refractive indices of the glasses in their fines increase with deepening colour, ranging from 1.46 for very clear colourless glasses to 1.75 for the deep red browns. These figures are in keeping with our observations, for we have found for the very deep brown (yet still translucent) objects that we can actually obtain fringes in transmission. This is possible only for glasses of quite high refractive index and we would estimate from the reasonable visibility of such transmission fringes—particularly when matched on titanium oxide coated flats—that the refractive index of such lunar objects is not far from 1.75.

The smooth perfection and regular circle geometry of the fringes in some cases proves that such objects are closely spherical and it is self-evident that they must have frozen-in in free conditions from liquid droplets, in
such a way that shape was controlled only by surface tension forces. When it is conjectured that many of the objects have lain near the lunar surface for very long periods (possibly many millions of years) the high specularity evidenced by the fringes indicates a complete absence of any atmospheric corrosion or leaching effects.

It is significant that a number of the fringe patterns show that the objects concerned have been high-speed projectiles, confirming our previous conclusions. Thus Fig. 9 is a fringe pattern from a spherule and it reveals the existence of a long micro-crack, of V-section and progressively diminishing in depth from a maximum of half a light wave. This is a micro-crack that surely originates from impact. Fig. 10 is more striking, for on this object the fringe pattern quite clearly demonstrates that small regions have been chipped off, almost certainly because of an impact. Were an object to break up through internal strain it could hardly throw off the kind of flake shown by these fringes to have chipped away here.

The overall evidence that many spherules have been high-speed projectiles is overwhelming. The adhered tails, the micro-craters, the occasional split open spheres, and finally the interferometric evidence for shock, all point the same way.

INTERFEROGRAMS OF CYLINDERS

The interferograms of cylinders lying on their sides are intriguing. Split cylinders can be balanced on their hemispherical ends and such objects give normal circular Newton's rings, as is to be expected. The case differs with intact cylinders lying on their sides. The fringe pattern of Fig. 11 is typical of many. It is clear that the cylinder has been part of a thread of molten glass which froze-in before being able to divide by surface tension forces into two separate droplets. The interferometric waist is evidence for this. In two instances, one of which is shown in Fig. 12, the cylinder was in the process of breaking into three drops but froze-in first. The relatively high proportion of split cylinders indicates that this situation creates strain. Indeed some of the broken pieces of cylinder still show residual strain under polarized light.

It is noteworthy that at x800 we also found numerous minute amber-coloured cylinders in the dust, which were far too small to be extracted and handled.

DISCUSSION

The first point of interest is the enormous number of the objects. If our material is representative, then extractable objects which can easily be handled amount to no less than 40,000 per kg of lunar dust. To this must be added the incredible number of spherical and cylindrical micro-objects present. If indeed the whole Moon is covered with fines, then the number of glass 'marbles' existing there is virtually incalculable. Two related hypotheses are proposed here to account both for the numbers and the variety. All the evidence points to the existence of a vast number of meteoric impact craters on the Moon. Now it is generally agreed, because of similarity in chemical constitution and age, that the huge number of tektite objects found on Earth, in any one tektite field, have been created by one single meteoric impact. Really small tektitic objects would have little chance of surviving both initial atmospheric resistance conditions and subsequent atmospheric leaching effects, but it is possible that one meteoric impact on Earth could have produced many more glassy objects than we now find.

Clearly if one impact produces vast numbers of recognizable objects, then the multitude of lunar craters can be expected to yield a similar quantity of tektitic objects. There are two possible sources for tektitic objects. One is ablation, a melting off of the incoming meteorite, in which case tektites should be meteoric material, but this does not seem to be so. The other source is earth rock splashed to great distances after melting, as a result of the fierce heat of impact. Tektite shapes encourage this belief. By analogy one can anticipate that a fierce large meteoric impact on the Moon should cause melting and subsequent splashing of the melt. Because of the absence of atmosphere, all splashed droplets will assume a spherical form. The smaller objects will freeze solid in flight, the larger may land and spatter. Different source regions, and they are numerous even in any one limited area, can produce objects of different composition, accounting for the different observed colours of objects. Clearly, such droplets are the required projectiles. Furthermore there are two possible associated events. The impact which melts the rock and throws up the globules could equally well shatter the surrounding area (of similar material)
and hurl up a vast cloud of solid micro-particles. The spherules would shoot through this falling cloud and we
would have then a satisfactory condition for the creation of micro-crater impacts. Also, by radiation effects, a
considerable area of the surrounding surface dust would be heated. This could well explain the apparent rolling
of objects in heated dust, and also help to account for the sintering of the tails. Indeed if the associated heat
were intense enough, some of the dust could be melted to form micro-droplets, which could conceivably have a
different origin from those of the larger spherules and cylinders.

One difficulty about this conjecture seems to be the following. One would have expected to find some spheres
of much larger size. After all, many earth tektites are about one inch across. Our sample of fines was of course
pre-sieved, yet no other observer has in fact recorded the finding of large spheres. This could obviously be a
purely statistical effect, a result of sampling from only one region. It could also possibly be a function of life-time
in flight before collision. If numerous large spheres are found in other Moon landings, then this conjecture will
be confirmed.

A closely related alternative hypothesis, which might well explain the absence of larger spheres, is as follows.
Suppose the incident meteorite producing the crater leads to extensive melting of the floor of the crater, that is,
creates a large pool of molten glass. Either as a consequence of entrapped gas, or as a secondary volcanic effect,
let us postulate that whilst the pool is still molten a violent blow-out of explosive gas takes place. Such a situation
would create an enormous fountain of small glass droplets and glass threads. This kind of mechanism could also
be linked with eruptive clouds of surrounding solids, to give the necessary conditions for the micro-craters. This
fountain concept might well account for the absence of larger objects. If this view be correct, one can predict that
the inside floors of many of the larger craters will be solidified lakes of glass.

REFERENCES

ADLER, I., WALTER, L. S., LOWMAN, P. D., GLASS, B. P., FRENCH, B. M., PHILPOTTS, J. A., HEINRICH, K. J. F. AND
from Tranquility Base. Science, 167, 654-656.

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Surrey.
Dr. H. J. Peake, Principal of the Sheffield City College of Education, was invited to address the Annual Conference at Sheffield because of his personal involvement with the discussion on Q. and F. levels as a member of the Schools Council's Second Working Party on Sixth Form Curriculum and Examinations. The paper is a transcript of his talk.

MAY I first of all thank you for this opportunity to come to your meeting to talk to you about sixth form reform. I think I probably ought to say at the very start that though, for the last five years I have been a Principal of a College of Education, I have, previous to that, been Headmaster of a grammar school and have taught, which is a point that should be made. (It is very often assumed that people in Colleges of Education have never taught in their lives.) I therefore do know something about the problems that are being discussed and debated from the point of view of the classroom teacher.

The last fifteen years have seen a continuing debate about the sixth form and in particular the argument about specialisation or non-specialisation. The debate has invariably been about examinations, about entry into higher education and the competition for university places. Until relatively recently it has not been concerned with curriculum and curriculum reform. One of the things that has got to be faced up to fairly soon by some of our colleagues is this; we can only achieve the objectives that are laid down by the Schools Council if we look to curriculum reform. The tragedy of the last two years' debate on Q and F levels has been our obsession with examinations; we have not really started to look at, and examine the content of the typical sixth form curriculum. Integrated Science is obviously a move in the right direction. There is no doubt in my mind that we have got to give careful appraisal of the whole question of what we are teaching sixth formers and what we are expecting them to learn. We must try to get away from subject divisions.

During these fifteen years, there have been many abortive attempts to try and put the sixth form right. Some of you will remember A. D. C. Peterson's attempts, the agreement to broaden the curriculum, debates about major and minor subjects or more recently, the Headmasters Association 'I' Levels. I think it is worth stating that the Schools Council has only been in existence for five years. During this time an immense amount of work has been done, many publications have been produced and various projects instigated but curriculum reform and conceptual analysis are still in their infancy.

In June, 1966, a Working Paper published by the Schools' Council (No. 16) enunciated three principles and then tried to indicate the way in which these principles could be put into effect in the schools. These principles were as follows:

First of all curriculum reform was necessary; second, specialisation must be reduced; and third, the choice of subjects should be made as late as possible so as to avoid pre-determining career options and subject studies at University Level.

The proposals and suggestions in this paper were not accepted but the principles were re-affirmed and two Working Parties were established roughly two years ago to try and find ways in which these three principles could be embodied by a reform both of the curriculum and examination system in the sixth form.

The first Working Party had as its remit the examination of the sixth form curriculum in relation to university entrance. The second sixth form Working Party significantly set up later was given the all-embracing remit to look at the curriculum of the sixth form and to make recommendations. It was not empowered to look into selection for the Universities, but it was allowed to look into selection for other Institutions of Higher Education, the Colleges of Education, the Polytechnics, and so on. So straight away you hit the fundamental problem. The university approach, the non-university approach.
Fortunately, the two Working Parties had some sort of dialogue, papers were interchanged and we did meet together from time to time, but some of the resulting difficulties over Q and F undoubtedly arose because in my opinion the cart was put before the horse; we looked at examinations before we looked at the curriculum.

Well, the two Working Parties set about trying to do their jobs. The first Working Party immediately entered into negotiation with the Standing Conference on University Entrance. The second Sixth Form Working Party started the philosophical discussion of what was needed for the sixth former at the end of the 1970's and the beginning of the 1980’s and on. We (in Working Party No. 2) quickly found ourselves up against the question of what they were at in Working Party No. 1. Were they going to determine a pattern for 15 per cent of the sixth form which would dominate the rest of the sixth form curriculum?

May I say one or two things about fundamental changes that have happened or are happening at present which vitally affect the issue. The first one is the introduction of the comprehensive system. Margaret Thatcher or no Margaret Thatcher, the majority of authorities are moving rapidly to some form of comprehensive system, (some of you will be teaching in comprehensive schools), but whether it is a comprehensive school or a grammar school, or an independent school, the size of the sixth form has increased immeasurably even since I became a Headmaster in 1957. It is not unusual now to be talking about large sixth forms in the region of 250-300 and the average size falling in the region of 150. Many of us were educated in sixth forms with 50 in the first year and 25 in the second. So there is the increase in size but there is also an increase or rather a complete change in the diversity of the sixth form. My own sixth form friends just before and during the beginning of the war were committed largely to university entrance, following specialist courses. Now we don’t know what we mean by “sixth form”. Many schools have got people repeating O Levels, they have got people who have not even taken O Level, but have reached the magic age of 16 or passed the barrier of the statutory leaving age of 15. The sixth form in many schools is now more comprehensive than the first form, trying to cope with problems of university entrance, needs of industry and commerce, secretarial courses, courses in this and that, and what is more trying, to cater for immigrants who are still having difficulty with communication in the English language. This is not an exaggeration of the position. Sixth forms are larger, though far more important, the emergent new sixth form has a wide range of ability, and a wide diversity of courses. There is also the impact of the raising of the school leaving age, this is happening by consent but it is likely to happen by legislation. There is also the impact of the C.S.E. and an almost fanatical belief in some circles that C.S.E. Mode 3 is the only acceptable way of examining.

We have terrific pressure on Higher Education, the Colleges of Education have almost doubled their numbers in the last five years. My own college which was the second largest in the country with 860 students five years ago has now 1300 students. We are today about the fourth largest and out of 160 colleges there are about 25 with more than 1000 students. This explosion with all its stresses and strains, and I mustn’t digress, is now going to happen in the polytechnic sector. Sooner or later Higher Education has got to receive a cool hard look but in the meantime young peoples lives are being held at jeopardy in a rat-race where, depending on your grades and your choice of subjects, you may or may not get into the institution to which you want to go.

The second Working Party tried to look at a sixth form curriculum which would meet the needs of all students and probably made the great mistake of trying to do an impossible task. In the meantime the Standing Conference on University Entrance and the first Working Party were trying to get University Entrance on to a more rational footing and to our utter amazement both Working Parties felt that it was necessary to increase the spread of subjects in the sixth form beyond three to a minimum of five. So one of the things I want you to grasp is that the idea of a wider range of subjects throughout the two-year sixth form was reached independently by two working parties. There was a lot of disagreement as to whether this should be a five and five subject structure or a five and three structure, whether examinations should take place in the sixth year and in the seventh year, the place of O Level in the set-up, and so on. You may be surprised to know that it was no business of ours to discuss the relationship of O Level to C.S.E., the organisation of schools or the relationship between schools and Further Education, or Robin Pedley’s ideas of Comprehensive Further and Higher Education. Within the profession one of the burning issues is the relationship between C.S.E. and O Level, another is the question: are all the sixth formers going to leave schools for Further Education? Also, what are we going to do about the number of students with two A Levels who won’t get into Higher Education degree courses in two or three years time unless something is done about it?
Some of us had strong reservations about examinations in three successive years and there is no doubt that this single factor united the opposition because there is no body more divided that the teaching profession in what it wants in the sixth form. We have received evidence from all the associations, from umpteen individuals, from professional bodies, and confusion is worst comfounded. The remedies offered are nearly all mutually contradictory. When the Governing Body of the Schools' Council met to determine the future of the Q and F proposals nobody was surprised when associations who had given provisional approval withdrew their approval and took pre-determined positions; for instance the N.U.T. wanted to use the situation to obtain the merger of C.S.E. with O Level. The big debate in the Joint Four, I think it is fair to say, was specialisation or no specialisation. This may be unkind, but I think that in the debate vested interests came out very strongly.

Could I now say one or two other things before I come to the present position. Working Parties 1 and 2 were in agreement and are still in agreement that there is a desperate need for a more balanced curriculum. We are also agreed that in a new sixth form there is a need for an objective beyond O Level and yet below A Level which many of these new sixth formers will find is within their grasp and will have some significance in the world outside. There is also a strong feeling that we did not wish to divide the university aspirant from the non-university sixth former. Indeed we all must know that there are many university aspirants who are at the moment shopping around to find somewhere a place in Higher Education. We were also agreed that there is no point whatsoever in continuing to use O Level as a criterion for entry into Higher Education. We were appalled to find the increasing use of even O Level grades to determine preliminary offers and provisional places in the university sector. One problem of course is this: if there is a competitive entry for university places and you replace three A Levels by a five-subject requirement then though you may call them sub-A-Level if you aren't careful a standard is required which is equivalent to that required of three A Levels.

So I think Working Party No. 2 is a little bit concerned lest we find ourselves broadening the curriculum while making it even more difficult for the less able sixth former to cope. I think this is why we felt that some form of qualifying examination at the end of the first year of the sixth form had advantages and why we felt that five and three was better than five and five. The N.U.T., the majority of whose members are not sixth form teachers, is very much in favour of the five and five structure, whereas the Standing Conference on University Entrance is narrowly in favour of the five and three. Three examinations in three successive years delayed the agreement for hours because most of us who had been practising teachers felt that this was a fundamental weakness and that we might well lose the lot because of this. This is what has happened.

The heated debate that took place centred round a large number of things. A lot of teachers felt that the Schools Council was trying to dictate and it was time for the grass-roots teachers to make it plain that they were in control of the situation. They achieved that and I don't blame them because there was a breakdown in publicity and communication which gave the impression that the Schools Council were going to say "this you must do". Legally of course, no Body can do this, only the Secretary of State can determine the pattern of examinations and even his powers, or her powers, are somewhat dubious.

Let's forget the manoeuvring of associations trying to establish their point of view. The issues seem to divide into the following:

First of all a strong lobby for the status quo: "We don't like what we have got but we prefer it to anything else;" in effect a very powerful and noisy lobby for specialisation. Second the C.S.E. lobby who wanted freer examination methods but particularly wanted to see the end of O Level. A third lobby who were after a comprehensive system of education from the cradle to the grave and saw an opportunity to achieve these aims. The fourth lobby, consider Mode 3 examinations to have a professional dignity which no other examination methods have, and that continuous assessment should be a distinctive feature.

One of the weaknesses of this last point of course is what you might call national integrity. It is vital that a sixth former leaving with a piece of parchment can go anywhere in the British Isles and have his parchment recognised at its face value. There was some fear that regional examination boards operating a very much more permissive system would result in a lack of credibility from area to area.

While we are on the subject of examinations, in my opinion one of the most interesting parts of the joint statement is the Annexe where kites were flown and coats trailed, in particular the paragraph on examinations: methods of examining. I think it is a pity there hasn't been a bigger debate on that section and I am quite certain the next two years will see a full scale discussion of this. The solutions offered in the debates were so
varied they couldn’t be summarised this morning but as I said earlier nearly all of them could be paired off as mutually contradictory. One of the amusing exercises to indulge in is to do just this because then you will realise how difficult it is for a committee, however representative and however informed, and however generous in its interpretation of advice given, to get a consensus that isn’t a compromise and an ineffective one.

In the end there was a full debate and when it came to the crunch the proposals were rejected in their present form. Why then bother to talk about it today? But you see, it isn’t all lost, there are terrific gains.

First of all I think we have established that the Schools Council can be subjected to powerful grass-root teacher influence and made to modify its policy. I think that if we can get the teachers articulate and getting their views through, even in spite of their representatives sometimes, this is a good thing. The important thing is the decision of the Schools Council itself and I want to read the decisions that have been taken for I think you will then see why I consider that there have been immense gains as a result of this exercise.

First of all the three principles which form the basis of the working parties are re-affirmed; remember that they were to reduce specialisation, to broaden the curriculum and to defer subject choices.

Second, there should be a single examination system at the age of 16 and this should be under the Schools Council. How this is going to be achieved is now being discussed, but O Level and C.S.E. certainly are not going to co-exist side by side in their present form.

Third, there should be some form of extended C.S.E. examination under the Schools Council available for older students. I think what they mean here is for instance in History it will be possible to choose two C.S.E. syllabuses one which will meet the needs or the lack of maturity of a 15–16 year old and another that will meet the needs of a more mature approach of the 16–17–18 year old. Because, if I may add a gloss, the biggest users of O Level, and this may surprise you, are not the schools, but Further Education.

Fourth, that content and structure of all sixth form examinations should be revised so as to include improved forms of assessment and a reduction of factual content. Having just seen a sixth-form daughter going through the A Level process then the underlining of the last few words, “the reduction of factual content” would seem to be an urgent necessity. “Thank God for a good memory”, should be written over all A Level papers.

Five, all sixth form examinations should be available on a single subject basis and be under the Schools Council. This is of course a direct attack on and negation of the group ideas which were mentioned in the Annexe of the Report. There was a body of opinion that felt that you could only get a broad curriculum by legislation, you would never get it by consent, and this says legislation is off, it is unrealistic, it must be a single subject examination.

Six, that no solution to the problem of sixth form examinations would be acceptable which necessarily involved a new major examination such as the proposed Q level at the end of the first year in the sixth form. If I may add a gloss, the universities and some of the head teachers are talking now about a two stage examination, a part one and a part two. If you are not careful you will find that the new proposals alter the names and retain the structure. Life gets a little hard at times.

Seven, the Council rejects the Q examinations which lead in practice to three examinations in three years. (This is just making sure).

Eight, that the Council affirms that it is desirable to reduce the present level of specialisation to broaden the scope of study in the sixth form; they further recognise that for the most aspirants for degree courses and for many others, this will involve increasing the number of subjects studied beyond O Level, above the present normal pattern of three. Council realise that this policy will mean devoting less time than at present to main subjects, they recommend that it should be possible to confine the study of these subjects in the sixth form to 25 out of 35 periods per week.

Immediately people ask does this mean a 4-year course at the university? There is some evidence that provided the curriculum is balanced this isn’t necessary.

The Council also proposes, after considering the further report from its Working Parties to initiate a programme of research and development into the new examinations the result of which it hopes to complete in Autumn, 1972. It hopes it will be in a position in the light of this during 1973 to make a firm recommendation for the institution of the new system.
My guess is the first candidates for the new A Level, let's call it that, will be in 1978, at the earliest.

To summarise, after a lot of heated debate the members of the two Working Parties who were praying that they would be liquidated have found themselves with another mammoth task. They have been told "we don’t like three examinations in successive years but we do re-affirm breadth of curriculum, new type examinations, less emphasis on factual knowledge. Now produce a better scheme." It looks to me as though the five subject spread is on and the big question is going to be at what stage do people jettison two of their subjects, whether it is at the end of the first year or whether they in fact take the five for two years. I think five is here to stay, although there are suggestions of four.

May I come to the whole question of breadth of curriculum. If you start to analyse this and look at the needs of the scientist, and I as a mathematician-physicist understand some of the points of view of the scientist, I hope, then you have got to have as it were a supporting cast. You can’t approach a science course without an adequate basic knowledge of mathematics. Subjects like biology increasingly require statistical processes and Maths would seem to be an essential element. But then all of us who have studied physics feel that we need some basic know-how of chemistry, so you are up against the critical problem of how to prepare adequately for a science course at, say, degree level.

There is another factor which I ought to have mentioned earlier and I must stress: to me the crucial argument for diversification and breadth in the sixth form is the fact that most of our students will have to be re-trained two or three times during their working career. None of us know, can forecast or project the impact of technological advance and the manpower needs of the next twenty years.

I must say I think we can only give a balanced curriculum in the sixth form and even below the sixth form if we look very hard at new kinds of subject groupings, integrated science is one possibility, the Schools Council Humanities Project another. Some universities are offering combined study degrees and inter-disciplinary courses of various kinds. Colleges of education have been doing this for some years because of the needs of the schools. It is my considered opinion after two years of intensive debate that however we try to increase the number of subjects at A Level on the traditional subject pattern in order to broaden the curriculum we are doomed to failure and that the only hope is for an inter-disciplinary approach in those areas where it is appropriate. You are all geologists and it must always seem strange that science as taught in most schools, tends to ignore Geology, ignore Astronomy and ignore the impact of many things which affect our daily lives. We mustn’t develop that. It is because simplicity and vastness are both beautiful that we seek by preference simple facts and vast facts; that we take delight, now in following the giant courses of the stars, now in scrutinizing with a microscope that prodigious smallness which is also a vastness, and now in seeking in geological ages the traces of a past that attracts us because of its remoteness.

HENRI POINCARE
*Science and Method*, p.23.
DYNAMIC MODELS OF OCEANIC VOLCANIC ACTIVITY

W. J. Phillips

GEOLOGY is usually presented as a series of completely independent and unrelated courses, in which the emphasis is placed on systematic classifications rather than on the consideration of possible explanations of the formation of the observed features. This division of interests is continued and tends to isolate the igneous petrologist, who usually thinks in terms of the chemistry of silicate liquids, from the structural geologist who is concerned with the physics of solids. Adopting the general principle of uniformitarianism, this paper is an attempt to introduce petrology by the analysis of the physical processes observed during a recent eruption of a relatively simple oceanic volcano.

THE STRUCTURE OF HAWAIIAN VOLCANOES

The Hawaiian volcanoes are gently convex domes with slopes of only six degrees. The comparative simplicity of the frequent, voluminous non-violent eruptions of the Kilauea volcano on the south east side of the island of Hawaii makes it ideally suited to illustrate the fundamental processes of volcanism. Here the processes can be studied in isolation from many of the great complications of structure and contaminating rocks that characterize the continental volcanoes.

On Mauna Loa, three systems of almost vertical fractures, known as rift zones, extend from the summit (Fig. 1). Lavas have been extruded from vents sited on these rift zones, which in consequence have been built up to give the mountain the form of a shallow three-sided pyramid. Near the summits of the volcanoes, there are many craters which are not surrounded by debris. These craters cannot be seen until the edge is approached and consequently they are known as pit craters. The Chain of Craters, near the summit of Kilauea, consists of a series of pit craters which are roughly circular in plan with vertical or overhanging walls. The pit crater known as the Devil’s Throat was only 10 metres in diameter at the top, 76 metres deep and 36 metres in diameter at the bottom when it was described in 1926 by H. J. Steams. Many of the older pit craters have inward sloping walls because of subsequent collapse of the walls, and in these cases the bottoms are covered by debris. The increasing diameter with depth and the complete absence of extruded material indicates that the pit craters were formed by the collapse of the central portions, sometimes by as much as 250 metres.

At the Kilauea summit there is an oval shaped depression, 3 kilometres wide and 4 kilometres long. The rim of the depression is 157 metres high on the north-west side, but is almost level with the floor of the depression on the south side. Large depressions of this kind, which are usually more than 2 kilometres in diameter, are called calderas. The floor of Kilauea is formed of lava flows which slope gently outwards from a small crater near the southern end. This crater, called Halemaumau, is about 370 metres in diameter and is usually partly or completely filled with lava. Calderas and pit craters occur near the summits of the volcanoes and are both collapse structures.

Tilt bases have been set up at a number of points around Kilauea. They consist of three concrete piers set permanently in the ground at the apices of an equilateral triangle with sides 50 metres long. Sensitive releveving of those piers can record tilts of 1 mm. in 5 kilometres. Since 1955 it has been possible to make reasonably accurate determinations of the focal points of earthquakes in Hawaii and during this period the deepest earthquakes that have been recorded appear to originate from a zone approaching a depth of 60 kilometres beneath the summit of Kilauea.

Some of the disturbances recorded during eruptions are unlike the earthquakes associated with tectonic activity in the earth’s crust. While lava is pouring out at the surface the seismograph records show traces which indicate that the entire region around the vent, oscillates gently to and fro. These disturbances are called harmonic tremors and from seismographic evidence it is known that they are generated near the earth’s surface, probably by the rapid flow of magma through the feeding conduits. Because harmonic tremors rarely occur when no eruption in progress, their occurrence is excellent evidence that lava is streaming through conduits underground.

THE VOLCANOES FORMING THE ISLAND OF HAWAII
after G.A. MacDonald and H.T. Stearns

Contour interval 1000 feet

EXPLANATION
- Cinder and spatter cones
- Fissure vents
- Pit craters
- Caldera
- Historic lava flows on Hualalai, Mauna Loa and Kilauea
- Trachyte lava flow
- Trachyte pumice cone
- Laupahoehoe volcanic series
- Hamakua volcanic series

Section
HUALALAI MAUNA LOA Mokuaweoweo Caldera KILAUEA Caldera

[16]
The volcanic activity and the formation of volcanic materials and structural features were particularly well recorded during the 1955 and 1959-60 eruptions of Kilauea and are shown in two excellent colour films produced by the United States Geological Survey. It is possible to gain a good understanding of the type of activity involved, and also of the mode of formation of many of the volcanic rocks and structures by studying the records of some of the recent eruptions.

THE 1959-60 ERUPTION OF KILAUEA

A series of deep earthquakes was recorded at Kilauea during 1958. By October of that year, measurements at the tilt bases installed in a ring around the Kilauea caldera revealed that the entire caldera rim was tilting outwards and that the summit area was swelling. Until February 1959 the summit region continued to swell. After the occurrence of several moderate earthquakes just south of the Kilauea caldera on February 19th, the swelling stopped and between May and August the tilt was reversed slightly, indicating that the summit area had subsided slightly. Between August 14th and 19th a great number of deep earthquakes shook the summit area. Between August and October the tilt measurements indicated a further swelling of the summit area and during November the rate of tilting was three times as great.

On November 14th, earthquakes in the caldera area increased ten fold in frequency and intensity, and at 8.00 p.m. lava broke through along a kilometre long fracture which appeared about half way up the 200 metre high south wall of Kilauea Iki pit crater, just east of the Kilaeua caldera. Abruptly the earthquakes stopped but the seismographs recorded strong harmonic tremors as the ground oscillated.

Within an hour of the outbreak, cameras were set up about two kilometres away to obtain a film record of fountains spurting to heights of 15 metres. These fountains fed many lava streams which poured down to the bottom of the crater where they spread across the flat, 37 acre (15 ha) floor of the pit crater formed in 1868. During the next twenty-four hours the number of eruptions along the fracture decreased until only one fountain remained active and this built a small spatter cone. The rate of the lava pouring from the single vent fountain increased steadily until November 21st when the eruption stopped suddenly. It is estimated that 40 million cubic yards (30.8 x 10^6 m^3) of lava poured into Kilauea Iki crater and filled it to a depth of 100 metres forming a lake 140 acres in extent and slightly higher than the vent. As the incandescent lava poured into the rising lake it flowed under the flexible crust floating it upwards.

During the eruption the tilt measurements showed a deflation of the summit, but when the fountain ceased on November 21st, swelling commenced once more and the feeble harmonic tremors which persisted were soon augmented by a growing swarm of small shallow earthquakes.

On November 26th the main vent reopened and continued for 15.5 hours during which time 4.7 million cubic yards (3.6 x 10^6 m^3) of lava were poured in the lava lake increasing the depth to 125 metres, well above the level of the original vent. Again the fountain ceased abruptly and this time lava poured back down the vent. Within eight hours the level of the lava lake dropped 10 metres, leaving a ring of black frozen lava around the sides of the crater. It is estimated that 6 million cubic yards (4.6 x 10^6 m^3) of lava poured back down the vent, i.e. at a rate almost twice that of outpouring.

During the next three weeks, seventeen more eruptions of increasingly short duration but with increasingly violent fountaining took place at the Kilauea Iki vent. The highest fountain, consisting of incandescent lava, drops and gas, reached 600 metres in height on December 19th.

A large cone of spatter and pumice fragments was built up on the leeward side of the vent and the smaller fragments were scattered by the wind over a wide area.

After the eighth eruption the lava lake was 124 metres deep and contained 58 million cubic yards of lava, but after each period of fountaining the lava poured back down the vent. It is estimated that 133 million cubic yards (102 x 10^6 m^3) of lava was poured into Kilauea Iki crater, but only 40 million cubic yards (30.8 x 10^6 m^3) remain, the remainder having poured back into the vent after eruption ceased. Sometimes a slowly moving whirlpool 16 metres across formed directly over the vent. But the reverse flow of the lava was most spectacular at night when incandescent lava with huge slabs of the fractured, dark coloured surface crust could be seen pouring back over the lip into the vent.
Tilt measurements around Kilauea caldera showed that the volcano was swelling during the activity in Kilauea Iki crater, and although surface activity ceased on December 21st swelling continued until early January 1960.

During the last week of December a swarm of small earthquakes was recorded on the seismograph at Pahoa, on the east rift zone of Kilauea, about 40 kilometres east of the summit caldera. Early in January the frequency and size of the earthquakes increased. On January 13th the village of Kapoho was shaken by frequent very shallow earthquakes, and a slab of land 0.8 kilometres wide and 3.2 kilometres long on the north side of the village subsided by as much as 1.2 metres between two fractures to form a small graben structure. At 7:30 p.m. an eruption commenced along a fracture 1050 metres long near the centre of the subsiding graben at Kapoho, and the earthquake shocks gave way to harmonic tremors. At first the lava fountains erupted from the entire length of the fracture, but later the fountains were restricted to the central section which then became the main vent.

On the second day ground water gained access to the underground lava and large jets of steam roared out of the fracture from many points and gave rise to great clouds of ash laden steam. Steam jets occurred within a few feet of lava fountains and some vents alternated between blasting out white steam and molten lava.

A river of lava 90 metres wide poured from the vents and slowly flowed down the graben towards the sea. Within two days the lava reached the sea three km. away. A week later the graben was filled by the increasing depth of the lava flows, and flows spread laterally over about 2500 acres (1000 ha) of land completely destroying the village of Kapoho. However, 500 acres (200 ha) of new land were added to the island as the flows built up in the sea. Nearly 160 million cubic yards (120 x 10^6 m^3) of lava was extruded from the Kapoho vents.

On January 17th, only four days after the eruption started in the east rift area, the summit of Kilauea began to subside rapidly. By the end of January many small shallow earthquakes occurred at Kilauea caldera as the summit subsided. On February 7th the lake of still liquid lava present in the Halemaumau crater since 1952, drained away and the floor of the Halemaumau depression settled about 50 metres.

By April 1st the rapid subsidence and the shallow earthquakes had ceased in the region of the Kilauea summit, and the tilt measurements indicated that the summit area had subsided by about 1.5 metres. It was estimated that the volume of material that would have to be removed from below the summit to bring about the observed subsidence was approximately equivalent to the volume of lava extruded from the flank eruptions at Kapoho nearly 40 kilometres to the east.

The U.S. Geological Survey films provide a direct view of the formation of this type of lava rock and its surface structures, and also show that during the activity vast volumes of gases are released as well as the molten lava rock material. Tremendous heat energy is associated with the extrusion of gas and liquid lava, but the process is not one of combustion. The combination of volcanic gases with atmospheric oxygen, i.e. combustion, occurs near the surfaces of the liquid lava and causes a slight increase in the temperature in these limited areas. The volcanic gases consist largely of steam (60% to 80% of the total), together with hydrogen, hydrogen sulphide, hydrogen chloride, carbon monoxide, carbon dioxide, hydrogen fluoride and small amounts of other gases. Water, carbon dioxide and sulphur dioxide are also formed by the reaction of some of the gases with atmospheric oxygen. Great quantities of steam are also produced when the molten lava comes in contact with ground water or sea water. The lava consists largely of the ions of the elements O, Si, Al, Mg, Fe, Ca, Na and K, which during cooling may be organized to form crystals of some of the silicate minerals and small amounts of iron oxide.

**THE PHYSICAL PROPERTIES OF LAVA**

The most spectacular feature of the Hawaiian volcanic activity is the extrusion of lava as a bright yellow liquid at a temperature of about 1150°C. The colour changes rapidly to orange, red, dull red and then black as the lava cools to 900°C or less. The colour depends on the temperature, so we can regard it as a dependent variable with respect to the independent variable, temperature. In fact the temperature of the liquid lava is estimated by using an instrument called an optical pyrometer, in which the colour of the lava is compared with that of an electrically heated cell.

The density of the lava is also a dependent variable with respect to temperature. It is about 2.65 grams/cc. when the lava is liquid and about 2.9 grams/cc. after the lava rock has cooled.
When the very hot brightly coloured lava is extruded, it behaves like a liquid and flows readily. However, as it cools, not only does the colour change but the lava flows much more slowly. The partly cooled lava might be described as a more viscous liquid.

The behaviour of the outer surface of the flow is particularly interesting. This outer skin cools most rapidly and quickly becomes black in colour, but as the inner part continues to flow, the skin may be drawn and pushed into ripples which produce a ropy surface structure known technically by its Hawaiian name pahoehoe. When it deforms in this way we might say that the surface of the lava has deformed in a ductile or plastic manner.

Later, and at even lower temperatures, the outer skin can no longer bend in response to the movements below the crust. Instead the cooled outer crust may fracture into rigid slabs which sink into the still liquid lava, or are carried forward on top of the viscous lava as it flows. At this stage the cooled lava rock on the surface of the flow is described as a brittle solid, which fractures easily as a result of the movement of the lava below.

Clearly the manner in which the lava deforms depends on the temperature. At very high temperatures it behaves like a viscous liquid, but at lower temperatures it deforms like a plastic material and finally at the lowest temperatures it fractures like a brittle solid. It is important that we should understand the fundamental meaning of the terms viscous, plastic and brittle which have been introduced here in a purely descriptive sense.

**THE DEFORMATION CHARACTERISTICS OF ROCKS**

**The elastic deformation of rock**

A force is that which deforms a body, or which changes the velocity of a moving body. If a force is applied to a moving body the velocity changes, i.e., it accelerates or decelerates, by an amount which is proportional to the magnitude of the force. The force required to change the velocity is also proportional to the mass of the body, so we have the simple relationship, known as Newton's second law, which is

\[ \text{Force} = \text{Mass} \times \text{Acceleration}. \]

The unit of force can be defined from this relationship. If the mass is 1 gram and the acceleration is 1 cm/sec\(^2\), the force is 1 dyne. This is the c.g.s. unit of force.

The force we experience most frequently is that due to gravitation, i.e., the attraction between the earth and another body. The acceleration due to gravity varies with the elevation and position on the earth's surface, but an approximate value is 980 cm/sec\(^2\). Consequently the gravitational force on 1 gram is about 980 dynes and is the weight of 1 gram.

Pressure is force per unit area. We can obtain the value of the pressure due to the weight of the lava on the surface of the earth. The mass on each square centimetre of the surface is equal to the density multiplied by the depth of the lava flow. The pressure on this area due to the column of lava is obtained from the relationship.

\[ \text{Pressure} = \text{Density} \times \text{depth} \times \text{gravitational acceleration}. \]

If the lava flow is 385 cm thick, the pressure at the base is:

\[ P = 2.65 \times 385 \times 980 \text{ dynes per square centimetre} = 1 \times 10^6 \text{ dynes/cm}^2 \text{ approximately.} \]

A bar is a unit of pressure equal to \(10^6\) dynes and this is very close to atmospheric pressure. Consequently the pressure at the base of a lava flow 3.85 metres thick is approximately equal to 1 bar or to atmospheric pressure.

The pressure due to the liquid lava depends on the depth and increases at about 2.65 times the rate of increase of pressure with depth for water. The pressure due to a column of rock is known as the lithostatic pressure while the pressure due to a column of liquid is known as the hydrostatic pressure.

We must now consider the effect of force on stationary bodies, that is upon rigid material. If a body is subject to a force it undergoes deformation, and its volume or shape, or both, change. The force per unit area acting on a plane is known as the stress. If the force is acting perpendicular to the plane it is known as normal stress. The pressure due to a column of lava can be regarded as the vertical stress acting on the horizontal plane, i.e. the plane perpendicular to the radius of the earth. If the liquid is stationary, then at any point the stresses acting in all other directions would be equal to the vertical stress, and this is the significant feature of hydrostatic pressure.

The deformation produced by a stress is known as the strain. If the deformation completely and instantly disappears when the stress is removed the body is said to behave elastically. Elastic behaviour can be represented by a spring (Fig. 2). The elastic strain is obtained by dividing the increase in length by the original length. This gives the increase in length per unit length and is known as the linear elastic strain. In certain circumstances the strain is proportional to the stress applied. This is Hooke's law. The ratio of the linear stress to the linear strain is a constant (E) known as the elasticity (or Young's) modulus.

If a cube deforms and becomes a rhomb, the body is said to have suffered distortion and the stress that produces this is called a shear stress (Fig. 2). The small angle which the side of the rhomb makes with the side of the original cube is a measure of the shear strain. During elastic deformation the ratio of the shear stress to the shear strain is a constant known as the modulus of rigidity (G). The rigidity is a measure of the body's resistance to distortion, and in the mechanical sense, a solid is a body which exhibits high rigidity.
If a body suffers an increase in the stresses acting from all directions, such as are produced by changes in the hydrostatic pressure with depth, the volume of the body changes. The volume strain is the change in volume per unit volume, and the hydrostatic pressure divided by the elastic volume strain gives a constant known as the bulk modulus. The reciprocal of the bulk modulus is known as the compressibility and this is a measure of the body's resistance to compression.

When we are considering the deformation of rocks which are not at the surface, we must remember that they are undergoing a certain amount of compression due to the pressure set up by the weight of the rocks above. If this pressure is equal in all directions at any particular level, only the volume changes, and this is always the state in liquids. However, if the horizontal stress differs from the vertical stress, the rock may deform by changing shape. The amount of distortion depends on the difference between the stresses, i.e. the differential stress acting on the body.
Earthquake waves

There is a limit to the amount of elastic deformation that a rock can undergo, and when the stress exceeds a certain limit, known as the elastic limit, the amount of strain increases more rapidly and the rock may fracture. After fracturing, the rock on either side of the fracture rebounds and this results in the sudden release of elastic strain energy. This elastic rebound produces elastic waves which travel out from the plane of fracture which is known as the focus, and give rise to earthquakes. There are three main kinds of elastic waves; the P and S waves which are body waves, with which we are particularly concerned here, and surface waves.

The P waves are longitudinal waves in which each particle vibrates to and fro in the direction of propagation. The velocity of these compressional waves depends on the compressibility, rigidity and density of the rock, and is given by the relation

\[ V_p = \sqrt{\frac{\lambda + 2\mu}{\rho}} \]

where \( \lambda \) is related to the compressibility, \( \mu \) is the rigidity and \( \rho \) is the density of the rock. In general the velocity of the P waves is greater in rocks of greater compressibility, but smaller in rocks of greater density.

The S waves are transverse waves in which the particles vibrate at right angles to the direction of propagation. The velocity of the S waves depends on the rigidity and the density of the rock and is given by the relation

\[ V_s = \sqrt{\frac{\mu}{\rho}} \]

The velocity of the S waves is highest in rocks of high rigidity and is zero when the rigidity is zero. Since the P and S waves depend on different combinations of the elastic properties of rocks, they travel at different velocities, and generally the P waves travel at about 1.7 times the velocity of the S waves. Consequently the interval between the times of arrival of the P and S waves gives an approximation of the distance from the focus and the time of fracturing. Seismograph records also provide information of the physical properties of the earth at different depths. For example, estimates of the rigidity may be obtained from the calculated \( V_s \) and density, since \( \rho = \frac{V_s^2}{\rho} \). This paper is concerned with the physical properties of the rocks forming the outer part of the earth, but before we study the evidence obtained from earthquakes, it is necessary to consider the other deformation characteristics of rocks.

Viscous flow

It is appropriate to consider the behaviour of liquid lava next. In terms of its mechanical behaviour, a perfect liquid cannot resist a shear stress however small. A perfect liquid has zero rigidity. However, in liquids the intermolecular attractive forces hold the molecules close together and energy has to be expended in dragging one molecular layer over its neighbour. The liquid is said to be viscous. The rheological model which represents the flow of liquids is called a dashpot, which consists of a liquid-filled cylinder with a piston. The liquid will flow past the piston slowly but steadily when a force is applied (Fig. 2).

If we consider laminar flow, that is the flow of layers of liquid relative to adjacent layers, then at low velocities the resistance to flow is proportional to the velocity gradient set up by the flow. In other words, the stress required to overcome the resistance to flow is proportional to the velocity gradient. The velocity gradient represents the amount of strain in unit time and can be regarded as the strain rate. In these circumstances the ratio of the stress to the velocity gradient is a constant which is known as the viscosity of the liquid. The unit of measurement of viscosity is the poise, and this is defined as the viscosity when the stress is 1 dyne per square centimetre and the velocity gradient is 1 cm/sec. per centimetre. A liquid which behaves in this manner is known as a Newtonian fluid and its viscosity is independent of the stress and time.

The rate of flow of a liquid in a cylindrical tube varies from zero at the margins to a maximum at the centre. However, the mean velocity (\( v \)) in streamline flow in a cylindrical tube is given by the equation:

\[ v = \frac{(p_1 - p_2)^2}{4 L \eta} \]

where \( p_1 \) and \( p_2 \) are the pressures at the ends of a length (L), in a tube of radius (r) containing a liquid with a viscosity (\( \eta \)). It can be seen that the rate of flow is increased if the pressure difference (\( p_1 - p_2 \)) or the radius increases, but is reduced if the viscosity increases. This equation for laminar flow will be used to obtain estimates of the rate of flow of a melt in a cylindrical vent.

Liquids such as rock melts have complex compositions and structures, and do not behave like ideal Newtonian liquids. In some liquids, once flow starts the molecules tend to be orientated along the planes of shear. Under these conditions the interaction of the molecules is reduced and the viscosity may decrease as the rate of shear increases. Laminar or streamlined flow occurs only at low velocities. When the velocity increases beyond a certain limit, turbulence occurs, in which eddies or vortices produce disordered motion. The complexity of the motion makes it impossible to calculate the resistance to flow, but since some energy is used as the kinetic energy of the vortices, the resistance to flow increases.

The viscosity of melted lava has been measured in the laboratory at different temperatures and the relationship is shown in Fig. 3. The viscosity is dependent on the temperature and increases rapidly as the lava cools. The viscosities of all liquids decrease with increasing temperature because the increase in energy tends to weaken the molecular attraction in the liquids. The relationship between viscosity and temperature is complicated, but essentially the natural logarithm of the viscosity is equal to \( \frac{A}{T} \) where \( A \) is a constant and \( T \) is the absolute temperature. A decrease in the temperature produces an increase in the logarithm of the viscosity. Consequently there is a very large change in the viscosity of the melt for small changes in the temperature within the temperature range of melting or solidification.

The viscosity of a liquid is also dependent on the hydrostatic pressure, because the molecules are pushed closer together and more energy is required to move one molecular layer past the adjacent layer. The relationship is such that the natural logarithm of the viscosity is equal to \( (kP) \) where \( k \) is a constant and \( P \) is the pressure. An increase in the pressure produces a large increase in the viscosity. The viscosity of a magma decreases as it rises to the earth's surface because the pressure decreases.

[21]
Plastic deformation

We have considered rock as a brittle solid which undergoes elastic deformation, and we have considered a rock melt as a viscous liquid. There is abundant evidence in deformed rocks, including the pahoehoe lava structure, that rock can deform in a ductile manner. The rock undergoes permanent deformation by flow without loss of cohesion, and this is usually described as plastic deformation or flow. In ideal plastic deformation the material can resist stress by elastic deformation up to a yield point. Material which undergoes cohesive or plastic flow after the yield strength has been exceeded, is represented by a rheological model which consists of a weight and a dashpot in series, and arranged so that the weight has to be moved before the dashpot comes into operation (Fig. 2). The weight represents the yield strength of the rock. A spring has been added to this model in Figure 3 to indicate that some elastic deformation may also occur.

Beyond the yield point in ideal plastic materials, a constant stress will cause the material to flow at a constant rate. In real materials, a continuous but small increase in the stress is required to maintain the plastic flow, and this is represented graphically in Figure 2. When the stress is released there may be a certain amount of elastic recovery, but the significant feature of plastic deformation is that there is permanent deformation. The energy which is stored during elastic deformation of rigid materials is lost in the form of heat during plastic flow.

The strength of rocks

The term 'strength' is used with many different meanings with regard to the deformation of rocks. The strength of a rock is defined as its resistance to failure. Failure may occur by flow without loss of cohesion, or by fracture which implies loss of cohesion and the release of elastic strain energy. A tensile stress tends to pull a rock apart and is resisted by the bonds holding the ions and molecules together. The tensile strength of a rock is therefore the maximum tensile stress that a rock can withstand before fracturing.

Rocks exhibit rigidity and can resist shear stresses to varying amounts. Consequently it is necessary to consider the simple concepts concerning the manner in which the stresses act. The stresses acting at a point can be resolved into three principal stresses acting at right angles to each other (Fig. 4a). One of these acts approximately parallel to a radius of the earth, and is the lithostatic pressure due to the weight of the rocks, while the other two principal stresses are approximately horizontal.

Under normal conditions established over a long period, the stresses acting in all directions at a point may be nearly equal and we can regard the situation as one of hydrostatic equilibrium. The horizontal principal stresses are then equal to the lithostatic pressure.

Imagine that the material below flows outwards. The rocks which are resting on this extending layer will themselves tend to be stretched, and will suffer a tensile stress in the horizontal direction parallel to the plane of the diagram (Fig. 4b). The lithostatic pressure at a particular point retains a constant value but the magnitude of the horizontal stress decreases from this value as the extension stresses build up. The principal stresses in this situation are now:

- Vertical lithostatic pressure = Maximum principal stress.
- Horizontal principal stress in the plane of the diagram = Minimum principal stress.
- Horizontal stress perpendicular to the diagram = Intermediate principal stress.

In this discussion we can neglect the intermediate principal stress and concentrate on the difference between the maximum and minimum principal stresses, which is known as the differential stress.

In any plane which is inclined to the principal stresses, the stresses acting on the plane can be resolved into a normal stress perpendicular to the plane, and a shear stress acting parallel to the plane (Fig. 4c). The shear stresses are greatest on the two planes which are parallel to the intermediate principal stress and which are at 45° to the maximum principal stresses. The shear stresses are zero on the three planes which are perpendicular to the three principal stresses. The normal stresses range from a maximum acting parallel to the maximum principal stress, to a minimum acting parallel to the minimum principal stress.

A rock can resist a certain amount of differential stress by elastic deformation. If the differential stress exceeds a particular stress, known as the yield stress, a rock may deform by cohesive flow, and a sphere may deform into an ellipsoid as shown in Figure 4d. The yield strength of a rock is the differential stress immediately before cohesive flow begins.

If the build up of the differential stress is much faster than the ability of the rock to deform by plastic flow, the rock will fracture. The differential stress required to produce fracturing may be regarded as the breaking strength of the rock. The fractures commonly dip at about 60° as shown in Figure 4e. On these planes within the rock the combination of the shear and normal stresses are such that the critical conditions for fracture are attained first. Movement on sets of these inclined fractures will produce an extension of the rock mass in response to the outward movement of the material below. Note that the extension cannot be achieved by the opening of vertical gaps. The lithostatic pressure keeps the fracture planes tightly closed, and therefore, the extension of the rock mass in the horizontal direction can be effected only by movement on inclined planes. Fractures of this kind, with the downthrow on the hanging wall are called dip-slip or normal faults.

Fig. 3. Deformation Characteristics of a Basaltic Lava Flow.
If a material undergoes little permanent deformation before fracturing it is said to be brittle. A material which undergoes large permanent deformation before fracturing is said to be ductile. A rock may be brittle under certain circumstances but ductile under others.

For example, at high temperatures the outer cooled zone of the lava has a very low yield strength, and it deforms in a ductile manner. At low temperatures the outer crust of an active flow becomes brittle and fractures easily due to movements of the lava below. Thus it can be seen that increased temperature lowers the yield strength and increases the ductility of a rock, and the manner in which a lava flow deforms clearly depends on the temperature.

An increase in the confining pressure results in increases in the yield strength, the ductility and the breaking strength. However, in the outer part of the earth, the effects due to the increase in confining pressure are outweighed by the effects due to the increase in temperature with depth. Consequently rocks exhibit lower yield strengths and greater ductility with increasing depths down to about 200 kilometres.

**Relaxation Time**

The manner in which a rock deforms in nature, also depends upon the length of time during which the stress is applied. Rocks clearly behave as elastic solids with respect to the passage of elastic earthquake waves, the period of which is about 1 second. However, stresses very much smaller than those associated with earthquakes can cause plastic flow within the rocks if the stress is applied for a very long period.

Flow is due to the rearrangement of the molecules under the influence of external stresses. The molecules relax under the stress and this relaxation depends on time. Since

\[ \text{Rigidity} = \frac{\text{Shear stress}}{\text{Shear strain}} \quad \text{and} \quad \text{Viscosity} = \frac{\text{Shear stress}}{\text{Shear strain/time}} \]

it follows that viscosity has the dimensions of Rigidity x Time. This is known as the relaxation time.

We can use this relationship to estimate the limiting viscosity below which transverse earthquakes will not be transmitted. If the calculated density is 3.4 g/cc. and the calculated velocity of the transverse waves is 4.5 km/sec., then the rigidity may be obtained from the relationship \( \mu = \rho v^2 \), and is about \( 6.8 \times 10^{11} \) dynes/cm². If we consider a relaxation time of 10 seconds, equivalent to the period of earthquake waves, then the corresponding viscosity is the rigidity x time and is about \( 6.8 \times 10^{12} \) poises. This means that if the viscosity is greater than about \( 6.8 \times 10^{12} \) poises, the rock will transmit transverse
earthquake waves. It will be seen later that only shallow bodies of molten rock may be located by earthquake waves since the viscosity increases with increasing pressure.

During the last 10,000 years, Scandinavia has experienced a gradual uplift as a result of the melting of the ice sheet. The calculated shear stresses produced by this decrease in the load are less than ten bars (1 bar = $10^6$ dynes/cm$^2$). This indicates that the rocks at depth have a yield strength of a few bars and flow under differential stress of less than ten bars, provided the differential stress is present for a long time. In this case the relaxation time is of the order of 10,000 years.

**A CONCEPTUAL MODEL OF THE PHYSICAL PROPERTIES OF THE OUTER PART OF THE EARTH**

The concepts of ideal elastic, plastic and viscous deformation have been introduced here in order to give a more precise meaning to these terms, which were used to describe the behaviour of the lava during flow and cooling. These fundamental concepts form the bases from which we can attempt to understand the very complex mechanisms of the natural deformation of rocks. Clearly the manner in which the rock deforms depends largely on the temperature and on the time of duration of the stress, but is also dependent to a lesser extent on the pressure, differential stress and strain rate. The manner of deformation also depends on the composition of the rocks, but this can be neglected in this initial study which is concerned with the relationships between the physical factors. Subsequently the models could be elaborated in order to take into account composition variations and other factors.

We are now in a position to build up a conceptual model of the physical properties of the outer part of the earth, so that we can consider the nature of the processes that may lead to volcanic activity.

It will be sufficient to consider evidence concerning the physical properties of the earth down to a depth of 300 km. Depth is the only completely independent variable. The mean density of the earth is about 5.5 g/cc, and since the density of the surface rocks is 2 to 3 g/cc, density must increase with depth. The estimated densities at a number of depths are shown in Figure 5. The pressure depends on the depth and also on the density of the rocks. Consequently the pressure increases at an increasing rate with depth.

![Fig. 5. Conceptual Model of the Physical Properties of the Outer Part of the Earth.](image)
Measurement of the temperature in mines and boreholes which reach depths of 7 kilometres, show that temperature increases with depth. The geothermal gradient ranges between 10°C and 40°C per kilometre near the surface. This gradient cannot be continued to great depths because it would imply unreasonably high temperatures. The oceanic geothermal gradient shown in Figure 5 is based on surface heat flow measurements and the experimentally determined melting characteristic of rocks of appropriate composition. The earth can be regarded as a hot body with an outer layer which has cooled (See Sass 1971).

The temperature range in which a rock melts and undergoes a marked decrease in viscosity, is higher at greater pressures. In other words the melting temperature increases with depth. For an increase in pressure approximately equivalent to an increase in depth of 1 kilometre, the melting temperature is raised by about 4°C. Lava is extruded at a temperature of about 1100°C, so if we regard this as the melting temperature at the surface, the increase in the melting temperature with depth can be represented by a line of (Fig 5). It can be seen that the estimated oceanic geotherm approaches the melting temperature gradient closely at depths of about 100 kilometres. At greater depths the geothermal gradient must be very small since the temperature at the centre of the earth is probably only a few thousand degrees.

There is a marked contrast between the geothermal gradient and the pressure gradient. In the outer part of the earth the temperature increases rapidly with depth and its effect outweighs that due to pressure. At greater depths the effect of increased pressure tends to outweigh the effects due to the smaller increase in temperature.

Observations of earthquake waves show that below the thin veneer of sediments on the earth's surface, there is a layer in which the velocity of the longitudinal waves ($V_p$) increases downwards from about 5 km/sec. to about 6.8 km/sec. This layer, which is known as the crust, is only 6 to 8 kilometres thick in oceanic regions. The Mohorovivic discontinuity separates the crust from the underlying zone known as the mantle, at the top of which the $V_p$ is about 8.1 km/sec. Since the earthquakes preceeding the Hawaiian volcanic activity commenced at depths of about 60 kilometres we will not consider the nature of the crust here.

<table>
<thead>
<tr>
<th>EARTHQUAKE WAVE VELOCITIES</th>
<th>VISCOSITY</th>
<th>DEFORMATION CHARACTERISTICS</th>
<th>DEPTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_s$</td>
<td>$10^2$</td>
<td>Increase in viscosity of the melt with increasing pressure.</td>
<td>Km.</td>
</tr>
<tr>
<td>$V_p$</td>
<td>$10^7$</td>
<td>Brittle Zone: Cohesive strength probably exceeding 100 bars.</td>
<td></td>
</tr>
<tr>
<td>70% of all earthquakes</td>
<td>$10^{32}$</td>
<td>Plastic Zone: Yield strength probably less than 10 bars.</td>
<td></td>
</tr>
<tr>
<td>originate in this zone</td>
<td>$10^{33}$</td>
<td>Estimated from the uplift after deglaciation</td>
<td></td>
</tr>
<tr>
<td>LOW VELOCITY CHANNEL</td>
<td>$10^{36}$</td>
<td>Estimated from the equatorial bulge</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^{37}$</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^{38}$</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^{39}$</td>
<td>300</td>
</tr>
</tbody>
</table>
Study of time travel curves of longitudinal and transverse waves that have travelled through the upper mantle, shows that the velocities of these waves do not increase regularly with depth. In the zone 10° to 20° from the earthquake focus, the waves that have travelled through the upper mantle arrive later and with decreased amplitudes. In 1926 Beno Gutenberg interpreted this effect in terms of decreases in the velocities of the waves starting at depths of about 50 kilometres, and reaching minimum velocities at depths of 100 to 150 kilometres. The magnitude of the velocities prior to the start of the decrease are regained at depths of 250 to 300 kilometres (Fig. 5).

The greatest decreases amount to about 5% of the $V_s$, and about 3% of $V_p$, but the decrease varies in different areas. The low velocity layer acts as a wave guide and consequently is sometimes referred to as the low velocity channel. The lower velocity is probably due to the lower viscosity of the material which forms the layer.

About 70% of all earthquakes originate at depths of 40 to 60 kilometres in the zone just above the low velocity channel. Gutenberg and Richter (1954) have made an analysis of the distribution of earthquakes and demonstrated that nearly all the more important earthquakes occur along two world wide systems. One system coincides with the lines of recent mountain building on the margins of continental masses, and all the earthquakes with foci greater than 70 kilometres occur along this continental fracture system. The second system coincides with the mid-oceanic ridges and all earthquakes along these zones originate at a depth of less than 70 kilometres. The earthquake and volcanic activity of the Hawaiian area with which we are particularly concerned here, has the characteristics of that associated with mid-oceanic ridges.

It is possible to measure the gravitational effect produced by a mountain range which is an excess weight super-imposed on the earth's surface. It is found that the gravitational attraction is very much less than expected, and so it is necessary to postulate that below the mountain the material is less dense than the adjacent material at a similar depth. It appears therefore that the mass of vertical columns of the earth is everywhere very similar, regardless of the topography. The difference in height is largely compensated by differences in density. This condition is known as isostasy and implies a close approach to hydrostatic equilibrium. Soon after the principle of isostasy was established, it was concluded that a relatively strong "lithosphere" layer, was underlain by a layer of relatively small strength which permits gradual movements to approach a hydrostatic equilibrium. Joseph Barrell (1914) called this hypothetical layer the "asthenosphere", and the recognition of the low velocity channel has shown that in many parts of the world there is a layer of relatively low viscosity between 50 and 250 kilometres in depth.

The ice sheet over the northern Baltic was 2 to 3 kilometres thick. Most of the ice melted between 40,000 and 9,000 years ago, and observations of raised beaches and tide gauges have shown that in the area of greatest uplift the land has risen about 340 metres. This is regarded as an example of isostatic re-adjustment which is still continuing at a rate of about 1 cm/yr. If it is assumed that the adjustment takes place by Newtonian viscous flow then the estimated coefficient of viscosity is about $10^{22}$ poises. It is more likely that the asthenosphere behaves in a plastic manner and does not flow until the differential stress exceeds the yield strength. However, estimates of the yield strength of the upper mantle below Scandinavia indicate that it is very small and is probably less than about 4 bars.

If it is assumed that the earth behaves as a viscous liquid, then it has been calculated that the flattening due to the earth's rotation should be 1/300. The observed flattening is 1/298.25, and is significantly different from the calculated value. One explanation of this discrepancy is that the earth's rotation is decreasing due to tidal friction and that the present shape is related to a higher rate of rotation some million years ago. This explanation implies a very long relaxation time due to an extremely slow rate of flow, and if it is correct it suggests that the viscosity of the deeper parts of the mantle would be of the order of $10^{26}$ poises. This is about one thousand time greater than the viscosity of the low velocity channel, the asthenosphere.

Earthquakes result in the most intense and rapid deformation of rock in the outer part of the earth, and it is estimated that the large scale stresses involved are of the order of 100 to 200 bars.

In the last column of Figure 5 an attempt has been made to show the deformation characteristics of the outer part of the earth. The rocks we are familiar with are characterised by high strength in response to stresses imposed for relatively short periods say up to 10,000 years. Should the differential stress exceed the breaking strength of the rock then the rock fractures. The rigidity of this brittle zone calculated from the resulting transverse earthquake waves using $V_s = \sqrt{\mu/\rho}$ is about $10^{12}$ c.g.s. units. If we take a relaxation time greater than $10^4$ years or $10^{11}$ seconds, then the corresponding viscosity is greater than $10^{23}$ poises.

[26]
The increase in pressure with depth would tend to increase the viscosity but this is more than counterbalanced by the reduction in the viscosity due to the increase in temperature. At about 100 kilometres the viscosity estimated from the post glacial isostatic uplift is about $10^{22}$ poises and the estimated yield strength is probably less than 4 bars. Material in this zone will deform by viscous flow rather than by fracture, and so this might be regarded as the plastic zone. At greater depths the rate of temperature increase is reduced and the viscosity increases and it seems likely that the yield strength also increases slightly.

We now have a conceptual model of the physical characteristics of the outer part of the earth. This model shows the values of some of the physical properties calculated from observations of natural processes. If we assume that the conditions in the zone between depths of about 100 and 200 kilometres, represent a close approach to hydrostatic equilibrium, then we can regard volcanic activity as a consequence of a disturbance of this equilibrium state, and the operation of processes which tend to restore the equilibrium. It will be assumed that the material at this depth is static, so that the possible disturbances of the equilibrium state which are most likely to produce a melt at this depth can be considered. The possibility that the material is not static will be considered in the final section.

THE DISTURBANCE OF EQUILIBRIUM

In this initial study it is assumed that the composition of the mantle is constant in the zone between depths of about 60 and 300 kilometres, so that an assessment can be made of possible variations in the physical properties which may result in a disturbance of the hydrostatic equilibrium. Hydrostatic equilibrium implies constant density and temperature at each level, and a progressive increase in pressure with increasing depth. The increase in pressure causes increases in the density and viscosity with increasing depth. Consequently, a decrease in pressure will result in marked decreases in the viscosity and density.

One explanation of the origin of a rock melt postulates that if a fracture forms there would be a large decrease in the pressure, and that this would result in the formation of a melt of lower viscosity which would rush into the fracture.

The formation of normal faults has been considered above and it was seen that the shear fractures form as the result of differential stress. The lithostatic pressure remains constant, and the differential stress builds up as the result of the reduction in one of the horizontal principal stresses. After fracturing the differential stress is reduced and in the case of normal faults, the minimum principal stress increases towards the value of the lithostatic pressure. Since the viscosity depends on the lithostatic pressure which in turn depends on the depth, no decrease in the viscosity can occur solely as the result of fracturing at a particular level.

The conceptual model of the outer part of the earth also shows a relationship between temperature and depth. We can regard the variation in temperature indicated by the geothermal gradient as the result of the cooling of the outer part of the hot body. If the rocks at any particular level received heat at a constant rate and remained stationary, then the temperature would be almost constant at that level but would be decreasing very slowly as heat was lost by the exceedingly slow process of conduction. In this very simple model there is a direct relation between temperature and distance from the surface.

The dependence of viscosity on temperature is clearly shown by the films of flowing and cooling lava, and by the experimental work (Fig. 3). Consequently, a localised increase in the temperature would result in the formation of a mass less viscous and less dense than the material above and to the sides. In this situation it is possible that convection would occur.

Rigid mathematical treatment of convection presents great difficulties and it is necessary to resort to experimental work. The relation between the factors which tend to promote or to inhibit convection has been studied experimentally in thin layers of liquid heated from below. A dimensionless number known as Rayleigh's number is obtained from the ratio:

$$R = \frac{a \times g \times d^4 \times dT}{b \times n}$$

where

- $a$ = the coefficient of thermal expansion.
- $g$ = the gravitational acceleration.
\[ d = \text{the depth of the layer.} \]
\[ dT = \text{the temperature difference between top and bottom.} \]
\[ b = \text{the thermal diffusivity.} \]
\[ n = \text{the kinematic viscosity (i.e. viscosity divided by the density).} \]

The Rayleigh number is the ratio of the magnitude of the factors that tend to promote convection to those that tend to inhibit convection. It can be seen that convection is aided by a large coefficient of expansion due to the buoyancy of the lighter liquid, and this is accentuated by a large temperature difference. The depth of the layer is particularly significant since it occurs as the fourth power. On the other hand convection is inhibited by:

- high value of the thermal diffusivity since it prevents the build up of a large temperature difference, and by
- high viscosity which inhibits flow. Rayleigh found by experiment that in a thin layer heated from below, convection started when the ratio exceeded a value of about 1,500.

The relationship demonstrates clearly that an increase in temperature and the consequent large decrease in the viscosity and small decrease in density, all have the effect of increasing the Rayleigh number and in leading to an unstable situation in which convection will occur.

It can be seen from Figure 5, that the estimated viscosity of a melt at 1100°C, would be about \(10^{20}\) poises at a depth of 100 km. due to the increase in pressure, while the normal viscosity in this zone is probably \(10^{22}\) to \(10^{23}\) poises. A local increase in the temperature by 200°C to 300°C would produce a marked decrease in the viscosity and also a decrease in the density, which would disturb the hydrostatic equilibrium and lead to penetrative convection.

**THE EFFECT OF THE DECREASE IN THE VISCOSITY OF THE MELT**

Imagine that a column of melt has risen by penetrative convection into the overlying plastic zone. The upward rate of flow of the melt can be considered in a greatly simplified way in terms of the laminar flow in a cylindrical pipe. The mean rate of laminar flow in a pipe is given by the equation:

\[ V = \frac{\text{Intrusive pressure} \times r^2}{4 \times n \times L} \]

where

- \( r = \text{radius} \)
- \( \eta = \text{viscosity} \)
- \( L = \text{length} \)
- Intrusive pressure = \(g \times L \times (d_r - d_m)\)
- \( d_r = \text{density of the rock} \)
- \( d_m = \text{density of the melt} \)

Let us assume that at a depth of about 100 kilometres the viscosity of the melt would be about \(10^{19}\) poises, and that \((d_r - d_m) = 0.04\), and that the radius of the column is 10 kilometres = \(10^6\) centimetres.

\[
\text{Mean linear rate of flow} = \frac{g \times L \times (d_r - d_m) \times r^2}{4 \times \eta \times L} = \frac{10^3 \times 0.04 \times 10^{12}}{4 \times 10^{19}} = \frac{10 \times 10^{12}}{10^{19}} = \frac{1}{10^6} \text{ cm/sec.}
\]

This is a very slow rate of flow in a very wide vent, and it amounts to about 33 cm/year.
The volume rate of flow is the mean linear rate multiplied by the cross sectional area of the column which is \( \pi r^2 \). In the particular example above the volume rate of flow is:

\[
\frac{\pi r^2}{10^6} = \frac{\pi 10^{12}}{10^6} = \pi 10^6 \text{ cc/sec.}
\]

The viscosity of the melt depends partly on the lithostatic pressure and so the viscosity decreases as the melt rises. We can consider the consequences of the decreasing viscosity by assuming that the following factors remain constant:

1. The temperature of the melt.
2. The differences between the density of the melt and the adjacent rock.
3. The volume rate of flow.

The simplified relationship from above is \( r^4 = n \times 10^5 \). If we select a particular depth, the viscosity of the melt can be estimated from Figure 5 which shows the probable relationship between the melt viscosity and depth. For example, at a depth of 75 kilometres the melt viscosity would be reduced to about \( 10^{15} \) poises. Consequently, \( r^4 = 10^{15} \times 10^5 = 10^{20} \) and \( r = 10^5 = 1 \) km. Now that we have an estimate of the radius, the mean linear rate of flow can be calculated. The change in the diameter of the column and in the mean upward rate of flow as the viscosity

---

**Fig. 6. The Effect of the Decrease in Viscosity of the Melt with Decreasing Depth.**

<table>
<thead>
<tr>
<th>Depth (Km)</th>
<th>Viscosity (poises)</th>
<th>Radius of vent (cm)</th>
<th>Rate of flow (cm/sec)</th>
<th>Reynold’s Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>( 10^3 )</td>
<td>( 10^2 )</td>
<td>( 10^2 )</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>( 10^7 )</td>
<td>( 10^3 )</td>
<td>( 10^2 )</td>
<td>( \frac{3}{10^4} )</td>
</tr>
<tr>
<td>25</td>
<td>( 10^{11} )</td>
<td>( 10^4 )</td>
<td>( \frac{1}{10^2} )</td>
<td>( \frac{3}{10^9} )</td>
</tr>
<tr>
<td>50</td>
<td>( 10^{15} )</td>
<td>( 10^5 )</td>
<td>( \frac{1}{10^4} )</td>
<td>( \frac{3}{10^{14}} )</td>
</tr>
<tr>
<td>75</td>
<td>( 10^{19} )</td>
<td>( 10^6 )</td>
<td>( \frac{1}{10^5} )</td>
<td>( \frac{3}{10^{19}} )</td>
</tr>
</tbody>
</table>

Constant volume rate of flow = \( \pi 10^6 \) cc/sec.
of the melt decreases, is shown in Figure 6, with the original conditions shown at the bottom. It can be seen that
the radius of the column decreases and the rate of flow increases as the result of the decreasing viscosity with
decreasing depth.

These simple calculations are based on the equation of laminar flow. At a certain critical velocity, turbulent
flow occurs and the relationship would not apply. The critical velocity at which turbulence occurs in a cylindrical
tube depends on the density and viscosity of the liquid and also on the radius of the tube. These factors are related
in the following way:

$$\text{Critical velocity} = k \times \frac{\text{viscosity}}{\text{radius} \times \text{density}}$$

where \(k\) is a numerical dimensionless constant known as the Reynolds number. Reynolds found by experiment
that turbulence starts when \(k\) is about 1,000. It can be seen from this relationship that turbulence is promoted
by decreasing viscosity and increasing radius. We can use the Reynolds number to test our estimates of the rates
of laminar flow. Assuming that the density of the melt is about 3 grams/cc. the Reynolds number can be
calculated for each depth and is shown on the right hand side of Figure 6. At the greater depths the Reynolds'
numbers are very small and this suggests that our assumptions that the flow was laminar is quite reasonable. At
the shallowest depth considered, the Reynolds number is 30 and this indicates an approach to the critical
conditions of turbulent flow. The velocity of extrusion of the lava fountains recorded during the 1959 eruption
was about 360 metres per second, but this consisted of a large volume of gas which will be considered later. The
rate of rise of the melt in the outer cooler parts of the earth are very much higher than the rate of loss of heat
by conduction which is about \(3 \times 10^{-9}\) cm./sec, so that it is reasonable to assume that the temperature of the
melt remains constant during its ascent towards the surface.

THE EFFECT OF A DECREASE IN THE DENSITY OF THE ROCKS

It was assumed in the above discussion that the difference between the densities of the rock and melt
remained constant at about 0.04 grams/cc. If we regard the equation of laminar flow as representing a constant
volume rate of flow in an upward direction, then it can be seen that as \((d_i - d_m)\) decreases, the radius must
increase. When the density difference approaches zero the radius approaches infinity. In other words, the melt
spreads sideways and forms a sill (Fig. 6).

The estimates obtained above are concerned with the movement of the melt in a cylindrical vertical channel.
Before this situation is achieved some work has to be done to push aside the adjacent material in order to create
the channel. The initial upward penetration would be caused by the expansion of the melted rock. When the
column or bulge is one kilometre in height the intrusive pressure if the density difference was 0.04, would be
approximately \(10^3 \times 0.04 \times 10^5\) centimetres = 4 bars. This intrusive pressure is the pressure in excess of the
lithostatic pressure which acts on the melt and causes it to rise. An intrusive pressure of about 4 bars would
probably be sufficient to overcome the yield strength of the material above and it would be displaced by plastic
flow which would continue under a constant differential stress due to the intrusive pressure. At shallower depths
the yield stress probably increases, but once the column is initiated, the intrusive pressure increases due to the
increased height of the column and the pressure would be concentrated on a smaller area as the diameter
decreased.

THE FORMATION OF DYKES

When the melt rises into the brittle zone, the rocks cannot be displaced by plastic flow, since the rate of
plastic flow in the cooler rocks is very much smaller than the rate of rise of the melt. Consequently the pressure
of the melt causes the rocks to fracture. The melt may continue to rise along a planar fracture, but if it
consolidates in the fracture, a dyke is formed.

Consider a vertical tabular mass of the less dense melt, as represented in Figure 7a, with the long horizontal
dimension perpendicular to the plane of the diagram. At a point at some lower level within the dyke, the
hydrostatic pressure is due to the weight of the rocks above the dyke plus the weight of the melt. The vertical
pressure at a point in the wall at the same level is due to the weight of the rocks above, and since these are more
dense than the melt, the lithostatic pressure is greater than the hydrostatic pressure of the melt. Consequently,
the pressure on the walls tends to close the dyke and squeeze the melt upwards. This fluid pressure from below
can cause the pressure of the melt at the top of the dyke to exceed the lithostatic pressure temporarily. It is important to note that while the lithostatic pressure due to the weight of the rocks, remains constant at any particular depth, the hydrostatic pressure of an incompressible liquid rising from below when there is no open channel available, may exceed the lithostatic pressure because the liquid transmits the pressure from a greater depth. This is a simple hydraulic effect similar to the mechanism of hydraulic car brakes. The pressure due to the weight of rocks over a wide area, is transmitted to a higher level and concentrated on a small area by the liquid.

Consider the rock just above the top of the dyke. The dilation of the dyke will cause a stretching in the rocks immediately above the melt, and will set up a differential stress very similar to the situation described for the formation of a normal fault. Just above the dyke the horizontal principal stress perpendicular to the dyke, will be reduced and becomes the minimum principal stress (Fig. 7b). The build up of the differential stress is resisted by the tensile strength of the rock.

The pressure at a point in the melt at the extreme top of the dyke is equal in all directions. This fluid pressure acts against the principal stresses in the adjacent rocks. Since the melt is less dense and is being forced upwards, its pressure will exceed the principal stresses in the rock temporarily. When the fluid pressure is greater than a principal stress by an amount which is equivalent to the tensile strength of the rock, the rock will fracture. Clearly the intrusive pressure will overcome the minimum principal stress first. Since the minimum principal stress is horizontal, the fluid pressure will displace the rocks horizontally, thus forming a vertical fracture above the dyke into which the melt flows virtually simultaneously (Fig. 7c). This process is known as hydraulic fracturing. The differential extension stresses are temporarily reduced just above the dyke but the pressure of the melt rapidly builds up, causing dilation, and leading to another episode of hydraulic fracturing each time the fluid pressure exceeds the minimum principal stress by an amount equal to the tensile strength of the rock.

The critical condition for hydraulic fracturing and dyke extension, is the difference between the fluid pressure and the minimum principal stress in the horizontal plane. The effective stress acting on a plane is the difference between the normal stress and the fluid pressure acting on the plane. In the case of a dyke, the horizontal minimum principal stress is the normal stress which inhibits the extension of the dyke fracture, while the fluid pressure tends to extend the fracture. Since the tensile strength of the rock also inhibits the extension of the fracture, extension of the dyke cannot occur until the fluid pressure exceeds the combined minimum principal stress and the tensile strength of the rock. In other words, fracture occurs when the effective stress exceeds the tensile strength. Clearly there is a limit to the magnitude of the fluid pressure which depends on the strength of the rocks.

It is interesting to contrast the extreme conditions of the formation of normal faults and dykes.

A normal fault will form when the differential stress exceeds the breaking strength of the rocks. Experimental studies show that the breaking strength of sedimentary rocks often exceeds 800 bars, while the breaking strengths of igneous rocks probably exceeds 2000 bars. However, shear fractures will develop in rocks at much lower values of the differential stress provided a pore fluid is present under pressure.

A dyke may develop when the differential stress is very small, provided the fluid pressure exceeds the tensile strength of the rock. The melt forms its own fracture by repeated episodes of hydraulic fracturing. Experimental studies show that the tensile strengths of sedimentary rocks generally range between 10 and 100 bars, while the tensile strengths of igneous rocks are commonly in the range 50 to 250 bars.

Clearly a certain proportion of the intrusive pressure is used to break the rock and open a fracture.

If we assume that the difference between the densities of the melt and the rocks is 0.1 grams/cc., we can obtain an estimate of the intrusive pressure required to open a fracture in terms of a column of melt. Since the intrusive pressure $= g \times (d_r - d_m) \times \text{height}$, then the height of a column of melt which will produce an intrusive pressure of one bar is:

$$\text{height} = \frac{10^6}{10^3 \times 0.1} = 10^4 \text{ cm}.$$  

This simple estimate suggests that a column of melt, 0.1 g/cc less dense than the adjacent rock, and 5000 metres in height, would generate an intrusive pressure which could extend a fracture in rocks with a tensile strength of about 50 bars.

[31]
THE FORMATION OF SILLS

In our simple conceptual model of the outer part of the earth it was assumed that the density of the rocks is constant at any level but decreases upwards. Consequently, the intrusive pressure exerted by the less dense melt acts in a vertical direction. In the section concerned with the rise of a melt in the plastic zone, it was pointed out that when the difference between the density of the melt and rock approaches zero, the square of the radius must approach infinity in order to maintain the volume rate of flow upwards. This explanation of the formation of a sill emphasizes the fact that when the melt reaches a level at which its density is equal to the density of the adjacent rocks, the melt flows along the more or less horizontal plane and hydrostatic equilibrium is re-established. Consider the mechanics of this situation in rocks.

The differential stresses in the adjacent rock are shown in Figure 7d. At the top the rock has been stretched and so the horizontal stress becomes the minimum principal stress. At the sides the rocks have been compressed in a horizontal direction due to dilation of the dyke, so that the horizontal principal stress is greater than the lithostatic pressure which in this area is the minimum principal stress.

The upward rise of the magma stops when the intrusive pressure due to the difference between the densities of the melt and the rocks at this level, cannot overcome the minimum principal stress plus the tensile strength of the rock. The intrusive pressure is still greater than the lithostatic pressure so that the melt can lift the overlying rocks.

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Fig. 7. The Formation of Dykes and Sills.

[32]
rocks but cannot break through to a higher level. The melt flowing in from below will tend to accumulate at this level. The intrusive pressure acting at the sides is greater than that acting at the top, due to the extra weight of the melt above this level. When the intrusive pressure exceeds the lithostatic pressure by an amount equivalent to the tensile strength of the rock, hydraulic fracturing occurs and the melt flows into a fracture as it develops in an approximately horizontal position thus forming a sill (Fig. 7e).

Clearly the melt cannot rise to a level at which its density is equal to the density of the adjacent rocks. The height to which a melt can rise before spreading is modified by the tensile strength of the rock. In the outer part of the earth the rocks are inhomogeneous and the form of the intrusive mass is modified by variations in the dip and in the tensile strength of the rocks. The probable form of a sill in gently inclined sedimentary rocks is shown in Figure 7f.

THE EXTRUSION OF LAVAS

The preceding discussion concerning the movement of a melt in the brittle zone where the strength of the rocks is relatively large, suggests that a silicate melt would be unlikely to be extruded onto the earth's surface simply as a consequence of its lower density. It is necessary to consider the effect of the gases and in particular water vapour, that are extruded with the silicate melt.

Gases dissolve in liquids to form true solutions. The degree of solubility depends on the nature of the gas and the liquid, and also on the pressure and temperature. If the molecules of the gas and liquid do not combine chemically, the solubility is due merely to the attractive molecular forces and is usually low.

At any given temperature the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid at equilibrium. This principle, known as Henry's law, is strictly applicable to ideal solutions at low pressure and high temperature. However, we can apply the general principle of Henry's law to obtain an understanding of the relationship between the silicate melt and dissolved water vapour at high temperature, but with varying pressure.

At any particular temperature the gas phase is said to be in equilibrium with the solution containing gas molecules, if the number of gas molecules passing from the liquid to the gas balances the number of molecules passing from the gas into the liquid. The pressure exerted by the gas is called the vapour pressure.

Water is the most common constituent of the volcanic gases erupted on Hawaii so it is important to consider the solubility of water in basalt lava. This has been done experimentally and the graph, Figure 8a, shows the maximum solubility of water in molten Columbia river basalt at 1100°C. It can be seen that the amount of water that can be dissolved in the basalt at 1100°C increases with increasing pressure. At atmospheric pressure little water is likely to remain in solution, but at 1,000 bars pressure equivalent to a depth of about 4 km., the basalt can dissolve 3% water by weight.

At saturation the vapour pressure is equal to the lithostatic pressure due to the weight of the overlying rock or melt. If the lithostatic pressure becomes less than the saturated vapour pressure, then the basalt liquid will be oversaturated in the dissolved gas, and some gas bubbles will separate from the liquid until the saturated vapour pressure is attained and equilibrium is restored. The formation of bubbles within a liquid is known as boiling or ebullition, but in the case of lavas it is usually referred to as vesiculation.

We are familiar with the boiling of water at constant atmospheric pressure due to an increase in temperature. At 100°C water vapour bubbles separate in the liquid water. Here we are concerned with the separation of water vapour bubbles in a silicate liquid at constant temperature due to the decrease in the lithostatic pressure.

During eruptions gas bubbles are seen to burst through the surface of liquid lava flows and lakes, and many lava rocks contain abundant vesicles below the upper skin of the flow, suggesting that many gas bubbles were trapped in the lava during its consolidation. The amount of water extruded during volcanic activity at Kilauea ranges between 0.4% and 1.1% by weight.

When the volume of a definite quantity of gas is reduced at constant temperature, the molecules are confined to a smaller space and since collisions are more frequent, the molecules exert a greater pressure. The relationship was first reported by Robert Boyle in 1662 and is now known as Boyle's law, which states that at constant temperature the volume of any definite quantity of gas varies inversely as the pressure of the gas. If the
pressure on a gas is increased below a certain critical temperature, at first the density increases but at a particular temperature the gas phase may condense into a liquid phase. Above the critical temperature there is no sharp change from a gaseous to liquid phase, but a continuous increase in the density of the gas occurs until the density of the liquid phase is approached. The critical temperature of water is 374°C so we are concerned here with water in a supercritical state. The pressure required to liquify water at the critical temperature is only 220 bars, and the density of the water at these critical conditions is about 0.3 grams/cc.

The approximate decrease in the volume of one gram of water vapour with increasing pressure at 1,000°C is shown in Figure 8b. At atmospheric pressure, one gram of steam at 1,000°C will occupy more than 7,000 ccs. With increasing pressure there is at first a very marked reduction in the volume and this is the section in which Boyle's law is applicable. At greater pressures the rate of decrease in the volume is very much smaller due to the closeness of the molecules.

If we assume that a melt contains 1.5% water by weight we can represent its rise to the surface by the line AB on Figure 8a and by Figure 8c. It can be seen that this melt is likely to be unsaturated at depths greater than about 3 km, equivalent to pressures greater than about 750 bars. However, when this melt reaches a depth of about 3 kilometres it will be saturated with respect to water and the saturated water vapour pressure will be equal to the lithostatic pressure. If this melt rises above this depth it will be oversaturated and the vapour pressure will be greater than the lithostatic pressure. Consequently, some water vapour will separate as bubbles in order to reduce the vapour pressure of the dissolved water. Nucleation of a bubble will not occur until the excess vapour pressure exceeds the surface tension, but this pressure is likely to be a very small fraction of a bar and it can be neglected here. At this depth the bubbles of water vapour will have a density of about 0.17 grams/cc. Will the bubbles rise quickly and escape from the melt which itself is rising?

The rate of rise of bubbles is given by Stoke's law.

$$v = \frac{2 g \rho r^2}{9 \eta}$$

where $r$ = the radius of the bubble

$g$ = the gravitational acceleration

[34]
\[ \rho = \text{the density of the melt} \]
\[ \eta = \text{the viscosity of the melt} \]

It is interesting to compare the rate of rise of bubbles with the rate of rise of a melt in a vent, assuming \( r = 0.1 \text{ cm.}, \rho = 3, \eta = 10^3 \) and the radius of the vent, \( R = 100 \text{ cm.} \)

<table>
<thead>
<tr>
<th>Rate of rise of bubbles</th>
<th>Rate of rise of melt</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ v = \frac{2 \ g \rho \ r^2}{9 \ \eta} ]</td>
<td>[ V = \frac{g (d_r - d_m) R^2}{8 \ \eta} ]</td>
</tr>
<tr>
<td>[ = 2 \times 10^3 \times 3 \times (0.1)^2 ]</td>
<td>[ = 10^3 \times 0.01 \times 10^4 ]</td>
</tr>
<tr>
<td>[ = \frac{2}{3 \times 10^2} \text{ cm./sec.} ]</td>
<td>[ = \frac{10^2}{8} \text{ cm./sec.} ]</td>
</tr>
</tbody>
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The rate of rise of the bubbles depends on the radius of the bubbles, and the estimates indicate that initially the rate of rise of the bubbles is very much smaller than the rate of rise of the melt containing the bubbles.

The vesiculated magma is called pyromagma. Since the density of the gas is about 0.2 grams/cc., vesiculation will result in a slight but significant reduction in the overall density of the melt containing bubbles, and will enhance the continued upward rise of the melt.

As the pressure of the rock acting on the rising melt continues to fall it will have the following effects: (a) more bubbles will form due to the reduction in the solubility, (b) previously formed bubbles will grow due to the addition of more gas, and (c) the bubbles will expand due to the expansion of the gas as the lithostatic pressure decreases.

At first the effect of vesiculation would be to enhance the rise of the melt due to the overall decrease in the density. Near the surface the volume of the gas is very much greater and the rise of the vesiculated magma is due to the expansion of the large volume of gas rather than the density difference.

Consider 99 grams of melt containing 1 gram of water. At depths greater than about 2 kilometres this amount of undersaturated melt would occupy less than 40 ccs since its overall density would be less than 2.5 grams/cc. The first gas bubbles to form at a depth of about 2 kilometres would have a density of about 0.1 g/cc and this would result in an overall decrease in the density of the melt, and the pyromagma would begin to accelerate to the surface. If the one gram of gas had separated from the 99 grams of melt when it was extruded above the surface, the volume of the 99 grams of melt would still be about 40 ccs but the volume of the one gram of gas would be in excess of 7,000 ccs. This involves a change from a viscous liquid containing gas bubbles, to a highly mobile gas containing fragments of liquid which consolidates as glass shards, pumice fragments or spatter on the cones (Fig. 8c). The lava fountains are formed by the forceful expansion of the gas carrying incandescent fragments of liquid high into the air.

If the melt stops rising before it is saturated with water, vesiculation may not occur, and the melt may form a laccolith or sill. A melt with only 0.5% water by weight may rise to about 1 kilometre depth represented by the line CD (Fig. 8a), and it may then spread sideways. The discussion up to this point has assumed a constant high temperature. What happens when the melt stops rising and cools?

When the temperature drops to a certain level, crystals of silicate minerals may form and the first of these do not contain any water in their structures. Consequently, the relative proportion of water in the remaining liquid increases as the crystallization proceeds. The increase in the relative amount of water remaining in the liquid at constant pressure may be represented by the line DE in Fig. 8a. At E the liquid is saturated in water.

The vapour pressure of the dissolved gas depends on the temperature, and it will decrease slightly as the melt cools. Crystallization does not commence when the crystal-liquid equilibrium temperature is reached, because no
change can occur at equilibrium. Nucleation occurs after a certain amount of undercooling and crystallization the continues at constant temperature, due to the release of latent heat, until equilibrium is attained between the crystals and liquid. During this period of crystallization at constant temperature, the vapour pressure of the dissolved gas may increase due to the increased concentration of gas in the remaining liquid (Fig. 9c).

After this initial period of crystallization at constant temperature, during which the vapour pressure may increase, crystallization continues with cooling and the vapour pressure decreases steadily. If during the initial crystallization the increase in the vapour pressure exceeds the confining pressure which remains constant, then vesiculation will occur. Since this boiling occurs during falling temperature it is known as retrograde boiling. The formation of bubbles will result in an increase in the intrusive pressure, and if this exceeds the combined minimum principal stress and the tensile strength of the rocks, hydraulic fracturing may occur and the less dense, partly crystallized, vesiculating melt may force its way to the surface. However, the extrusion of partly crystallized melt does not necessarily indicate that retrograde boiling has occurred.

THE MAIN PHYSICAL PROCESSES ASSOCIATED WITH VOLCANIC ACTIVITY

The conceptual model of the physical characteristics of the outer part of the earth shows that in the zone between depths of about 100 to 200 kilometres, a state of hydrostatic equilibrium is closely approached. Consideration of the possible variation in the physical properties reveals that the hydrostatic equilibrium would be disturbed by an increase in the temperature, since this results in a marked decrease in the viscosity and also a decrease in the density of the hotter mass.

The less viscous and less dense melt ascends by penetrative convection. At first the rate of rise is slow but occurs over a relatively large area. The rock material above has a low yield strength and is displaced by plastic flow. However, as the melt ascends, two important changes occur. The rising melt retains a virtually constant temperature but undergoes a progressive reduction in the viscosity due to the decrease in pressure, and this results in an increased rate of flow in a narrowing cylindrical channel (Fig. 6). Simultaneously the yield strength of the surrounding rocks increases with decreasing depth due to the normal decrease in temperature. Consequently, although the rate of movement of the melt increases, the rate of displacement of the rocks by plastic flow decreases.

At depths of about 60 kilometres below the summit, the build up of the intrusive pressure greatly exceeds the rate of plastic flow, so that the melt continues its ascent by repeated hydraulic fracturing. The earthquakes recorded before an eruption consist of repeated shocks of similar magnitude, originating from foci which decrease in depth. These characteristics are well explained by the hydraulic fracturing mechanism.

The swelling of the summit before and during eruptions indicates that the melt does not always reach the surface directly by flow along simple cylindrical vents or dykes. Within a few kilometres of the surface the melt lifts the overlying rocks rather than break through them, and a magma chamber with a laccolithic form probably develops (Fig. 9a). It is necessary to consider the relative values of the intrusive pressure of the melt, the principal stresses in the adjacent rock, and the vapour pressure of the gases dissolved in the melt. Three relationships will be considered.

1. At an early stage in the formation of the magma chamber, the horizontal stresses in the rocks at the top are only slightly smaller than the lithostatic pressure. The melt stopped moving upwards when the intrusive pressure was still greater than the lithostatic pressure but lower than the combined minimum principal stress and tensile strength of the rock. The melt flowing in from below could lift the rocks but not break through to higher levels. The relationship between the intrusive pressure, the minimum principal stress and the tensile strength is shown in the form of an equation at the top of the magma chamber in Figure 9a.

2. At the bottom of the magma chamber, the hydrostatic pressure in the magma is due to the weight of the overlying rocks and the melt in the chamber (Fig. 9a). Consequently the intrusive pressure acting at the edges of the laccolith is greater than the intrusive pressure acting against the overlying rocks at the top. Lateral movement of the melt is opposed by the lithostatic pressure acting at the edge and by the tensile strength of the rocks.

[36]
3. The gases are retained in solution in the very hot melt by the pressure of the overlying rocks and melt. In the situation under consideration it is assumed that no vesiculation has occurred because the vapour pressure does not exceed the combined lithostatic pressure and surface tension forces. The vapour pressure of the dissolved gas will be nearest the lithostatic pressure at the top of the magma chamber.
What changes occur which result in vesiculation and the extrusion of lava fountains? This question can be made more specific. What changes will occur in the three situations just specified, as a result of the continued swelling of the summit area due to the continued inflow of melt into the magma chamber?

Swelling of the magma chamber will cause a progressive reduction in the horizontal principal stresses in the overlying rocks (Fig. 9b (1)). When the combined minimum principal stress and tensile strength is lower than the intrusive pressure at the top of the chamber, hydraulic fracturing will occur and a radial vertical fracture develops (Fig. 9b (2)). The orientation of the minimum principal stresses and the zones on Mauna Loa and Kilauea are shown in Figure 9d. The melt will rise to a higher level along the dyke-like fracture. The minimum principal stress will be temporarily increased, but further swelling will result in the reduction of the horizontal principal stress at the top of the dyke and another episode of hydraulic fracturing. In this manner dykes will develop along the rift zones near the summit, and the melt will rise to higher levels.

It is assumed that the vapour pressure remains constant throughout the melt. As the melt rises into the dykes above the magma chamber the lithostatic pressure is reduced. If the melt reaches a level where the vapour pressure exceeds the lithostatic pressure, vesiculation will occur (Fig. 9b (3)). The separation and expansion of the gas bubbles in the melt at the top of the dyke will result in an increase in the intrusive pressure and in the continued and accelerated upward extension of the dyke by hydraulic fracturing. Immediately prior to the extrusion of lava fountains at Kilauea Iki, repeated earthquake shocks were recorded with a frequency of about 1.5 seconds. These shocks are probably due to repeated hydraulic fracturing caused by the very rapid rate of rise of the expanding vesiculating melt near the surface.

Vesiculation and extrusion will continue as long as melt continues to flow into the fracture. However, the rate of extrusion will probably exceed the rate of flow of melt into the chamber and slight subsidence will occur. This subsidence will result in an increase in the horizontal principal stress above the magma chamber (Fig. 9b (4)). When the horizontal stresses below the level of vesiculation exceed the intrusive pressure, the fracture will close and the supply of melt will be cut off along the fracture, though flow and extrusion may continue along a single large vent which has been eroded out along the fracture.

Once a vent has been formed the intrusive pressure no longer has to overcome the strength of the rocks, and the melt could form a column in hydrostatic equilibrium with the adjacent rocks. The reason for the periodic cessation of the eruptions may be the slower rate of flow of the melt from depth into the magma chamber, so that the supply of melt to the level of vesiculation ceases (Fig. 9b (5)). During the extrusion, the upper part of the vent is occupied almost entirely by expanding gas. When extrusion ceases the empty vent is usually choked by debris falling from the sides, but when the lava lake in Kilauea Iki rose above the vent, lava poured back down the vent at more than twice the rate at which the liquid was extruded.

Further swelling after a period of eruption and subsidence may lead to another episode of activity at the summit.

In the preceding discussion it was assumed that the vapour pressure of the dissolved gases remained constant. The vapour pressure depends on the temperature and also on the amount of gas dissolved in the melt (Fig. 9c). If cooling of the melt in the magma chamber resulted in the start of crystallization, it is possible that the vapour pressure might increase at first due to the increased concentration of gas in the remaining liquid. Consequently, the vapour pressure might exceed the lithostatic pressure at the top of the magma chamber and vesiculation might occur. Vesiculation would lead to an increase in the intrusive pressure and this might result in hydraulic fracturing and the extrusion of the expanding vesiculating melt at an accelerating rate. In this case the extruded lava would contain crystals. However, the extrusion of partly crystallized lava does not necessarily mean that the extrusion occurred as the result of a retrograde increase in the vapour pressure.

It seems likely that the earliest melt flowing into the summit area would have the highest gas content. Subsequently, the melt might contain less gas and the vapour pressure associated with this might be insufficient to produce vesiculation even after the reduction of the horizontal stress due to continued swelling, or to partial crystallization.

The swelling of the magma chamber results in an increase in the intrusive pressure at the outer edges of the laccolith. When this intrusive pressure exceeds the combined lithostatic pressure and tensile strength of the rocks, hydraulic fracturing opens up approximately horizontal fractures, and the magma flows laterally along the rift.
zones (Fig. 9e). The path followed by the melt would be controlled to some extent by the layered structure of the rocks which dip gently outwards from the summit and rift zones. However, as the melt descends relative to the level of the magma chamber beneath the summit, the intrusive pressure increases due to the increased head of liquid, and the melt would be able to break through the overlying layers. Consequently, as the melt moves laterally it tends to approach nearer the surface. If the vapour pressure remains constant, while the lithostatic pressure decreases, due to decreasing depth, an area will be reached on the flanks where the vapour pressure exceeds the lithostatic pressure. In this area vesiculation and extrusion occurs. Generally, less gas is associated with flank eruptions than with summit eruptions and this observation is compatible with the mechanism proposed here.

The summit area of Kilauea continued to swell for four days after the start of the flank eruption in 1960. Then subsidence commenced at the summit and finally was approximately equivalent to the amount of lava extruded at Kapoho. The lava lake in Halemaumau drained away. The subsidence of the summit was accompanied by many small earthquakes as the rocks fractured during the subsidence. Clearly the pit craters and calderas in the summit area are collapse structures which are related to the draining away of the melt from the summit magma chamber due to flank eruptions.

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**Fig. 10. Ocean Floor Spreading**

**OCEAN FLOOR SPREADING**

This paper has been concerned with the physical processes which are associated with the migration and extrusion of magmas in oceanic areas, and it was assumed that the melt developed from a static zone at a depth of about 100 km. In 1960 Harry Hess proposed the hypothesis that the mid-oceanic volcanic ridges are situated over the rising sections of convection cells in the mantle, and that the oceanic crust is continuously created by a process of lateral accretion and spreading away from the oceanic ridges. Within a few years this hypothesis was confirmed, largely by the study of the symmetrical patterns of the reversals in the magnetic anomalies which occur in the basaltic rocks on either side of the ridge crest. The concept of ocean floor spreading forms a very important part of the unifying concept of plate tectonics.

One model of the convective flow in the mantle below oceanic ridges is represented in Figure 10. This model shows a wide zone below 200 kilometres in which the flow is slow and opposite to the direction of ocean floor spreading. This very slow encounter flow affects a large volume of the mantle, and is heated from below by conduction. The increase in the temperature as the material moves laterally, leads to an unstable situation which
eventually results in convection. The relatively hot and less viscous material rises, and due to the progressive decrease in the viscosity with decreasing pressure, the mass rises at an increasing rate in a zone of decreasing width, similar to the rise of a melt discussed above (Fig. 6). It seems likely that this hot, less viscous material spreads laterally along the low velocity channel, and carries with it the more rigid overlying material which forms the oceanic plate.

In the discussion above concerning the disturbance of equilibrium and the origin of melt, it was assumed that an increase in temperature occurred in a static zone about 100 km. in depth. It is now necessary to consider a modification of the model in order to take into account the large scale convection movements in the mantle, and in particular the effect of the rise of relatively hot material below the oceanic ridges.

The rate of ocean floor spreading ranges from less than 1 to 6 cm./year. Where flow rates in excess of 0.1 cm./year occur, the effect of heat transfer by flow dominates the effect of heat transfer by conduction. It is probable that the rate of rise of the material below an oceanic ridge, exceeds the rate of spreading of the adjacent oceanic floor. Consequently, heat is transferred up to the low velocity zone by the convective movement of the mantle. This relatively hot material probably stops rising and spreads laterally when it has reached a level at which the density distribution leads to hydrostatic equilibrium, although this will be modified by the higher yield strength of the cooler material above as in the case of sill formation.

The melting temperature decreases with decreasing pressure (Fig. 5). Since the rate of rise is sufficiently fast that the high temperature is maintained, it is possible that the material will reach a level at which its temperature exceeds the melting temperature (Fig. 10). At this point there would be a very rapid decrease in the viscosity and a melt might form which could rise into the lithosphere by penetrative convection and hydraulic fracturing, instead of spreading laterally to form part of the asthenosphere. The portion of the mantle which melts, rises along oceanic ridges and forms the dyke-like masses by which the oceanic plates are continuously regenerated, and under certain circumstances, the melt may also be extruded to build up basaltic shield volcanoes.

After studies of the mineralogy and petrography of rocks, this oceanic ridge model may be improved by the addition of data concerning the probable variation in the chemical composition of the different layers, and the consequent modification of the physical processes can be considered. The understanding of the continental volcanic activity which is characteristic of the destructive margins of the plates, requires a different and more complicated physical and chemical model.

Acknowledgements:

The author wishes to express his gratitude to Dr. Peter Marsden for carefully reading and correcting the manuscript.

REFERENCES


INTEGRATED SCIENCE: A “CLASSICAL” APPROACH TO CURRICULUM DEVELOPMENT

William C. Hall

William C. Hall, a joint organiser of the Integrated Science Project was invited to address the Conference because of the general interest in the concept of integrated science and the involvement of a number of members of the Association in the project, particularly in the advisory Geological Working Party. The paper is based on Mr. Hall's lecture. Two sections of it are reproduced, with permission, from a manuscript to the Institute of Physics and the Physical Society.

The Schools Council Integrated Science Project (SCISP) has adopted a “classical” approach to curriculum development which can be summarised as: 1. Aims and objectives. 2. Learning experiences. 3. Evaluation and assessment. 4. Modification of items 1–4. (5. Diffusion).

Although none of these stages can be developed in isolation, it is convenient to consider each of them in turn.

AIMS AND OBJECTIVES

One of the best justifications for having clearly defined aims in any scheme is, I believe, to be found in Lewis Carroll's "Alice's Adventures in Wonderland":

The cat only grinned when it saw Alice. It looked good natured she thought, still it had very long claws and a great many teeth so that she felt that it ought to be treated with respect.

"Cheshire Puss" she began timidly as she didn't know at all whether it would like the name. However, it only grinned a little wider. It is pleased so far, thought Alice and so she went on "would you tell me please which way I ought to go from here?"

"That depends a lot on where you want to get to", said the cat.

"I don't much care where", said Alice.

"Then it doesn't matter which way you go", said the cat.

"So long as I get somewhere", Alice added, as an explanation.

"Oh you are sure to do that!", said the cat, "if only you walk long enough".

It seems perfectly reasonable for any teacher (and any pupil) to know the intended destination of a journey. The aims of SCISP are shown below:

Knowledge

1.A To recall and to understand that information which would enable pupils to take A-level courses in biology, physics, chemistry or physical science, would enable them to follow a job in science and technology, would enable them to read popular scientific reporting and would enable them to pursue science as a hobby.

2.A To understand the importance of patterns to the scientist and to use these patterns in solving problems (both of a laboratory and of a household type).

3.A To be able to recognize scientific problems.

4.A To understand the relationship of science to technical, social and economic development, and to be appreciative of the limitations of science.

Attitudes

1.B To be faithful in reporting scientific work.

2.B To be concerned for the application of scientific knowledge within the community.

3.B To have an interest in science and technology and be willing to pursue this interest.

4.B To be willing to make some decisions on the balance of probability.

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[41]
5.B To be willing to search for patterns, to test for patterns, and to use the patterns in problem solving.

6.B To be sceptical about suggested patterns.

Skills

1.C To work independently and to work as part of a group.
2.C To discover and to use available resources such as books, apparatus and materials.
3.C To organize and to formulate ideas in order to communicate to others, and as an aid to understanding, critical analysis, etc.

It will be seen immediately that not only are we concerned with knowledge and its application, but attitudes and skills are also important to the project.

The aims are then translated into specific objectives for each section of the sample scheme, and these objectives are printed in the Teacher’s Guides.

LEARNING EXPERIENCES

Objectives cannot be achieved in a vacuum. It must be decided what content would be most suitable for achieving objectives, and also what would be the best way of teaching this content. (In teaching it is a salutary experience to ask two questions: “Why am I teaching this?”, followed by “Why am I teaching this in this particular way?”) These two aspects of learning experiences can be labelled ‘content’ and ‘approach’.

(a) Content

The content of the work has been divided into three main sections which are entitled Building Blocks, Energy, and Interactions. During the first part of the course (which lasts for 28 weeks) pupils are concerned with the nature and size of different Building Blocks (ranging from the electron, through to communities and populations, and then on to planets and galaxies); the next 25 weeks are mainly concerned with the transference of energy and doing work; the final section of 35 weeks deals with interactions of Building Blocks. It is during this last part that the three major problems of ‘race’, ‘the environment’, and ‘atom power’ are introduced, and it is here, in particular, that the limitations of science are emphasized.

Integration of content is achieved in three main ways. Firstly, biological examples are sometimes used to illustrate physical phenomena, and physical science is used as a tool in those areas which are mainly biological or geological; secondly, Building Blocks are seen to be connected, and the integrating theme of size runs through this first part of the course, and thirdly, interactions of physical science Building Blocks are seen to be comparable. No attempt is being made to force integration of content. Indeed, during the last year, the differences between the major areas of science will be emphasized! For example, the measuring instruments of the physical scientist are sharp, whereas those of the social scientist are blunt, variables are readily isolated in physical systems, but this is not true of biological systems.

Whilst integration of content is important, the most important form of integration in this scheme will be the search for patterns, and then the use of these patterns to solve ‘problems’ (both of a laboratory and of an everyday kind). A pattern is defined as a generalization (for example, a law) or an explanation (for example, a theory). This is why the scheme is entitled ‘Patterns’, and it can be summarized in the form of a tetrahedron.

```
Searching for and using Patterns to solve problems

Building Blocks

Energy

Interactions
```

Approximately one-tenth of the time is spent on what could loosely be termed ‘geological’ topics.

[42]
(b) **Approach**

Problem solving is the ultimate cognitive activity. However, a problem can be presented in a variety of ways. In the Integrated Science Project a sound framework of scientific concepts and patterns is first established before pupils are faced with the task of solving problems. (This is in contrast to the approach where the pupil is faced with a problem and then asked, “What can you discover?”) The structure of the scheme as shown in the adjacent diagram is based on R. W. Gagné’s *Conditions of learning* (1967).

![Diagram](attachment:image.png)

The course which we are developing is structured and the learning sequence is important. All too often I think teachers have confused what has been called a “discovery” approach with dropping children into a problem solving situation and telling them to get on with it. This has caused frustration and worry for the child. We are saying that before a child can be faced with problem solving there must be the very definite progression which is summarized above.

Adopting such a structure does not imply that the course is wholly didactic! Indeed, a ‘guided discovery’ approach to the establishing of concepts and the finding of patterns has been adopted. This framework lends itself admirably to assessment of pupils, because questions can be set at each of the four ‘stages’.

**EVALUATION AND ASSESSMENT**

By evaluation we mean feedback on Teacher’s Guides, Pupils’ Manuals, Technician’s Manuals, Background Books, teaching techniques, approaches and assessment items. In assessment we are attempting to determine how successfully pupils have achieved the course objectives.

Evaluation takes the form of regular visits to schools by team workers, the completing of questionnaires by teachers, and the writing of “letters” by pupils to the Project headquarters.

If all the aims are important then all should be assessed. The assessment of attitudes (in particular) is demanding much thought and research before the first G.C.E. examination in 1973. As a result of passing the examination pupils will be awarded a double O-level credit. (A single credit will also be available).

**MODIFICATION**

As a result of evaluation and assessment, aims and objectives, learning experiences, and assessment techniques, are all modified, so that when the material is published in Spring 1973 it will have been thoroughly tested in the classroom.

[43]
I would like to close with two quotations which I feel are very relevant to what we are trying to do in SCISP. In 1864 the Headmaster of Winchester said:

"Compared with other things the scientific fact either as conveyed by a lecturer or as reproduced in an examination is a fact which produces nothing in a boy's mind. It is simply a barren fact which he remembers or doesn't remember for a time and which after a few years becomes confused with other facts and is forgotten. It leads to nothing, it doesn't germinate, it is a perfectly unfruitful fact. I think except on the part of those who have a taste for the physical sciences and intend to pursue them as amateurs or professionally such instruction is worthless as education".

I have tried to show that what we are doing in Integrated Science is not merely getting facts across. What is more important to us is the process that scientists are involved in (searching for patterns and using these to solve problems).

In the second quotation, Jean Jacques Rousseau (about 200 years ago) said:

"Teach your scholar to observe the phenomena of nature, you will soon arouse his curiosity, but if you will have it grow do not be in too great a hurry to satisfy this curiosity. Put the problems before him and let him solve them for himself, let him not be taught science, let him discover it. If even you substitute authority for reason he will cease to reason and become a mere plaything of other peoples thought".

I think both of these people would have objected strongly to the statement made to the Leverhulme Committee by a headmistress. She said that "In this school we teach the theory of evolution as fact"!

Geology stands to (civil) engineering in the same relation as faith to works . . . .

The success or failure of an undertaking depends largely upon the physical conditions which fall within the province of geology, and the "works" of the engineer should be based on the "faith" of the geologist. The how and the why fall within the province of the latter, and the practical application of this knowledge is the special function of the former.

BOYD DAWKINS
On the relation of geology to civil engineering (James Forest Lecture 1898).
A SURVEY OF THE DISTRIBUTION OF GEOLOGICAL FIELD WORK BY SCHOOLS IN BRITAIN – 1968

George P. Black

The conservation of those localities which together form the basis of geological education and research in Britain is the principal duty of the Geological Section of the Nature Conservancy.

Research sites are used by relatively few people and in general their conservation is relatively straightforward. Educational sites, on the other hand, are visited by a large and steadily growing number of students and this intensive use leads to difficulties of access, the need for site maintenance and friction between owners and occupiers on the one hand and visiting parties on the other. Over the past few years, educational sites have been the most rapidly expanding field of activity for the Geological Section; to deal with the problems they create, it was soon found necessary to discover the origins, numbers and destinations of geological field parties of all types.

In 1965-66 the Geological Section carried out a survey of the distribution of geological field work by students from universities and technical colleges in Britain during the years 1963, 1964 and 1965. Only excursions lasting two or more days were taken into account. The results were published (Black, 1966) and have subsequently proved of great value to the Section both in defending threatened Sites of Special Scientific Interest and in planning programmes of site revision. The table from the 1966 paper is reproduced in Table 1.

It was soon realised, however, that field parties of undergraduates were not the most numerous users of educational sites and that there was a pressing need to carry out a survey of field instruction by schools. It was envisaged that trips of less than two days' duration would play an important part in school field work and the scope of this survey was therefore broadened beyond that of its predecessor to take all forms of field work into account.

Through the co-operation of the Examination Boards a list of schools presenting candidates for Ordinary and Advanced level in geology in 1966, 1967 and 1968 was compiled and a questionnaire was sent to each school asking for details of field work in these years.

It was found that 894 schools had entered candidates for the G.C.E. examinations in one or more of the three years involved. Schools teaching geology were fairly evenly distributed throughout England. They were virtually absent from Scotland and it was noticeable that the number of schools teaching geology per unit of the population in the Welsh Counties was consistently about twice the figure for England. From the returns to the questionnaire it was also apparent that many of the 894 schools presented only one or two candidates and presumably did not run formal courses in geology; a number appeared to act as examination centres for candidates from elsewhere and could supply no information concerning the field studies they had carried out.

There were numerous examples of schools which had run geological courses but had abandoned the subject after a year or two — the cause of this appeared to be the departure of the geologically qualified teacher. Other schools, on the other hand, were seen to have taken the subject up, apparently when a suitably qualified teacher had joined their staff. The degree of mobility of teachers of geology seemed surprisingly high and the intermittent nature of the geology courses in some schools was seen to be a direct result of staff changes, the availability of a suitable teacher determining whether the course was held or not. It can be directly inferred from the results of the questionnaire that many schools are not concerned whether they run 'O' and 'A' geology courses or not. It would further appear that many schools do not recruit teachers of geology as such, though they are pleased to utilise any talents their science teachers may have in this direction.

In 1955 the number of G.C.E. candidates was 797 at Ordinary level and 391 at Advanced level (Anon 1957). By 1963 the numbers had increased to 3382 and 1062 respectively (Kirkaldy, 1964, p. 122). And from the information supplied by the Examination Board, the figures for 1968 were 7,050 and 1,881.

GEOLOGY, VOL. 3, 1971, pp. 45-47.
Table 1. The distribution of university student field instruction in geology in Britain, 1963-1965.

<table>
<thead>
<tr>
<th>Location</th>
<th>Student-days</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGLAND:</td>
<td></td>
</tr>
<tr>
<td>Cornwall</td>
<td>2646</td>
</tr>
<tr>
<td>Devon</td>
<td>3429</td>
</tr>
<tr>
<td>Dorset</td>
<td>5996</td>
</tr>
<tr>
<td>Isle of Wight</td>
<td>2228</td>
</tr>
<tr>
<td>Bristol District</td>
<td>606</td>
</tr>
<tr>
<td>Gloucester District</td>
<td>2317</td>
</tr>
<tr>
<td>Shropshire</td>
<td>4217</td>
</tr>
<tr>
<td>South Midlands</td>
<td>381</td>
</tr>
<tr>
<td>Peak District</td>
<td>949</td>
</tr>
<tr>
<td>Ingleborough</td>
<td>2354</td>
</tr>
<tr>
<td>Northern Pennines</td>
<td>1713</td>
</tr>
<tr>
<td>Lake District</td>
<td>2132</td>
</tr>
<tr>
<td>Norfolk</td>
<td>60</td>
</tr>
<tr>
<td>Yorkshire Coast</td>
<td>808</td>
</tr>
<tr>
<td>Northumberland and Durham Coast</td>
<td>245</td>
</tr>
<tr>
<td>TOTAL</td>
<td>12005</td>
</tr>
<tr>
<td>WALES:</td>
<td></td>
</tr>
<tr>
<td>Pembroke</td>
<td>4860</td>
</tr>
<tr>
<td>Gower and South Wales Coalfield</td>
<td>2204</td>
</tr>
<tr>
<td>Mid-Wales</td>
<td>333</td>
</tr>
<tr>
<td>North Wales</td>
<td>3430</td>
</tr>
<tr>
<td>Anglesey</td>
<td>1178</td>
</tr>
<tr>
<td>TOTAL</td>
<td>13017</td>
</tr>
<tr>
<td>SCOTLAND:</td>
<td></td>
</tr>
<tr>
<td>Southern Uplands</td>
<td>110</td>
</tr>
<tr>
<td>Ayshire</td>
<td>899</td>
</tr>
<tr>
<td>Midland Valley</td>
<td>1016</td>
</tr>
<tr>
<td>Southern Highlands</td>
<td>170</td>
</tr>
<tr>
<td>Central Highlands</td>
<td>245</td>
</tr>
<tr>
<td>Glencoe and Loch Leven</td>
<td>925</td>
</tr>
<tr>
<td>Arran</td>
<td>4521</td>
</tr>
<tr>
<td>Mull</td>
<td>573</td>
</tr>
<tr>
<td>Ardnamurchan</td>
<td>271</td>
</tr>
<tr>
<td>Rhum</td>
<td>170</td>
</tr>
<tr>
<td>Skye</td>
<td>2444</td>
</tr>
<tr>
<td>Banff Coast</td>
<td>196</td>
</tr>
<tr>
<td>North-West Highlands</td>
<td>1162</td>
</tr>
<tr>
<td>Northern Highlands</td>
<td>215</td>
</tr>
<tr>
<td>Shetland</td>
<td>100</td>
</tr>
<tr>
<td>TOTAL</td>
<td>57483</td>
</tr>
</tbody>
</table>

The total amount of field work revealed by completed questionnaires was 69,738 student days in session 1967/68 although only about half of the schools approached replied. As it is probable that schools which replied were those most interested in geology, and in particular in geological field work, it is probably not valid to double this figure to obtain a rough approximation to the true total; however it appears safe to conclude that the total amount of schools' field work with G.C.E. candidates in 1967/68 was in excess of 100,000 student days. This figure considerably exceeds the number of days (57,483) of undergraduate field work in 1964/65, though it must be remembered that the school total includes day trips, whereas the under-graduate total does not.

Of the total amount of field work, 76.5% was carried out in England, 18.0% in Wales and 5.4% in Scotland. The most popular area was the Craven Pennines with 9.8% of the total followed by Dorset with 7.3%, the Yorkshire Moors and Coast 5.9%, the Lake District 5.6%, Derbyshire 5.4%, Snowdonia and Anglesey 4.1%, Pembroke 4.1%, Glamorgan 4.1%, Kent 3.6%, and Shropshire 3.1%.

[46]
The distribution of field instruction in geology by schools differs significantly from the pattern found for under-graduates by the 1965 ‘University’ survey. Under-graduates spent 52.3% of their field work in England, 20.9% in Wales and 22.6% in Scotland. Compared with these figures, the ‘Schools’ survey shows a four-fold reduction of field work in Scotland, while the English figure has risen by half and that for Wales remains more or less constant. The 1965 survey showed Dorset to be the most popular area for field work, accounting for 10.4% of the total and this was followed by Pembrokeshire (8.5%), Arran (7.9%) and Shropshire (7.3%). Some localities which were popular with under-graduates, as for example Skye with 4.3%, were almost unvisited by school parties who spent only 0.4% of their total time there. In general, school parties show a more even spread over the country as a whole and strong tendency to avoid the more complicated areas.

The degree of mobility of school parties is noteworthy and is best seen in the case of the G.L.C. Parties from London spent 74 student days in Bedford, 21 in Berkshire, 70 in Buckinghamshire, 185 in Cornwall, 105 in Derbyshire, 532 in Devon, 1,302 in Dorset, 797 in Essex, 90 in Gloucestershire, 100 in the Isle of Wight, 189 in Hertfordshire, 436 in Kent, 40 in Leicestershire, 15 in Lincolnshire, 792 in London, 109 in Oxon, 430 in Shropshire, 131 in Somerset, 10 in Suffolk, 904 in Surrey, 102 in Sussex, 40 in Wiltshire, 776 in the Lake District, 281 in the Craven Pennines, 205 in the Yorkshire Moors and Coast, 31 in the Yorkshire Wolds, 10 in Cardiganshire, 130 in Glamorgan, 32 in Merioneth, 28 in Pembroke, 322 in Snowdonia and Anglesey, 234 in Arran and 96 in Skye. Similarly wide distribution of field work can be seen elsewhere, pupils from Warwickshire for example visiting 25 other counties or districts and ranging as far afield as Cornwall, Snowdonia and Arran.

On the other hand, some counties show a remarkable tendency to use local facilities. Pupils from Berkshire, Cumberland, Durham, Hereford, Hertford, Huntingdon, Kent, Lancashire, Leicester, London, Northumberland, Nottingham, Sussex, Warwick, Glamorgan and Pembroke, accounted for over half of the use of geological sites in their home counties.

Popular field work areas similarly drew their visitors from far afield. South-west England (Cornwall, Devon, Dorset, Gloucestershire and Somerset) was the scene of 16.2% of the total field work—11,298 student days. Only 26.3% of this figure was carried out by local schools. Pupils from the Home Counties (21.5%), London (19.7%), the Black Country (11.2%) and Lancashire and Cheshire (8.8%) travelled into the area for instructional purposes and round trip distances in excess of 700 miles did not act as a deterrent.

Like the earlier survey of under-graduate field instruction, the survey of field work carried out by ‘O’ and ‘A’ level candidates in geology in schools is the first of its kind to be undertaken in Britain. The results have in some ways been somewhat unexpected and will be taken into account in shaping the Conservancy’s policy towards the conservation of educational geological sites in the future. It is expected that subsequent surveys of both University and school field instruction will show changes in the national pattern of field work and it is hoped that these will be related to developments in conservation.

REFERENCES

GEOLGY AND SCENERY IN THE SWINDON AREA. AN EXAMPLE OF AN AUDIO-VISUAL PRESENTATION OF GEOLOGY IN THE PRIMARY SCHOOL.

Stephen W. Hannath

Mr. Hannath demonstrated the use of an audio-visual method of introducing geology to Primary School children. He stressed the importance of seeking the relationship between geology and "the world about us", as illustrated in the study web given in the accompanying paper. The latter, based on his demonstration, contains the kind of material that could be useful to other teachers. Mr. Hannath hoped that other members of the Association would provide similar material for Primary School teachers in their respective areas.

INTRODUCTORY NOTES FOR TEACHERS

This audio-visual attempt introduces the geology of the Swindon area and explains the resulting features of the natural landscape. Something of the cultural landscape has also been included as this is, to a great extent, a natural concomitant of the former.

This aid is directed at the 9–13 year age-group but with suitable preparation and use by the teacher could be of some value at both lower and higher ends of the educational time scale.

It is appreciated that the aid introduces a number of new ideas and concepts and therefore it should not be used to cover this topic on its own. Explanations, observations and the opportunity of practical field work are all necessary if it is to be of greatest value. Some teachers may feel that it would be better to split it up into ten-minute sections rather than try and attempt everything at once.

A 'study web' has been included to give teachers some possible lines of follow-up work to help give deeper and wider understanding of ideas introduced in the aid. A copy of the commentary has been included for teachers to read prior to using the aid, or for those who wish to give their own commentary. A book list both for teachers and pupils has been included to help with follow-up work.

I would like to express my thanks to the Swindon Geological Society for permission to copy various slides used.

THE SLIDES

1 Liddington Hill (General view from vale)
2 Liddington Hill (General view from vale)
3 Geological Map
4 Local rocks (Photo of labelled specimens)
5 Topographical map
3 Geological map
5 Topographical map
3 Geological map
6 Geological section (Diagrammatic section NW/SE across the vales and scarps from Lower Lias in Glos—to Upper Chalk in Wilts)
5 Topographical map (to illustrate the frequency of rivers)
7 A spring (Photo of a reliable spring in the Cotswolds at junction of Fuller's Earth Clay and Oolite)
8 Spring diagram (Labelled diagrammatic section through a typical spring)
9 Spring model (Labelled varnished wood and sponge model to illustrate permeable and impermeable layers)
10 Spring line village—Wroughton (Photo)
11 Water supply diagram (Water Department diagram of local water supply showing strata, bore-holes, reservoirs, etc.)
12 Chalk downs (Typical view of Marlborough Downs)
13 Arable downland (General view of newly ploughed land)
14 Beech trees on Marlborough Downs (Photo)
15 Ogbourne chalk pit (General view of pit at Ogbourne St. George)
16 Chalk pit (General view of Upper Chalk near Lambourne)
17 Flint in chalk pit (Photo of flint layers in Ogbourne pit)

[48]
You can write with it, it is really a very pure limestone. In the chalk may be found lumps of another rock—flint. This is limestone again, but a different type from the one before. The brown where it says 'River Thames' is the remains of an old coral reef; and Cotswold limestone found in the Cotswold Hills and coloured yellow on the map.

Perhaps the view from your bedroom or classroom window is similar to ours—towards the well known Liddington Hill. This hill is part of the Wiltshire Downs or hills. On top are the remains of an Iron Age castle. It was such an easy place to defend and send smoke signals from. But have you ever thought about why the hills are there at all? Why is the Swindon countryside the shape that it is? Well, it all depends upon the nature of the rocks under the soil. Look at this map. It's called a geological map because it shows the different kinds of rock in the area. Each type of rock is a different colour on the map. The big area coloured green is chalk rock. Moving towards the top of the map we then come to a band coloured bluey-green and then another—these are both clay rocks. Surprised? Yes, clay is counted as a rock even though it is soft. Just underneath the word ‘Swindon’ there is a little, but important, patch of yellow and red dots—this is an area of limestone. Above the word ‘Swindon’ and again running across the map is a band of pink. This is limestone again, but a different type from the one before. The brown where it says 'River Thames' is another type of clay rock and finally all the area coloured red and yellow at the top of the map is made of limestone rocks again, a third type.
Now let us look at a map of the shape of the countryside [5]. Look very carefully—the parts coloured yellow and brown show areas of high land and the green shows low land. Look carefully at the different areas of green and yellow and now let us look again at the rock map [3]. Can you see that the high land occurs at the same places as the chalk or limestone rocks, and the low land occurs where we have clay rocks? Look again [5, 3]. You see that rocks and the shape of the land are very closely linked. Now if we imagined the countryside to be a big cake and we cut ourselves a nice slice and looked at it from the side, we would see the different layers—not of icing sugar and marzipan though—but of the rocks themselves underground [6]. Here they are! We see that chalk and limestone make the hills, and clay rocks make the valleys. This is because chalk and limestone rocks are tougher than clay rocks and the clay gets worn away by the rivers and the weather, but the chalk and limestones do not get worn away as much and stand up as hills.

Have you thought of what happens to the rain that falls onto the ground? Well, different things may happen according to the different type of rock. Chalk has lots of minute holes in it and acts like a big sponge soaking up the rainfall. That's why you see very few rivers on the chalk downs [5]. A similar thing happens when the rain falls on the limestone—it soaks through but not quite as easily as through the chalk. However, on the clay the water cannot easily pass through—it either forms puddles or runs off into streams. See how many more rivers and streams there are in the clay areas. What happens when the rain soaks through a layer of rock and then meets clay which it cannot pass through? Well, it will probably make its way out of the ground as a spring. Here [7] is a spring occurring where the limestone meets the clay at the surface. Here [8] is a side-on picture showing what happens, and [9] a model. Years ago springs were very important for supplying drinking water and many villages were built where there was a reliable spring. Seen here [10] is an example of a village which was first sited because of the good water supply—Wroughton. Good springs occur here between the chalk and clay. Nowadays, of course, we just turn on the tap wherever we live and there we have our water. Today, water is pumped up from below the ground [11] where it is trapped in the rocks at Latton and Ogbourne. The germs are killed with chlorine gas and the water piped to reservoirs and then to our houses. Trapped deep in the local limestone and chalk there is a good supply of water ready for the growing town of Swindon.

Now we know something about the local rocks, let us make a journey around Swindon and see the scenery these produce. We'll start on the chalk downs [12]. This is still a typical view of downland scenery, rolling, rounded, grassy hills, although the scene is changing. One hundred years ago many sheep grazed on these hills, as seen in this picture, but today [13] more and more fields are being ploughed for the growing of crops. Only in a few places on the downs can clumps of beech trees [14] still be seen. It is believed that thousands of years ago beech forests covered much of the downs but man cut them down. Many remain, however, in Savernake Forest. Very often white scars occur on the hillsides where the chalk shows through, like this one [15] at Ogbourne St. George. Here [16] is a part of another chalk pit, but notice the dark line at the top. You can see just how thin the soil is on the chalk hills and so when farmers plough their land they turn up many lumps of chalk rock. In this chalk pit [17] you can see the black and grey lines of flint as they occur naturally. Stone Age man used pieces of flint for tools and weapons—if you do not know why, then carefully break a piece of flint—but mind your eyes—and then feel the edges. Because flint was available on the chalk downs for making tools and weapons, Wiltshire became a great centre of life in early historical times. The Salisbury Plain was, of course, the centre of this early history. Large pieces of flint have also been used for buildings as in this cottage [18] on the Wiltshire Downs and this church [19] of Holy Rood in Swindon itself. Blocks of chalk have also been used for buildings as in part of this house [20] under Liddington Hill. Chalk is also used in the making of lime for farmers, and 30 miles away, at Westbury, chalk is dug from the downs to make cement.

When you are on the chalk downs look out for fossils like these [21]—at the edges of ploughed fields and anywhere where the chalk crops out on the surface.

Often seen left behind resting on top of the chalk downs, thousands of years after much of it has been worn away, are large pieces of sandstone [22] known as Sarsen Stones. This view is of the Valley of the Rocks near Lambourne and here [23] is a piece of Sarsen Stone which again has often been used for building. Here [24] is a wall built of Sarsens and here [25] is the Avebury Museum also built with Sarsens—note the Sarsen cobbles stones around the museum. Around the turn of the century there was a thriving industry on the chalk downs of cutting and shaping Sarsen Stones for building and for kerb stones. Windsor Castle is made of Sarsen Stones which were originally supplied from a different area nearer London. However, it was the Marlborough Downs which supplied the stone to repair the Castle about twenty years ago. The huge pieces of stone in the Avebury Ring [26] are
actually pieces of Sarsen Stone which Bronze Age people found lying around on the chalk and used to make their temple [27]. Some of the blocks weigh over forty tons—the weight of six double decker buses. This [28] is a picture of a piece of Sarsen Stone, the only one of its kind in the country. The special thing about it is the grooves at the top of the stone. These grooves were worn by Bronze Age men sharpening their axes and weapons on the stone, and is another piece of evidence of the importance of this area in early history.

Now [29] we are on the edge of the downs looking down towards Swindon, and here again [30] is this view. Let us go down into the wide clay valley, or vale as it is called, and look [31] towards Swindon Old Town hill from behind Princess Margaret Hospital. Looking at our section again [6], we see that the old town hill is there because of an outcrop of hard Portland limestone which has not been worn down as quickly as the surrounding clay. One hundred years and more ago, the limestone was quarried for building stone and here [32] the old quarry edges can still be seen at the edge of Old Town Gardens. Keep your eyes open when you are in Old Town and you will see many buildings and walls built of blocks of limestone like this old barn [33] near Princess Margaret Hospital, and the old chapel of the Goddard family in the Lawns [34]. The famous engineer, I.K. Brunel, an important man in Swindon's history, built his railway village [35] in the local Portland limestone. The houses have lasted well, but are now being modernised and repaired. Swindon Council is being careful to preserve the 'good' things of the past for all of us to enjoy. Here [36] are the limestones again near Commonweal School, showing what Old Town looks like under the surface, and they occur here with sands which have been quarried in the past for making concrete. This pit has been specially preserved by the Nature Conservancy so that you may visit it. Again the Portland limestone contains many fossils like these [37]; be on the lookout. There are some good views from Old Town hill, like this one [38] from Okus Road near the hospital, and again from here [39] looking down from the Lawns towards the new estates on the clay below. At the bottom of the hill is Queens Park [40] with its attractive lakes. This [41] was once a brickworks and so we are back on the softer clays again which supplied many of the bricks used to build old Swindon and buildings like this school [42] in the town. Here [43] is an old house by Queens Park which once belonged to the brickworks and is built of local bricks. At the beginning of the century there were 13 brickworks working in and around Swindon. The men working at these brickworks would have found lots of fossils like these [44]:

Not far away we have this familiar view [45], Coate Water. This is a man-made lake made by damming the River Ray [46]. The water does not soak into the ground quickly, remember, because there is clay underneath and this does not allow water to drain away easily. Those of you who play football in a clay area know what happens to the pitch when it rains hard. Just behind Coate Water in Bayhouse Lane are brickworks at Badbury [47] which use the local clay. The pit from which the clay is dug is in front of the chimney and kilns. However, as this picture shows [48], the brickworks look run-down and in fact the last bricks were baked in October 1969 because of the coming of the M4 motorway close by. The smoke from the brickworks chimney would have blown onto the motorway and would certainly have caused accidents.

Travelling away from Swindon now, towards Cirencester, we come to the hard ridge of coral limestone at Blundson Hill [49]. We are looking down from the limestone ridge towards the clay vale of the River Thames below. All along this limestone ridge from Wooton Bassett to Faringdon may be found fossils like these [50].

Down in the clay valley in another brickworks [51]. This one belongs to Hills of Swindon and is sited at Purton. You can see the big machines that dig out the clay. The claypits of brickworks are wonderful places for finding fossils. You may find some like these [52]. But be sure you get the owner's permission before you go in.

Looking again at the geological map [3] we now move to the top left hand area (north-west) coloured yellow and representing Cotswold limestone. Here is an area of great natural beauty known as the Cotswold Hills. Yes, hills again, because we are on hard limestones. The Cotswolds are famous for their stone buildings like this cottage [53]. Blocks of Cotswold limestone have been used to build the walls of the cottage, thin slabs of limestone have been used to tile the roof and small blocks of limestone have been used to build the wall around the garden. This limestone can be quarried almost anywhere in the Cotswolds so, if your great-great grandfather lived in the Cotswolds and wanted to build a house for his family, he just dug out the stone that was needed from his own garden. The stone is still quarried today as in this quarry [54] near Cirencester and run by another Swindon firm. The stone is either crushed and used for making roads or drives or sold in blocks for walls, gardens, or fireplaces. In places in the lower Cotswolds—the area nearer to Swindon—the rivers have worn down the limestone for many years and have carried away millions and millions of small limestone pebbles. Today these [51]

Geology map, topography map, communications map, etc. (Scale, symbols, points of compass, etc.)

Local industries past and present based on geology. (Water, sand, gravel, limestone, clay for bricks – Fuller's Earth Clay of Cotswold, Chalk for lime and cement manufacture, Flint.)

AUDIO VISUAL AID

Collecting and Sketching

Visits

Local architectural patterns based on building materials.

Fossils in the rocks.

Origin of Swindon's Rocks (all sedimentary rocks).

Rock Tests

Settlement patterns.

Stone age settlements. Flint tools, Safety of hill forts, Base of access on chalk hills.

Settlement patterns.

Permeable rocks.

Impermeable rocks.

Springs and old sources of supply of water.

How rocks are worn down.

The Landscape

Soils

Agriculture

Flora

Fauna

Water supply today from water trapped in limestone and chalk.
deposits of limestone pebbles, known as gravel, are dug out of the ground by cranes with drag buckets such as this one [55]. The gravel is washed and graded into different sizes by this machine [56] and then may be mixed with cement to be made into blocks like these [57] to be used for building. The blocks dry out the colour of Cotswold limestone and look like this [58] in new buildings. The blocks are much cheaper than real blocks of limestone and yet the building fits in with the Cotswold scene.

Look at the Cotswold cottage again [53]—did you notice that it has a newer piece of building at the back? This has been built with these gravel blocks and you can see just how well it blends in. Many new buildings in Swindon are built with these blocks. As the gravel is dug out, the pit fills with water and old pits like this one [59] have been made into recreational lakes for sailing, hydroplane racing, water skiing and fishing. In the gravel and old quarries in the Cotswolds, look for fossils like these [60]. This view [61] of the Cotswolds—rolling hills, narrow winding valleys with plenty of trees at the bottom—is typical. If we were to journey right to the edge of the Cotswolds we would come to a very steep slope down to the River Severn. Views like this one [62] at Birdlip are famous. The cliffs show what the limestone is like under the surface.

Swindon then is an area of varied geology and the different rocks give us changes in scenery—hill scenery and valley scenery, seen again in our section [6]. Next time you journey in and around Swindon keep a lookout for examples of rocks and fossils and try to remember why the countryside is the shape it is.

**BOOKLIST**

**Children's Books**


Many of the books on the children's book list are suitable for teachers also. One great advantage of reading children's books is that it is so much easier to grasp the salient points in a much shorter time. The appropriate ones have been marked with an asterisk(*).

**Teachers' Books**


Pinehurst Junior School
Beech Avenue
Swindon, Wiltshire.
Most people it seems would agree that one of the prime purposes of a museum is the provision of displays of various objects generally considered to be of interest to the general public. It is in this connection that a museum has an obvious educational role. It will have more in common, however, with the Public Library than with the Schools. Pupils in schools are legally obliged to attend and they are usually grouped with colleagues who share a common stage of intellectual development. Visitors to our museums, on the other hand, enjoy greater freedom of choice; the great majority enter singly or in groups based on social rather than intellectual considerations, although parties from schools, colleges, and other establishments are received in great numbers.

In whatever way visitors come to museums, the success or failure of the visit educationally must be directly related to the extent to which each individual can be happily involved. By tradition the whole setting imposes certain limitations in this respect. In many museums, the only form of communication between Curator and visitor is by means of the exhibits, and even this is rarely exploited to the full by members of museum staffs. Too few visitors enjoy the advantages of really good display. But things are improving slowly. It is true that in many museums visitors can proceed beyond the public galleries to seek the assistance or advice of the staff but this rarely allows any active involvement on the part of the visitor.

Greater opportunities for involvement are, however, being offered to certain sections of the public. Most museums nowadays offer special services to schools. These usually include the lending of specimens and small displays; the reception at the museum of parties and individuals from the schools; and the visits to schools by museum teachers or lecturers. The National Museum, at Cardiff, following the early example of other British and foreign museums, has organised such a scheme for over twenty years. Some of the most acceptable material offered on loan by both the Arts and Science Departments, judging by the pattern of requests, is that which is designed for actual handling.

Long before the establishment of this Schools Service, the staff of the Department of Geology had always arranged separate collections of specimens in a Research room for examination by students. Despite the fact that specimens were in time mislaid, defaced and sometimes destroyed, this service has been maintained because the demand for such a service, particularly from ‘A’ and ‘O’ level students has never faltered. The specimens allocated for use by students are all up to accepted museum standards and the material is designed to be used alongside the textbooks. The application of tests (to the minerals and rocks in particular) has, from the very beginning, been firmly discouraged and no laboratory facilities are offered. Although obviously accepting the value of such a service, my colleagues and I have long expressed a desire to go one stage further; to involve the student much more in the actual study of specimens and, at the same time, to offer the new service to a much wider range of people.

**AN ‘ACTIVITIES’ ROOM**

Since November, 1970, members of the public who apply at the Reception Counter of the Museum can be admitted to a so-called activities room — a do-it-yourself laboratory — where they can investigate geological specimens with the aid of simple equipment and under supervision. It has been a deliberate policy to give very little publicity to this development and so, comparatively few visitors have so far been received. A complete log is being kept and very valuable experience is being gained by members of the staff regarding the organisation of such a room. Notices informing the public about the laboratory are intentionally small in size and are not displayed in conspicuous places. When supervision is difficult, they are withdrawn but, even then, no application for entry is completely refused.
A description of the accommodation, the activities and the methods employed might be of interest to teachers in general and to teachers of geology in particular.

The laboratory was, originally, a basement corridor. This was completely refurnished. Supplies of water, electricity and gas were provided but no attempt has been made to create a sophisticated laboratory. The total floor area is a mere 8 m² but this seems to be quite adequate because it is not our intention to cater for large school parties; we are much more interested in small groups or individuals. It is encouraging to find that some of the less traditionally inclined Junior Schools have sent along small groups not exceeding ten pupils. Children have also come from some of the Special Schools in the neighbourhood. It was particularly pleasing to find that amongst our very first visitors was a family group consisting of a young husband and wife with an eight year old son and a six year old daughter.

One of the main purposes of the venture is to encourage visitors to investigate geological specimens and to try to persuade collectors to proceed further than the mere act of collecting. Visitors who come in response to our notices are obviously of greatest interest to us, but even those who come seeking identifications for their own specimens are always persuaded to visit the laboratory. Although we do not confine our attention to children, there are obvious signs that they will eventually come in greater numbers than adults.

STUDYING THE PROPERTIES OF MINERALS

In each of the three categories of geological materials—minerals, rocks and fossils—simple tests have been devised. The first of these take the form of odd-man-out tests which consist of a cardboard tray containing three unlabelled specimens, one of which is always different in some respect from the other two. Alongside the tray a suggestion is always offered regarding a simple test that might be applied to detect the “odd one out”. To take an example, one tray contains two specimens of hematite, with one specimen of magnetite. Alongside there is a large horseshoe magnet complete with its keeper. Apart from the obvious test for magnetism children are very interested in the keeper. They have to discover for themselves that the magnet operates best when this small piece of metal is removed—a good exercise for any age group.

Another tray has two pieces of malachite and one of sulphur. Alongside is a photograph of the upper part of a child’s face, featuring the eyes. The sulphur is obviously seen by normal people to be yellow in colour and accordingly different from the two green specimens. One child of six, however, who, having understood what the tests entailed from an elder brother, selected the sulphur as the “different” one. On being asked why, he explained that it was the biggest.

The most interesting response of all came from a child of five who selected one of the pieces of hematite from the first-mentioned tray as the one that was different simply because she “liked it”. This leads on conveniently to another point. The specimens in each tray can be subjected to tests other than the ones suggested and these can range from elementary non-geological considerations to quite advanced properties.

Each tray in this first group contains two almost identical specimens alongside a third different one. There is, in addition, a second group of trays in which all three specimens are of different kinds but only one displays a recognisable reaction when the suggested test is applied. One tray for example has specimens of limestone, quartzite and shale; the test is for reaction to dilute hydrochloric acid and so it is the first mentioned rock that is different in this respect from the other two.

Other trays dealing with minerals commence with simple considerations of size, shape and weight, this latter test being conducted in the hand, without the use of a balance. Then comes colour, feel and odour. The smelling test always provides amusement. The tray contains two pieces of calcite and one of kaolin (or china clay). Alongside is a small quantity of water in an evaporating dish and a photograph of a child’s nose. It usually takes time for the visitor to realize that the earthy odour of kaolin is remarkably increased by dipping the mineral in the water. The calcite remains colourless in both wet and dry conditions. Some visitors become sufficiently involved in this test to liken the odour of the wet kaolin with that experienced in a newly dug garden, especially after rain.

Tests follow dealing with the property of streak. This is the colour of the powder of a mineral which is always constant and commonly very different from the various colours that the mineral can adopt in mass. One tray has
Top left:–
Testing for refraction of light in glass and smelling oil of cloves.

Middle left:–
Testing with acid.

Bottom left:–
Demonstrating the nature of polarized light with string and slit cards.

Top right:–
Examining crossed polaroids.

Bottom right:–
The simple test for magnetism.
Top left:--
Two cleaved fragments of blende, a cleavage rhomb of calcite and the vital instrument for demonstrating the cleavage difference – a simple “home-made” contact goniometer.

Bottom left:--
An octahedron, a trapezohedron and a rhombdodecahedron. All are constructed from unit cells of polystyrene – cubes of 15.2mm side.

Right:--
A crystal of chalcanthite made from unit cells of polystyrene – triclinic parallelopipeds of sides 12.2, 21.4 and 11.9mm.
Top, middle and bottom left:—
Models showing stages in the evolution of glaciated landscape before, during and after glaciation.

Top right:—
If, on a contoured map of an island drawn on a sheet of polystyrene cuts are made vertically through the material along the contours and the cut portions pushed upwards to the appropriate heights then a terraced three dimensional model is readily produced.

Middle right:—
This model can easily be cemented into position and the terrace obliterated by the use of a suitable filler.

Bottom right:—
Such a model can be cut through vertically, horizontally or obliquely (as in the photograph) to allow for the insertion of a sheet of paper or card to simulate a coal seam or an igneous dyke.
A model in polystyrene showing mesa and butte landscape.

An "explodable" model of a volcano.
two specimens of hematite and one of pyrite. Alongside is a small file and a white card on which some powder from another mineral has been streaked by the stroke of a finger through it. Another tray has three specimens accompanied by an unglazed piece of porcelain on which minerals have already been scratched or streaked.

Then come tests for magnetism and for solubility in water. This latter topic leads on to tests for taste, with appropriate precautions always being taken.

Tests for differences in hardness commence with the use of a needle as the testing apparatus followed by others in which most of the ten minerals in Mohs’ scale of hardness are used. The property of fracture is readily introduced; the glass-like or conchoidal fracture of quartz being readily distinguished from the even fracture of chert or the hackly fracture of cast iron. Differences in lustre (the way in which mineral surfaces reflect light) are also easily introduced by contrasting metallic, vitreous, resinous, pearly and/or silky lustres. With care, the reactions to acids, such as acetic, citric and even dilute hydrochloric acid can be demonstrated with little difficulty.

A particularly interesting property is that of Diphaneity; even Upper Junior children find little difficulty with the various properties which come under this heading, viz: transparency, translucency and opacity. Mention can appropriately be made here to the usefulness of such studies in increasing a child’s vocabulary.

Approximate measurements of the specific gravity of specific minerals are speedily produced by the use of a simple beam balance in which identical steel washers act as units of weight and can be hung on numbered pegs which are equally spaced along the beam on either side of the fulcrum. For example, one washer on peg No. 10, 10″ away to the left, balances two washers on peg No. 5, 5″ away from the right. By weighing a mineral specimen suspended by cotton thread from a conveniently placed peg, first in air and then in water, the two readings can be expressed in washer-weight units. For a child at a suitable stage in its intellectual development, this is a splendid experiment. The fact that a substance loses weight when weighed in water is a real discovery. It needs care and patience, however, to lead the child to an appreciation of the fact that for differently sized piece of the same mineral, if the weights in air are divided by the respective weight losses when weighed in water, the answers are always the same. This constant—the specific gravity—provides an accurate clue to the identity of a mineral. In this connection also, there are tests involving a heavy liquid—mercury. These call for strict supervision. The test tray contains a very small, strong glass jar containing mercury together with two jars of water. Alongside is a small lead weight suspended by string. The phenomenon of the lead weight floating on the mercury never fails to produce a good response from the participant.

The fluorescence of minerals is tested by means of an ultra violet lamp and the radioactivity by using a geiger counter—with the necessary precautions being observed.

There are simple tests involving aspects of crystallography. Many trays contain natural crystals of different minerals, some involving the shapes of crystal faces, others the number of the faces and others the angles between the faces. This latter consideration involves the use of a simple contact goniometer. We advocate the use, first, of a simple ungraduated type, then a home made graduated type and then possibly a more sophisticated manufactured type. These instruments are indispensable in the next set of tests that have been devised for distinguishing between the cleavage fragments of different minerals in which the angles between cleaved faces are so diagnostic. This, for the present at least, is the last of our “odd man out” type of test.

Practically all the tests mentioned above are applicable to a wide range of intellectual development. This is certainly so if the accompanying apparatus is omitted. It is very unlikely that a participant achieves no measure of success whatever; every possible choice of specimen can be justified in some way. Furthermore, the range of possible answers provides a useful scale for an assessment of the result.

Furthermore, the material in the trays allows for further observation. It is possible to search for properties common to all three specimens. Any line of investigation suggested by the child can be encouraged within reason. Another important activity is the recording of the tests with special attention being paid to the terms used.

The remainder of our experiments are of a more traditional nature. They are designed primarily for use by th ‘O’ and ‘A’ level student, although both younger and older people are encouraged to take part. There is a portable gas burner, blow pipes, platinum wire and other simple chemical apparatus, together with expendable mineral specimens for testing. None of this apparatus has yet been used but we are hoping that someone will venture to...
A particularly successful range of apparatus and specimens is concerned with the passage of light through minerals. There are optical boxes, mirrors, glass prisms and lenses, etc., so that reflection, refraction and total internal reflection can be studied. Refractive indices can be measured and use made of a simple gem refractometer. Double refraction, as exhibited by calcite, provides the basis for intelligent observation and experiment. The specimens offered include transparent calcite, quartz, selenite and glass. A black spot on a white card is viewed through each mineral in turn until the double image produced by calcite is obtained. An even better device, is to produce a tiny circular beam of light by piercing a card with a pin and placing it in the slide carrier of a projector. If a specimen of transparent calcite is now placed in front of the card then it is a matter of simplicity to produce, not one, but two spots of light on a screen.

It is in this section of the "activities" room that we have some very simple apparatus which, in the opinion of our visitors, provides the most interesting experiment of all. The tests involve the use of small sheets of polaroid—the plastic which contains thousands of very small platey crystals of an iodine compound. The usual practice is for visitors to be given two pieces of polaroid and to be shown that they are both transparent. They are then encouraged to discover the fact that if one is placed behind the other and slowly rotated, two positions are found when no light passes through. The next step is for a flake of mica to be offered in addition and the test this time is for the visitor to find that when the two pieces of polaroid are held in the crossed or opaque position, the insertion of the mica between them allows light to pass through the three media together.

Immediately this is seen the test can be extended to various other transparent materials. Glass, obsidian and fluor spar are readily found to have no effect between crossed polaroids. By experimenting with other minerals, it can be found that the light is extinguished in different positions for different minerals.

It has been found necessary at this stage to offer a simple explanation of the phenomenon and to illustrate this by using simple apparatus. An elastic string is stretched between, and firmly attached to, two fixed points. It is readily demonstrated that shock waves produced by twanging the string can be transmitted along its length, either in a vertical, horizontal or an oblique direction. Light can be considered as travelling along a similar straight course in which the wave action is a combination of vertical, horizontal and an infinite number of oblique directions. Circular discs of different sizes, threaded on a string, in strict order of decreasing size and then increasing size, can be used to simulate the passage of light waves. The action of the sheet of polaroid can be simulated by the use of two rectangles of card in which long, narrow slits have been cut. If one such card is threaded with the elastic string then it is possible to show how shock waves travelling in a vertical plane can pass through the slit when the card is held vertically but not when the slit is held horizontally. A slit card can be threaded on the string together with the discs and the action of the polaroids demonstrated. The first vertical slit behaves in the same way as the first polaroid and the second horizontal slit behaves in the same way as the second polaroid.

The behaviour of transparent minerals when viewed under polarized light provides important clues to their identification. Even minerals which seem to be opaque in the mass are found to be sufficiently transparent when cut in extremely thin slices to allow for the passage of light. Such thin sections are mounted between sheets of glass and in this protected state can be examined under a 'petrological' microscope—one in which pieces of polaroid are inserted above and below the 'stage' upon which the thin section is placed. There are in the 'activities' room a number of thin sections of mineral and rock which can be placed between the sheets of polaroid provided or in the petrological microscope which is also provided for the purpose.

Arrangements are under way whereby students will be able to make their own thin sections. Apparatus for polishing specimens is already available, although it has not yet been put into operation. Many children, teachers and others have been particularly interested in this activity.

**MAKING MODELS OF CRYSTALS**

In addition to advocating the use by students and visitors of simple home-made instruments such as the contact goniometer, we also try to interest them in the making of crystal models from clay and polystyrene.

Methods of making two types are demonstrated. First, the conventional one illustrating the external form of crystals. By cutting block polystyrene or any of the modelling clays with a sharp and preferably large-bladed knife it is possible to produce excellent crystallographic models. Some textbooks give the angles between various
crystal faces, but even without this assistance it is possible, if wooden or plastic crystal models are already available to make temporary copies by aligning the models alongside the modelling material and by placing the flat blade of the knife along one of the crystal faces it is fairly easy to project this face with a simple cutting action into the modelling medium. The first few faces are readily produced; difficulties come towards the end of the process but it is possible with patience to copy even the most difficult form.

The whole purpose of such an exercise should be to provide the student with an expendable model. If the mineral represented has cleavage then it is splendid practice to simulate this property by cutting the model along the appropriate planes. The developing of additional crystal faces is a further possibility.

The second type of model is based on the concept of the unit cell. Scientists as long ago as the 18th century had surmised that the external form of crystals was the reflection of some kind of inner regularity and that this must be due to some regularity of arrangement of constituent building blocks. But the very existence of such building blocks was a matter of great controversy. It was the famous French crystallographer René Just Hauy who eventually convinced the majority of his colleagues of the existence of such a 'primitive form'—and on the basis of his studies of crystals of calcite. Although it is now known that calcite is not built up in the manner he thought his basic idea has given rise to the modern assertion that any larger crystal structure is composed of a regular stacking of much smaller "building blocks". Each tiny block, or "unit cell" as it is called is the smallest speck of the crystal which can exist separately and yet display all the properties of the mineral. It is obvious that it must contain enough of the various atoms to establish the chemical formula, the pattern of atomic arrangement and the directions and proportions of the crystal structure.

On the basis of the shape of the unit cell, definitions of the various crystal systems are much simplified, for example, the cubic system includes all crystalline minerals whose unit cells are cubes. It is possible to get the measurements of the unit cells of most of the common minerals from a good textbook and with this information to make enlarged models. By duplicating these forms it is possible to simulate the regular crystallographic stacking and produce various crystal forms for all the systems. In the cubic system it is fairly easy to produce large numbers of small polystyrene cubes and with patience to build up a cube, an octahedron, a rhomb dodecahedron and even a trapezohedron. Similar solids can be built for at least one mineral in each of the crystal forms although the triclinic does present certain difficulties.

Amongst the equipment in the laboratory is an assortment of plastic spheres from which models of various unit cells can be constructed. By good selection it is possible to show how the size and shape of a cell is governed by the atoms or ions which it includes.

### MAKING RELIEF AND GEOLOGICAL MODELS

As with the study of crystals we advocate that the actual construction of relief and geological models appreciably helps the student in the understanding of certain basic geomorphological and geological concepts.

The first method demonstrated in the 'activities' room has the advantage of being quick and very economical and the resulting product clearly illustrates the significance of contours and the importance of vertical scale.

The first step is to transfer contour lines from a map onto a sheet of polystyrene. The sheet is then cut along the contour lines, using either a blade or a fine-saw or the simple, electrically-operated horseshoe-shaped polystyrene cutter which is now available on the market. When the cutting is complete the sections between each two contour lines can be raised and pinned to produce a tiered or terraced model. If the vertical scale that is first adopted produces an unnatural looking model, the pins can be removed and a more appropriate scale chosen for the second attempt. Once an appropriate scale has been chosen the terraces can be fixed using vegetable glue and the terraces filled in with a filling compound. The best material is plaster of Paris mixed with fine sawdust in order to retard the setting process. If the infilling is allowed to protrude very slightly beyond the edges of the polystyrene terraces, a smoother finish can be imparted to the whole surface by the use of wet and dry abrasive papers.

In order to illustrate the concept of contours in an even more convincing fashion a slightly more elaborate version of this type of model can be prepared. Part of a 6 inch to the mile or 2½ inch to the mile map is affixed directly onto a sheet of polystyrene and by cutting carefully along actual contour lines—through both paper and polystyrene—a convincing model-map can be produced.
Although the examples made in the ‘activities’ room are simple ones, the principle has been applied by the technicians in our Department to the making of very elaborate relief models.

The making of models to illustrate simple geological structures is also demonstrated. Traditionally, one of the best types in this class consists of layers of naturally and differently coloured wood glued together and placed horizontally or in an inclined position and then cut and shaped to simulate a block of country. The readily traceable layers of wood illustrate natural sections and outcrops. The manufacture of such a model, however, calls for great skill, time and energy. By replacing the wood with readily worked materials such as polystyrene, plastic foam or foam rubber, it is possible to make a wide range of models, quickly and cheaply. It is always easier to glue these layers together but if a suitable method can be devised whereby the layers are only clamped together tightly enough to be worked upon to produce a top surface for the model, then it is possible, with obvious advantage, to take the layers apart.

Simple models of inclined strata which can be used to illustrate the significance of strike-lines are produced from the type of model described on page 62 by cutting through the thin shell of polystyrene and plaster at any angle and inserting a very thin sheet of coloured polystyrene, which can be trimmed to fit the outcrop pattern and which can be used to simulate a coal seam or a bed of limestone or sandstone.

It is more difficult to produce satisfactory models of folded beds, but examples are shown of what can be done with foam rubber. It is obviously easier to produce models of faults and other structures if only unclinal strata are considered.

It is also possible to show the visitor how to make relief models which show successive stages, represented by separate models, in the evolution of scenery.

This technique is best explained by reference to a set example, namely, the development of landforms associated with the glaciation of an upland area. The first step here is to produce three similar, preferably ready-made, cardboard boxes of a convenient size. The first box should be filled to a convenient level with any light waste material. This is then covered with a mixture of Plaster of Paris (preferably Kaffir-D) and sawdust which is moulded by hand to simulate a hilly upland area, preferably with rounded hills and river valleys. After the mixture sets, those parts of the cardboard sides which project above the solid model can be cut away. These off-cuts can be used as templates to produce similar sides on the two cardboard boxes which are awaiting a surface cover. With the use of tinfoil separators, two thin reinforced plaster formings can be readily produced from the surface of the first model.

After setting, these formings can be fitted upon the two remaining boxes whose sides have been cut in preparation. One of these models can now be painted white to present the period during glaciation. This model will need certain modifications; the river valley will of necessity be partly filled with ice and this will mean that some extra material will have to be inserted and a corresponding adjustment made in that side of the model on which a section of the valley and its contained ice will appear. The other model can be painted in various shades of green, to suggest the stage before glaciation.

Attention is then given to the model with which the exercise started. Corries or cwms and glaciated valleys, etc., can be developed with little difficulty so that the finished product can represent the final or present stage of development.

A similar technique is used in the making of ‘explodable’ models to illustrate the geological evolution of a chosen area. One of these illustrates the stages in the development of a volcano. The initial cone is readily made out of a block of polystyrene or with reinforced plaster. Further volcanic accumulations to represent either lava or ash can be made from plaster, reinforced or not as is convenient, and each separated from the bed below by a layer of tinfoil. If needs be, it can be arranged for the various layers to be parted along vertical sections, if necessary, so that the whole model can be separated along a vertical plane that traverses the centre of the volcano, this being in addition to the separation that is possible between the various stages of growth.

Similar models can be made to show stages of development in actual areas for which geological details are available at depth.

Finally, a number of diagrammatic models are produced to illustrate various types of geomorphological phenomena by fashioning blocks of polystyrene using heated implements.
There are two types of scenery, namely karst and mesa-butte, which lend themselves admirably for models in polystyrene in which the main effect is produced by using an electric soldering iron. In producing a model of a karstic region it is easy to build up layers of polystyrene of different thicknesses to represent the various beds of limestone. Swallow holes, caves and gorges are readily simulated by delicate application of the iron. By using a heated knife or similar blade, it is possible to develop good simulations of bedding and jointing.

As in the above model, it is again possible to build up horizontal or gently inclined beds in layers of polystyrene to represent beds of sandstone. Buttes can readily be built up out of fragmentary material and isolated from the mesas, care being taken with the correct sequence and thicknesses of the layers in these outliers. By holding the soldering iron in a vertical position it is possible to insert the heated end downwards along the edges of the mesas and the buttes and to produce splendid simulations of the erosion of the sandstone, which is such a well-known feature of this type of scenery.

The item is a brief summary of the various materials that we have in the experimental 'activities' room at the National Museum and an outline of some of the ways in which we try and get visitors of all ages to become involved in the study of these materials and the concepts of geology.

National Museum of Wales,
Cathays Park, Cardiff.

Geology, though it has become a popular science, may be difficult to define. If we ask what is Geology? We are told it is the "Doctrine of the Earth". No one can venture upon such a science as this, in its most comprehensive sense, nor was it ever undertaken but by speculators in theory; it has remained for this age to apply the principles of experimental Philosophy to a knowledge of the earth's surface.

The principles of Geology, like those of Geometry must begin at a point, through two or more of which the Geometrician draws a line, and by thus proceeding from point to point, and from line to line, he constructs a map, and finally to a map of the world: Geometricians founded the science of Geography, on which is based that of Geology. But it may be asked, what gives it such general interest? We answer, the interest which every man naturally feels in the soil on which he treads, and from which he derives his food.

WILLIAM SMITH
The first page of Abstract: Views of Geology—a work in the press at the time of Smith's death in 1839.
GEOLOGY IN EDUCATION TODAY

(Presidential Address)

Douglas A. Bassett

In the Preface to volume one of Geology Professor Leslie R. Moore, our first president, stated that “it is doubtful if any other geological journal has been launched in quite such an exciting and, one hopes, an auspicious time”. Being that the Association itself started only a year or so earlier, Professor Moore’s words apply equally well to the Association.

Other geological societies and other journals have obviously been launched in exciting periods. The Geological Society of London is a prime example. It was the first such society in the world devoted exclusively to our subject, and formed when geologists were laying the modern foundations of the subject and were adding a new dimension to science as a whole. The Geologists’ Association is another. It was founded in 1858 during one of the most exciting decades in the nineteenth century as regards Natural History, and at a time when geology was generally considered to be the ruling science of the day.

It is acknowledged, however, that we in the second half of the twentieth century are in a period of unprecedented changes and of an unprecedented rate of change. So great is the rate of change that we seem to be continually surprised by it. I find it particularly significant, for example, that a contemporary historian of Arthur Schlesinger’s calibre has to admit, in revising a book he wrote in 1949, that although he was then aware that the “constantly accelerating velocity of history” was the major shaping factor of our time, he had little conception how fast the process actually was (1970, p).

Because of these unprecedented and revolutionary changes education becomes progressively more important, and as the American educationalist Robert M. Hutchins says in his book The learning society (1968, p4), education seems “destined to become the principal pre-occupation of all states” from the closing decades of this century onwards.

The theme of one of the very first presidential addresses to a newly formed association concerned with furthering the teaching of geology therefore virtually chooses itself.

In the context of a general climate of opinion sympathetic towards and concerned with the concepts of unified science or integrated science, it is appropriate that in discussing the relations of geology and education that I also consider the place of geology amongst the other sciences.

Many able scientists and many philosophers and historians of science have found considerable difficulty in recognising common features among the various scientific disciplines. It appears that this will always be the case if attention is focused solely on the subject matter of the disciplines. A sense of unity is revealed, however, in considering the methods adopted by the various sciences and in considering the meaning of science.

The first part of my address, therefore, will be an attempt to provide an outline of the aims and nature of science in general including a brief discussion on the relationship which exists between the scientist and his work. The second part will deal with the characteristics of geology. In one sense, what I am attempting in these two sections overlaps what Serge von Bubnoff (1963), Charles Lapworth (1903) and many others have already considered and with much greater authority than I can hope to command. But I believe that I am considering the problems in a wider context, and that I pay relatively more attention to the nature and method of science and to the characteristics of the men involved.

THE AIMS AND THE NATURE OF SCIENCE

I shall first discuss the aims, then the nature, including the methods of science and finally highlight some of the characteristics that I feel are not usually given enough prominence.

The aims of science

“The value of every science” according to Adam Sedgwick (1850, pp. 145-146) “must ultimately rest on its
utility; but in making the estimate we ought not to be guided alone by motives of narrow gain. The objects of nature appear destined to answer two purposes; the one, to supply the physical wants of the various inhabitants of the globe; and the other, to excite our curiosity, and stimulate our intellectual powers to the discovery of . . . the contrivance of the Divine Artist, and the ends and uses of the various parts”.

This dual aspect of science is apparently, albeit surprisingly, not always appreciated. At least, this is the impression one gets when so many senior scientists are at pains to make this point.

Sir Edward Appleton and Sir George Thomson, for example, in their respective presidential addresses to the British Association for the Advancement of Science in 1953 and 1960, emphasise that although science is already valued for what it can do to increase man’s control over nature, it also aims at understanding the nature of things; that science “has interest as well as utility”, that it is “illuminating as well as fruitful”.

The distinction between basic and applied science has, of course, been appreciated for many centuries. The first to put the matter clearly, however, was Francis Bacon who distinguished between research that increases our power over nature and research that increases our understanding of nature—Experiments of Use and Experiments of Light and Discovery—and who emphasised that what is done for use should so far as possible be done in the light of understanding.

Unhappily, the distinction made by Bacon is not the one that many people now make when they differentiate between the two conceptions of science. To use the words of P. B. Medawar, “The notion of purity has somehow been superimposed upon it, and in a new usage that connotes a conscious and inexplicably self-righteous disengagement from the pressures of necessity and use. The distinction is not now between the empirically founded sciences and those whose axioms were supposedly known a priori; rather it is between polite and rude learning, between the laudably useless and the vulgarly applied, the free and the intellectually compromised, the poetic and the mundane” (1967, pp. 121, 122).

It is essential, however, that we consider the two conceptions of science, not as a dichotomy, but as two aspects of the same thing. And it may well be advisable to view these conceptions in a wider context as advocated, for example, by Charles Lapworth and J. D. Bernal.

Lapworth, in a Presidential Address to the Geological Society of London which deserves very careful study (1903), refers to “the corporate geological organism” which has three necessary functions—research, practice, and education. This thesis is illustrated by reference to the very successful combined work of the Geological Survey, the Museum of Practical Geology and the Royal School of Mines during the forties and fifties of the last century under the inspiring leadership of the man who virtually created all three institutions, Henry de la Beche.

Lapworth maintains that: “Whenever either function remains long unexercised, or falls into disuse, there follows of necessity, a weakness throughout the entire organism, which must in the end become lethargic and crippled, and fall behind in the race”. “When, on the other hand, all three functions are most vigorously exercised, the progress of the science must be at its swiftest and its surest”.

A very cursory review of the history of geology in this country suggests that this diagnosis is probably correct.

J. D. Bernal, in his epoch-making The social function of science (1939, p.96) considers that science as an occupation has three aims—which are not mutually exclusive: the entertainment of the scientist and the satisfaction of his native curiosity; the discovery and integrated understanding of the external world; and the application of such understanding to the problems of human welfare.

The first of these three ‘aims’ is one that is too rarely emphasized. It is, however, very clear that science is one of the most absorbing and satisfying pastimes and that as such it appeals in different ways to different types of personality.

It is in the context of these various ideas, as suggested by the geologists Sedgwick and Lapworth and by Medawar and Bernal, that I think we ought to reconsider the statement made in the ‘A’ level report published in volume 2 of Geology—“that geology is above all a useful science” (p.81).

The nature of science

Formulating a comprehensive and satisfactory definition of science is virtually an impossible task. It is, however, useful to follow Medawar’s example (1967, p.113) in coining a definition which reflects the popular conception of science. For example:

[66]
"Science deals with facts and almost exclusively so. It is the compendium of all certified and certifiable facts and its goal is the creation of a universal encyclopaedia of factual knowledge".

"Over against fact stands theory and speculation which tend to falsify. The best science is, therefore, the one which relies least on interpretation".

According to such a view, which is apparently widely held, science is like an enormous picture puzzle. The scientist discovers the pieces and as the American physicist Henry Margenau has put it, "trusts that benevolent nature or providence has shaped and adjusted them so that they will fit together" (1961, p. 28). When enough pieces or facts are available and put in their proper places, a recognizable pattern results, and a problem has been solved.

That problem or puzzle is consequently finished once and for all and a new one in some adjacent field is started.

Such a description accurately describes the view of the nature of geology adopted by the Geological Society of London in the early years of its existence and described in detail in Martin Rudwick's paper on its early history. (1963). The following quotation, taken from the small booklet entitled Geological Inquiries, issued by the Society in 1808, illustrates the approach.

"To reduce Geology to a system demands a total devotion of time, and an acquaintance with almost every branch of experimental and general Science, and can be performed only by Philosophers; but the facts necessary to this great end, may be collected without much labour, and by persons attached to various pursuits and occupations; the principal requisites being minute observation and faithful record. The Miner, the Quarrier, the Surveyor, the Engineer, the Collier, the Iron Master, and even the Traveller in search of general information, have all opportunities of making Geological observations . . . ".

This emphasis on facts, which was in some ways a reaction to what was considered as the unbridled licence of geological speculation during the later years of the eighteenth century, was not restricted to geology. It pervaded a great deal of science, as is demonstrated in J. N. Hays' article on the Society for the Diffusion of Useful Knowledge (1964).

It is not difficult to see, however, that such a view contains a number of important errors. First it presents facts as given and as significant in themselves, and second, it mistakes the encyclopedia of certifiable facts for understanding. It is not surprising, therefore, that this overemphasis on facts could not continue for long otherwise there would have been no progress.

In the Presidential Address to the Geological Society of London in 1901, the petrologist J. J. H. Teall says that by the turn of the century the state of advancement of a science was being measured, not by the number of facts collected by but by the number co-ordinated.

He quotes the contemporary authority De Morgan who says:—

"Modern discoveries have not been made by large collections of facts, with subsequent discussion, separation, and resulting deduction of a truth thus rendered perceptible. A few facts have suggested an hypothesis which means a supposition proper to explain them, the necessary results of this supposition are worked out, and then, and not till then, other facts are examined, to see if these ulterior results are found in Nature . . . What are large collections of facts for? To make theories from, says Bacon; to try ready-made theories by, says the history of discovery; it's all the same, says the idolator; nonsense, say we".

Teall then reminds us that James Hutton appears to have been of De Morgan's way of thinking. He pondered over the facts that he had observed in England, France and Scotland, and formulated his theory of the earth. He then went again into the field to test the consequences of his theory, and verified them. He never seems to have thought it worth while to describe isolated facts, or the structure of particular districts, except in so far as they illustrated his theory: although no one was better qualified to do this, as all readers of his description of the unconformity at Siccar Point, of the granite-veins in Glen Tilt, or of the geological features of Arran, will readily admit. His joy at the discovery of the granite-veins in Glen Tilt can be easily understood. His theory required that they should exist, and they were found, not by chance, but because they were looked for (Teall, 1901, p. 1 x iii).

The importance of hypothesis is also illustrated in the following note, taken from an address given by J. B. Jukes to the Geological Society of Dublin, in 1855 (Jukes, 1871, pp. 306-308):

[67]
"I had once been working hard for about five weeks, trying to understand and delineate on the one-inch map a complicated bit of mountain ground a few miles south of Conway, in North Wales. It was made up of interstratified slates, sandstones, and feldstones, with large and irregular masses of intrusive greenstone, the exposed parts of each being frequent, but not continuous. Many a weary day had I climbed the sides and clambered along the crags of a hill, some five or six miles in length, by two or three in breadth, and the highest peak of which was not more than 1800 feet above the sea, trying in vain to reduce to order the seemingly endless complexity of its structure, and having at length on the map as curiously complex a patchwork of incongruous colours and unnatural forms as Punch, had he turned geologist, could have devised; when one evening, as, after a hard day's work, I was descending a steep bit of ground, almost in despair at all my labour seeming to be thrown away, I hit upon the clue to a great fault or dislocation. I had only time to verify the observation, but it gave me at once the solution of all the puzzle; and in two or three days I was enabled to map the whole district, with as near an approach to accuracy as the scale of the map admitted of. The country was chopped up by a series of large parallel faults, that were quite easy to be seen when once the clue to one of them and its bearers were obtained, but which there was nothing to render a priori probable, and which could not have been discovered without that thoroughly exhaustive process of examination which I was enabled to apply to the district. I have ever since regretted that, in my haste and joy at acquiring a right notion, I obliterated all my former work from the map which contained it; for I should have been glad to preserve it now as a curious instance of the contrast between laborious hypothesis and the simplicity of natural truth."

In other words, any advance in any science, from visible to inferred form, is possible only by means of hypothesis. A hypothesis, to adapt the words of the American philosopher Hugh Miller (1939, p. 10), is the nerve and sinew of all scientific investigations in its grasp of larger-than-visible fact. The inferences of science are drawn not from observations but from theories. In science, as Kenneth Boulding puts it, "expectations are deliberately created by necessary inferences from theoretical models" (1965, p. 54):

However, as Margenau and others have pointed out, the entire Anglo-Saxon scientific tradition, particularly in our schools and colleges, appears preoccupied with facts, and behind this one sees "the shadow of Francis Bacon denouncing the idols of the market place and of the theatre, of David Hume insisting on the primacy of hypothesis. A hypothesis, to adapt the words of the American philosopher Hugh Miller (1939, p. 10), is the nerve and sinew of all scientific investigations in its grasp of larger-than-visible fact. The inferences of science are drawn not from observations but from theories. In science, as Kenneth Boulding puts it, "expectations are deliberately created by necessary inferences from theoretical models" (1965, p. 54).

It is not appropriate in a brief outline of this kind to discuss the principle of induction in detail. If J. M. Harrison is correct, however, in saying that geology is "unnatural amongst sciences because it has been forced to advance by inductive reasoning" and W. H. Bucher, (1933) is correct in his approach to the problems of diastrophism, it is relevant to note that the validity of the principle is being very seriously challenged by men such as Karl Popper (1959) and P. B. Medawar (1969) who are, in turn, being vigorously opposed by others, particularly by N. R. Hanson (1958). Medawar goes as far as to imply that any man of science who professes to establish laws of nature by induction, should be regarded as long overdue for leave!

The whole problem is complicated because the scientists themselves are not helpful to anyone trying to discover their method. They appear to be victims of self-deception presumably because they do not think deeply enough about methodology. Charles Darwin, for example, is a notorious example.

In his *Autobiography*, begun in 1876, when he was sixty-seven years old, he paid what has been described as "unnecessary" lip-service to inductive methods. "I worked on true Baconian principles, and without any theory collected facts on a whole sale scale" (Barlow, 1958, p. 119). In a letter written in that same year he stated "I determined to work with not a single idea in my head, and no one can know the year of blind labour I had".

In the Third Notebook on Transmutation of Species, on the other hand (De Beer, 1960), he gives an acceptable description of the hypothetico-deductive method advocated by Popper and Medawar. This leads, as it does in Darwin's notebooks, to the question of observation and perception, and I shall return to these problems later.

The Scientific method. It is relevant also to draw attention to the current discussions regarding the general problem of scientific method.

Study of the method of science grew comparatively rapidly with the scientific triumphs of the nineteenth century and science's great acceleration into the twentieth. And the tendency to think of science as a set routine applicable to any subject probably reached its climax in Karl Pearson's work, and particularly in his book, *The Grammar of Science* (1892).

The method was formalized as involving the following six successive operations (Simpson, 1963, p. 81):

1. A problem is stated.
2. Observations relevant to the problem are collected.
3. A hypothetical solution of the problem consistent with the observations is formulated.
4. Predictions of other observable phenomena are deduced from the hypothesis.
5. Occurrence or non occurrence of the predicted phenomena is observed.
6. The hypothesis is accepted, modified, or rejected in accordance with the degree of fulfilment of the predictions.

Nowadays, however, the phrase, "the scientific method", is often described as one of "the most overworked and hackneyed phrases in the literature of science and science education" (Kuslan and Stone, 1968, p. 15) and the logical steps described above almost ridiculed.

There is certainly no question that although such a cut-and-dried method may work in particular instances and that each of the six operations is essential in various phases of scientific research, the formulation fails as an overall characterization of science.

It ignores the most difficult, the most creative and the most important elements of scientific endeavour. Namely: how does one discern a problem, or decide what kind of questions are to be asked? How does one determine what observations are relevant? etc.

In contrast to such a logical sequence one has to juxtapose the often quoted words of P. W. Bridgeman: "The scientific method, as far as it is a method, is nothing more than doing one's damnedest with one's mind, no holds barred" (1954, p. 450); and also those of James B. Conant: "The stumbling way in which even the ablest of scientists in every generation have had to fight through thickets of erroneous observations, misleading generalizations, inadequate formulations and unconscious prejudice is rarely appreciated by those who obtain their scientific knowledge from text-books" (1951, p. 44).

Conant's well-known Science and Common sense (1951) is one of the most vigorous criticisms of the rigid formulation. Although he probably does over-emphasise his case, Conant demonstrates clearly the role of speculation, intuition and just plain hunch in the finding of hypotheses.

The rigid formulation also fails because it implies that there is only one method whereas it is known on the basis of the study of a wide range of past and recent scientific achievements that there is a bewildering variety of procedures that leads to great results (Moles, 1957).

It fails because it does not reflect how extremely difficult it is for a trained scientist to break out of a prevailing mode of thought. As James Geikie has reminded us, even a cautious thinker like Charles Lyell, when confronted with the 'glacial theory', found it less difficult to 'sink' the whole of Central Europe under the sea and cover the sea with floating icebergs, than in conceiving that the Swiss glaciers had been large enough to reach to the Jura. And this in spite of the unquestionable fact that while there was absolutely no evidence for a marine submergence, the former track of the glaciers could be followed mile after mile.

The formulation also leaves unexplained the almost hypnotic fascination that science has exerted through time and the violent reactions against scientific advance. One of the reasons for these apparently irrational outbursts is that the relationships between a scientist and his ideas are far more intimate than is ordinarily believed—a theme which is dealt with fully in Michael Polanyi's Personal knowledge (1962).

The part of Polanyi's argument concerning conflicts amongst scientists can be summarized very briefly thus:—To the extent to which a new idea in science represents a new way of reasoning, the discoverer cannot convince others of it by formal argument, for as long as he argues within their framework he can never induce them to abandon it. Demonstration must be supplemented, therefore, by forms of persuasion which can induce a conversion. "The refusal to enter on the opponent's way of arguing must be justified by making it appear altogether unreasonable. Such comprehensive reflection cannot fail to discredit the opponent. He will be made to appear as thoroughly deluded, which in the heat of the battle will easily come to imply that he was a fool, a crank or a fraud. In a clash of intellectual passions each side must inevitably attack the opponent's person". (1958, p. 151).

The major scientific controversies in our subject, whether those between the Plutonists and the Vulcanists or between the Catastrophists and Uniformitarians during the eighteenth and nineteenth centuries, or that centred around the concept of continental drift during this century, must be seen in this way. They are not scientific arguments but conflicts between rival scientific visions. They commonly do not lie altogether within science and therefore become conflicts between scientific and other values.
It would appear, therefore, that the scientific method as a logical analysis of scientific research is an analysis after the fact. In Hugh Miller's words, "What we must learn is the empirical truth that observation, hypothesis and verification are the method of science, and that logical character is not a character of thought at all, but only a form of the verbal descriptions that convey thought" (1939, p. 14).

It is for this reason that examples of scientific method are to be found in published reports of scientific work rather than during the work itself.

**From the complex to the simple.** One point that needs emphasising is that the major qualitative changes which precipitate these controversies are commonly of a unifying kind. As a science advances, particular facts are comprehended within, and therefore in a sense annihilated by, general statements of steadily increasing explanatory power and compass—whereupon the facts need no longer be known explicitly. Stratigraphy before Nicolaus Steno and biostratigraphy before William Smith, for example, were almost all facts in the same sense that biology before Charles Darwin was very largely facts. This is equivalent to saying that the factual burden of a science varies inversely with its degree of maturity. This emphasises the fact that science is a progression from the complex to the simple, and not vice versa—a point which is very often not appreciated. Science is a "perpetual effort to reduce the complexities of the world to simple terms" (Millikan).

**Specialization.** The impression that science is travelling from the simple to the complex is commonly attributed to the emphasis on the collecting of facts and to specialization.

The dangers of specialization are regularly catalogued as, for example, in F. R. Jevons’ book (1969). One of the main ones, which is considered at some length in M. King Hubbert’s Presidential Address to the Geological Society of America (1963), significantly entitled "Are we retrogressing in science", is the possibility of a reversion to authoritarianism.

According to one view of science, specialization does not "spring from accident, or from a whimsy of the scientist, but is a fateful consequence of the very character of science (Weizsacher, 1951, p. 9).

According to another, less well publicised, view the rule "analyse into parts, and study them one at a time" is so widely followed that there is some danger of its generating into a dogma; and the rule is often regarded as the touchstone of what was properly scientific. According to this interpretation science has, for a century or more, advanced by analysing complex wholes into simple parts with the result that synthesis has been neglected.

Starting with the work of Sir Ronald Fisher, however, it has been demonstrated that not all systems allow this analysis into single parts. Fisher’s problem was to get information about how the complex system of soil and plants would react to fertilizers by giving crops. The conventional method of study was to analyse plant and soil into a host of little physical and chemical sub-systems, get to know each sub-system individually, and then predict how the combined whole would respond. Fisher decided, however, that this would be far too slow, and that the information he wanted could be obtained by treating soil and plant as a complex whole. So he proceeded to conduct experiments in which the variables were not altered one at a time.

At first scientists were shocked: but second thoughts have convinced many people that his methods were sound. In consequence a new scientific strategy has been initiated—commonly referred to as general systems analysis—and the name and many of the ideas are attributed to Ludwig von Bertalanffy (1951). The best known examples of the application of general systems theory to the earth sciences are those in geomorphology (Chorley 1962).

It is now claimed that the development of the computer, in providing a tool which, for the first time, permits the scientist to reduce staggering volumes and varieties of data to manageable proportions, could initiate a period of synthesis.

A third view of specialization is outlined by P. B. Medawar (1967) who maintains (p. 115) that one of the distinguishing marks of modern science is the disappearance of sectarian loyalties and that newly graduated biologists have wider sympathies today than they had in his day.

**Dynamic and static aspects of science.** What has been said in the last few paragraphs emphasises the dynamic as opposed to the static view of science. One of the major exponents of this aspect of science is James B. Conant who states, in the work from which I have already quoted more than once:— "It is not the present moment which
is of interest to the scientist or to those who look over his shoulder... It is the future...

The activity we associate with the word "science" is "the sum total of the potential findings of the workers in the laboratories; it is their plans, hopes, ambitions in the process of realization, week after week, year after year, that is the essence of modern science".

This dynamic view is expressed with equal force by Karl Popper when he says that "we shall have to get accustomed to the idea that we must look upon science not as a 'body of knowledge', but rather a system of hypotheses; that is to say as a system of guesses or anticipations which in principle cannot be justified but with which we work as long as they stand up to tests..." (1959, p. 317).

To Conant, present scientific knowledge is of interest only to encyclopedists. And in this sense he overstates his case. The theories, laws and data of science which are to be found in libraries, herbariums and museums are, in Conant's words, "deposits of the past" and therefore "essentially dead".

Translated into the context of geological maps this is tantamount to saying that the map is significant only as the basis for future research. This is, however, only part of the truth.

Dynamism, therefore, does not characterize the whole of science: there is a static side, as reflected in the following definition by Bertrand Russell. "Science, as its name implies, is primarily knowledge: by convention it is knowledge of a certain kind, namely that which seeks general laws connecting a number of particular facts".

Science is cumulative. The emphasis on this dynamic aspect of science brings me to another characteristic of science which is too rarely mentioned—that it is cumulative.

In the words of the great historian of science, George Sarton: "The making of knowledge, unlike that of beauty is essentially a cumulative process... Nothing that has been done or invented gets lost... This cumulative process is so obvious that even very young men may be better informed and more learned than their illustrious predecessors and they have a chance to see further". (1948, p. 40).

Such a cumulative process is only possible because science is self-correcting. Despite the vigour of argument and counter argument, a consensus is sooner or later achieved. Literally thousands of controversial proposals have been published but sooner or later, sufficient evidence has accumulated to permit acceptance, rejection, or modification, and eventual interpretation into the body of scientific knowledge. Errors are exposed by the natural course of scientific growth, and the appropriate adjustments are made. The rapidity of the corrective process is immeasurably increased by the existence of a well-financed, closely-knit international community of scientists. This evaluation process is feasible today only because of the existence of thousands of scientific research publications.

**THE CHARACTERISTICS OF GEOLOGY**

So far in this address I have tried to look at the features common to all the sciences. There are, of course, other features which are peculiar to one or more sciences and it is appropriate that I now make reference to some of the singular features of geology and also to its status relative to other sciences.

The descriptions and definitions of the subject that were included as "space-fillers" in volumes one and two of *Geology* clearly (underline) the fact that what is given directly in other sciences—the course of events—is in geology precisely the object of study.

This historical nature of geology has been appreciated virtually since the creation of the science in the early part of the nineteenth century. But it also has many other and very different characteristics. For this reason it is probably the most diverse of all the sciences and its status as in part a historical science is complex. As George Gaylord Simpson has clearly stated (1963, p.24):

"For one thing, it deals with the immanent properties and processes of the physical earth and its constituents. This aspect of geology is basically nonhistorical. It can be viewed simply as a branch of physics (including mechanics) and chemistry, applying those sciences to a single (but how complex!) object: the earth. Geology also deals with the present configuration of the earth and all its parts, from core to atmosphere. This aspect of geology might be considered nonhistorical insofar as it is purely descriptive, but then it also fails to fulfill the whole definition of a science. As soon as theoretical, explanatory relationships are brought in, so necessarily are changes and sequences of configurations, which are historical. The fully scientific study of geological configurations is thus historical science. This is the only aspect of geology that is peculiar to this science, that is simply geology and not also something else. (Of course I do not mean that it can be studied without reference to other aspects of geology and to other sciences, both historical and nonhistorical.)"
These and allied points are also made in the detailed discussion of the nature of geology by Bubnoff (1963).

No transformation in men's attitude to Nature has been more profound in the whole history of thought than the change in perspective brought about by the discovery of the past. And, because of this, as Conant rather reluctantly admits (1951), no other natural science has been influenced to the same extent as geology by philosophical trends or lent itself so readily to philosophical speculation. The study of the past not only brings one into territory which has been fought over by theologians, scholars and scientists but, as Conant points out, it raises some difficult questions for all who insist on treating scientific theories as fruitful conceptual schemes.

It has been customary for many non-geologists to consider geology as at best a derivative science of second or third order. In other words, no to consider it as geology at all, but as physics and chemistry writ large. Recently, however, Stephen Toulmin has argued (1962, p.152) that scientists are sometimes tempted to speak as though there were only one definite sequence in which the sciences had become truly 'scientific': physics in 1687, chemistry in 1789, zoology in 1858, physiology in 1865, and so on. In determining this sequence, one has of course to employ a particular criterion—that a truly 'scientific' science must be built round a general and established theory, which specifies explanatory mechanisms in universal and abstract terms. But, as Toulmin points out, this is not the only possible criterion. For it could be argued that a fully-fledged science must display a proper grasp of the historical development of its subject matter, and succeed in demonstrating how this has evolved down the ages. By using this criterion one ends up by ordering the sciences differently. Geology would, by this standard, have come of age first, zoology second, and the physical sciences have been 'growing up' only during the twentieth century.

According to Hugh Miller this difference between what he calls the 'theoretical' and the 'evolutionary' sciences is of fundamental importance.

He maintains that in the post-Darwin period, when the existence of evolutionary movement everywhere in nature is axiomatic, although everyone speaks of universal evolution, the presence of evolutionary character is really admitted only in some branches of biological and geological science. Science, according to Miller, has remained a curiously heterogeneous mixture. At its one extreme there is historical science, dealing exclusively with human fact. In the middle there are biology and geology, really advancing to a genetic method of synthesizing historical and theoretical analysis. And at the other extreme there is theoretical science, erecting a conception of immutable physical structure to which large historical change is wholly irrelevant. What really happened was that science successfully resisted the spread of evolutionary doctrine from biology and geology to other fields of analysis. The historian of society refused to modify his purely historical analysis, and the physical theorist clung to his purely theoretical analysis, so that social science and inorganic science did not appropriate the genetic method made possible by evolutionary doctrine, and the historical, genetic and theoretical analyses were all pursued as independent and equally authentic sorts of analysis.

According to arguments of this kind geology can no longer be considered a marginal subject. It occupies an important, if not a critical, position in the structure of science.

GEOLOGY AND EDUCATION

Having given a very brief outline of some of the characteristics of science in general and some of the special characteristics of geology, I now wish to discuss some of the problems of teaching these subjects.

It is not an exaggeration to claim that the teaching of science in general is at the threshold of a new and dramatic era. It has been said that "the greatest scientific event" in the United States since World War II "was the discovery of the high schools" (Roy, 1966, p.47). For the first time a massive effort is being made by scientists and educationalists to design entirely new curricula in almost every field of science. In geology, for example, we have the Earth Science Curriculum Project sponsored by the American Geological Institute with the support of the National Science Foundation and which Dr. Marjorie Gardner described so vividly at our Conference in Keele in 1968.

A great deal has been written about these various projects in recent years. The E.S.C.P., for example, has been described in a number of papers in the Journal of Geological Education of the National Association of Geology Teachers in the United States. One of the most recent of these is a review of the nine research studies and the several surveys carried out on the effectiveness of the Project (Champlin, 1970).
The many other projects are described in separate pamphlets and are summarized in works such as the book *Teaching children science* (1968) by Louis Kuslan and A. Harris Stone.

There are in addition a number of books which discuss the basic problem of teaching science. Two of these, which I read after preparing my address, discuss many of the points that I have raised. They are: *The teaching of science. Education, Science and Society* (1969), by F. R. Jevons, Professor of Liberal Studies in Science at the University of Manchester, which is an attempt to clarify the aims of science teaching by first examining the nature of science and its social teaching; and *The contribution of science to education* (1967), by R. A. R. Tricker, who was until recently one of Her Majesty's Inspectors of Schools, which includes a number of stimulating essays.

I am conscious that in adding to the already considerable bulk of literature on this subject, and especially when the specific theme that I have chosen for the second half of my address has already been outlined in two comparatively recent addresses by Professor J. F. Kirkaldy (1964, 1969), I may be hindering rather than helping the situation. I feel, however, that there are a small number of points, which arise more or less naturally from the first part of my address, and which need emphasising.

I shall start by reminding you of the rather self-evident statement that modern societies must meet the necessities imposed upon them by what A. N. Whitehead described as "steam" and "democracy". "Steam" or technology requires an even higher level of skill and specialized knowledge; democracy requires that whatever is good be shared to the utmost.

Because of the rapidity of change which I emphasised earlier and because of the inherent lag in the education process—in that pupils are being taught the arts of living and working in the future—strictly vocational training is not as effective as it was in the past. In the words of Charles Carter (1964), "though it may seem to have the simple function of providing the developed skills needed by society", technical education "must in reality prepare people to develop skills which have not yet been imagined, required by technical or commercial processes not yet conceived; and it must do this in a way which has regard to the universal need of general education".

The role of the two kinds of knowledge is, therefore, no longer clear cut. It could well be that the most practical education in an advanced industrial country is the most theoretical one, and that an educational system that aims at understanding will make the most impressive contribution to power and prosperity, whereas one that aims at power and prosperity will fail in that ambition, and fail as well to bring about understanding. This would be another example of the general rule that the benefits of education are indirect. Epictetus was wise when he told us to observe that, though sheep eat grass, it is not grass but wool that grows on their backs.

It seems generally accepted, however, that we need education in depth as well as education in breadth. When applied to education in science this is not unlike saying that one should try and reflect both the dynamic and static aspects of science in our educational system.

I shall consider the dynamic aspect first. There seems little doubt that, as far as possible, a method of instruction should have the objective of leading the child to discover for itself. Telling children and then testing them on what they have been told inevitably has the effect of producing bench-bound learners whose motivation for learning is likely to be extrinsic to the task—pleasing the teacher, getting into university or college, or artificially maintaining self-esteem.

If, therefore, we accept the contention that intellectual activity is the same, whether we are considering the mental processes of a scientist at the frontiers of science or of a child in the lower levels of our secondary schools, then we should consider the child who is learning geology as a "geologist". We should consequently give careful thought to the contention that it is much easier for a child to learn geology by behaving like a geologist than by doing something else. That "something else" usually involves what Jerome Bruner (1965) describes as a "middle language"—class room discussions and text-books that talk about the conclusions in a field of inquiry rather than centering upon the inquiry itself.

I am reminded of the words of the German structural geologist, Hans Cloos (1954), who answers his own rhetorical question "You asked for a book on rocks" in the following words: "You wanted to penetrate the innermost secrets of the mountains with the help of dry printed words and symbols. Did you realize that you were asking the impossible? . . . To piece together the shape of a single large fold from a hundred small outcrops, or of an old volcanic hearth as big as a province, and, moreover, to set such features in motion, so
that they appear to move as they once did, requires both the natural example and lively personal communication between man and man”.

If the contention is a true one, we need to scrutinize the methods of the scientist in detail and we need to study the thought processes of the student of science at the same time. If the claim made earlier, for example, that hypotheses play a vital part in the advance of science and that speculation, intuition and just plain hunch play an important part in the “method” of the scientist and geologist, we should consider whether the young geologist can be taught to master this gift. According to Bruner (p.13), for example, two facts and a relation joining them is and should be an invitation to the child to generalize, to extrapolate, to make a tentative intuitive leap. The step from mere learning to using what one has learned in thinking is an essential one in the use of the mind.

In studying the work of the scientist and of the novitiate we must also consider the problems of perception. One of the first things to realise about observations, for example, as Professor W. I. B. Beveridge (1950, p.98) clearly illustrates, is that not only do observers “frequently miss seemingly obvious things”, but what is even more important, they “often invent quite false observations”.

The example that is regularly quoted of acute observers failing to “see” obvious but nevertheless unexpected features is that of Charles Darwin and Adam Sedgwick who visited Cwm Idwal in Snowdonia in 1838. In Darwin’s words: “Neither of us saw a trace of the wonderful glacial phenomena all around us; we did not notice plainly scored rocks, the perched boulders, the lateral and terminal moraines” (Darwin, 1888).

The false observations that Beveridge mentions may be due to optical illusions, where the senses give wrong information to the mind, or the errors may have their origin in the mind.

Probably the most ‘notorious’ case of erroneous observation is that of Johann Jacob Scheuchzer who identified a specimen found in a quarry at Oeningen as *Homo diluvii testis*—or the men who witnessed the flood (Jahn, 1969). Georges Cuvier, who later correctly identified the specimen as a salamander commented—“Nothing less than total blindness on the scientific level can explain how a man of Scheuchzer’s rank, a man who was a physician and must have seen human skeletons, could embrace such a gross self-deception” And the reason for the misidentification was simply that Scheuchzer was obsessed with the concept of a Deluge.

We know, for example, that two geological observers can furnish very different descriptions of the features in one and the same quarry, though their eyesight is normal and they are visually aware of the same objects.

The two examples of extremely competent geologists “seeing differently” that come immediately to my mind, are P. G. H. Boswell and O. T. Jones in their respective studies of the Ludlovian of the Denbigh Moors and of Charles Lapworth, on the one hand, and Peach and Horne on the other in their respective studies of Girvan (Williams, 1959).

Many people would argue that O. T. Jones and Boswell saw the same things. They made the same observations since they began from the same visual data. But they interpreted differently what they saw.

The philosopher N. R. Hanson, on the other hand, argues very persuasively that observation and interpretation are inseparable and that there is a sense in which seeing is a theory-laden undertaking. His argument obviously raises the whole question of the relationship between observation and theory. This is discussed in great detail by Michael Polanyi (1962, p.4 et seq.) who claims that of two forms of knowledge, we should consider as more objective that which relies to a greater measure on theory rather than on more immediate sensory experience and that theoretical knowledge is more objective than immediate experience.

I said earlier that Darwin commented on the act of observing. In a letter written in 1860, he says, “I have an old belief that a good observer really means a good theorist”. And in another letter, written in 1861, he makes a statement that takes us back to what I was discussing in the first section of my address. “About thirty years ago there was much talk that geologists ought only to observe and not theorize; and I well remember someone saying that at this rate a man might as well go into a gravel pit and count the pebbles and describe the colours”. And he continues by saying “How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service”.

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I suggest, therefore, that students and teachers alike could learn a great deal about the way in which geologists "see" things by considering the two examples quoted above as well as other contemporary and historical geological controversies in the light of the ideas put forward by Hanson and Polanyi.

The messages received by a geologist pass through a "filter" or censor, and messages which support an existing image are much more likely to get through this filter than messages which are contradictory to this image. This is illustrated in a rather humorous way in the phrase "well educated geognost" which was current in the early years of the nineteenth century (Bakewell, 1815, p.485). Geognosy was the name given by the great Abraham Gottlob Werner to his own particular brand of geology, and a "well educated geognost" was, to Werner's rivals at least, a person who had lost the use of his own eyes by constantly looking through those of his master.

The problem of perception is obviously as relevant in the class room as it is in the field. Biologists and educationalists who study the acquisition of knowledge and understanding of the external world by the developing child, find themselves forced to recognize that in neither of these processes is the subject a merely passive recipient of whatever the "objective" imposes on to it. On the contrary both in learning how the world works, and even in apprehending it in perception, an active and indeed creative participation of the "subject" is essential (see, for example, Gregory, 1966). One cannot suppose that whatever is shown will be seen: one cannot ignore the mind's need to be prepared for seeing.

The zoologist M. L. Johnson Abercrombie has carried out experiments on perception and reasoning for some ten years amongst preclinical students at the Department of Anatomy, University College, London. The results, which are described in her book The anatomy of judgment (1960), are very relevant to us and we could, with considerable advantage, initiate similar studies in our class rooms and laboratories.

Among the valuable results of Dr. Abercrombie's work was the disclosure of unexpected barriers to learning imposed by emotional difficulties, and the application of a technique to overcome such difficulties.

This brings me to something that I should probably have said earlier. We shall inevitably have to turn to the educationalist and the psychologist for guidance. In my own reading I have found the following five books invaluable: the very highly praised The process of education (1965) by Jerome Bruner, Professor of Psychology at Harvard University; The knowledge most worth having (1967), being the series of papers delivered at a five-day Liberal Arts Conference sponsored by the undergraduate College of the University of Chicago and edited and introduced by Wayne Booth; How children learn (1968) by John Holt, one of the best known of a new breed of teachers; Schools without failure (1969), by the psychologist William Glasser, in which the author maintains that American schools, at least, are designed for failure; and particularly The lives of children (1969) by George Dennison, which John Holt has described as by far the most perceptive, moving and important book on education that he has ever read, or indeed ever expects to read. All five books were first published in the United States but are now fairly readily available in this country.

In this context it is appropriate to remind ourselves that the recent concentration of interest on the educational process has resulted in a revolutionary avowal of the obvious--namely that there are three elemental factors in education--what is taught (knowledge, wisdom), and the teacher and the taught. Educational systems have long centred about knowledge and the teacher. What is now happening is a very belated result of the inspiration of Jean Jacques Rousseau, Johann Heinrich Pestalozzi, Friedrich Wilhelm August Froebel and others--simply to shift the centre of gravity from knowledge to the learner, recognizing that it is the learner and his characteristics which alone can guide us in our effort to make something organic of education.

The evidence is that every child who has not sustained some damage to his brain can learn the basic subjects; that all subjects can be taught at an earlier age than had been suspected; and that it can no longer be said that any member of the human race is ineducable.

Take the exciting words of Jerome Bruner (1965, p.33):

"We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development. It is a bold hypothesis and an essential one in thinking about the nature of a curriculum. No evidence exists to contradict it; considerable evidence is being amassed that supports it."

Add to them René Dubos' judgment (1968) that the most important recent discovery in genetics, as far as man is concerned, is that only a very small percentage of the genetic endowment--less than 20 per cent--becomes
expressed in a functional way. Most of the genes are rendered inactive by repressions: the environment determines what part of the geno-type is expressed and what part is repressed.

Here, surely, are some of the big challenges that we must meet.

Turning now to the problem of providing breadth as well as depth in education, we need to instil into our students the realization that the things being taught or learned or examined are living parts of a larger, developing unity. Teachers of science have long clamoured for general or integrated science courses and there has been much experimentation in this field. In one sense this integrated course, this developing unity is the very subject matter of geology.

History automatically introduces a unifying feature into the study of nature, and the history of nature is the most distinctive feature of geology. With the considerable growth in interest amongst chemists and biochemists in the early conditions of life on earth—as outlined in Professor Leslie Moore’s Presidential Address (1970)—and the union of geology and geophysics made possible by the concepts of continental drift and plate tectonics (Wilson, 1969), the subject progressively presents a more unified and comprehensive picture of the history of nature. We nevertheless lack a comprehensive survey of the present state of our knowledge.

Detailed geological study can be shown to be a living part of another developing unity, that of our intellectual tradition, by studying the history of our subject.

It is currently fashionable to advocate this type of historical approach and many eminent men have extolled its virtues both for the practising scientist and for the student. Lord Acton, for example, claims that, “There is nothing more necessary to the man of science than its history and the logic of discovery” (quoted in Popper, 1959) and the American anthropologist Loren Eiseley has amply demonstrated the point with unusual eloquence in the books The immense journey (1958) and The firmament of time (1961).

In similar vein, the Russian geologist V. V. Belousov maintains that without an historical perspective a truly educated scientist cannot evolve and he stresses the need for young scientists to know the history of their science in order that they become aware “that all they now possess in science has been inherited from the preceding generation of scientists” (1970).

Belousov points out, however, that the authors of modern books on geology “are in such a hurry to depict the subject as it is understood today, that there is usually no place left for the history of the problem”. And he could have added that historical study receives very little attention in formal courses of geology. The teacher or lecturer argues that it is almost impossible to find room in the time-table for a careful study of the work of our predecessors and also keep pace with the ever rising tide of modern geological information. In countering this argument—which, incidentally, has been in vogue almost as long as there have been formal courses in geology—it seems fair to state that it is strongly influenced by the erroneous belief that science progresses from the simple to the complex. In defending it on the other hand, it has to be admitted that the very great majority of the published work on the history of geology comes nowhere near the ideals set by Loren Eiseley. Much of the material probably appears completely irrelevant to the teacher.

Unifying the curriculum in this way is easier said than done, however. Many historians of science (H. H. Thomas, for example) see very clearly the ‘unfortunate’ result on education of specialization in science and advocate the teaching of the history of science as a remedy. But they make no reference to the fact that many historians have as restricted a viewpoint as the most specialized scientist.

The following sentences from Herbert Butterfield’s well known The Whig interpretation of history (1931) are very reminiscent of the specialist in a scientific discipline outlining the dynamic aspects of science.

“It is only by undertaking an actual piece of research and looking at some point in history through the microscope that we can visualise the complicated movements that lie behind any historical change (p.21)”.

“The historian seeks to explain how the past came to be turned into the present but there is a very real sense in which the only explanation he can give is to uphold the whole story and reveal the complexity by telling it in detail” (p.22).

And again many of the scientists who advocate the unifying nature of the study of the history of science forget that the discipline of history has its own techniques and its own apparatus for the handling of sources, and that it is not just a matter of “getting up” a little history.
There is a wealth of modern work on the history of virtually every branch of geology, and a great deal of it is of a very high standard. I counsel you, for example, to read the discussion of the eighteenth century 'Denudation Dilemma' in Gordon Davies’ book *The earth in decay* (1969). Ten arguments were marshalled by the opponents of fluvialism (pp. 237-243) and it is a very useful exercise to have your students consider them in detail, because even in the light of present knowledge some will not be easy to answer. I counsel you also to read the papers by Walter F. Cannon (1960a, b) and the books by C. C. Gillispie (1951) and Reijer Hooykaas (1963). But there is as yet no single text suitable for use with students. The Symposium organised in New Hampshire to bring together geologists and historians interested in the history of geology augured well. But the published volume (Schneer, 1969) is unfortunately a series of excellent but disconnected papers on very restricted themes.

When, however, we do get a modern synthesis of our knowledge of the history of nature and another on our knowledge of the history of geology, we may well be approaching the ideal described by Sir Julian Huxley in his Fawley Foundation Lecture (1962).

In conclusion, I have tried, in this the centenary year of the 1870 Education Act, to look at some of the wider and more difficult problems confronting us as members of The Association of Teachers of Geology. Much of what I have said is not as clear as it should be and many of the connecting links in my arguments are not as sound as they might be.

I am aware that reflections are not of much value unless they lead at least to suggestions for action. I suggest, therefore, that we should take serious note of the way in which the Geological Society of America celebrated its 75th Anniversary—by examining the structure of geological science “from the ground up”—and as a result to impress upon the senior geologists of this country the need for further detailed study of the fabric of geology if only to unify the many papers incorporated in the anniversary volume, *Fabric of Geology* (Albritton, 1963).

I suggest also that we organize a publication which would provide a synthesis of current knowledge of the history of nature by impressing upon senior biologists, physicists and geologists alike the need for such a unified presentation; and, at the same time, organize the preparation of a synthesis of our current knowledge of the history of geology as part of the history of science by enrolling the combined services of historian and geologist.

Lastly, whilst these studies are in progress, I should very much like to see the Association set up a panel of practising teachers and of specialists in human behaviour to consider the implications of the work of the other groups on the role of geology in education.

I firmly believe that the philosophers of biological evolution are right in stressing that the teaching process has a much deeper significance than is generally realized. According to this view, the teaching process can be said to mark a new and enormously important development in evolutionary history—not just a step in evolution, but a new departure in the evolution of evolutionary mechanism. It amounts in effect to a new mode of heredity. Human young are equipped by their ancestors not only with sets of the traditional genes, shaped by millions of years of natural selection, but also with a new kind of ‘genes’, the facts and concepts of some two and a half millennia of scholarship.

Seen in this light, the facts and concepts of science and its ways of thought can certainly be ranked as particularly important. Since it is obvious that science is one of the major forces for change in the modern world, its ‘genes’ have particularly powerful evolutionary effects; so they form specially significant factors in the new genetics of the intellect.

REFERENCES


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National Museum of Wales
Cardiff

Geology, now deservedly one of the most popular and attractive of the physical sciences, was, not many years ago, held in little estimation; and even at present, there are not wanting some who do not hesitate to maintain, that it is a mere tissue of ill observed phenomena, and of hypotheses of boundless extravagance. The work of CUVIER now laid before the public, contains in itself not only a complete answer to these ignorant imputations, but also demonstrates the accuracy, extent and importance of many of the facts and reasonings of this delightful branch of Natural History. Can it be maintained of a science, which requires for its successful prosecution an intimate acquaintance with Chemistry, Natural Philosophy and Astronomy—with the details and view of Zoology, Botany and Mineralogy, and which connects these different departments of knowledge in a most interesting and striking manner—that it is of no value? Can it be maintained of Geology, which discloses to us the history of the first origin of organic beings, and traces their gradual development from the monade to man himself—which enumerates and describes the changes that plants, animals, and minerals—the atmosphere, and the waters of the globe—have undergone from the earliest geological periods up to our own time, and which even instructs us in the earliest history of the human species—that it offers no gratification to the philosopher? Can even those who estimate the value of science, not by intellectual desires, but by practical advantages, deny the importance of Geology, certainly one of the foundations of agriculture, and which enables us to search out materials for numberless important economical purposes?

ROBERT JAMESON
THE ANNUAL CONFERENCE: SHEFFIELD 1970

A Report based on the Record of the Proceedings prepared at the Conference by Mrs. P. E. Lunn.

The third Annual Conference of the Association was held at Earnshaw Hall, University of Sheffield, from Friday evening, 11th September, to Sunday morning, 13th September 1970.

One hundred and thirty-four members and guests were in attendance.

The meetings were chaired by the retiring President, Dr. D. A. Bassett (Keeper of Geology, National Museum of Wales) and the newly elected President, Professor T. Neville George, (Head of the Department of Geology, Glasgow University).

Friday evening: 11th September — Extra-Ordinary General Meeting and Annual General Meeting.

The President welcomed the members and guests and formally opened the Conference.

The Extra-Ordinary General Meeting had been called to consider changes in the Rules of the Association. The proposed changes, details of which had previously been circulated, were carried unanimously.

Opening the Third Annual General Meeting the President tendered apologies for Mr. J. M. Branson's absence because of ill-health. It was suggested that a letter of sympathy be sent to Mr. Branson who was a founder member of the Association and someone who had diligently worked to further the teaching of geology in schools over many years.

The Minutes of the Second Annual General Meeting, previously circulated, were approved.

The President then asked the Secretary and Treasurer to present their reports.

The Officers reported that: the membership had increased from 361 to 490 during the year; the Inland Revenue had recognised the Association as a Charitable Organisation for purposes of Income Tax; a large number of enquiries had been received from teachers, indicating a growing need amongst members for practical advice.

The Balance Sheet for the year 1969/70 was presented and accepted.

The Secretary reported that the Council had expressed deep regret over the death of Miss C. M. Gray.

The meeting then elected the Officers and Members of Council for the forthcoming Session. Professor T. Neville George was elected as President; Dr. Douglas A. Bassett and Professor David L. Dineley as Vice-Presidents; Dr. John R. Harpum was re-elected as Secretary, Mr. John Myers as Treasurer and Mr. Denis Hart as Editor; Mr. Peter Carr, Mr. Stephen W. Hannath and Dr. Edwin G. Spinner were elected Members of Council for a period of three years and the six members of Council eligible for re-election were re-elected.

There being no further business the President formally declared the Third Annual General Meeting closed.

Schools Council Integrated Science Project

Mr. William C. Hall, attending the Conference by invitation, outlined the reasons for S.C.I.S.P. and its relation to other projects. A paper based on Mr. Hall's lecture is published elsewhere in this volume of the Journal.

Saturday morning: 12th September — First Session.

Practical Mineralogy and Crystallography for Schools: Mr. D. Emlyn Evans.

Mr. D. Emlyn Evans (National Museum of Wales) outlined the plans for a small laboratory or 'activities room' for students and laymen alike, to be opened at the National Museum in Cardiff later in the year.

He displayed simple apparatus which would be available and discussed the kind of tests that could be carried out on mineral specimens. He also demonstrated the kind of models that could help in explaining the external morphology and the internal structure of crystals. A paper based on his talk is given elsewhere in this volume of the Journal.

Volcanic Activity: Dr. W. J. Phillips.

Dr. W. J. Phillips, University College of Wales, Aberystwyth, described the 1959-60 eruption of Kilauea in Hawaii and illustrated some of the spectacular phenomena associated with the eruption by showing two colour films. He then discussed the mechanics of volcanic activity and demonstrated the need to integrate the approaches of the petrologist, structural geologist, chemist, etc. A comprehensive paper outlining Dr. Phillips' thesis is given elsewhere in this volume of the Journal.

Saturday afternoon: 12th September.

Q. and F. Level Examinations: Dr. H. J. Peake.

Dr. H. J. Peake, Principal of the Sheffield City College of Education, outlined the setting up and role of two Working Parties to consider Sixth-Form reform. The debate on the report of the working parties was discussed at some length and the implication of the proposed examination structure considered.

The transcript of his lecture is given elsewhere in this volume of the Journal.

Saturday morning: 12th September — Second Session.

Three excursions were organised by members of the staff of the Department of Geology, University of Sheffield. By request they were to the same venues as in the previous year.

The first excursion, led by Professor L. R. Moore, was a tour of the Peak District; the second, led by Dr. A. C. Higgins,
visited fossil and mineral localities; and the third, led by Dr. R. W. Mayhew and Dr. M. Romano, examined sedimentary structures and discussed mapping techniques in the Millstone Grit succession.

Saturday evening: 12th September.
Chairman: Professor T. N. George
Glass Spherules in the Lunar Dust: Professor Samuel Tolansky.

The Distinguished Guest of the Association at the Conference was Professor Samuel Tolansky, F.R.S., Royal Holloway College, University of London, who gave an address on his investigation of glass spherules (‘marbles’) in lunar dust. The text of a paper on this subject by Professor Tolansky and originally published in *Endeavour* is given elsewhere in this volume of the Journal.

Sunday morning: 13th September — First Session.
Audio-visual Presentation of Geology in Primary Schools: Mr., S. W. Hannath.

Mr. S. W. Hannath (Pinehurst Junior School, Swindon) described how he had introduced geology to his pupils and outlined the various projects they had undertaken. He illustrated his talk by slides which he had specially prepared for classwork to accompany a formal script. The text of a suggested guide for teachers is given elsewhere in this volume of the Journal.

**THE GEOLOGISTS’ ASSOCIATION**

The Association, founded in 1858, exists to foster the progress and diffusion of the science of Geology, and to encourage research and the development of new methods. It holds meetings for the reading of papers and the delivery of lectures, organises museum demonstrations, publishes Proceedings, Books and Guides and conducts Field Meetings. Candidates for election must be recommended by two or more members. Admission Fee, £1.00 Annual Subscription £2.00

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AN ENQUIRY INTO THE TEACHING OF GEOLOGY AT C.S.E. LEVEL

A Progress Report presented to the Association at the Annual Conference, Sheffield, September, 1969.

An Analysis of replies to a Questionnaire

After an Interim Report was given to the Council of the Association on 11th January, 1969 it was decided to prepare a questionnaire to be sent to all teachers known to be concerned with Geology at C.S.E. level. Twenty-seven questionnaires were distributed. Of these seventeen have been returned. The addition of two replies from members of Council makes a total of nineteen completed questionnaires. And of these, 11 were from members of the Association.

Section A

Of the nineteen teachers three were following a Mode 1 scheme, one a Mode 2 scheme, thirteen a Mode 3 scheme, one might follow a Mode 3 scheme in the future and one was not following any of the three schemes. Of the three following Mode 1, one has used it for 3 years, one for 2 years, and one for 1 year. The one teacher following Mode 2 had done so for 3 years. Of the fourteen teachers concerned with Mode 3, one started work on devising a syllabus in 1964, three in 1965, two in 1966, five in 1967 and three in 1968. Ten of these had, or will have, candidates completing the course within 2 years. The majority of the teachers started from scratch when planning their syllabus, and most had no difficulty in getting their syllabus accepted.

Section B

Crystallography Five teachers felt that a study of crystals was necessary, while another five thought it was desirable although not necessary. Nine teachers thought it was not important enough to be included as part of a geology course. Six only made any indication of which crystal systems should be included, with cubic and hexagonal being the only two listed by all six. Further comments showed that, in general, this part of the subject is dealt with very simply.

Mineralogy The questionnaire gave a list of eighteen minerals and teachers were asked to underline those they thought should definitely be included and to delete those that they thought should definitely be excluded from a geology course. Only one of the teachers felt that the list was too short and added Malachite, Azurite and Chalcopyrite to a list comprising sixteen of the eighteen given, making a total of nineteen minerals to be taught. The smallest number of minerals underlined was seven: the average was twelve.

Petrology The method of answering was as before. Nineteen rocks were listed. The average number chosen by teachers was 14 although one answer added some to the list to make a total of 25 rock types, to be taught. The lowest number was nine. The rocks most commonly excluded were: Pegmatite (excluded by 6 teachers), Pumice (5), Rhyolite (4). Most teachers felt that none of these should be specifically excluded although one teacher excluded 9 of the listed rocks, leaving a selection with no igneous rocks at all. Fifteen of the nineteen rocks were chosen by more than half the teachers: Conglomerate, Sandstone and Limestone (all chosen by 18), Granite, Basalt, Shale and Coal (all 17), Gabbro (16), Breccia and Clay (15), Flint (14), Mudstone (13), Dolerite (12).

Palaeontology The method of answering was as before. Fifteen fossil groups were listed. The average number chosen for inclusion in a course was nine, although results for this varied between six and thirteen. Most teachers chose to exclude two or more of these groups. The groups most commonly excluded were: Mummulites (14), Bryozoa (13), Vertebrates and Goniatites (both 5). Eleven of the fifteen fossil groups were chosen by more than half the teachers: Brachiopods (18), Bivalves, Ammonites, Trilobites (11, 17), Corals (16), Echinoids (15), Graptolites, Gastropods and Crinoids (all 13), Coal Measures Plants (12).

Geological History All the teachers but five clearly indicated that the whole span of geological time should be taught but only one wanted it dealt with in any detail. Again the majority of teachers (18 of the total) was in favour of certain sections of geological time having greater stress and that the geological history represented in the school area should determine them.

Physical Geology In this part of the course considerable overlap may occur with a course in geography. Teachers were asked whether or not they thought such overlap caused a lowering of the status of geology. Fifteen of the teachers thought that the status of the subject was not affected if such overlap occurs. However, some added that topics generally regarded as part of a physical geography course were, in their own courses, excluded or limited. Eighteen teachers said that if overlap of course content occurs then pupils should still be allowed to follow both courses.

Maps, Structural Geology An understanding of 1-inch-to-the-mile geological maps was thought to be necessary by three of the teachers and desirable by eleven. Three thought it was not important. An understanding of simple black and white geological maps was thought to be necessary by six and desirable by eight. Three thought it was not important. An ability to interpret geological photographs was thought to be necessary by five and desirable by ten. Three thought it was not important.

Economic Geology  All teachers thought this was a necessary part of the course, whilst twelve said it should not be limited to raw materials found in the school area. More teachers (14 in all) wanted a brief study of the uses of raw materials then a study of the processes of extraction, refining, etc., (only 9).

Additional Comments  It is not possible to generalise on the comments added at the end of the completed questionnaire but some of the individual comments may be of interest. Many stress the need for an emphasis on practical work and one explained that for one period each week the pupils spent the time cleaning fossils, polishing rocks and corals and building geological models. One teacher found an overlap between geology and geography an advantage when having a total of only 1½ hours of teaching time per week for geology in the 5th form. For two teachers pupils in a single class had to be prepared for both C.S.E. and G.C.E. and this influenced the type of syllabus they prepared. At two schools the pupils following a C.S.E. geology course were post-5th-formers—at one they studied C.S.E. geology if incapable of doing 'A' level in the 6th form, and at the other school they did C.S.E. geology whilst studying for 'O' levels if they had previously gained a good grade at C.S.E. geography. One point which comes out from the complete study of all the questionnaires is that there are considerable differences not only in course content but also in the quantity of geological information given to the pupils.

Peter J. Perkins (Convener).

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Middle & Upper Lias M. K. Howarth
Lower Lias    L. Bairstow

Compiled and introduced by J. E. Hemingway

Edited by J. E. Hemingway, J. K. Wright and H. S. Torrens

A number of unbound copies of this guide are still available from Dr. H. S. Torrens, Department of Geology, The University, Keele, Staffs., at 25p. per copy.
GEOLOGY FOR TOURISTS

The Lake District is an admirable environment in which to introduce those with leisure and curiosity to geological patterns and relationships, which after all lead far towards an understanding of the environment of Britain's largest National Park. This opportunity has been exploited for eleven years by the Department of Adult Education of the University of Newcastle upon Tyne in collaboration with the Lake District National Park Planning Board. Each summer, for six weeks, talks are provided for visitors on each weekday evening in Keswick and Ambleside on some aspect of the National Park. On Mondays the topic is solid geology and on Tuesday's glacial geology, while on the remaining evenings there are contributions on, respectively, plants, animals and aspects of human geography. Each week's programme can be followed as a coherent series. The talks begin after visitors have had their evening meal and last for just over an hour. Attendances in 1970 at Keswick averaged 64 per night in the Moot Hall, the black and white Tyrolean-looking building in the very centre of the town, part of which is also occupied by a National Park information centre.

The geological talks have been consistently the most popular. Most of them are given by members of the Cumberland Geological Society, which also provides an exhibition of rocks and minerals. Encouraged by the response a geological coach excursion, with some walking and hammering, was introduced in 1966, and the bus is seldom less than completely full. The itinerary varies with the leader, but a normal route is clockwise around the Skiddaw-Carrock Fell massif (the larger coaches cannot cope with a narrow bridge anticlockwise) taking in Skiddaw Slate—Borrowdale Volcanic and Skiddaw Slate—gabbro contacts. A new venture in 1971 will be a geological boat excursion on Windermere taking off from the National Park Centre at Brockhole, strictly for the contemplative geologist.

Over the years we detected a positive correlation between attendance at the evening talks and rainfall, but latterly the correlation has broken down and nothing is more heartening to an enthusiastic geologist or ecologist than, on a warm, calm, limpid Keswick evening ideal for strolling by the lake or rowing on its surface, to be overwhelmed by eager listeners in an overcrowded room and to be besieged afterwards by questioners. He feels that this is what national parks, holidays and adult education are for—enlightenment and refreshment in new environments.

A. G. Lunn.

A SIMPLE TECHNIQUE FOR POLISHING ROCK AND FOSSIL SPECIMENS

It is sometimes an advantage when examining rocks or fossils to be able to see a polished surface. In some limestones, for instance, many details of fossil corals and algae that show up on a polished surface would otherwise be difficult or impossible to see. Textures of most rocks, and in particular the igneous ones are usually more apparent when a face is polished.

**Requirements**

1. **The Rock**
   - Not all rocks are suitable for polishing. Clays and most shales, soft sandstones, rubbly limestones, and certain schists cannot be polished. Hard, fine-grained rocks such as rhyolite and flint take a high polish but require much hard work.
   - Compact limestones such as the Carboniferous and Wenlock are very suitable, while serpentine will yield striking results.

2. **Equipment**
   - (i) A flat steel or cast iron plate—preferably at least 5mm. thick and 20 cms. to 30 cms. square. Dimensions are not critical and suitable material can often be obtained from scrap metal dealers.
   - (ii) A piece of plate glass approximately the same size as the metal plate. Ordinary window glass can be used but is easily broken.

3. **The abrasive**
   - The most suitable abrasive is carborundum grit—obtainable from most 'respectable' ironmongers or laboratory suppliers. (B.D.H. Chemicals Ltd., Poole. Price range 40p to 50p for 500 g.).

   - Three grades will be necessary:
     - 80 - 120 coarse
     - 180 - 240 medium
     - 600 fine

   - Metal polish—e.g. "Brasso"
   - A piece of felt or a wad of soft cardboard.

**Method**

1. Wet the metal plate and dust a quantity of coarse carborundum grit (120 grade) over its surface. (A tin with nail holes punched in the lid forms a useful shaker.)

2. Place the rock surface to be polished face downwards upon the plate and exerting pressure, rub to and fro.

3. Turn the specimen from time to time to ensure that rubbing goes on in varied directions. Keep the plate wet and add more coarse grit when necessary.

   - After 'several' minutes rubbing a flat surface, free from pitting, should be obtained.

   - Much time and effort can be saved if the worst irregularities on the initial rock surface can be removed on a mechanical grindstone or grinding wheel attachment to an electric drill, before the specimen is rubbed on the plate (the aid of your colleague in charge of the Metal Workshop could be requested).

   - Unskilled use of mechanical tools can be dangerous and should not be undertaken by children.

   - An old coarse file can be effective in removing projections from many rocks.

4. The flat surface obtained by rubbing with 120 grade grit will have a coarse texture. The next stage is to eliminate the scratches of the coarse powder and improve the surface by repeating the rubbing process using water and the medium 240 grade grit to produce a smoother flat matt finish.
TRANSPARENCIES FROM PEELS

Prepared peels of carbonate rocks, especially limestones, can be easily projected onto a screen, which has many advantageous uses in the classroom. The method of peel preparation is fully described in 'Davies and Till', Journal of Sedimentary Petrology, 1968, pp. 234-7. The method is as follows:-

Preparation of Limestone Peels
1. Grind a piece of limestone down to a smooth surface using three grades of carborundum powder. A practical size for the specimen is 10 cms. x 8 cms.
2. The specimen should then go through a series of immersions in various solutions to etch and stain the polished surface.

Three glass dishes will be needed for this purpose each with a different solution.

Solution A = 1.75% HCI – (Dilute concentrated HCI 20 times i.e. 50mls. HCI to make up 1000mls. of solution).

Solution B = 100 mls. of Potassium ferricyanide (which will stain iron oxide blue) + 150mls. of Alizarin Red S which will stain calcite red.

Alizarin Red S 0.2grms. to 100mls. HC1; Potassium ferricyanide 2.0grms. to 100mls. HC1.

Solution C = 150mls. of Alizarin Red S.

The specimen should be immersed in Solution A for 45 seconds, Solution B for 45 seconds, and then washed in distilled water before immersion in – Solution C for 10 seconds.

3. The specimen should then be allowed to dry for 20 minutes.

4. The specimen should be placed in a sand box to hold it rigid while acetone is sprayed onto the surface. The film (dull face to specimen) should then be rolled on before the acetone evaporates and all air bubbles squeezed out. There are several films that can be used, either 'Ethulon' tracing film, Xylonite or Kodatrace.

5. The specimen should then be left for 15 minutes before peeling off the film.

Hundreds of these peels can be made from just one specimen, but only 3 or 4 can be actually peeled off before the specimen needs to be ground, etched and stained again.

The finished peel can then be examined and handled by children and stuck into their exercise books. It can be examined by individual pupils under the microscope (if the school has one). All the class can however, examine the peel together if it is projected by an Aldis projector, of which every school should have at least one.

To project the peel, it must be framed in a 2in. x 2 in. transparency frame. 'GePe' 24mm. x 36mm. glass slide binders prove very useful for this purpose. The glass not only protects the peel from wear and dust but from the heat of the projector bulb also.

To prepare the transparency the peel should be cut into a rectangular shape measuring not more than 4cms. x 3cms. Scissors will be found sufficient for this purpose. Depending upon the size. Perhaps two or even three transparencies can be made from one peel. It can also be cut to ones likely to show any special feature. If 'GePe' frames are used, then the shiny side of the peel should be placed on the grey half of the frame and the white half clipped in position on the top. The finished slide is then ready for projection from the white side of the frame.

This method works excellently for Carboniferous limestone and Jurassic oolites. Pisolites do not work so well, probably because in a 24mm. x 36mm. frame, too little surface area is shown. One other disadvantage is that if the peel is not of an even thickness, then when projected the thicker parts may appear to be opaque.

'GePe' slide binders cost 50p for 20 frames; the chemicals are to be found in most schools' chemistry laboratories and although Xylonite is rather expensive the transparencies work out at less than 5p each.

TESTING A PUPIL'S UNDERSTANDING OF GEOLOGICAL STRUCTURES

The understanding of geological structures is an important part of most courses in geology. Geological structures are one of a number of topics that require an understanding of three dimensions. Three dimensional models are of great value in teaching pupils such features as folds, faults, unconformities, offlap and overlap. They can also be used to show the relationship between rock strata and topography. The use of wooden blocks to show all of these features has been described and illustrated elsewhere (Perkins, 1971).

The purpose of this note is to introduce the idea of using wooden blocks in testing the understanding of geological structures. The author uses this method of testing a great deal with pupils in the 4th and 5th form groups that are following courses to C.S.E. as well as with those on G.C.E. courses. Not only has it been found useful in occasional classroom tests but also in practical examinations at the end of the course. An ide;
of the different ways in which the blocks can be used can be gained by considering the following possible test questions, the first three of which are accompanied by diagrams of models:

1. Describe the separate stages in the geological history of the area shown in the block model. (All rocks are to be regarded as of sedimentary origin).

2. Study the structures shown on the block model provided. On your own block show this structure after it has been affected by a vertical fault with a throw of 100 m. The position of the outcrop of the fault plane is shown by the broken line. The height of the blocks represents 400m.

3. By drawing on this block model, complete the structure to show a reversed fault with the downthrown side as indicated by the fault line.

4. Use the plain block provided and draw a structure that consists of an eroded symmetrical syncline cut by a vertical fault which runs at right angles to the axis of the fold.

In the first of these questions the pupil is simply required to examine a block model and describe what it represents. He may, of course, use sketches in his answer to explain parts of his description. In the second example again he is provided with a completed model. His understanding of what happens when rocks are faulted is tested by requiring him to redraw the structure in a faulted condition. The purpose of the third question is similar in that the structure is only completed correctly if the pupil understands what a reversed fault is and how it affects a uniformly dipping sequence of strata. The last question is, perhaps, the most obvious way of using wooden blocks for testing purposes when the pupil has to draw a structure on a plain block.

Peter J. Perkins

Reference
GEOLOGY

The Pool, now called Oceanographer Deep, has the form of a basin which the continental ice ages began. There is some evidence in the cores which have been recovered that the surface temperature of the North Atlantic decreased progressively from that time to the point much later in the Pleistocene at which the continental ice ages began. From the appearance of small marine fossils in the cores, it has been possible to fix the transition to the most recent geological period at about 1,850,000 years ago. There is some evidence in the cores which have been recovered that the surface temperature of the North Atlantic decreased progressively from that time to the point much later in the Pleistocene at which the continental ice ages began. Studies at Woods Hole also suggest that there was a pronounced cooling of the surface of the earth about 900,000 years ago, possibly because of the onset of glaciation on a continental scale.

Although these dates are valuable in themselves the technique by means of which they have been obtained may in the long run be even more important. Its most striking feature is that it has been possible to use purely magnetic measurements to fix the dates at which the various layers of the sediments were formed.

Nature 216, 253-254.

Contributions are anonymous, but each story by Nature-Times New Service is clearly identified.

Extracts from these items have been included regularly in the Welsh Geological Quarterly and copies of some of the earlier issues were circulated to members of the Association after the conference at Keele two years ago. Because of the obvious popularity of these extracts, the Editor feels that they should be issued in a more permanent form and made available to the very many members who have joined the Association in the last two years.

The extracts are, almost without exception, verbatim copies of the first few paragraphs in The Times. References to the original sources are given in parentheses after the quotation.

1967 (October to December)

CONSTANT HOT WATER AT THE BOTTOM OF THE SEA

The Times October 23 1967

A new pool of hot brine at the bottom of the Red Sea has been discovered by the United States Survey ship Oceanographer. According to a statement from the Environmental Science Services Administration in Washington the pool of brine was discovered during a journey into the Indian Ocean.

It lies 340 miles north of the area in which three deep-lying pools of hot brine have already been found.

The Pool, now called Oceanographer Deep, has the form of a basin 300 ft. deep lying at a depth of 4,800 ft. The basin seems to be about a mile by three-quarters of a mile across.

Hot spots like these have excited great interest among oceanographers since the first reports of the discovery of these phenomena in 1964.

For earlier discoveries and measurements see Nature 203, 590-591 (1964); 214, 1,215 (1967).

NEW DATE FOR BEGINNING OF ICE AGES

The Times October 24 1971

A new date for the beginning of the Pleistocene period has emerged from a study of three cores recovered from the sediments on the bottom of the North Atlantic by the research vessel Chain from the Woods Hole Oceanographic Institution.

From the appearance of small marine fossils in the cores, it has been possible to fix the transition to the most recent geological period at about 1,850,000 years ago. There is some evidence in the cores which have been recovered that the surface temperature of the North Atlantic decreased progressively from that time to the point much later in the Pleistocene at which the continental ice ages began. Studies at Woods Hole also suggest that there was a pronounced cooling of the surface of the earth about 900,000 years ago, possibly because of the onset of glaciation on a continental scale.

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Nature 216, 253-254.

THE BOTTOM OF THE SEA

The Times October 25 1967

A vivid description of the appearance of the edge of the continental shelf 150 miles off Cape Cod, Massachusetts, has now been provided by the crew of the American research submersible Alvin on one of its first, really deep descents last year.

The vessel spent more than two hours in a cleft in the edge of the continental shelf called Oceanographer Canyon. The floor of the canyon is at a depth of 1,460 metres, some 400 metres less than the limit of operation of the research vessel.

This descent is of some significance because observations of the bottoms of the really deep oceans have so far been dependent on television cameras operated from the surface. Dredging is commonplace but the samples recovered in this way are often hard to interpret unambiguously.

Several deep descents have also been made by special devices such as the Bathyspheres designed by Jacques Piccard, but the submersibles now coming into service in the United States make possible movement above the ocean bottom.

Science 158, 370-372.

PLOTTING FLOODS BY SATELLITE

The Times October 30 1967

A network of communications satellites which could help in the control of floods, disease of crops and mineral exploration was described last week at the Convention of the American Institute of Aeronautics and Astronautics, Anaheim, California.

The satellites would include colour television cameras and they would orbit the earth over the polar regions.

The network was described by Dr. John Taber, of the T.R.W. laboratory.

Called “earth resources satellites”, the proposed spacecraft would photograph the earth in great detail. Colour photography would be used to distinguish between normal and diseased cotton fields, it will be suggested.

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AID TO EARLY WARNING OF EARTHQUAKE
The Times November 2 1967

A new type of instrument, which may help in devising an earthquake early warning system, has been developed at the Geophysics Department, Cambridge University, in conjunction with the measurement group of the National Physical Laboratory. The instrument incorporates a laser for making recordings over hours or weeks of the build-up of stress within the earth.

The instrument uses the visible red light generated by a helium-neon laser. It works by comparing a standard beam a 100 metres long with two points fixed on the Earth's surface about the same distance apart.


SURVEYOR V REPORTS BACK FROM MOON
The Times November 7 1967

A full account of the appearance of the surface of the Moon has now been provided by the designers of the instruments carried there on September 11 this year by the spacecraft Surveyor V.

One of the simplest of the pieces of equipment carried on Surveyor V has provided one of the most striking of the conclusions reported. Substantial amounts of magnetic dust were found to be sticking to a bar magnet mounted on one of the three landing feet. Comparison with experiments carried out in the laboratory, and with the amount of dust sticking to an unmagnetized bar carried alongside the magnet, suggests that iron is present in the surface dust, most probably in the form of one of the magnetic oxides compounded in a rock similar to a terrestrial basalt.

Science 158, 631.

WHY ICARUS WILL MISS THE EARTH
The Times November 8 1967

The Government is right to have assured Mr. Keith Stainton, Conservative M.P. for Sudbury and Woodbridge, that the earth will not be hit by the asteroid Icarus on June 15 next year.

There is, however, a possibility that a much smaller collision did take place in 1947. This is the conclusion of a group of Russian astronomers who visited the area 350 miles inland from Vladivostock where a swarm of meteorites fell on February 12 that year.

More than 1,000 fragments of that shower of meteorites were afterwards recovered from a patch in the Siberian tundra 1.6 square kilometre in area. More than 200 craters ranging in size up to 27 metres in diameter were found in the region, and fragments of meteoritic material weighing several kilograms were found in some of them.


ISOPOE ‘CLOCK’ FOR DATING SEA SEDIMENT
The Times November 10 1967

The possibility that the radioactive isotope aluminium—26 could be used for fixing the date of ocean sediments in the early Pleistocene is suggested in an argument by Dr. Yuji Yokoyama, working at the French National Centre for Scientific Research at Gif-sous-Yvette, near Paris.

The burden of Dr. Yokoyama’s argument is that the isotope is formed in the atmosphere by the bombardment of cosmic ray particles in much the same way as radioactive car is produced there.

Nature 216, 569-571.

WHERE LIFE MAY HAVE BEGUN
The Times November 10 1967

It has seemed likely for some time that the first forms of life recognizable as men appeared in Africa two million or so years ago. Now it seems that Africa has also provided the earliest traces so far of primitive life.

Two palaeontologists from the German Federal Republic, Drs. A. A. Prachnowski and Manfred Schidlowski, have found traces of chemicals, normally associated with living things in Precambrian rocks from South Africa which are thought to be more than 2,150 million years old.

They have also found microscopic shapes in the same rock which are reminiscent of some contemporary forms of life, but they emphasize that these objects may be accounted for in other ways than by the presence of primitive life-forms more than 2,000 million years ago.

Nature 216, 560-563.

THE GALAPAGOS ON A SEA OF ROCK
The Times November 14 1967

The ocean floor to the north of the Galapagos Islands, just south of the Equator and 10° west of South America, seems to be spreading outwards at a rate of 3 cm. a year.

This is the conclusion of a group of oceanographers from the Lamont Geophysical Laboratory in New York who have used Oceanographic research vessels to make magnetic survey of the Pacific in the neighbourhood of the Galapagos. The technique which has been used is that used in the past few years to demonstrate that the continents have drifted away from each other in the geological past.

Science 158, 775-780.

CREATURES’ 135m-YEAR ANCESTRY
The Times November 16 1967

A suggestion for spreading subterranean shrimp-like creatures through limestone regions of a large part of the central United States, has been worked out by Dr. J. R. Holsinger, of the United States National Museum, Washington. The creature between 4mm. and 20mm. long, live in fresh water. Accord- ing to Dr. Holsinger’s theory, they are derived from an ancestral stock living in shallow coastal waters some 135 million years ago, during the Cenozoic period or even earlier.

The creatures are members of the genus Stygonectes. All species listed in the genus lack eyes and pigments, which suit their underground habitat. They live in fissures in limestone and in underground pools, and are scavengers, feeding on small particles of soil coated with bacterial and vegetable matter.

Smithsonian Institution Bulletin 259, 1967
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APE SKULL FIND IN EGYPTIAN DESERT.
The Times November 17 1967

The discovery of the fossilized skull of an ape in the Egyptian desert 100 kilometres south of Cairo was reported yesterday to the annual conference of the American Society of Vertebrate Palaeontologists at New Haven. The skull, believed to be the oldest of any primate to have been found in the Old World, was unearthed on an expedition to the Egyptian desert led by Professor E. L. Simons, of Yale University.

The interest of the discovery is that it may throw light on the emergence of the primates in the period before the emergence of human-like creatures but at a time when the foundations for their existence were being established.

Nature – Times News Service

EXPLANATION FOR THE EARTH WOBLING
The Times November 17 1967

A possible explanation for the way in which the Earth wobbles on its axis at intervals of 428 days has been put forward by Dr. I. I. Shapiro, of the Massachusetts Institute of Technology, and Dr. G. Colombo, of the University of Padua. They are concerned with a phenomenon known since the 1890's as the "Chandler Wobble", after the astronomer who first described it.

That there should be a wobble of some kind is not surprising. Simply because the earth is flattened at the pole, it should wobble much as does a spinning top. The difficulty is that the known flatness of the earth would suggest that successive wobbling should be separated by intervals of 300 days or thereabouts. The observed wobbling every 428 days is too far from the prediction to be counted consistent with what is known about the Earth, at least if the analogy with a solid rigid body is in any sense correct.


SEARCH FOR THE CHEMICALS OF LIFE
The Times November 20 1967

The need for caution in the interpretation of chemical evidence about the origin of life is the principal theme of an article just published by Professors Eugene McCarthy and Melvin Calvin, of California University, Berkeley. Professor Calvin is visiting professor at Oxford University.

The burden of the argument is that some of the chemicals extracted from ancient rocks, which have recently been considered as proofs of the antiquity of life, may, instead, have been produced by chemical processes not requiring the intervention of living things.

Nature 216, 642-647.

WHY MANGANESE FORMS ON THE OCEAN FLOOR
The Times November 21 1967

Experimental information which may help to account for the occurrence of small nodules containing large amounts of manganese on the ocean floor has been produced by a team of oceanographers at the University of California, at Los Angeles. The team, Drs. B. J. Presley, R. R. Brooks and I. R. Kaplan, have recovered cores of sediments from the bottom of the Pacific off the coast of California and Central America.

The occurrence of large numbers of manganese nodules on the floors of the deep oceans has excited a good deal of interest in the years since the Second World War, partly because of the possibility that these might be recovered mechanically and used as a source of a rare metal.

Science 158, 906. Nature 216, 673-674

WORKING OUT THE SEA'S SALINITY
The Times November 22 1967

A scheme for working out the salinity of the seas in which ancient sediments were formed has been proposed by Dr. Bruce W. Nelson of South Carolina University. The issue is important because of the difficulty of inferring the conditions under which ancient rocks were laid down from the appearance of these materials.

The new method rests on a number of surveys of recent sediments carried out in Chesapeake Bay, and on a chemical analysis for the ratios of the phosphates of iron and calcium in those deposits. The research has exploited the variation of salinity along the length of the estuary of the Rappahannock which runs into the bay.

The salinity may be 20 times greater at some parts of the estuary than at others. Analysis has shown also that the amount of iron and calcium phosphates may vary from one place to another in a way that is not obviously linked with the changing amount of salt in the water.

Even so, the work now completed seems to have demonstrated convincingly that the proportion of calcium phosphate in the phosphate deposits is linked with the salinity of the water. The more saline the water, the greater the proportion of calcium in the phosphate deposits.

Dr. Nelson says that the fraction of calcium phosphate in a sediment can be an extremely sensitive indication of salinity, at least as far as recent sediments are concerned. He claims that it is superior to other geo-chemical methods for estimating the salinity of the water in which sediments are deposited.

Science 158, 917-920

TRACE FOSSILS IN ENGLISH CHALK
The Times November 27 1967

A new catalogue of trace fossils in the chalk sediments of the south of England has been compiled by Dr. W. J. Kennedy and is now published by the British Museum (Natural History).

Bulletin of the British Museum (Natural History) Geological Series 15, No. 3.

MAGNETISM AND SURVIVAL OF THE SPECIES
The Times November 28 1967

The notion that some of the reversals of the direction of the Earth's magnetic field may have been accompanied by significant changes in the viability of particular species has been given another airing by Drs. James Hays and Neil Opdyke of the Lamont Geophysical Observatory. More important, they have now also described a study of a core of sediments from the Antarctic which is more than 16 metres long and appears to span a time interval of 5m. years.

The most productive of the three cores now studied comes from the South Pacific, some 25° east of Cape Horn. It was
have been prompted to carry out a study of sounds associated
used, with some success, for the prediction of rockbursts and
ear. Usually, however, they are too faint to be audible, and
are in principle, in the frequency band accessible to the human
must be detected by means of delicate instruments.

Before a landslip has been known for some time. These sounds,
operations.

The Times December 6 1967

Men and African apes may have shared a common ancestor
as recently as five million years ago. This is the conclusion put
forward by V. M. Sarich and A. C. Wilson, of California
University, Berkeley.

If correct, this conclusion will conflict with the inferences
about the age of differentiation between men and apes which
some anthropologists have made on the basis of fossil studies.

The new study is based on chemical differences between the
serum albumin. The chemical structure of these proteins changes
in the course of evolution just as does the appearance or the
stature of an animal. Chemical differences between the proteins
in the serum albumin of man and, say, chimpanzees, must have
accumulated since the point in time at which these species evolved from a common ancestor.

Science 158, 1,182.

WHEN DID MAN AND APE EVOLVE?
The Times December 8 1967

Although the last Ice Age is only about 10,000 years or so
behind us, uncertainty and even disagreement persist about the
sequence of events that preceded the last melting of the ice.
How long, for example, did the last glaciation continue? How
many glaciations were there altogether? And how long were

recovered by a piston device from the ocean bottom in 2,785
fathoms of water. The core seems to represent an uninterrupted
accumulation of sediments.

Science 158, 1001-1011.

COSMIC RAY TRACKS MICA
The Times December 2 1967

Samples of mica have been found to contain visible defects
caused by the passage of electrically charged particles in
cosmic rays. The details, which are described in the current
issue of Nature by Dr. F. M. Russell of the Rutherford High
Energy Laboratory at Harwell, may be useful as a means of
studying the occurrence in cosmic rays of the particles of
matter called mu-mesons.

At present the mu-mesons in cosmic rays are best studied
by installing equipment for detecting fast electrically-charged
particles beneath a sufficiently thick layer of water or earth so
that other kinds of cosmic ray particles are filtered out. Mine
shafts, lake bottoms and such places as Holborn tube station
are frequently used for this purpose.

Crystals of mica occurring naturally contain evidence of the
passage of these cosmic ray particles, because they have been
buried under a suitable depth of earth and rock for a large
part of their history. Because of the length of time mica
crystals have been buried at these depths, the chance of finding
evidence of the passage of cosmic ray particles is correspond­
ingly increased.

It is relevant that crystals of mica contributed valuable
evidence to the study of radioactivity at the beginning of this
century, chiefly through the study of the so-called telechoic
haloes. These are the patterns of concentric circles, usually
coloured, formed around small particles of radioactive
materials such as radium.

Nature 216, 907-909.

HOW TO PREDICT LANDSLIPS
The Times December 6 1967

A scheme for predicting the time and the place at which
landslides may occur is suggested by two scientists at the
Department of Geological Engineering, University of California
at Berkeley. The technique, which has not yet been used to
detect a real landslide, would depend on the detection of the
sounds known to be associated with but to precede a landslide.

The association of sounds with the period immediately
before a landslide has been known for some time. These sounds,
are in principle, in the frequency band accessible to the human
ear. Usually, however, they are too faint to be audible, and
must be detected by means of delicate instruments.

The authors of the research at Berkeley, John Cadman and
Richard Goodman, explain in an article in Science that they
have been prompted to carry out a study of sounds associated
with landslides by the way in which similar phenomena are being
used, with some success, for the prediction of rockbursts and
other phenomena of a kind frequently encountered in mining
operations.

Science 158, 1,182.

CONTINUING DOUBT ABOUT ICE AGES
The Times December 16 1967

Fossil algae provide ice age temperatures
The Times December 12 1967

The distribution of certain fossils in ocean sediments has
now been used as a means of assessing the temperature of the
ocean surface during the last Ice Age.

In the current issue of Science, Dr. A. McIntyre, of the
Lamont Geological Observatory, describes how he has been
able to tell the temperature of the oceans from the distributions
in deep sea sediments of fossils of organisms in the family of
marine algae known as Coccolithophoridae.

These organisms have inhabited wide areas of the Atlantic
for tens of thousands of years. They have mineral skeletons
stable enough to leave a permanent fossil, while individual
species of the organisms seem to be sensitive to temperature so
that they exist only within narrow ranges of temperature. A
further convenience of these organisms is that they live near
the surface, so that their distribution is directly under climatic
control.


AUSTRALIAN CRATER WAS COSMIC COLLISION
The Times December 15 1967

Geological evidence which confirms that the crater known
as Gosses Bluff in central Australia is a relic of the impact of some extra-terrestrial object has been collected by Dr. Robert
Dietz, of the Institute of Oceanography at Miami, Florida.

Dr. Dietz has been able to uncover a regular pattern of
shattering in rocks for 12 miles around the ring structure in
the central Australian desert, and he interprets this as the
consequence of the mechanical shock after the impact of an
object which may have been several thousand feet across.

This fits in well with earlier suggestions that the structure
is a relic of a massive upwelling of the earth's crust beneath
the point of impact of a large meteorite or possibly a comet.
Structures of this kind are known as astroblemes.

Nature 216, 1082-1084.
the comparatively warm intervals in between? There seems to be quite general agreement that the whole period of what is called Pleistocene lasted for rather more than 2 million years. Very little else seems agreed upon however.

So much is clear from the article in the current issue of *Nature* by Dr. N. J. Shackleton and Dr. C. Turner of the Sub-department of Quaternary Research at Cambridge University. They are concerned with estimating the interval between the last glaciation and the one that preceded it. They have been working with geological samples collected from the bed of an Ice Age lake in Essex.

They disagree quite sharply with what has recently seemed one of the most accurate and promising ways of dating the sequence of events within the Pleistocene—the collection and examination of sediments from the bottom of the deep oceans.


WATER AND THE CRATERS ON THE MOON
The Times December 18 1967

The surprising theory that the maria and gullies visible on the surface of the moon may have been caused by the action of water at some time in the geological past has been put forward by Professor Harold Urey, of the University of Southern California. Professor Urey has, in the past few years, been deeply concerned with theories of the origin of the Solar System, particularly from a chemical point of view.


DID MAGNETISM STIMULATE EVOLUTION?
The Times January 8 1968

A reassuring calculation has been made of the extent to which living things on the earth would have been exposed to increased doses of radiation from cosmic rays at times in the geological past when the direction of the planet's magnetism was undergoing a reversal.

The calculation will cast doubt on a theory recently in fashion that the reversal of the earth's magnetism would be marked by its temporary disappearance, an accompanying increase in the natural background of radiation, a consequent increase in the rate of genetic mutation and, therefore, an increase in the rate of biological evolution.

There is no dispute about the fact that the earth's magnetism does reverse its direction at intervals of a few hundred thousand years. The magnetization of rocks in the geological past can be used to infer the direction of the magnetic forces at the time of their formation. This record shows that there have been nine such reversals in the past 4 million years. It is also beyond dispute that the pattern of magnetic forces around the earth serves as a means of keeping out a proportion of the cosmic rays which would otherwise reach the planet's surface.

*Nature* 217, 46-47

DATING THE GLACIERS OF ANTARCTICA
The Times January 16 1968

Study of the volcanic rocks in Taylor Valley, Antarctica, has shown that major glaciation took place at least 2.7 million years ago. This is the result of a survey carried out by Dr.

MORE DESERTED BURROWS IN CHALK
The Times December 27 1967

Further observations have been made on the nature and origin of burrows in chalk deposits. Dr. R. G. Bromley, of University College, London, has been investigating the extensive branching systems of burrows that have been preserved in the chalk hardgrounds of Europe, south-west Asia and north Africa, and concludes that they were probably formed by the crustacean *Thalassinides*. His findings are reported in the current issue of the *Journal of the Geological Society of London*.


EVOLUTION OF CRATERS ON THE MOON
The Times December 28 1967

The regular and rounded craters on the surface of the moon seem not to have begun like that. The most detailed analysis so far of the photographs of the moon's surface recovered by the Lunar Orbiter rockets launched from the United States suggests that craters begin as irregular structures which become rounded with the passage of time.

The photographs so far obtained in the course of a programme intended, among other things, to suggest suitable landing sites for the first American astronauts, cover 8 per cent. of the visible surface of the moon—that pointing towards the earth. The analysis of the photographs described in the current issue of *Science* has been carried out by Dr. N. J. Trask and Dr. L. C. Rowan of the United States Geological Survey.

*Science* 123, 1968

R. L. Armstrong of Yale University, and his colleagues, and reported in this week's *Science*.

The result ties in well with the recent estimates of the duration of the Pleistocene Period based on the analysis of sediments recovered from the bottoms of deep oceans. The most recent of these studies have indicated that the temperature of the oceans may have begun to fall sharply between 2,300,000 and 2,500,000 years ago. The antiquity of the ice in Antarctica known from earlier geological studies has for some time been one of the factors in favour of a longer estimate for the age of the Pleistocene.

*Science* 159, 187.

HOW TO RECHARGE UNDERGROUND WATER WELLS
The Times January 16 1968

The feasibility of recharging an underground aquifer by means of a well sunk to the stratum has been proved by experiments carried out at The Dalles, Oregon, by a team of hydrologists with the United States Geological Survey. The interest of this development is that it may be possible in some areas to use partially depleted underground aquifers as long-term storage reservoirs in regions where natural water is plentiful but intermittent.


AERIAL LOOK AT GEOLOGICAL STRUCTURE
The Times January 17 1968

The use of aerial photographs for studying the structure and origin of the pre-Cambrian rocks in East Africa has been
The Geology of the East Midlands

Edited by P. C. Sylvester-Bradley and T. D. Ford

This work is a compendium of nineteen chapters by seventeen authors, each an acknowledged expert in his own field. It is designed to appeal to teachers, students and research workers alike, in providing a chronological account of the geological history of the East Midlands over the last 1000 million years. All the geological formations present in the area are covered in a series of review chapters. Each of these sets out to survey the present state of knowledge of a formation, to bring up to date the interpretation of that knowledge, to incorporate the results of recent research work, and to indicate the nature and extent of the gaps in the present state of knowledge. The chapters thus provide the teacher with a survey of each formation in a comprehensive and easily digestible form; they provide the visiting scientist with the basic facts concerning his own specialism; they provide the student with the facts necessary for his studies, and make clear the wide possibilities for further research. The increasing interest in the 'hidden' geology at depth in the East Midlands is covered and possibilities for discoveries of economic interest assessed. Each chapter is accompanied by maps, charts and correlation tables, and by a list of localities where the various formations may be studied, with comprehensive bed-by-bed guides where necessary. A bibliography of about 1000 works relating to the geology of the East Midlands is included.

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worked out by Dr. John V. Hepworth of the Institute of Geological Sciences, South Kensington. Some of the applications of the method, which should make it possible to distinguish between masses of rock with different geological histories, appears in the current issue of the Quarterly Journal of the Geological Society of London.

Although the use of aerial photographs for geological purposes is not new, the interest of Dr. Hepworth's study is that it provides a powerful demonstration of how to glean precise information from them. By comparison with field surveys of course, the technique has great advantages. For one thing, it is possible to obtain synoptic surveys of large and inaccessible areas in a comparatively short time.


SICILIAN EARTHQUAKE A SURPRISE
The Times January 18 1968

In spite of the significant death roll in the Sicilian disaster, the earthquake with a magnitude of 5.6 was small in comparison with the largest earthquake. In other words, in terms of energy it was 1,000 times less strong than the earthquake in Messina in 1908, but approximately equivalent to that in Skopje in 1963, when £500m. worth of damage was caused.

Because this part of Sicily was not believed to be susceptible to earthquakes, the seismosity of the area was not well known. It has now been found, however, from the profile of the island that there are certain small faults, and the epicentral area is characterized by recent geomorphological features, most of them attributable to earth movements, which occurred during or since the Pleistocene Period.

Until now the east coast of the island has been the most likely spot for earthquakes. This week's shocks, in an area which is geologically young and seismologically unstable, have therefore come as a surprise to seismologists. In such an area, movements of the earth can be large and comparatively easy, and because of this there is unlikely to be a build up of stresses that would result in an earthquake.

Nature – Times News Service

DRILLING DEEP IN CARDIGAN BAY
The Times January 20 1968

A borehole 2,000 ft. deep is being sunk in the north-east corner of Cardigan Bay to determine the nature of rocks and other material under the sea. This is part of a joint project, conducted by the University of Wales at Aberystwyth and the Institute of Geological Sciences, under the direction of Professor A. Wood and Dr. A. W. Woodland. The project, which is costing some £30,000, is being financed by a grant of £4,500 from the Natural Environment Research Council and by the Institute of Geological Sciences.

Cardigan Bay is particularly interesting because the rocks found there are not the same as those on the Welsh mainland or in Ireland. The geophysics of the area has been investigated by a team from Birmingham University, and the new project is a continuation of that work.

What the Birmingham team found, by measuring the velocity of seismic waves from artificial explosions, is that there is a basin of low-velocity material lying offshore extending to a depth of about 1,000 feet. This is surprising because the Llanbedr slates, which lie nearby, are dense, fine-grained rocks formed by compression of shales and clays. From this it has been concluded that there is a large fault or downthrow just west of the Merioneth coast.

Boring started in October, 1967, and by December it had penetrated to 800 ft. Of this, the upper 14 ft. consists of unconsolidated sand, followed by boulder clay to a depth of 192 ft. Banded material—mainly silts and clays—extends throughout the rest of the succession. According to Professs Wood, occasional thin layers of plant material have been found and one sample has yielded the remains of a freshwater algae called Chara. Dr. M. R. Dobson has tentatively suggested that the first 800 ft. may be of Pleistocene age, but it has also suggested that it could be older than that.

Nature – Times News Service

USING CORAL TO WORK OUT SEA LEVEL
The Times January 23 1968

Analysis of radioactivity in coral rocks in Barbados has used to fix with unfamiliar accuracy the three times during the past 250,000 years at which the sea-level has been comparable with the height of the sea at present. This work is important because it suggests how radioactive analysis might be used to follow the alternations of high and low sea-levels that accompany the successive thawing and refreezing of the glacial ice.

Previous attempts to fix the dates of the periods of high sea-level has involved various fossils found in rocks deposited from the sea. On the basis of research like that, it has been inferred that the height of the sea was comparable with that at present 80,000 and 12,000 years ago.

The radioactive analysis used in this work involves the measurement of the proportions of the isotopes uranium-235 and thorium-230 in geologically ancient rocks.

The first of these isotopes decays into the second by spontaneous radioactivity at a known rate. The method is potentially valuable because it can be applied to materials older than the 50,000 years or so that represents the limit of the ages determinable by analysis for radioactive carbon. One drawback is that the method cannot be applied to materials which natural radioactive materials are rare, which is why it most easily applied to materials such as coral formed by deposition from the sea.

Science 159, 297

ORGANIC CHEMICALS FROM ROCKS
The Times January 25 1968

How did the primitive earth acquire hydrocarbons? And why are there substantial amounts of carbon in some kind of meteorites? It is at least possible that these materials were produced by a chemical reaction between hydrogen gas and calcite, a form of calcium carbonate commonly found in association with limestone.

One immediate consequence of this suggestion, which is from experiments carried out at the University of Georgia the Lawrence Radiation Laboratory at Livermore, California is that it will complicate the lives of those who seek to link the occurrence of hydrocarbons in pre-Cambrian rocks, for example, with the origin of life.

In the American experiments samples of calcite have been heated in closed tubes filled with hydrogen under a variety...
conditions. Chemical reaction between hydrogen and calcite sets in at about 500°C. Water and methane were always found among the products of the reaction, and sometimes ethane and carbon monoxide as well. One surprising feature of the chemistry is that carbon dioxide was never found in the reaction vessels.

The most interesting products of these reactions, however, were the deposits of carbon—closely resembling graphite in physical properties—and of heavy hydrocarbons, formed under some conditions.

Science 159, 317

COCOS ISLAND AS OCEANIC STEPPING STONE
The Times January 27 1968

How did living things first reach the Galapagos Islands? This has been a puzzle ever since Darwin found that the islands, 700 miles west of South America, were populated by strange forms of tortoises and iguanas which had evolved in isolation for several millions of years. There is now some evidence, suggestive though not conclusive, that Cocos Island, halfway between the mainland of Central America, 900 miles to the north, and the Galapagos Islands, may have served as some kind of a stepping stone.

This possibility has been frequently considered in recent decades. Other theories suggest that some tens of millions of years ago, a long peninsula reached out from Central America to within 200 km. of the islands.

To distinguish between this and other possibilities, it is clearly important to determine the age of the rocks on Cocos Islands. Dr. G. B. Dalymple of the United States Geological Survey and Dr. Allan Cox of Stanford University have collected samples of the lava lying on the surface of the island and estimate the age of this material by radioactive methods based on the spontaneous decay of a potassium isotope into argon gas.

The result tends to support the view that Cocos Island itself may well be old enough to have served as a stepping stone.

Nature 217, 323-326

VOLCANIC FLOW ON THE MOON
The Times January 30 1968

Photographs of the other side of the moon which have been recovered from the United States Lunar Orbiter satellite seem to have provided convincing evidence of phenomena resembling lava flows on the surface.

In the current issue of Science there is a photograph of an unnamed crater lying at 128° E. and 28° S. from which Dr. S. B. Hixon has been able to come to several conclusions.

From the general topography of the surface in the neighbourhood of this crater, several independent flows of material are recognisable from the shapes of their perimeters. As with coal tips like Aberfan, so on the surface of the moon, a flowing heap of rock ends up by standing on what seems to be a scalloped base.

Science 159, 420

DO EXPLODING STARS KILL LIFE?
The Times January 31 1968

The notion that cosmic rays flung off by the exploding stars called supernovae may have been responsible, in the geological past, for the disappearance of certain forms of life on earth has been revived by two scientists from the United States, Dr. K. D. Terry of Kansas University and Dr. W. H. Tucker of Rice University, Texas.

This was first suggested some years ago by the Russian astronomer Shklovsky. The incentive for the new theory is a recalculation of the processes responsible for supernovae explosions.

There is now no question that supernovae are probably responsible for a substantial fraction of the cosmic rays reaching the earth, possibly for all of them. The essence of the theory which Dr. Terry and Dr. Tucker have put forward is that supernovae exploding within 100 light years or so of the solar system would deliver such large quantities of cosmic rays on to the surface of the earth that living things, particularly animals, would be grievously harmed and even destroyed.

If their calculations are correct, occurrences like these might be expected every 10 or 100 million years or so—often enough to account for the way in which certain groups of animal species have disappeared suddenly from the fossil record.

Some years ago it seemed reasonable to suppose that a supernova explosion was really a gigantic thermonuclear explosion in which hydrogen and other materials in the centre of the star would be detonated by increasing pressure and temperature.

Now it seems more likely that the catastrophic explosion of a star which is recogniseable as a supernova is a consequence, not of thermonuclear energy conversion, but of the collapse of the inner core of a star under the forces of self-attraction due to gravity.

Science 159, 421

MOVEABLE CORALS FOUND ON REEF
The Times February 5 1968

Corals which are usually considered to be fixed to the coral reefs which they help to build have been found moving about freely on the Australian Great Barrier Reef. One species of these corals even lives in association with worm-like creatures which help to pull it along.

These findings have emerged from studies carried out at Lizard Island, on the northern half of the Great Barrier Reef, by Dr. T. F. Goreau of the University of the West Indies and Professor C. M. Yonge, of Glasgow University.

Nature 217, 421-423

FOSSIL SQUID 300 MILLION YEARS OLD
The Times February 6 1968

The fossil of a small marine animal, thought to belong to the order that includes squids, has been found to be enclaved in Mazon Creek, Illinois. The rocks in which it was embedded were formed in the Pennsylvanian era of the earth's history, a geological age which began about 310 million years ago. The oldest fossil squid known hitherto is only 150 million years old.

The fossil, about an inch long, is described by Dr. R. G. Johnson and Dr. E. S. Richardson, of Chicago University, in the current issue of Science. It has 10 tentacles, arranged in a crown, in the centre of which can be seen a black oval area which may have been an ink sac. The tentacles are lined with a double row of minute hooks.

Science 159, 526
DRILLING THROUGH THE ANTARCTIC ICE CAP
The Times February 12 1968

American scientists have for the first time succeeded in drilling through the Antarctic ice to the bed-rock beneath. The drillers, from the Cold Regions Research and Engineering Laboratory at Hanover, New Hampshire, reached the rock on January 29, after drilling 7,100 ft. deep. The drilling began in November, 1967.

The ice cores should provide a great deal of useful information about the history of the earth. Preliminary investigation has shown two layers of material in the cores at depths of 4,370 and 4,627 ft., where the ice is probably 10,000 and 14,000 years old. The material appears to be volcanic ash, and the research workers will be trying to establish whether the deposition of the ash was the result of worldwide or only local volcanic activity.

The last 18 ft. of the core contains dirty ice with grey and black rock fragments up to 2½ in. in diameter, tentatively identified as volcanic material. Detailed analysis is expected to provide information about the rate of snow accumulation in the Antarctic, seasonal temperature variations and average annual temperatures. Air trapped in the ice will provide information about the composition of the Antarctic atmosphere over the last 100,000 years or so. Meteorite particles embedded in the ice should provide evidence of the rate at which meteorites have been arriving at the earth's surface since ancient times.

Nature – Times News Service

INFRA-RED SURVEY FROM THE AIR
The Times February 13 1968

Infra-red images of the land are being used to reveal variations of temperature between different features of the terrain. One striking example of how this works has been provided by Mr. R. E. Wallace and Mr. R. M. Moxham, of the United States Geological Survey, Mernlo Park, California, who have been investigating the San Andreas fault system in the Carrizo Plain area of California by this technique and have found that, as well as showing the fault line, features such as soil moisture, nature of the rocks and movements in the fault can be identified.

The fault itself is more than 600 miles long. It is a fracture in the earth's crust which has been responsible for a number of earthquakes. During the great earthquake of 1857 the beds of streams in the Carrizo Plain area were shifted as much as 30 ft. by movements in the fault line.

Wallace and Moxham say that cumulative shifts of up to 3,200 ft. can still be seen in the displacement of valleys crossing the fault, for example, and they suggest that the total cumulative shift in the fault since prehistoric times might be hundreds of miles. It is hoped that studies of past movements along the fault line will aid earthquake prediction techniques that are being developed.

U.S. Geological Survey Professional Paper 575-D. p.147

FOSSILS SHOW MOVEMENT OF THE EARTH
The Times February 15 1968

There is now further evidence that the land on the western seaboard of California has moved in relation to the rest of the state. A sideways shift of about 200 miles along the San Andreas fault line has been put forward to account for the anomalous distribution of Miocene fossils in the San Francisco area of California.

On the west side of the fault, the warm-water mollusc Turritella inezana has been found in the Point Arena area, about 100 miles north of San Francisco, while on the east side of the fault the most northerly area in which this mollusc has been found is near San Benito, about 100 miles south of San Francisco and 200 miles south of the limit on the west. These findings by W.O. Addcott of the United States Geological Survey, reinforce earlier theories that a large movement to the right occurred after the early Miocene period.

U.S. Geological Survey Professional Paper 593-D

VOLCANIC LAVA ON THE MOON
The Times February 19 1968

Further evidence of volcanic activity on the moon has been extracted from the photographs returned to the earth from the American moon satellite Orbiter V. An interpretation of some of these photographs published in the current issue of Nature shows that volcanic activity must have played an essential part in the formation of the crater Tycho.

The crater, named after the sixteenth-century Danish astronomer Tycho Brahe, is a prominent structure 90 km. across and lying on the south-east part of the moon. It is conspicuous especially at full moon, not merely because of its size but because there is a pattern of bright streaks apparently radiating outwards from the crater. These streaks consist of material lying on the surface of the moon, apparently after ejection from the crater.

The photographs of Tycho obtained from Orbiter V have been analysed at the Lunar and Planetary Laboratory of Arizona University by Dr. R. G. Strom and Dr. Gilbert Fielder. Dr. Fielder is on leave from the London University Laboratory.

It seems clear that the lunar surface to the north and northwest of Tycho has many of the characteristics of lava flows. Six quite distinct flows of surface material have been picked out in the photographs of Tycho. They range in length from 3 km. to 20 km. One of them is 6 km. wide. Some of the flow of lava appears to have been towards the walls of the crater and five of the six flows appear to have originated from smaller craters which have eventually been engulfed by the lava. The material from these craters has a rope-like appearance, which suggests that it could not have been volcanic ash or solid debris.

Nature 217, 611-615

EVIDENCE FOR METEORITE FORMATION
The Times February 26 1968

Observations which throw some light on the origin of meteorites have been reported in the current issue of Nature by Mr. J. F. Kerridge of Birkbeck College, London. Meteorites are the rock-like objects from interplanetary space that penetrate the atmosphere of the earth and reach the ground without burning up by frictional heating. So far, they are the only objects of extra-terrestrial origin that can be examined in the laboratory.
The new observations which Mr. Kerridge has described are based on a study of small samples of a meteorite which fell near Orgueil, France. This meteorite is interesting because there is some reason for thinking that it consists of an aggregate of primitive cosmic material which came together in the early stages of the formation of the solar system. Mr. Kerridge has examined fragments of this meteorite, using an electron microscope, and has shown that it contains among other things a mineral called olivine.

This is important because there is evidence in the geological history of the earth that olivine and materials like it are formed only at comparatively high temperatures. Indeed, it looks from observations that Mr. Kerridge has described that the Orgueil meteorite was subjected to a temperature of at least 500°C at some stage. Mr. Kerridge says this is incompatible with the notion that the meteorite consists of unaltered primitive cosmic material.

Nature 217, 729-730

SMALL SEISMIC DISTURBANCES OBSERVED
The Times February 29 1968

The most detailed study so far of the origin of the disturbances of the earth's crust known as microseisms has been provided by an analysis of records kept at the large installation of seismographs built originally for the detection of atomic weapons tests in Montana, United States.

The results of the study, which have been published in the current issue of the journal Science, are based on records obtained from more than 500 independent seismographs distributed over 200 sq. km. of Montana. Microseisms are vibrations of the earth's crust which travel round the world in much the same way as do the seismic disturbances produced by earthquakes or explosions.

Science 159, 872

RARE HORSE GIVES CLUES TO EVOLUTION
The Times March 2 1968

The Przewalski horse is one of the rarest animals in the world. The latest International Zoo Yearbook says that only 64 male and 83 female Przewalski horses were living in 35 zoos between February and August last year, although there may still be a few more in the wild. It is believed to be the horse pictured by Stone Age man in the caves of Lascaux 10,000 to 15,000 years ago, and it is considered by most authorities to be the ancestor of modern breeds.

The Przewalski horse is particularly interesting to zoologists working on the evolution of horses. Dr. R. M. Statcher, of the Western Reserve Medical School, Cleveland, Ohio, is interested in the anatomical characteristics of the Przewalski horse which distinguish it from other members of the horse family. In a recent paper in Acta Zoologica et Pathologica, he gives results of vertebrae counts from the spines of 61 skeletons of the Przewalski horse, and he compares these with similar counts from four other horses—the domestic horse, donkey (E. asinus), mule (E. caballus, E. asinus) and hemione (E. hemionus).

He also attempts to relate these figures to the number of pairs of chromosomes to a cell in each horse. Dr. Statcher has indeed found that there is a correlation between the chromosome complement and the vertebrae in the five horses. Compared with the other horses, Przewalski horses have the longest thoracic segment of the spine, the next to the longest lumbar segment, the shortest sacral segment, and the next to the smallest number of lateral joints in the lumbar spine.

It also has the highest chromosome count.

Acta Zoologica et Pathologica No. 43, p.45

JAWBONES OF EARLY HOMINID ARE FOUND
The Times March 4 1968

The continuing controversy about the earliest ancestors of human beings will be reinforced by a new find now reported by Dr. Louis Leakey.

In January, 1967, Dr. Leakey, who was at the National Centre for Pre-history and Palaeontology in Nairobi, announced the finding of fossil jawbone fragments of a very early member of the family to which human beings belong—the Hominidae. This find was believed to put the ancestry of human beings back to about 20 million years ago—a much longer period than had previously been assumed.

Dr. Leakey named his new finds as belonging to Kenyapithecus africanaus. The deposits in which they were found were dated by radioactive methods and placed in the Miocene period. The earliest fossils previously recognised as belonging to the Hominidae came also from east Africa, and were given a date about 14 million years ago.

Nature 217, 827-830

UNUSUAL CRATERS ON THE MOON
The Times March 6 1968

Close-up photographs of the moon from automatic spacecraft now suggest that both volcanic and meteoric processes were involved in moulding the lunar surface. For years astronomers have debated the origin of lunar craters. One school favoured the view that most of them were formed by the impact of meteorites; others believed that volcanic processes must be responsible. The controversy still continues to some extent however, because the appearance of volcanic and impact craters can be very similar.

Three astronomers working at the Air Force Cambridge Research Laboratory, Massachusetts, have produced evidence of a volcanic origin for a relatively rare type of lunar crater. The astronomers are W. Salisbury, J. E. M. Adler, and V.G. Smalley, and their report is included in the current issue of Monthly Notices of the Royal Astronomical Society.

The Massachusetts group used particularly clear photographs taken by a telescope in Arizona to study what are known as dark-haloed craters. These are small craters—usually less than 5 km. across—which are unusual because they are surrounded by a halo of dark material.


WHEN THE YEAR HAD MORE DAYS
The Times March 9 1968

The fine ridges that can be seen on the surface of certain corals and seashells probably correspond to the annual, monthly and even daily growth of an animal. By counting the ridges on two species of fossil shells Professor W. B. N. Berry and Dr. R. M. Barker of California University, have estimated that in
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the Cretaceous period of the earth’s history (135 to 75 million years ago) there were 370.3 days in the year.

The suggestion that fossil shells throw some light on the length of ancient days was first made by Professor John Wells, of Cornell University. The ridges on shells are often said to be caused by temperature variations, changes in diet and other environmental factors. Writing in *Nature* five years ago, Professor Wells described how he had marked off a year’s growth on a species of living coral and counted the number of ridges. To his gratification he found that there were about 360, to him a sure sign that the ridges represented the daily growth of the coral.

Professor Wells went on to examine fossil corals about 400 and 300 million years old and found that on average their annual growth rings contained about 400 and 390 rings respectively.

This indication of more days a year in earlier times ties in well with astronomical calculations. These suggest that although the period of the earth’s rotation round the sun has remained constant, the earth’s rotation about its axis has been gradually slowing down. The energy dissipated by tidal forces on the surface and perhaps the interior of the earth is thought to have produced a slowing down in rotation of about two seconds every 100,000 years. If days were shorter in earlier times, there must have been more days in a year, and calculations suggest that there were 424 days in a year 600 million years ago, decreasing steadily to the 365 enjoyed today.

*Nature* 217, 938-939

AMINO-ACID: A LABORATORY SYNTHESIS
The Times March 12 1968

A discovery that fills an important gap in the overall picture of how biological molecules arose on the earth is reported by G. Steinman, A. C. Smith and J. J. Silver in the current issue of *Science*. They have shown that the sulphur-containing amino-acid called methionine is produced when an aqueous solution of ammonium thiocyanate, a simple inorganic chemical, is irradiated with ultraviolet light.

In primeval times, before life began, the earth’s atmosphere almost certainly contained varying amounts of such gases as hydrogen, hydrogen cyanide, methane, ammonia, and hydrogen sulphide. Chemically, this must therefore have been a reducing environment and it seems reasonable to believe that amino-acids arose from the reaction of water with the condensation products of these gases. Once these biological molecules had appeared, life could evolve.

*Science* 159, 1108

AMPHIBIAN FOSSIL FROM ANTARCTICA
The Times March 14 1968

A fossilized fragment of the jaw bone of a large amphibian has been discovered in Antarctica. The discovery, announced in New York yesterday, has been hailed as one of the most important fossil finds of this century.

It is the first fossil of a higher vertebrate to be discovered in Antarctica and it indicates that land vertebrates once inhabited the continent. The discovery has profound implication for the theory of continental drift.

The fossil is only 2¼in. long and has been identified as part of the jaw of a labyrinthodont amphibian by Dr. Edwin H. Colbert, Curator of Vertebrate Palaeontology at the American Museum of Natural History. Labyrinthodonts are a major group of extinct amphibians which had very characteristic teeth. The dentine and enamel layers of the teeth were highly infolded so that when they are sectioned they have a complex labyrinthine structure.

Labyrinthodonts are of special interest to palaeontologists because they may well have been ancestral to all the other classes of land vertebrates.

*Nature* – Times News Service

HOW MAN CHANGES VEGETATION
The Times March 15 1968

Pollen found in peat taken from different levels of Borth Bog, in North Cardiganshire, has disclosed that man was most destructive to the forest in this area during the Iron Age and Roman periods and between the fourteenth and eighteenth centuries.

Dr. P. D. Moore, of King’s College, London, has analysed pollen from Borth Bog, on the southern side of the Dovey estuary, which is to be a national nature reserve, and from the peat which covers higher ground in this part of Wales.

*Nature* 217, 1006-1009

MOLTEN ROCK UNDER JAPAN
The Times March 19 1968

The crust of the earth under Japan may be made of layers of very soft material, possibly even molten, interleaved between layers of harder rock. This conclusion is based on measurements of shock waves in the ground generated by earthquakes, and is reported by Dr. Keiiti Aki, of the Massachusetts Institute of Technology, in the *Journal of Geophysical Research*.

Dr. Aki used a seismograph to study earthquake shock waves in Japan. Briefly, all a seismograph does is to detect any movement of the ground, magnify the movement in some way, and record it in some permanent form.

Because Japan is an earthquake zone, it has a dense network of more than 100 seismograph stations, operated by the Japan Meteorological Agency. These stations monitor the whole of the country and, because there are large numbers of earthquakes occurring in the earth’s crust beneath Japan, very precise measurements of the shock waves can be made.

Measurements of seismic waves from earthquakes beneath Japan, made by the Japanese seismograph network, show inconsistencies in the behaviour of two kinds of seismic waves—known as Rayleigh and Love waves. This indicates the presence of some peculiarity in the earth’s crust under Japan. The essence of the problem is that the speed of the Love waves is too great to be explained by any theory that can account for some features of the Rayleigh waves.

Writing in the *Journal of Geophysical Research*, Dr. Aki resolves this problem by assuming that the crust under Japan is made up of alternative layers of hard and soft material. If 2 per cent of the thickness of the crust beneath Japan consists of soft material, the measurements of the seismic waves can be accounted for.

*Journal of Geophysical Research*, 73, 585
OOZE ON THE FLOOR OF THE OCEAN
The Times March 19 1968

Calcareous and siliceous deposits cover large areas of the ocean floor. They consist largely of the remains of small animals, Foraminifera and Radiolaria, which live in the plankton in the surface waters and on dying settle to the ocean floor.

Foraminifera usually have shells of calcium carbonate. Radiolaria do not have a shell, but have instead a central capsule and usually a skeleton of spicules. In most Radiolaria these spicules are made of silica.

The processes leading from the living planktonic stage to sediments on the ocean floor is not fully understood. Last year, Dr. W. H. Berger, of the Scripps Institution of Oceanography at San Diego, California, announced that selective solution of foraminiferal shells occurred at depths, and this alters the composition of the foraminiferal ooze.

Science 159, 1237

A GRAVEYARD FOR FROGS
The Times March 21 1968

A deposit containing several thousand fossil frogs has been discovered in Makhtesh Ramon, Israel. This large collection of fossils should provide very detailed information about the evolution and development of pipid frogs. Species of this family are still living today in tropical and subtropical regions of South America and Africa.

Bulletin of the Museum of Comparative Zoology Harvard University

VARIATIONS IN PATAGONIAN GLACIERS
The Times March 29 1968

The glaciers of the Patagonian ice fields in Argentina have advanced and retreated three times during the past 10,000 years. According to a study carried out by John H. Mercer of Ohio State University, the movements of the glaciers occurred at the same time as similar movements in the northern hemisphere. This confirms the view that the advance and retreat of glaciers, at least in recent times, is a worldwide phenomenon.

American Journal of Science 266, 91

DATING ICE AGE EBB AND FLOW
The Times April 2 1968

The use of oceanic sediments for following the ups and downs of temperature during the Pleistocene Period has now led to a rather detailed reconstruction of the geological history of the past 120,000 years.

This argument, based chiefly on cores of ocean sediments collected from the Indian Ocean, is published in the current issue of Science by Dr. William E. Frerichs of the Esso Production Research Company at Houston, Texas.

Although there is at least a possibility that Dr. Frerich's conclusions, which depend on the occurrence of certain kinds of marine micro-fossils, may yet be linked with geological observations of a more conventional kind, geologists will no doubt wish for this to be done before throwing their hats in the air.

In the Indian Ocean and the Bay of Bengal, the end of the Pleistocene Period seems to have come between 8,630 and 8,920 years ago. Dr. Frerich's reason for this assertion is the sharp increase in the density of the micro-fossils of the creatures called radiolarians which occurs at just that point. He acknowledges that his date is somewhat later than those obtained from studies of other kinds of marine microfossils, and which usually place the ending of the Pleistocene between 11,000 and 12,000 years ago.

Science 159, 1456

EXPLAINING THE IRREGULARITIES IN OCEAN FLOOR
The Times April 3 1968

The ocean floors are slowly spreading outwards from the central ridges of the Atlantic and Pacific, while new material is being thrust upwards to form the crest of the ridges. This process may not have gone on at a constant rate; a recent study of the North Atlantic suggests that between 10 million and 40 million years ago the ocean floor ceased to spread.

The spreading of the ocean floor is most vividly demonstrated by its magnetic properties. On either side of the central crests it is composed of alternate strips of positively and negatively magnetized rock. Dr. F. J. Vine and Dr. D. H. Matthews of Cambridge University suggested five years ago that the strips were caused by the spreading of the floor. As molten rocks cool they become magnetized in the direction of the earth's magnetic field.

Every few hundred thousand years or so, in recent times at least, the earth's magnetic field has reversed its direction. Dr. Vine and Dr. Matthews pointed out that if spreading of the ocean floor occurred, then the new material that drifts away on both sides of the crests would be positively and negatively magnetised according to the magnetic field prevailing at the time.

A question of principal interest is whether the spreading of the floor has taken place at a constant rate. If it has, then the layers of sediment deposited on top of the ocean floor should become steadily thicker as one moves away from the crests of the central ridges.

Writing in this week's Nature, Dr. E. D. Schneider and Dr. P. R. Vogt, of the United States Naval Oceanographic Office, state that the sediment is not distributed in this uniform way. On all crossings of the North Atlantic at various latitudes they used seismic reflection to collect data on sediment thicknesses. They found that the sediment covering the central ridges was very thin but that on the immediately adjacent flanks of the ridges was between twice and five times as thick.

Nature 217, 1212-1222; Science 156, 1590

COMPUTER SIMULATES LUNAR CRATERS
The Times April 24 1968

A computer at the laboratory of the United Kingdom Atomic Energy Authority at Culham, Berkshire, has been used to study the way in which craters are formed on the surface of the moon. The computer was programmed to simulate plan views of the lunar surface, which were compared with photographs taken by the American Ranger spacecraft.

One of the scientists responsible for this work is Mr. C. A. Cross, an amateur astronomer, of Northwich, Cheshire. In the current issue of the Monthly Notices of the Royal Astronomical Society, Mr. Cross and Mr. D. L. Fisher describe how the computer at Culham—an English Electric KDF 9—was
programmed to draw diagrams, made up of circles of various sizes and in various positions, to represent the distribution of craters on the moon. Mr. Fisher was, until recently, a member of the computing laboratory at Culham.

Because the position of the simulated craters, which were placed at random, closely resemble the distribution of actual craters, it seems likely that the craters on the moon were formed in a random fashion.

Mr. Cross said this may be evidence in favour of the theory that the lunar craters are caused primarily by the impact of meteorites. He pointed out that meteorites may be expected to produce a random distribution of craters, whereas if volcanic activity is responsible the distribution is not likely to be random.

Monthly Notices of the Royal Astronomical Society

WERE THERE SEAS ON THE MOON?
The Times April 29 1968

The notion that certain dark rocks on the moon consist of volcanic lava has been challenged by Dr. John Gilvarry, of Stanislaus State College, California. He says there is evidence that seas used to exist on the moon, and that the dark rocks are marine sediments.

This conclusion, likely to be controversial among astronomers, is based on measurements and photographs of the moon made by spacecraft. The dark rock in question is the material on the floors of the lunar maria—broad flat plains, which cover half the visible side of the moon.

Nature 218, 336-341

ANOTHER STEP TOWARDS LIFE
The Times May 7 1968

Adenosine monophosphate, one of the most essential molecules in the biochemistry of living organisms, could have been formed spontaneously under the conditions thought to exist on the primitive earth. This finding is a further step forward in the attempt to explain how life on earth began. The result is reported by Dr. Cyril Ponnamperuma and his colleagues at the Ames Research Centre, California.

At first sight it is hard to understand how the ordered chemical machinery of life could have evolved from inorganic matter by the known laws of physics and chemistry. Indeed, the history of that evolution may never be exactly reconstructed but the possibility of doing so was dramatically shown by S. L. Miller of California University in 1953.

He passed electrical sparks through a chamber containing the simple gases, such as ammonia, methane and water vapour which probably composed the primitive atmosphere. Analysis of the resulting sludge showed that several kinds of amino-acid had been formed. Amino-acids are the units from which proteins are constructed; Miller's experiments implied that these essential prerequisites for life could have arisen under natural conditions.

Numerous experiments since then have established that many molecules of biological importance can be formed under conditions made to simulate those of the prebiotic earth. So far, these include amino-acids, polypeptides, adenine, guanine, certain sugars and molecules that possess the same basic structure as do haemoglobin and chlorophyll. Dr. Ponnamperuma and his colleagues have now shown how an important biochemical process, that of phosphorylation could have occurred under primitive conditions.

Nature 218, 442-443

NEW FACTS ON MOON ROCKS
The Times May 7 1968

First comparisons of chemical and magnetic data transmitted from the moon by Surveyor 7, with similar data from Surveyor 5 and Surveyor 6, suggest that the classical processes of melting followed by cooling and solidification, which have led on the earth to a partial separation of chemical elements, may have operated also on the moon.

At the least, chemically distinguishable rock types appear to exist. The difference observed is between the surface of the moon's southern highlands (Surveyor 7) and the flat plains known as maria (Surveyors 5 and 6).

Initial data from Surveyor 7, not yet published in the United States, have been supplied by the National Aeronautics and Space Administration to Dr. P. J. Adams of the Institute of Geological Sciences, London, for use in a review of the geology and geography of the moon. His review is published as an illustrated booklet and is accompanied by an exhibition in the institute museum in South Kensington.

The Moon, its Geology and Geography, by P. J. Adams

FOSSIL MAN PREY TO THE CROCODILE
The Times May 9 1968

On the banks of a Javan river half a million years ago a crocodile seized and ate a man-like animal. The evidence for this incident has come to light from a fossil jaw, first found in 1953, which has been cleaned and re-examined by Professor G. H. R. von Koenigswald, of Utrecht University. He has found a line of deep holes in the jaw which are exactly fitted by crocodile teeth. It may be that crocodiles account for the scarcity of the fossil evidence of man.

The first remains of Java man were found by Dubois in the 1890's; further discoveries in this century have been made by Professor von Koenigswald. The jaw which he has now re-examined belongs to Meganthropus a creature which is on the edge of belonging to the same genus as man.

When the jaw was freed from its matrix, four conical holes appeared, all in a straight line. These, say Professor von Koenigswald, could only have been caused by the bite of a large crocodile. The coherence of the fragments suggests that the jaw was still covered by skin and muscles when it sank to the bottom of the lake to be buried in mud.


WHEN WERE TOOLS FIRST MADE?
The Times May 13 1968

Bones in the Upper Miocene fossil beds of Fort Ternan, in Kenya, show evidence of having been deliberately smashed. Dr. L. S. B. Leakey, of the National Museum Centre for Prehistory and Palaeontology in Nairobi, who made this discovery, suggests that the damage may have been caused by some kind of blunt instrument, used perhaps by Kenyapithecus wickeri, an early member of the early Hominidae—the family to which man belongs. Remains of the creature have been found in the same fossil beds as the smashed bones.

Writing in this week's issue of Nature, Dr. Leakey describes examples of mammalian bones which have depressed fractures of the sort that could have been made by a blunt tool of some
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kind. He also mentioned a small broken skull with a depressed fracture with a semicircular outline, showing that part of the skull has been removed.

*Nature* 218, 528-30

**GULF STREAM KEEPS SAME COURSE**

The Times May 17 1968

Examination of fossils of micro-organisms collected from the bottom of the North Atlantic off the United States have provided evidence to suggest that the Gulf Stream has retained more or less its present pattern of flow for some thousands of years at least. This conclusion is reached by Dr. W. F. Ruddiman of the Lamont Geological Observatory in New York, and described in the current issue of *Deep-Sea Research*.

In this connection, stability is a relative matter. Dr. Ruddiman points out that although the Gulf Stream is only about 20 miles wide at any time, it does meander about, covering a range of two degrees of longitude or thereabouts.

What Dr. Ruddiman has done is to collect cores of sediments from the bottom of the North Atlantic and to examine the microfossils they contain. He has been chiefly concerned to pick out those fossils known to be sensitive to temperature and which are carried into the North Atlantic from the warmer seas in the south.

*Deep Sea Research* 12, 1968

**DO-IT-YOURSELF-FOSSILS**

The Times May 27 1968

A method for quickly petrifying plant tissue in the laboratory is described by R. W. Drum, Massachusetts University, in this week's *Nature*. Plant tissue is petrified by the natural waters, containing high concentration of silicates, that issue from volcanic springs in places like Yellowstone Park, in America, and in New Zealand, but this natural process is slow.

Dr. Drum has devised a way of duplicating it much more quickly in the laboratory. He soaks pieces of plant tissue for up to a day in a concentrated and acid solution of a chemical called sodium metasilicate. The sodium metasilicate is similar to waterglass used to preserve eggs.

The soaking is followed by washing and boiling in acid to remove all the organic material so as to leave the final product a silica replica of the original cells. So far only small pieces of plant tissue about a millimetre cube, have been petrified in this way.

What is the reason for wanting to petrify plant tissue? Dr. Drum points out that fossil plant material, naturally petrified with silica, has been extensively studied by botanists and has provided much information about the cellular structure of extinct plants. He believes that if the present-day plants, which are alleged to be related to fossil species, were silicified in the laboratory, they would help in the interpretation of the fossil material.

Another advantage of petrification is that it produces replicas of the inner surface of cell walls and the spaces within cells, whereas in most other replication methods material is only deposited on the outsides of cells, and this can obscure details of intercellular connexions.

*Nature* 218, 784-785

**MORE ABOUT THE ORIGIN OF LIFE**

The Times May 28 1968

The four compounds that are the sub-units of the genetic material DNA, responsible for coding genetic material, have all now been made from mixtures of simple gases under so-called prebiotic conditions—that is to say—conditions believed to be similar to those on earth before the advent of life.

This is reported by Dr. J. P. Ferris, Dr. R. A. Sanchez, and Dr. L. E. Orgel, of the Salk Institute, California, in the current issue of *Journal of Molecular Biology*.

Obviously the simple chemical sub-units—the amino-acids of proteins and the four bases of DNA—from which the complex molecules of living organisms are built must have been formed on earth before life could emerge. We can never know exactly how this happened, but in the past decade or so several groups of scientists have done experiments to see if these sub-units can be made in the laboratory from gases that were probably present in the primeval atmosphere of the earth.

By subjecting gas mixtures including nitrogen, methane and hydrogen sulphide to electrical discharges or irradiation with ultra-violet light and dissolving the products in water, at least 14 of the 20 common amino-acids have been made. This provides a plausible explanation of the origin of the sub-units of proteins.

*Journal of Molecular Biology* 33, 693

**SNAIL SHELLS REFLECT CHANGES IN CLIMATE**

The Times May 29 1968

In southern England the pattern of banding on the shells of a common species of snail—*Cepaea nemoralis*—has changed in response to the changing climate since about 4,500 B.C. This has emerged from statistical analyses, made by Dr. J. D. Currey, of York University, and Professor A. J. Cain, of Manchester University, of the banding patterns of subfossil snail shells collected at archaeological sites and of snails living near the sites today.

In living populations of these snails the number of individuals with banded or unbanded shells varies. The banding pattern is genetically controlled and subject to natural selection. The climate, in particular the temperature, is an important selection pressure.

In France and England snails with unbanded or partially banded shells are more frequent in regions with warm summers, whereas snails with five banded shells are more frequent in cooler regions. The mean summer temperature seems to be the critical factor.

Currey and Cain argue that if the climate does in fact play an important role in controlling the banding in present-day snail populations it should be possible to correlate long-term changes in the frequency of the various forms of snail with long-term changes in the climate.

This, of course, can be done only if the fossil shells are well preserved, and equally important, if their age is known fairly accurately. Currey and Cain therefore collected shells from 26 archaeological sites, taking care to ensure that they were contemporary with the archaeological remains, and also studied shells in collections.

*Philosophical Transactions of the Royal Society*, 253, 483
SOLAR LAKE ON RED SEA SHORE
The Times May 31 1968

A solar lake in which the surface layer acts like glass in a greenhouse and allows the water below to become very hot has been discovered on the shores of the Red Sea, about 20 km. south of Elat.

The discovery, reported in Nature by Dr. F. D. Por of Jerusalem University, was made during a routine survey of the Sinai coast. Skin divers found that the waters of the lake were so hot that they could not penetrate more than about a metre below the surface.

Temperature and salinity measurements made last February showed that the temperature increased from 16°C at the surface to 40°C at a depth of 1.5 metres. At 3-4 metres, the temperature of the Red Sea was 21°C. Salinity at the top of the lake was like that in the open sea, but waters at the bottom of the lake were twice as saline.

Nature 218, 860-861.

OCEAN RIDGES MAY RAISE SEA LEVEL
The Times June 4 1968

A mechanism often proposed to account for the changes in sea levels in the geological past is the formation and melting of the polar ice caps. Dr. Kenneth L. Russell, of Princeton University, now suggests that another event may have affected sea levels; he calculates that the rise of the great ocean ridges which split the continents apart could have displaced enough water to raise the sea level by more than 400 ft.

Gondwanaland is the name given to the supercontinent that once comprised South America, Africa, India, Australia, and Antarctica. Present evidence suggests that ridges arising from the underlying crust began to split up the supercontinent some 200 million years ago. The first split occurred along a north-south axis which left South America and Africa in one fragment and India, Australia and Antarctica in the other.

As the fragments drifted apart the ridge that divided them probably grew to dimensions similar to those of the present mid-Atlantic ridge. Treating this ridge as a wedge 2 km. high, 1,600 km. wide and 30,000 km. long, Dr. Russell calculates that the water it displaced would have caused a worldwide rise in sea level of over 400 ft.

Nature 218, 861-862

BASALTIC ROCK THEORY OF MARIA
The Times June 12 1968

Recent analysis of the composition of the lunar surface, based on the chemical analysis experiment on Surveyor VI, last November implies that the lunar maria are largely composed of material resembling a rock of a basaltic type.

American scientists have determined that in both this site in Sinus Medii and the site of the Surveyor V landing last September in Mare Tranquilitatis, the most abundant chemical element is oxygen, followed by silicon; aluminum is prominent in both samples but only the upper limits of concentration can so far be assigned to the amounts of carbon, sodium and iron present.

Far more interesting than the elements themselves is the fact that they are the same in both samples, making it improbable that the chemical composition of these sites is unique; it is far more likely that this composition is typical of large portions of the lunar maria that are similar in appearance and in optical and thermal properties.

Science 160, 1108-1110

SHIP STONE DUMPS ON EAST COAST OF U.S.
The Times June 20 1968

Geological surveys of the Atlantic coast of North America have brought to light several dumps of flint stones of European origin. American archaeologists writing in this week's Science say that the stones were brought as ship's ballast from the sixteenth century onwards. They suggest that flint stones washed up on shores would be a significant clue to the site of ancient shipwrecks.

Science 160, 1225

MORE HOT SPOTS ON THE MOON
The Times June 25 1968

A further 22 patches on the surface of the moon which are warmer than their surroundings during the lunar night have been identified by research carried out by Dr. Robert L. Wildey, of the Centre of Astro-geology at Flagstaff, Arizona. In previous investigations of the surface of the moon with sensitive infra-red detectors, nearly 100 of these patches had been identified. The new batch consists of features which are somewhat less prominent than those previously identified. The total now known is 119.

In the 22 patches whose position and properties are described in the current issue of the Monthly Notices of the Royal Astronomical Society, most are indentifiable with small features on the surface of the moon which themselves lie near the edges of the lunar seas or maria. Many of them have been observed on more than one occasion and Dr. Wildey has been able to gather enough information about the most prominent of them to be able to infer how rapidly they cool as the fortnight-lunar night wears on.

This step is an important clue to the nature of these hot spots on the surface of the moon.


EARLY JAW FROM HONG KONG DRUG STORE
The Times July 3 1968

A piece of bone bought in a Hong Kong drug store nearly 40 years ago has been identified as part of a human jaw, possibly 10,000 years old. Dr. T. Jacob, of Jogjakarta University, who describes the jaw, believes that it may belong to the ancestors of the early inhabitants of Melanesia.

The bone is part of a collection formed by Professor von Koenigswald of Utrecht University, who describes the jaw, believes that it may belong to the ancestors of the early inhabitants of Melanesia.

The bone is part of a collection formed by Professor von Koenigswald of Utrecht University, who describes the jaw, believes that it may belong to the ancestors of the early inhabitants of Melanesia.

Proceedings of the Royal Netherlands Academy of Sciences, 72, 3B, 232
OIL UNDER THE IRISH SEA?
The Times July 6 1968

Beneath Cardigan Bay there is a basin of sedimentary rocks which may contain oil or gas bearing structures. This is the outcome of a survey of the south Irish Sea carried out by Dr. D. J. Blundell, Dr. F. J. Davey, and Dr. L. J. Graves, of Birmingham University, reported in this week’s Nature.

The basin of sedimentary rocks is 30 km. wide, 120 km. long, and its maximum depth is between 3,500 and 6,700 metres . . .

The surveys of the south Irish Sea were carried out between 1965 and 1967. For the first two years the Birmingham geologists chartered coasters to carry their instruments. In 1967 the Royal Research Vessel John Murray became available.

Nature 219, 55-56

POSITION OF CONTINENTS IN PALAEOZOIC ERA
The Times July 9 1968

The direction of magnetization in ancient rocks has been used to plot the positions of the continents during the Palaeozoic era of the earth’s history, which lasted from about 570m. to 225m. years ago.

From the maps constructed on such evidence, Professor K. M. Creer, of Newcastle upon Tyne University, finds that the continents remained more or less static until the latter part of the era, when they began to drift over the upper mantle of the earth towards their present positions.

What Professor Creer has done is to construct for each continent a map of its movement relative to the south magnetic pole and to draw each map on a transparent plastic shell. The shells for each continent are then fitted over one another and aligned so that the tracks of the south pole relative to each continent coincide with each other as much as possible.

The pattern that emerges is that all the tracks roughly agree in showing the south pole moving in a great arc from Dakar, in Senegal, where it stood some 500m. years ago, to Johannesburg, where it arrived about 200m. years later. At roughly this point the polar wandering tracks for each continent began to diverge.

Nature 219, 41-42

NEW IDEAS ON ORIGIN OF TEKTITES
The Times July 11 1968

New ideas on the origin of tektites have been put forward by Dr. R. A. Lyttleton, of Cambridge University. Tektites are small, rounded, glassy objects found at several places on the surface of the earth. Dr. Lyttleton says that they may have been formed during an encounter between the earth and either a comet or a large meteorite.

Tektites have been collected from tracts of land as widely scattered as the Philippines, Czechoslovakia, Australia and Texas. Their rounded, aerodynamic shapes suggest that they may originally have been spherical drops of molten material from beyond the atmosphere. The question which has puzzled scientists is how material like this may have originated.

One thing at least is clear. Tektites do not arise from the streams of small meteor particles which produce showers of shooting stars when they burn up in the upper atmosphere. Tektites are much larger, and also differ in chemical composition from the small meteorites which occasionally reach the surface of the earth.

Several theories, some of them bizarre, have been suggested since it was first recognized in the nineteenth century that tektites may have a cosmic origin. The most popular suggestion has been that the tektites were produced by the collision between the earth and large meteorites in circumstances such that the intense heat of impact would melt rock.

On this view, beads of molten metal would be splashed from the impact side. One variant of this theory is that the tektites may represent molten material splashed off the moon by the impact of a meteorite.

Dr. Lyttleton now points out the drawbacks of these explanations. The novelty of his suggestion lies in the way in which he supposes beads of molten material would be formed.


SPACE DEBRIS ON EARTH 400 MILLION YEARS AGO
The Times July 12 1968

Chemical analysis of an ancient bed of rock in Australia suggests that 8,000 tons of extraterrestrial material was reaching the surface of the earth every day at the time the rock was being formed. Similar amounts of material are thought to reach the earth in present times, which means that the rate of arrival has remained fairly constant over the last 400 million years.

Extraterrestrial material arrives in all forms from microscopic dust grains to meteorites the size that caused the Arizona crater. Material like this usually contains chemical elements in proportions different from those naturally occurring on earth. For example, rocks in the earth’s crust contain roughly equal amounts of the rare metals osmium and rhenium, whereas in stony meteorites osmium is more than 10 times as abundant as rhenium.

Writing in this week’s Nature, J. W. Morgan, of the Australian Atomic Energy Commission, has estimated the amount of extraterrestrial material incorporated in a bed of Silurian shale at Etheridge Creek, Australia.

Nature 219, 147

PROTEINS IN Dinosaur BONES
The Times July 13 1968

More or less intact proteins, containing 20 or more amino-acids, have been recovered from individual dinosaur bones 150 million years old by Dr. M. F. Miller and Dr. R. W. G. Wyckoff, of the University of Arizona at Tucson . . .

The aim of this research is to study the chemical evolution of proteins. Some idea of the rate of evolution of proteins can be gained by comparing the composition of the same protein from living animals at different levels of evolution, but this evidence is necessarily indirect.

If it were possible to extract a protein—for example, the skeletal protein collagen, which occurs in tendons and bone—from fossils and compare its chemical composition with present day collagen, it would be possible to measure directly the rate of evolution of the protein.

In the past several analyses of proteins from invertebrate fossils have been made, and Wyckoff and his colleagues have found a protein with a composition similar to modern
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collagen in fossil bones and teeth from the Pleistocene period. But on a geological time scale that is a recent period, only 1,500,000 years ago. The protein that they have just extracted is about 100 times older, from the Cretaceous and Jurassic periods.

Both the Pleistocene and the Cretaceous and Jurassic proteins contain the same number of amino-acids, but they are present in different relative amounts. For example, only one Jurassic fossil yielded the amino-acid hydroxyproline, which is characteristic of collagen.

Proceedings of the U.S. National Academy of Sciences 60, 176

LOESS AND EARLY MAN IN CHINA
The Times July 15 1968

The development of civilisation in China may have been critically influenced by the geological events of the last great ice age which brought about the formation of the loess lands of northern China. According to Dr. I. J. Smalley, of University College, London, the ease of cultivation of the loess land may have supported the population growth of China’s earliest organized society.

Writing in the current issue of Man, Dr. Smalley suggests that when the glaciers of China retreated the fine powder left in their path was carried by the wind to form the loess deposits. These were cultivated by the Yang Shao people who in spite of relatively primitive agricultural techniques, were able to thrive and multiply on the loess lands. The loess was spread eastwards by the Yellow River, which passes through the area of the main loess deposit, and as the loess spread the Yang Shao people expanded with it.

Dessication and wind erosion of the top soil may have forced the Yang Shao people to evacuate the loess lands but by this time their cultural techniques would have been sufficiently advanced for them to exploit less favourable terrains.

Man 3

HOT SPOTS LIKELY UNDERNEATH SCOTLAND
The Times July 24 1968

Evidence that there may be a region of high temperatures in the earth’s surface less than 100km. below the southern uplands of Scotland has come to light from measurements of variations in the earth’s magnetic field. This may be a remnant of the volcanic activity which occurred in Scotland during the Tertiary, a geological period when much mountain building took place.

The evidence for the high temperature region is based on measurements of the earth’s magnetic field at a number of observing stations in southern Scotland and Northern Ireland, and is reported in the Geophysical Journal of the Royal Astronomical Society, by Dr. J. E. A. Osemeikhian and Dr. J. E. Everett, who, until recently, were at Cambridge University.

They say that variations in the magnetic field, measured in the vertical direction, are very similar from station to station, with the exception of stations at Eskdalemuir and at Glenlee in the southern uplands. At these two stations variations in the vertical field having periods ranging from about 20 minutes to an hour, are much reduced compared with the measurements at the other stations.

The magnetic field, measured in the horizontal direction, seems to vary in the same way at all stations with the exception of a site at Malin Head on the coast of Northern Ireland.


FIRES KILLED THE EARLY MARSUPIALS
The Times July 26 1968

A fascinating explanation of how some Australian marsupials become extinct has been proposed. The suggestion, originally put forward in a lecture last year by Dr. D. Merrilees, of the Western Australian Museum, has been published in full. Dr. Merrilees suggests that fires started by Australian aborigines may have so changed the vegetation that the marsupials could no longer survive.

It is known that man coexisted with the marsupials on the Australian mainland in the late Quaternary period, about 10,000 years ago. It is also known that the aborigines were able to light fires, and Dr. Merrilees says that even quite small bush fires, if they were repeated often enough, would have had a serious effect on the marsupial populations.

The proposal is interesting because of the light it throws on the extinction of large mammals by early man. Palaeontologists have suggested that in Africa the greater part of the extinction occurred before man developed efficient hunting techniques and weapons; later man, in spite of his better techniques, had a relatively small effect on the surviving species.

Dr. Merrilees suggests that this happened because fire, rather than hunting proved lethal for the large mammals. Looked at this way, the later development of better hunting weapons can be thought of as the response to, rather than the cause of widespread extinction of species.

Journal of the Royal Society of Western Australia 51

MAGNETIC TESTS SHOW EARTH’S HOT SPOTS
The Times July 26 1968

Measurements of the earth’s magnetic field at observing stations in Iceland seemed to have confirmed the presence of a mass of molten lava beneath the island, noted among geologists for its volcanic activity. According to the new measurements, the suspected mass of lava extends beneath the entire island at a probable depth of about 30 km.

The way in which the pressure of the lava is inferred from the magnetic measurement is, in essence, the same as the argument for the existence of a high temperature region beneath the southern uplands of Scotland, already described in Science Report. In southern Scotland, measurements of the way the earth’s magnetic field varies with time show localised irregularities, which may be caused by a region of high electrical conductivity beneath the southern uplands.

It is more difficult to make inferences about the earth’s structure from the Icelandic measurements because here the local magnetic field is also known to be influenced by the aurora—the Northern Lights. Dr. J. F. Hermance and Professor G. D. Garland, of Toronto University, who are interpreting the measurements allowed for the influence of the aurora by comparing the Icelandic measurements with measurements of the magnetic field at observing stations in Greenland.

Journal of Geophysical Research 73, 3797.
GALAPAGOS SEA FLOOR SPREADING

The Times July 30 1968

Another of the sub-oceanic regions where the floor of the oceans seems to be spreading away from a central rift valley has been discovered in the Pacific, extending eastwards from the Galapagos Islands towards South America. This is reported by Arthur D. Raff of the Scripps Institution of Oceanography, California, and is based on surveys of the earth's magnetic field between the Galapagos Islands and South America.

The magnetic field in this region changes noticeably from place to place, according to surveys which have been carried out. The pattern of the variations in the magnetic field measurements seems to be symmetrical about an axis extending eastwards from the Galapagos and is associated with a rise, having a central valley, in the general level of the ocean floor.

According to Dr. Raff, the pattern of the magnetic variations resembles similar patterns associated with the great oceanic rises, which are widely believed to represent regions where the sea floor is gradually spreading away from an axis marked by a rift valley. He estimated the rate of spreading of the sea floor from the axis to one side to be 3.2 centimetres a year for the area east of the Galapagos.

Many geophysicists believe that sub-oceanic rises such as the region now discovered in the eastern Pacific mark areas where convection currents in the earth's interior rise to the surface and then diverge to each side of the central axis. Dr. Raff has considered how this newly discovered region of spreading fits in with similar regions already known to exist in the Pacific. He suggests that the pattern of rifting in the Galapagos region may fit in with the notion that the lines of ocean spreading mark out polygons on the earth's surface, the polygons apparently receding from one another.

Journal of Geophysical Research 73, 3799

AMPHIBIAN FOSSIL FROM ANTARCTICA

The Times August 6 1968

The first animal fossil to be found in Antarctica is described in detail in this week's Science. The fossil, whose discovery was announced earlier this year (Science Report March 14), is a small piece of jaw bone belonging to a primitive amphibian which lived about 230 million years ago.

The presence of the fossil confirms that Antarctica was once joined to other land masses as suggested by the theory of continental drift.

The fossil was discovered on December 28 last by Dr. Peter J. Barrett of Ohio State University. It was embedded in soft sandstone rock three-quarters of the way up a ridge near the Beardmore Glacier, about 325 miles from the South Pole. The sandstone lies some 250 ft. above the base of a layer of rock which contains fossil leaves of the fern Glossopteris. This is one of the characteristic floras of the Permian Age, which ended about 230 million years ago.

The fossil fragment which is 3 in. long and 1 in. across has a wrinkled surface and two well-defined grooves which are characteristic of labyrinthodonts, primitive amphibians which lie on the line of descent between fishes and amphibians, reptiles and mammals.

Science 161, 460-462

EARTH'S MAGNETIC FIELD ORIGIN

The Times August 17 1968

Many attempts have been made to explain why the Earth has a magnetic field. So far, most of them have been found wanting, and only one, the dynamo theory, is widely accepted. This theory suggests that the magnetic field is set up by the action of electric currents generated by some sort of dynamo in the fluid core of the earth.

Because very little is known about conditions deep inside the Earth, there has been plenty of room for speculation. Even so, it is quite difficult to show theoretically, that the dynamo theory could work, even if the most convenient assumptions are made. One mechanism which seems to work was put forward in 1958 by Dr. A. Herzenberg.

This theory, which is really a convenient mathematical model rather than an attempt to suggest what the motions in the Earth's core actually are, suggests that a conducting stationary sphere in which two smaller spheres are rotating acts as a dynamo. Because all three spheres are assumed to be rigid, the model cannot immediately be applied to the Earth.

Experiments recently carried out at the School of Physics at the University of Newcastle and reported in this week's Nature, lend some further support to the theory. Dr. F. J. Lowesland and Dr. I. Wilkinson have designed a laboratory model which reproduces the conditions in Herzenberg's mathematical proof. To simplify the model, the rotating spheres are replaced by cylinders made of steel, which rotate in cavities in a steel block.

The cylinders are kept in electrical contact with the block by a thin film of mercury and the model allows the angle between the cylinder to be adjusted at will. When the two cylinders are rotated at more than a certain critical speed, the model does act as a dynamo and produces a magnetic field.

The real importance of the most recent experiments seem to be that they show that the model can reproduce some of the characteristics of the magnetic field of the Earth.

Nature 219, 717-718

During the period of the British Association Meeting in Dundee (August 21 to 28) the Science Reports were replaced by summaries of papers read at the Annual Meeting. They

OCEANIC SILICA CONTROLLED BIOLOGICALLY

The Times September 2 1968

An explanation of why sea water contains much less silica than river water has been constructed by Dr. S. E. Calvert, of the Grant Institute of Geology at Edinburgh, on the basis of information gathered from a great variety of sources. The nub of his conclusion is that silica is removed from the oceans as quickly as it is carried there by several agencies, and that biological activity of various kinds is chiefly responsible for carrying it away.

Nature 219, 919-920
LITTLE HOPE OF PREDICTING IRAN EARTHQUAKES
The Times September 4 1968

The earthquakes that have devastated north-eastern Iran are the consequence of a geophysical process that has been in process for some hundreds of millions of years.

Sensitive strain meters have been set up at the very localized earthquake zone of the San Andreas fault in California, and it is expected that a series of preliminary shocks may give something like 24 hours' notice of a major earthquake. But this system is not applicable in Iran, and another promising method, that of predicting earthquakes by local changes in the earth's magnetic field, has not yet been proved in action. There seems to be little hope, in the near future at least, of predicting seismic events in Iran.

Nature — Times News Service

SPREADING OF THE PACIFIC OCEAN FLOOR
The Times September 5 1968

Outcrops of basalt along the crest of a ridge on the floor of the Pacific Ocean, known as the East Pacific Rise, were discovered last year on a cruise of the research vessel Pillsbury, owned by the Institute of Marine Science at Miami University.

Writing in this week's Science, Dr. E. Bonatti of the institute, gives details of the discovery which are further convincing evidence for the theory of sea-floor spreading which results in continental drift.

According to the theory, new rock from the earth's mantle is injected into the crust of the earth beneath the sea along the axis of submarine ocean ridges. The scientists aboard the Pillsbury were searching in March and April last year for evidence of the predicted outcrops of fresh rock along the East Pacific Rise—a ridge of mountains which runs south from the coast of Mexico roughly parallel to the coast of South America for several thousand miles.

They concentrated on that part of the rise that lies between 14°S and 60°S, and discovered a band of outcrops of basalt extending for more than 800 kilometres along the crest of the ridge. The basalt was first detected by echo-sounding devices, which clearly distinguished between the hard basalt and softer, less dense sediments, and then by direct sampling and photography of the sea floor.

The band of outcropping basalt is relatively narrow, ranging from 40 to 80 kilometres in width and continuous along the ridge. At the edges there is a gradual transition from exposed basalt to basalt covered by a continuous layer of sediment.

Science 161, 886-888

FRESH LIGHT ON GENESIS OF PETROLEUM
The Times September 7 1968

Further light has been shed on the chemical history of petroleum by W. Henderson and his colleagues at Bristol University. From their experiments it seems that the natural heating and catalytic processes in rocks go a long way towards accounting for the complex mixture of chemicals found in petroleum.

Crude petroleum contains a wide variety of hydrocarbons, chemicals composed of carbon and hydrogen atoms. Very few hydrocarbons are found in living organisms, but some have a complex skeleton of carbon atoms, which suggests that they have been degraded from certain biological molecules which they resemble. This is one reason why petroleum is now thought to be derived from predominantly biological sources, but the chemical processes whereby organic material is transmuted into petroleum are not yet clear.

Petroleum deposits are almost always found in association with sedimentary rocks. The organic debris caught up in the sediment is likely to be subject to two kinds of chemical action: heating and the catalytic effect of the inorganic chemicals present.

What Dr. Henderson and his colleagues have done is to reconstruct this situation in the laboratory by heating a hydrocarbon for long periods and separating the wide variety of degradation products by sensitive chromatographic techniques. The hydrocarbons, which they used was octane, the backbone of which is a straight chain of 28 carbon atoms. In the course of heating, the octane was degraded to the full spectrum of shorter length molecules, with no marked bias to those containing an odd or even number of carbon atoms.

Nature 219, 1012-1016.

OLDEST FOSSILS ON EARTH FOUND IN SWAZILAND
The Times September 10 1968

Small spherical and cup-shaped structures rich in carbon have been discovered in sedimentary rocks from Swaziland which are more than 3,200 million years old. Although an unequivocal interpretation of these microscopically small objects is extremely difficult, a team of six American scientists led by Dr. A. E. J. Engel, of the University of California, believe they are true fossils, the oldest yet identified.

The oldest fossils so far identified beyond all doubt are the remains of filamentous algae in carbonate rocks near Bulawayo. These are at least 2,700 million years old. More recently, there have been discovered of still more ancient fossils. South African scientists have discovered what seems to be the remains of spherical single-celled algae and bacteria in sedimentary rocks in southern Africa known as the Fig Tree Series.

Dr. Engel and his colleagues now report, in the latest issue of Science, similar structures in even older rock, which underlies the Fig Tree Series. These rocks are called the Onverwacht Series and were deposited as sediments from water more than 3,200 million years ago.

The fossils left behind after the powdered rock had been dissolved in hydrochloric and hydrofluoric acid are tiny, spherical and cup-shaped objects only 30-thousandths of a millimetre in diameter which means, of course, that they can be seen only with an electron microscope. Not only have they the structure of authentic fossil algae but they also occur in close association with carbonaceous remains containing kerogen.

This is crucial to Dr. Engel's argument, because objects looking like fossil algae can be produced by non-biological weathering of rock. Kerogen however, is a mixture of organic substances, chiefly found in oil-bearing strata, which is generally believed to be formed from the remains of plants and animals.

Science 161, 1005-1008.

ANTARCTIC ICE SHEET PENETRATED
The Times September 11 1968

The first bore hole to be sunk through the Antarctic ice sheet has reached bedrock at a depth of more than 7,000 ft.
AN INTRODUCTION TO THE GEOLOGY OF CORNWALL
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The core of ice retrieved from the hole has revealed layers of volcanic ash deposited on the surface of the ice sheet some 20,000 years ago.

The hole was drilled at Byrd Station in west Antarctica by scientists from the United States Army Cold Regions Research and Engineering Laboratory, who a few years ago sank the first hole through the Greenland ice sheet. The principal feature of the drilling method is to fill the hole with a diesel oil mixture of the same density as ice to prevent the hole from collapsing.

Between 4,000 and 5,000 ft., several thin layers of dirt were encountered, each of them overlaid by a layer of refrozen melted water. The dirt particles are probably volcanic ash deposited on the surface of the ice sheet: the layer of ash would have absorbed the sun’s radiation and melted the first layers of snow that later covered it. The ages of the volcanic ash can be estimated by comparing the depth at which they are found with the average annual snowfall, making allowance for the way in which the deeper layers of ice are flattened out by the pressure of those above.

The scientists calculate that the layers of ash were deposited between 15,000 and 25,000 years ago. The ash could have come from the extinct volcanoes known to exist within 200 miles of Byrd Station.

The ice at the bottom of the sheet is at melting point, and there is a thin layer of water between it and the bedrock. This is an important factor in considerations of the movement of ice over the rock surface. The ice at the bottom of the sheet could be as old as 50,000 years.

_Science_ 161, 1011.

**DISCOVERY OF BURIED RIFT VALLEY**
The Times September 12 1968

The technique of using seismic signals to explore the structure of the earth’s crust has won a remarkable and somewhat unexpected prize in North America—the discovery of a pre-Cambrian rift valley between 50 and 200 km. across which is now buried under more than 20 km. of rock deposits.

The rift valley must have been formed early in the geological history of the earth at an age that has been estimated at about 1,350 million years ago. The scientific importance of the discovery is that it shows that geological processes now under way were already at work at a much earlier stage, but there also seems to be a good chance that the new discovery will throw light on the ways in which important concentration of minerals are brought about.

The new discovery is reported in the current issue of _Science_ by Dr. E. R. Kanasewich of Alberta University. He has combined the results of seismic surveys with those of other techniques of geophysical investigation—the search for variations of the intensity of the earth’s magnetism and variations in the strength of the gravitational forces due to the pull of the earth. By methods such as this the ancient rift valley has been traced for more than 450 km. from its narrowest part just north of Medicine Hat in Alberta to the region where it fans out over the United States border into Idaho.

_Science_ 161, 1002.

**DIET OF A DORSETSHIRE ICHTHYOSAUR**
The Times September 16 1968

A small ichthyosaur which lived about 150 million years ago has been found near Lyme Regis. By a fortunate accident its stomach contents have been fossilized with the skeleton, which has allowed Dr. J. E. Pollard, of Manchester University, to discuss the feeding habits of these extinct animals.

Ichthyosaurs were reptiles which had become highly adapted to life in the sea and looked something like sharks. They ranged in length from 2 ft. to 60 ft. and, like the dinosaurs, became extinct towards the end of the Cretaceous period, about 90 m. years ago.

The stomach of the Lyme Regis ichthyosaur contains thousands of small fossilized hooklets of the type which lined the arms of ancient cephalopods, the group of marine animals that includes octopuses and squids. The hooklets are a primitive feature of cephalopods; in modern members of the group they have been replaced by suckers, which are a more efficient method of grasping prey.

Dr. Pollard has failed to find any of the hooklets in the coprolites, or fossilized pieces of ichthyosaur dung, preserved in the Oxford and Manchester museum collections. From this it seems that the hooklets were retained in the ichthyosaur’s stomach, possibly because they would have damaged the delicate lining of the intestine. The hooklets may have been periodically regurgitated, just as the sperm whale vomits up the accumulated squid beaks from time to time, or they may have remained in the ichthyosaur’s stomach, possibly until they blocked the digestive tract.

Dr. Pollard estimates that the hooklets in the ichthyosaur’s stomach correspond to the ingestion of about 1,500 cephalopods. This could represent a lifetime’s diet because the ichthyosaur appeared to be quite young.

_Palaeontology_ 11, 376-388.

**EARTHQUAKES KEEP EARTH WOBBLING**
The Times September 20 1968

Large earthquakes may contribute to the slight wobble of the earth about its axis of rotation, and variations in the wobble may even be a sign that earthquakes are about to occur, according to L. Mansinha and D. E. Smylie at Western Ontario University.

The wobble in the earth’s axis of rotation is such that the North Pole completes an anticlockwise circular path about once every 14 months. The displacement, measured in terms of a few tens of feet, appears as a variation in latitude as determined by the position of the stars. Because of its rotation, the earth is not a perfect sphere but is flattened at the poles, and theoretical studies suggest that this flattening should damp down the wobble. Geophysicists have been searching for the factor that counteracts the damping and keeps the wobble in motion.

_Science_ 161, 1127-1129

**CARDIGAN BAY MAY HIDE NATURAL GAS**
The Times October 1 1968

A borehole sunk in Merionethshire has disclosed geological strata which could overlie repositories of natural gas. The strata which extend beneath Cardigan Bay, are similar to those found in the gas-bearing areas of the North Sea.

Geologists are interpreting the discovery with some caution, because several other conditions must be fulfilled for gas deposits to occur. What has been found so far are layers of rocks laid down in the Tertiary and Mesozoic eras of the earth’s history. Layers of this age, which have not previously been found in adjacent parts of Wales, provide the kind of environment in which pockets of natural gas can be trapped.
The significance of the Mesozoic and Tertiary age rocks shown by the borehole is that they often overlie the layers of sandstone in which gas may be trapped. Geologists and geophysicists have had several reasons to believe that layers of this age exist under Cardigan Bay. Seismic surveys which involve detonating an explosive and recording the velocities of the sound waves reflected from the different layers of rock, has indicated the existence of what could be Mesozoic strata.

This suggestion could be proved only by drilling a borehole, and to make matters more difficult the strata are mostly confined to Cardigan Bay. Geologists from the University of Wales and the Institute of Geological Sciences decided to sink a borehole at the coast near Mochras, where the land projects farthest into the area of the suggested strata.

Drilling was started last November and has now reached a depth of 3,000 ft. From an analysis of the types of rock in the core and the fossils embedded in them, Professor Alan Wood and Dr. A. W. Woodland believe that the strata lying from about 250 to 2,000 ft. below the surface were laid down in the Tertiary age (which lasted from about 90 to 2 million years ago) and that those between 2,000 and 3,000 ft. belong to the middle part of the Mesozoic, an era that began some 242 million years ago.

*Nature* 219, 1352-1354

**SPREADING OF THE OCEAN FLOOR**

*The Times* October 3 1968

The dating of a series of rocks dredged up from the bottom of the Atlantic has confirmed that the ocean floor is spreading out from the Mid-Atlantic Ridge at a rate of between one and three centimetres a year. Spreading of the floor is thought to constitute the conveyor belt which, according to the theory of continental drift, has split the continents apart and dragged them to their present positions.

The Mid-Atlantic Ridge is an underwater mountain range running roughly from north to south in the centre of the Atlantic Ocean. The valley in the middle of the range, known as the median rift, is thought to mark the line along which molten material wells up from the earth's crust, solidifies and gradually spreads out on either side of the central ridge.

Scientists from the Geological Survey of Canada obtained the rock samples during a traverse of a well-studied area of the ridge at latitude 45°N. The samples exhibit a fairly steady progression in age, ranging from 13,000 years for rocks in median rift valley to about eight million years for rocks dredged up some 40 miles west of the ridge.

*Science* 161, 1339-1342.

**CYPRUS MAY BE FROM OLD SEA FLOOR**

*The Times* October 8 1968

The Troodos mountain range of Cyprus may have been thrust up from the floor of an ancient ocean called the Tethys Sea, which once divided the Eurasian land mass from Africa and India, according to a geological survey made by Dr. I. G. Gass, of Leeds University. This range may have been part of a feature known as the mid-ocean ridge, the site at which new material is added to the ocean floor.

Dr. Gass believes that the continental shelf of Africa slipped under that of Europe and raised to the surface a sandwich of ocean floor formed of a layer of ocean crust, together with an underlying layer of the earth's mantle.

In the central part of the Troodos range the upper layer of this sandwich has been eroded away, leaving portions of mantle material exposed to the surface.

The interest of this suggestion is that material from the earth's mantle is very rarely exposed to the surface and its properties can be guessed at only from the way it reflects seismic waves. On feature which seems reasonably certain from such indirect measurements is the high density of the mantle material. Dr. Gass notes that a survey of gravity anomalies in Cyprus has indicated a large area in the Troodos range with a density to be expected of mantle material.


**DISCOVERY OF FOSSIL JELLYFISH**

*The Times* October 14 1968

Three new species of fossil jellyfish have been found in rocks laid down about 420 million years ago in Pennsylvania. The nearest known relatives of the jellyfish are animals that lived in Australia about 230 million years earlier.

The fossils were seen by an undergraduate from Rutgers University, New Jersey, during a field trip to study techniques in Palaeontology. The specimens had been exposed by a road cut through the rock near the Delaware Water Gap, Pennsylvania.

Dr. S. K. Fox, geologist in charge of the trip, recognised the fossils as unusual. A search through the literature established that such similar fossil had been found in the Western Hemisphere; the most nearly related specimens had been discovered in South Australia in 1947 and were assigned to a new class of jellyfish-like animals named diplozoa.

*Nature-Times News Service*

**WHY ISLAND CHAINS ARE CURVED**

*The Times* October 30 1968

An elegant explanation of why certain chains of islands lie on curves of a particular shape has been proposed by Professor F. C. Frank, of Bristol University. He suggests that the shape of the curves is a simple geometrical consequence of the way in which the oceanic crust is deformed by the downward movement of the ocean floor.

Within the past 10 years or so, geophysicists have come to believe that the floors of the world's oceans are in more or less continuous movement. Under-water mountain ranges, such as the Mid-Atlantic Ridge, mark the site at which new material is injected up from the mantle of the earth.

Spreading away from the ridge at something like a centimetre a year, the new ocean floor constitutes the conveyor belt which in geological time has split up the former great masses and dragged the fragments—today's continents—to their present positions.

The various moving belts of ocean floor must somewhere bend downwards and return into the earth's mantle. The deep ocean trenches are now thought to mark the sites where this process occurs; mountain ranges such as the Himalayas and Andes may lie above former ocean trenches.


**SOCIAL BIAS IN METEORITE SIGHTINGS**

*The Times* November 6 1968

Falls of meteorites are witnessed more often in the afternoon than in the morning. If afternoon falls are indeed
more common, as is sometimes supposed, this is important evidence for deciding where meteorites come from. But a re-working of the statistics, together with a cunning comparison with sightings of unidentified flying objects, has led two American scientists to suppose that the bias towards afternoon falls is an illusion based on the social habits of human observers.

Journal of Geophysical Research 15th October

THERMAL MOVEMENT OF ANCIENT ROCKS
The Times November 12 1968

A theory to explain a pattern of some 20 dome-like geological structures in Rhodesia has been put forward by Dr. C. J. Talbot of the University of Dundee, writing in the current issue of Nature. Dr. Talbot, like many geologists before him, has been concerned to explain how such a large number of these dome-like structures, on the average 64km. across can have been formed in the close aggregate in Rhodesia. His explanation, backed by mathematical calculations, is that each of the domes represents a point at which comparatively hot rock was welling up from the bottom of the ancient crust of the earth more than two,000,000,000 years ago. Dr. Talbot suggests that this process could have happened when the crust of the earth was much younger than at present, but says that the sources of heat within the earth are not strong enough to recreate the phenomenon.

The structures which have been found in the earth's crust in Rhodesia are called Batholiths and have been recognised elsewhere on the surface of the earth, particularly in the ancient rocks of the Canadian shield. The collection of them in Rhodesia amounts to nearly a score in number and the sizes range from 25 to nearly 200 kms. across. The gaps between the batholiths in the Rhodesian rocks are comparable in size with the domes.

Nature 220, 552-556.

MONKEY FOSSILS PROMISE LIGHT ON EVOLUTION
The Times November 15 1968

The fossil fragments found at Napak in Uganda promise to supplement the evidence for the evolution of monkeys, apes and ultimately of man.

The fossils, a cheek tooth and part of a brain case, have been identified by Dr. David Pilbeam, of Yale University, and Dr. Alan Walker, of Makerere University College, as belonging to two fossil monkeys of the primate group known as the Old World monkeys, or Cercopithecoidea. Living representatives of the group include baboons, mandrills and macaques.

The two palaeontologists say that these fossils are probably the oldest and best preserved Cercopithecoida yet discovered. The rocks in which they were found have been estimated to be about 19 million years old, evidence that the monkeys were living in the geological period known as the early Miocene.

The relevance of these fossils to the origins of man is not yet clear . . .

Nature 220, 656-660.

ORIGIN OF THE OLDEST ROCK CHEMICALS
The Times November 16 1968

Life on earth may have begun less than 1,000 million years after the earth's formation, much earlier than is commonly supposed, if a suggestion about the origin of the oldest known organic chemicals is correct. Two chemists at Bradford University, Dr. J. Brooks and Dr. G. Shaw believe that the chemicals may be derived from a material similar to that forming the outer coating of present-day pollen grains.

A complex mixture of organic chemicals, known for want of a better term as kerogen, is found in certain ancient sedimentary rocks. The rocks were formed from the hardened layers of sediment that accumulated at the bottom of ancient seas and lakes, a circumstance that leaves open two possibilities for the origin of kerogen.

It could be derived from the biological material of the organisms that once inhabited the waters, and later altered by bacterial action in the sediments, and the temperatures and pressures of geological action. In this case the scientists are faced with the problem of tracing the molecules in the kerogen back to their likely biological forerunners.

The other possibility is that the kerogen was formed by inorganic means, the molecules being the product of simple chemicals condensed together by natural physical processes. Scientists have argued that just this sort of chemical evolution must have preceded the spontaneous creation of the first biological systems, and hope has been raised that kerogen itself may represent prebiotic chemicals.

One of the props of this argument has been the lack of convincing evidence about what class of biological molecules the kerogen could be derived from. This is the gap that the suggestion of Brooks and Shaw seeks to fill.

Nature 220, 678-689.

DETECTING EARTHQUAKES BY BAROGRAPH
The Times November 19 1968

A series of atmospheric disturbances caused by an earthquake off Japan last May was distinct enough to be detected by sensitive barographs maintained by the Atomic Energy Authority in Britain.

This occurrence, the second of its kind on record, raises all kinds of interesting questions about the propagation of atmospheric disturbances like these over very great distances. The results of the investigation so far are reported in the current issue of Nature by Dr. F. H. Grover and P. D. Marshall.


NEW THEORY OF THE ICE AGES
The Times November 21 1968

A theory that the ice ages may have been caused by an extremely long-term but regular fluctuation in the activity of the sun has been put forward in the current issue of Nature by Dr. J. R. Bray, of Nelson, New Zealand.

At this stage, his arguments are necessarily speculative, but the fact that he is able to make them is a sign of how great is the accumulation of evidence about long-term variations in the climate of the earth, and in phenomena with a possible bearing on climate.

The first difficulty in work of this kind is to compile a record of the ordinary 11-year sunspot cycle stretching back into prehistory. One way and another, a chronology running back to the fifth century B.C. has been built up on the basis of observations of sunspots from Western Europe in the past three centuries, ancient Oriental records of sunspot activity, records of auroral activity (which is greatest when the sun is most active), and from a variety of sources such as the variation of the thickness of growth rings of old trees.
GEOLOGICAL EXCURSIONS in SOUTH WALES and the FOREST OF DEAN

Edited by DOUGLAS A. BASSETT and MICHAEL G. BASSETT for THE GEOLOGISTS' ASSOCIATION: SOUTH WALES GROUP

EXCURSIONS include:

FOREST OF DEAN
The sedimentation of the Old Red Sandstone in the Forest of Dean by J. R. L. Allen.
The Forest of Dean Coal and Iron Ore fields by R. A. Gayer and J. T. G. Stead.

CENTRAL AREA
Old Red Sandstone, Carboniferous Limestone and Coal Measures sections around Newport and Risca, Monmouthshire by H. C. Squirrel.
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Dr. Bray has compiled necessarily sketchy evidence for the
progressive changes in the activity of the sun at sunspot
maxima in the past 2,500 years. Among other things, he has
relied on the empirical law that the sunspot cycles that reach
greatest intensity are usually the longest.

*Nature* 220, 672-674.

**THE RED LADY OF PAVILAND IS DATED**

The Times December 2 1968

The Red Lady of Paviland, a fossil human skeleton, has
been dated to 16,510 B.C., give or take 340 years, by the
radiocarbon method.

Human material of this age is very scarce, and scientists
have been reluctant to damage the bones by removing the
material needed for dating purposes. The Red Lady, dated with
only 62 grams of bone, is the most ancient human fossil to
which this technique has been applied.

Fossil human skeletons are usually dated indirectly by
applying the radiocarbon method to charcoal or other materials
found near the skeleton rather than to the bone itself.
Although for the most part accurate, the method will lead to
an over estimation of age in cases where the skeleton has been
buried in a grave dug into older deposits.

The Red Lady was discovered in 1823 by Dean W.
Buckland in Goat's Cave, or Paviland Cave, on the coast of the
Gower Peninsula, Glamorganshire. Buckland supposed that
the skeleton belonged to a woman buried in Roman times, and
that the objects made of mammoth ivory, found next to the
skeleton, indicated that her kinsman had dug up an ancient
elephant from the floor of the cave and made ornaments from
its tusks.

More modern researches showed that the Red Lady is the
skelton of a young man, ceremonially buried under a deposit
of red ochre, and in apparently intentional association with a
mammoth skull.


**LASER BEAM TO MEASURE EARTH SHAKING**

The Times September 9 1968

A new method of detecting minute vibrations set up in the
eye by distant earthquakes or local land movements has been
developed by physicists at Seattle. The method, based on a
beam of laser light, may help to give warning of certain
geological events as well as information about the interior of
the earth.

*Nature* 220, 1018-1020.

**SEA LEVEL CHANGES OVER 35,000 YEARS**

The Times December 11 1968

The rise and fall of sea level during the past 35,000 years
has been traced by dating the fossil remains of animals that
lived near the shoreline. It seems that 15,000 years ago the
coastline of the world lay some 420 feet below their present
level.

A series of suitable fossils has been collected from a range
of depths off the eastern coast of the United States and dated
by John D. Milliman and K. C. Emery of the Woods Hole
Oceanographic Institution, Massachusetts, who have been able
to reconstruct the fluctuations in sea level during the
g eo logically recent past.

They find that 35,000 years ago the sea stood at the same
level as at present. A steady decline brought it to about 160 ft.
below present level 20,000 years ago. After a more rapid rate
of sinking the sea reached a low point of 420 ft. 5,000 years
later. From 15,000 years ago there has been a steady rise
towards the present level.

Strictly speaking, these results refer only to the eastern
coast of the United States where the fossils were found. But
Milliman and Emery believe that this land mass has remained
stable over the period and that the shifting shoreline reflects
worldwide changes in sea level.

They note that 40 dates for ancient sea levels obtained by
scientists in various parts of the world—for example in Mexico,
the Caribbean and Australia—all agree with the sea level history
inferred from the east coast data.

The low sea level 15,000 years ago implies that the most
recent ice age the earth has undergone was then at its maximum.
The pattern of surface-living micro-organisms bored out of
deep sea sediment suggests that a dramatic improvement in
world climate occurred 15,000 years ago. A general rise in
temperature at this time would have put the glaciers into
retreat.

*Science* 162, 1121-1123.

**MOON CRATERS LIKE FROZEN TIDAL WAVES**

The Times December 13 1968

Some lunar craters, such as the Orientale Basin on the
extreme western edge of the moon's visible face, are surrounded
by a series of ring-like mountain ranges. In pictures taken by a
Lunar Orbiter spacecraft the rings of the Orientale crater appear
remarkably like ripples formed when a pebble is thrown into a
shallow pool, and may have been created in a similar way.

Dr. W. G. Van Dorn, of the Scripps Institute of Ocean-
ography, suggests that a large asteroid must have collided with
the moon at sufficient speed to set up a tidal wave, or
tsunami, which spread across the lunar surface. If the waves
were simultaneously frozen some time later, a pattern very like
the Orientale Basin would have emerged.

*Nature* 220, 1102-1107.

**LAMPREYS OF 300 MILLION YEARS AGO**

The Times December 19 1968

Fossil lampreys have been found in N. E. Illinois, embedded
in rocks formed during the Pennsylvanian era of the earth's
history, which began about 310 million years ago. The close
resemblance of the fossils to modern lampreys suggests that
the animals have changed little during the past 300 million
years. Ancestors of the lamprey may have evolved some 400
million years ago.

Lampreys, like hagfish, are surviving members of the
jawless fishes, the first group of vertebrates to evolve. Other
members include the ostracodermia, heavily armoured fish which
originated some 450 million years ago which were probably
ancestral to all other vertebrates.

But from 400 million years ago until the lampreys and
hagfish of the present day no ostracodermia or related forms
such as lampreys have been found in the fossil record. Discovery
of lamprey fossils 300 million years old fills in a missing link
in the chain of evolution.

Before the discovery, made by two Chicago scientists, David
Bardack and Rainer Zangerl, palaeontologists had assumed that
there was little chance of lampreys being preserved as fossils. Their bodies, which lack scales, and soft skeletons, made of cartilage instead of bone, are usually destroyed before fossilization can begin.

*Science* 162, 1265-1267.

**MOON RILLES CARVED BY STREAMS**
**The Times December 27 1968**

The $2,500m. which the United States is spending each year to put a man on the moon may have only a relatively meagre scientific return. But one profit from the latest mission should be detailed photographs of the lunar surface which may answer some of the questions astronomers have been asking for years. It is in one sense discouraging that the thick albums of photographs so far sent back by unmanned lunar probes have posed almost as many questions as they have answered.

One of the problems now exercising selenologists is the origin of the meandering channels, which look surprisingly like dried-up river beds. Called rilles, these features have been known for years from telescope photographs of the moon. But the close-up pictures now available allow rilles to be examined in great detail.

This has been done by Stanton Peale, Gerald Schubert, and Richard Lingenfelter at the University of California. Writing in *Nature* this week, they say that the meandering rilles tend to have their sources either at the edges of the circular “seas”, called maria, or around the edges of craters with flat floors. Their study is based on the high-resolution photographs taken by the American Orbiter 4 spacecraft in 1967.

The three scientists visualize slushy ice-covered rivers flowing from the crater margins, and carving out the meandering rilles. The rivers would have to be ice-covered, otherwise the water would evaporate in the vacuum conditions, the weight of the ice layer providing enough pressure to keep water in its liquid state.

*Nature* 220, 1222-1225.

**OIL AND GAS DEPOSITS THEORY**
**The Times December 30 1968**

A theory to account for the variations of chemical composition among natural gas and oil reservoirs has been put forward in *Nature* by Dr. W. G. Meinschein, Dr. Yaron Sternberg, and Dr. Ronald Klusman of Indiana University.

Theoretically, this question is important because of the possibility that the chemical characteristics of a deposit may be due to its origin. An understanding of the causes of the variations may also be of commercial value, if only because it might explain why some gas wells consist of pure hydrocarbons and why others consist of 98 per cent carbon dioxide or even pure nitrogen.


**ASTEROIDS BURIED IN THE MOON?**
**The Times December 31 1968**

Scientists interested in the moon are having difficulty in explaining the surprising evidence which came to light earlier this year that massive objects lie embedded beneath the lunar surface. Named ‘mascons’ by their discoverers at the Jet Propulsion Laboratory of the University of California, they were found from the perturbations in the orbits of spacecraft circling the moon.

A series of papers in *Science* makes it clear that scientists are by no means agreed on the nature of mascons. The most favoured view is that they are enormous lumps of meteoritic matter that have buried themselves under the lunar surface. But some believe that flows of solidified lava in localised regions are responsible for perturbing the satellite orbits.

P. M. Muller and W. L. Sjorgen, the two scientists who discovered the mascons, are proponents of the meteorite theory.

*Science* 162, 1388-1390.
Rocks and Relief

B. W. SPARKS

Lecturer in Geography at the Department of Geography in Cambridge University and Senior Tutor of Jesus College.

A book with strong appeal to those in the last year of school and the earlier years of university study.

The book attempts to bridge the gap between the study of ‘rock’ (geology) and the study of ‘relief’ (geography). It gathers from primarily geological sources the data that should be grasped by those interested in the rock-relief relationship.

Three main topics are discussed—
— the effects of various rock properties on relief
— the effects of the different classes of rock on relief
— the effects of differences in deposition on the regional relief of Britain.

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REVIEWS

THE ELEMENTS OF PALEONOTOLOGY
Rhona M. Black 325pp + index. Cambridge University Press. Boards (SBN 521.07445.2) 90s, Paperback (SBN 521.09615.4) 45s.

This book is intended to function as an introduction to the field of paleontology. The field is a vast one, perhaps too large to treat in one volume. The book is divided into two parts. The first part (Introduction) deals, rather sketchily, with the principle divisions of the animal and plant kingdoms, the preservation and occurrence of fossils, and with fossils as indicators of environment. The second part considers the main groups of invertebrates (10 chapters) with some reference to microfossils, vertebrates and plants (4 chapters). A final chapter is devoted to the origin and evolution of life.

As unsupervised reading the text may be too difficult for some, but as supplementary reading to lectures/classes it should prove useful to many students. The text-figures are numerous, clear and very well produced. Some improvement might have been made by the addition of more annotations on some of the diagrams, with an increase in size and less dense spacing of diagrams. Nevertheless the text figures are a great improvement on those of earlier books. Several photographs of well preserved specimens, both in colour and black and white, add to the attraction of this book. The continuing increase in the number of people studying the subject, together with the decrease in the availability of good specimens for practical teaching, enhances the value of these photographs to students and teachers in understanding the morphology of the different groups.

It is pleasing to find that the study of microfossils is included in this book. However, in view of our increasing knowledge of the variety of these small fossils and their value as an aid in solving geological problems in industry, it is unfortunate that the treatment in the book is so brief. Other readers may lament that we begin “the seventies” with a new textbook on paleontology which concentrates on morphology. However, the treatment is, at least to this reader, a great improvement on many earlier introductory texts, and to add more information on the value of the different fossil groups to the science of geology as a whole, is probably beyond the compass of one volume. This book will probably be purchased by students reading first year courses in geology at Universities and by teachers for Sixth form reference libraries.

E. Spinner

JACKDAW No. 76. VOLCANOES compiled by Greg. Jeffries. Jonathan Cape. foolscap folder. 60p SBN 305.61600.5

A Jackdaw is a folder containing a selection of illustrative material on one particular topic. ‘Volcanoes’ is the first one to treat a topic of geological interest (the majority of the others are historical and a few geographical).

Fifteen exhibits are presented mostly in the form of pictures or broadsheets, there are two simple card models of a rather elementary nature to be made, a series of extracts from newspapers and some eye witness accounts. The brief notes that accompany the material include a short list of books for further reading; details of five films on the subject; explanations of some of the terms that are employed and a few ideas for using the exhibits.

Jackdaws are most attractive and instructive ‘toys’; a boy might well be happy to buy one on a subject that interests him, but when they cost 60p each and deal with only one topic they are far too expensive to buy in bulk as classroom sets. So, one aim of a Jackdaw would appear to be to provide a teacher with a choice of material ready to use; material that children are expected to study for themselves. Now, this means that most of the exhibits need to be pinned on the wall and it is a bad fault that some of them are printed on both sides of the paper. These double sided exhibits are well set out but if they are presented in their present format then two copies of them should be included in each folder.

A subject like volcanoes cries out for colour, yet all the photographs are black and white. It would seem to be well worth a little extra cost to have one or two in colour or perhaps coloured slide transparencies for projection could be included in the folder. Some of the photographs reproduced from newspapers are not sufficiently clear to merit a place among the exhibits.

The biggest criticism to be levelled at ‘Volcanoes’ is that insufficient attention is given to scale. For instance, one photograph depicts part of Crater Lake, Oregon, the caption states that the whole lake has an area of twenty square miles, but the questions that the picture poses are:—“How high are the cliffs around the lake?”; “How high is the island?”; “How deep is the lake?” Only the last one of these is answered and that only incidentally on one of the other exhibits. Far too many of the pictures have no indication of the size of the features they show. Another question arising several times from these exhibits, that is bound to be asked, concerns the thickness of the lava flows and the speeds at which lava travels. Again sufficient detail is not given. Nine photomicrographs are used to illustrate igneous rocks, the point about variation of crystal size is made and some of the minerals contained in the differing types of rock are listed, but there is no uniformity of magnification of the photomicrographs and none of the minerals within them is labelled.

On the credit side there is an excellent photograph of Edinburgh with an explanatory tracing overlay showing the vents, lava flows and also the directions of ice movements, and the eye witness accounts of the eruptions of Vesuvius and Mt. Pelée when read aloud command rapt attention.

Sufficient has been written to indicate that this Jackdaw has collected a very mixed bag, and this in itself is not a bad thing, some of the material would help to fascinate the first form, while another selection could be used with considerable effect with the sixth. The idea of the Jackdaw is excellent but the execution of this particular one is not quite so good as it might be.

D. Hart.

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FIELD STUDIES FOR SCHOOL: VOL. 7: FIELD EXCURSIONS IN THE EAST MIDLANDS. Edited by J. B. Neilson. Rivingtons. 184 pp. 7" x 5" Cloth £1.50 SBN 280.22907

This volume is another in the series of Field Studies produced by teachers for teachers. They are intended to help the newcomer to acquaint himself with the area by indicating some of the more interesting landscape features in it. The contributors are all geographers, it should be noted, therefore geologists must not expect particular emphasis to be given to geology.

The East Midlands is deemed to be an area bounded in the north by Humberside; by the east coast to the Wash; in the South by Peterborough and Leicester and in the west by Ashbourne and the Manifold Valley. Some 11 of the 26 excursions described would be of special interest to the geologist. They cover almost the full range of geological formations to be found in the East Midlands from the Pre-Cambrian rocks of Charnwood Forest; the fairly complete succession from the Carboniferous in Derbyshire to the Cretaceous rocks of the Lincolnshire Wolds and reference to glacial and river deposits.

In no case are there detailed descriptions of geological sites but clear grid references would enable them to be found. Geological information given seems to be reasonably accurate; the only obvious error encountered is the inaccurate chemical composition of gypsum (p.154). In most cases references indicate where more geological information is obtainable though it is surprising that the 'Geology of the East Midlands' published by Leicester University receives no mention.

Inevitably, with so many authors contributing, there is some considerable variation in the clarity of explanation and in the illustrations. It is unfortunate that several of the excursions are not even accompanied by a sketch map and that some of the maps that are included are far too congested and confusing. The basic requirement on these sketch maps is surely an indication of the route. This is omitted on some and very difficult to follow on others. Inevitably the lack of at least one additional colour contributes to this.

Most of the book is devoted to studies of rural or urban settlement where geology appears very much as background information. In all cases suggested classwork is indicated. The book has some 10 black and white photographs which are mostly of settlement and are likely to be of limited interest to the geologist.

Generally, this is a volume that invites comparison with Professor Kirkaldy's Geological Time which was published a few years ago and it is equally inevitable that the larger format and glossy appearance of the American book makes a better first impression. It says much for Professor Kirkaldy that he has produced, at one third of the cost, an equally informative and clearly written account of geological time. From the British student's point of view his book also has the advantage of using European examples wherever possible.

It is appropriate that a book written about time should treat the subject historically and this aspect, together with biographical notes on outstanding workers such as James Hutton and William Smith, will give students an insight into the history of stratigraphy in a very readable manner. The book is divided into seven chapters but falls readily into two main parts; firstly the purely geological efforts to erect a relative time scale and attempts to assess the amount of time and secondly, the application of isotopic studies to the rocks to produce an isotopic time scale. The first part considers the importance of unconformities, orogenies and fossils in the history of development of the geological column, and it is the weakest part of the book. It gives little indication of the painstaking and detailed work behind the single subdivision of Phanerozoic time which is given on page 15, and no indication of the recent quantitative approaches to determination. This is unfortunate because isotopic dates are of limited value without adequate relative dates.

The second part of the book (Chapters 5 and 6) considers the methods of isotopic dating and the employment of the results in the construction of an isotopic time scale. Each method is dealt with in a clear and concise manner and includes a little of the theory behind the methods and their limitation. Only a little chemical knowledge is required to understand the theory and I would think that this section would be extremely useful to 'A' and 'O' level candidates. Similarly, the isotopic time scale is dealt with thoroughly, clearly indicating where major boundaries are poorly dated. One particularly useful paper is a case history of the application of isotopic dating to the Scottish Highlands which puts in a nutshell many of the problems which arise when interpreting 'absolute' dates.

A. C. Higgins.


SBN 280 22905.4 221pp. Cloth (not boards) £1.40 5" x 7¼"

This pocket book, with contributors drawn from a variety of teaching and research posts, introduces twenty-nine suggested field excursions in south-western Scotland. As might be expected, the majority of excursions centre in and around the city of Glasgow, and suggested practical studies in industrial rural geography, ecological botany, zoology and archaeology are included. Little reference is made, however, to the rich variety of geological features of the Glasgow district. This may be because there already exist well-known geological excursion handbooks to the Glasgow district—which those of D. A. Bassett (1958) and of McCallien (1938)—but it is perhaps a reflection of the lack of emphasis on geology and physical geography throughout the volume that reference is not even made to these guide books in the Foreword and editorial Introduction of the volume reviewed here.

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The Dorset Coast

G. M. Davies

Few parts of England offer a better training-ground in geology than the coast of Dorset. All the principal structures of sedimentary rocks are to be seen there in diagrammatic clearness, and the fossils are plentiful. The Dorset coast is described almost foot by foot, from Pinhay Bay, to Studland.

2nd edn 14 photos, 33 figs 80p net

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"By those accustomed to the hopeless confusion of the Greywacke of the earlier geologists, the publication of Murchison's grand work on the "Silurian System" was hailed with feelings of the most profound relief and satisfaction. His clear and brilliant presentation of the physical and palaeontological proofs of an orderly sequence among the Palaeozoic Rocks below the Old Red Sandstone, as originally set forth in all their force and harmony in his magnificent volumes, naturally astonished and dazzled the majority of his scientific contemporaries, and secured for his nomenclature of these ancient deposits an almost universal acceptance . . ."

Charles Lapworth would, no doubt, have enthused with the same eloquence had he seen the great collection of scientific books and periodicals which RICHARD BOOTH, BOOKSELLERS, has among his stocks at HAY CASTLE in the lovely Wye Valley.

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Further afield in south-western Scotland, seven of the listed excursions include material which should be of interest to the geologist or geomorphologist, but only three of these, the excursions to Clydeside above Bothwell, The Forth Valley near Gargunnock, and The Upper Solway Coast, provide information which is not readily available in the existing geological guide books already mentioned or in M. Macgregor’s: Excursion Guide to the Geology of Arran. It would have been valuable to all teachers of field sciences, not just to geologists, to have had more suggested excursions for parts of south-western Scotland not covered by existing guide books.

Having critically examined the content of the handbook from the viewpoint of the geologist or geomorphologist, it is fair to add that there is much that is of value to the physical geographer who includes in his interests and teaching ecological aspects of botany and zoology and, taken as a whole, perhaps the book is not unduly weighted on the social side of geography.

The individual excursions contain background information on each topic or area concerned, followed in most cases by suggested routes to be followed, by suggested classwork, and a short bibliography. The type of classwork proposed varies greatly in quantity and character, from making up a sample shopping list and comparing prices in a large suburb with those in the city of Glasgow, to collecting invertebrate animals from the surfaces of stones in the Forth and Clyde Canal, and classifying them at least to the level of Class or Order. The entries on suggested classwork will be of value to teachers at all levels who lead field excursions because, as is well known, the excursion which includes definite tasks and exercises for the participants is much more likely to be successful than the one confined to the indication of features of interest. It is these practical suggestions at the end of each excursion which are of greatest value in this handbook. The suggested classwork may provide work topics not only for the excursions included, but also may suggest ideas for practical work on other, unlisted excursions led by the reader.

W. G. Jardine


Teachers are often advised to teach the history of geology to their pupils. One major difficulty, however, is that the original material is not readily accessible.

In recent years, however, a great many facsimiles of the original publications of the founders of geology have been published and usually with commentaries by eminent contemporary historians of geology.

Up to twelve years ago the writings of James Hutton were difficult to obtain but since 1959 the material has become progressively more accessible, with the result that the writings are more readily accessible now than at any time during the last 100 years.


Now we have reprints of three other works by Hutton under the one cover. First the 28-page Abstract of a Dissertation read in the Royal Society of Edinburgh, upon the Seventh of March, and Fourth of April, M.DCC.LXXXV, concerning the System of the Earth, its Duration and Stability.

The Abstract is unsigned and undated, but Dr. V. A. Eyles has established that it is Hutton’s work and that it appeared in 1785. The evidence for these deductions, first published in 1949 in the volume of the Transactions of the Royal Society of Edinburgh issued to mark the 150th anniversary of Hutton’s death, is given in full in Dr. Eyles’ introduction to the present volume.

Although Hutton occupied himself in the years following 1785 in accumulating “Proofs and Illustrations”, the Abstract, as Dr. Eyles points out, shows that his basic conclusions, the ideas that led to the establishment of the doctrine of uniformitarianism and the foundation of modern geology, had already crystallized.

The earliest form of Hutton’s well known statement about the “age of the earth” is given in the Abstract:

“But, as there is not in human observation proper means for measuring the waste of land upon the globe, it is hence inferred, that we cannot estimate the duration of what we see at present, nor calculate the period at which it had begun; so that, with respect to human observation, this world has neither a beginning nor an end”.

And there is much more that is well worth quoting. Take, for example, the first few paragraphs:

“The purpose of this Dissertation is to form some estimate with regard to the time the globe of this Earth has existed, as a world maintaining plants and animals; to reason with regard to the changes which the earth has undergone; and to see how far an end or termination to this system of things may be perceived, from the consideration of that which has already come to pass.

As it is not in human record, but in natural history, that we are to look for the means of ascertaining what has already been, it is here proposed to examine the appearances of the earth, in order to be informed of operations which have been transacted in time past. It is thus that, from principles of natural philosophy, we may arrive at some known of order and system in the oeconomy of this globe, and may form a rational opinion with regard to the course of nature, or to events which are in time to happen.

The solid parts of the present land appear, in general, to have been composed of the productions of the sea, and of other materials similar to those now found upon the shores. Hence we find reason to conclude,

1st, That the land on which we rest is not simple and original, but that it is a composition, and had been formed by the operation of second causes.
NATURAL HISTORY SOCIETY OF
NORTHUMBERLAND, DURHAM
AND NEWCASTLE UPON TYNE

GEOLOGY OF DURHAM COUNTY
By G. A. L. JOHNSON and GRACE HICKLING.


A GUIDE TO THE GEOLOGY OF NORTHUMBERLAND AND THE BORDERS
By D. A. ROBSON.

An introductory guide to the geology of Northumberland and the eastern borders lavishly illustrated with maps and line diagrams. 77 pages, maps and 40 text figures. Published 1965. Price 75p, by post 81p.

More detailed papers on the geology of Northumberland and Durham published by the Society include:—

THE GEOLOGY OF THE COAST SECTION FROM TYNEMOUTH TO SEATON SLUICE
By J. M. JONES.


THE CARBONIFEROUS, NAMURIAN ROCKS OF THE COAST SECTION FROM HOWICK BAY TO FOXTON HALL, NORTHUMBERLAND
By N. FARMER and J. M. JONES.


HOLY ISLAND DYKE
By B. A. O. RANDALL and N. FARMER.


Copies of these guides are available from:—
Hon. Secretary, Natural History Society, The Hancock Museum, Newcastle-upon-Tyne, NE2 4PT
Secondly, That, before the present land was made, there had subsisted a world composed of sea and land, in which were tides and currents, with such operations at the bottom of the sea as now take place. And,

Lastly, That, while the present land was forming at the bottom of the ocean, the former land maintained plants and animals; at least, the sea was inhabited by animals, in a similar manner as it is at present.

Hence we are led to conclude, that the greater part of our land, if not the whole, had been produced by operations natural to this globe; but that, in order to make this land a permanent body, resisting the operations of the waters, two things had been required; 1st. The consolidation of masses formed by collections of loose or inherent materials: Secondly, The elevation of those consolidated masses from the bottom of the sea, the place where they were collected, to the stations in which they now remain above the level of the ocean".

Second, the 96-page paper Theory of the Earth: or an Investigation of the Laws observable in the Composition, Dissolution and Restoration of Land upon the Globe, by James Hutton, M.D., F.R.S.Edin. and Member of the Royal Academy of Agriculture at Paris.

The paper was presented in 1785 and published in 1788 in Volume 1 of the Transactions of the Royal Society of Edinburgh. The material was later reprinted in very slightly modified form as the first part of the two-volume Theory of the Earth (1795), the remainder of the volumes being an extensive defence of his Theory written in answer to criticisms of his 1788 paper.

Dr. Eyles makes the point that it was Hutton's statement regarding the age of the earth, quoted above and repeated in slightly different words in later versions of the Theory, that led to the charge of impiety made against him in some quarters.

In this context it is interesting to note the suggestion made by Norton Garfinkle in his paper "Science and religion in England, 1790-1800" in the Journal of the History of Ideas (1955, pp. 376-388). He maintains that during the last decade of the eighteenth century, the pattern of English thought was altered profoundly. One of the most important developments was the growth of public concern about the relation of science to religion. When Hutton's 1788 paper appeared the reviewers in The Critical Review, The Monthly Review and The Analytical Review, etc. criticised Hutton's study solely on scientific grounds. But because of the appearance of new religious and political forces during the last decade of the century which combined to insist upon Biblical literalism, the reaction to the 1795 volume was very different.

Third, the 5-page paper Observations on Granite.

The paper was read to the Royal Society of Edinburgh on 4th January, 1790. It is of particular importance because it records an advance in Hutton's views on the origin of the igneous rocks. It was in this paper that he presented evidence that granite was an intrusive rock. As Dr. Eyles rightly points out, it sometimes seems to be over-looked that one of Hutton's achievements was the establishment of an entirely new class of rocks, the intrusive igneous rocks.

The following quotation from the paper illustrates one facet of Hutton's method of working:

"This was the question, with regard to granite, that I wanted to have resolved by means of the connection of that mass with the Alpine strata; that is to say, I wanted to see, whether the granite mass, in point of time, had been prior or posterior to these water-formed bodies; and, as to the manner of operation, I particularly desired to know, if that granite had been made to flow, in the state of fusion, among the broken and dislocated strata.

Having thus suspended my opinion, until I should have an opportunity of finding some decisive appearance, by which this important question might be determined with certainty, I considered where it might be most likely to find the junction of the granite country with the Alpine strata. Mr. CLERK of Eldin and I had an engagement to visit the Duke of ATHOL, at Blair. I concluded, that from Blair it could not be far before the great mass of granite, which runs south-west from Aberdeen, would be met with, in ascending the river Tilt, or some of its branches. Mr. CLERK and I were, however, resolved to find it out, to whatever distance the pursuit might lead us among the mountains of this elevated track. Little did we imagine that we should be so fortunate as to meet with the object of our search almost upon the very spot where the Duke's hunting-seat is situate, and where we were entertained with the utmost hospitality and elegance.

It is in Glen Tilt, and precisely in the bed of the river, that this junction is formed of the granite with the Alpine strata. But this circumstance, of being in the bed of the river, where the rocks are often washed bare, is of such importance, that had this junction been only to be found in the mountains covered with heath and moss, we might have been upon the spot, and yet been ignorant of the most material circumstances of the fact, which we wanted to explore.

I here had every satisfaction that it was possible to desire, having found the most perfect evidence, that the granite had been made to break the Alpine strata, and invade that country in a fluid state. This corresponded perfectly with the conclusion which I had drawn from the singular specimen of the Portsoy granite".

The specimen of Portsoy granite is described and illustrated in both the 1785 paper and the 1795 book; the latter is included in my anthology of Hutton in volume 2 of Geology.

The Hafner volume also contains a facsimile of the only biography of Hutton, John Playfair's Biographical Account of the late Dr. James Hutton, F.R.S.Edin., which first appeared in the Transactions of the Royal Society of Edinburgh (Volume 5, 1805) and was later reprinted in The works of John Playfair, Esq., 1822, Volume 4.

Additional aspects of Hutton's personality are given in letters to the distinguished contemporary diplomat, naturalist and antiquarian John Strange, F.R.S., published by Dr. and Mrs. V. A. Eyles in the Annals of Science for 1951 and also in extracts in the diary of one Sylas Neville, quoted in Dr. Eyles' Introduction to the Hafner volume.

The following extract is from a letter to Dr. Manning written on 2nd June, 1772:

"In consequence of your kind recommendations I was received with such civility by Dr. Monro and Dr. Hutton, particularly the latter, who has been of signal service to me. He is the oddity you described to me, but
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at the same time a mighty good sort of man. His study is so full of fossils and chemical apparatus of various kinds that there is hardly room to sit down”.

The volume under review is the fifth in a series of facsimile reprints under the general title “Contributions to the History of Geology”. The fourth volume in the series was the very famous *The Prodromus of Nicolaus Steno’s Dissertation concerning a Solid Body enclosed by Process of Nature within a Solid.*

The Hafner Publishing Company is to be complimented on initiating such a venture and Dr. George W. White of the University of Illinois for the consistently high standard of editing and for his general interest in the history of our subject. Dr. V. A. Eyles is also to be complimented, not only for his work in connection with the volume under review, but for his continued studies—his many publications—on James Hutton.

One serious disadvantage from the standpoint of both teacher and student of all the hardback books mentioned earlier is the price. It is to be hoped that the publishers will soon consider issuing paperback editions.

D. A. Bassett.

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**BOOKS FOR TEACHERS OF GEOLOGY**

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NOTES ON

THE PREPARATION OF PAPERS FOR PUBLICATION IN "GEOLOGY"

Papers should be submitted in clear legible typescript with double spacing and wide margins on quarto size paper, one side only of which should be used. Pages should be numbered consecutively.

The title should be as brief as possible and headings restricted, whenever possible, to main and secondary headings only. The headings, paragraphs, etc., should be clearly indicated. Footnotes should be avoided.

References must be arranged alphabetically at the end of the paper; papers by the same author should be listed in chronological order. The full reference must be given, i.e. author, date, title of paper, journal, volume and page numbers. In the case of a book, the name of the publishers, place of publication and number of pages should follow the author, date and title. Abbreviations used for the titles of journals should follow those given in the World List of Scientific Periodicals (4th ed., 3 vols., Butterworth, 1963-65).

The position of tables and text figures should be clearly indicated in the text.

Articles should not exceed 10,000 words (ideally 5,000 words). Illustrations should be kept to a minimum. Line drawings should be made in indian ink on stout white card or paper; stencil lettering should be used. Block size 6\(\frac{3}{4}\) wide by 8\(\frac{1}{2}\) deep or in the same ratio.