GEOLOGY AS AN ENVIRONMENTAL SCIENCE

Inaugural Lecture
delivered at the College
on November 4th, 1969

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' In the land of lobelias and tennis flannels
The rabbit shall burrow and the thorn revisit,
The nettle shall flourish on the gravel court,
And the wind shall say : "Here were decent godless
people :
Their only monument the asphalt road
And a thousand lost golf balls" '.

T. S. ELIOT.

GEOLOGY AS AN ENVIRONMENTAL SCIENCE

THE Department of Geology at Swansea began with the College 50 years ago next year. I feel honoured in having known all four of my predecessors in the Chair, Sir Arthur Trueman who founded the Department, T. Neville George, Duncan Leitch and Frank Rhodes.

The Department now has 16 on its teaching staff, 21 technical and administrative staff and well over 300 students. It has the largest honours school in geology in the United Kingdom and is the largest science department on the campus in terms of student numbers (though not, I hasten to add, in terms of income, staff or space).

I have chosen as the title of my address ' Geology as an Environmental Science '. This is, in a way, something of a contrivance, since I am using it in two rather different senses. Firstly I am using it in the sense that a major aspect of geology is concerned with interpreting the environments of the past, and in this part of my address I will attempt to give some account of my own work and that of my colleagues and students. In the second part I will consider geology as an essential part of the study of our present environment, both in Swansea and in the world as a whole.

My theme is I think appropriate not only because it represents my own interests, but also because it represents the main field of study both today and in the past of the Geology Department at Swansea.

The usual popular image of a geologist is of a forgetful old professor studying the rocks, oblivious of the sea lapping round his boots, armed with a hammer and a beard and spending most of his time searching for fossils. I do possess a hammer, I have had a beard and I do look for fossils, but geology has progressed a lot further than this. Even our own Works and Buildings Department appears to think at times, quite mistakenly, that we do not need such extravagances as fume cupboards and compressed air and constant temperature rooms. Geology is

the application of all sciences to the study of the earth and its history, so that every advance in both the physical and the biological sciences is potentially of value to us. In a sense then, the geologist needs to be a superscientist, a Baconian complete man, who takes ' all knowledge to be (his) province ', for even such matters as economics and human history and the aesthetic appreciation of the countryside and architecture come into our business. But of course, none of us can cover adequately and scientifically more than a tiny field in the vast and varied plain that is geology. Each of us can only know really well one group of minerals, one order of fossils or one part of the vast span of time represented by a single geological period.

I trust therefore that I will be excused if I do not attempt to follow the customary inaugural tradition of trying to survey the present state of knowledge in the whole of my subject. I shall, however, at least follow the pretentious pattern of other faculties in beginning the printed version of this address with a quotation, as my own puny blow in the battle against the C. P. Snow ' Two Cultures ' myth.

The quotation I have chosen is appropriately enough from T. S. Eliot's poem *The Rock*. I will consider first those ' thousand lost golf balls ' : in other words the geological record in all its inadequacy and fortuitousness. I will then go on to discuss the nettles on the gravel court that is our present man-made and man-afflicted environment.

First then, the environments of the past. Max Beerbohm said ' There is always something rather absurd about the past ', but it is not that the geological past itself was absurd any more than the historical past was absurd to the people living in it. What is absurd is the nature of our record of that past. Eliot's asphalt road and lost golf balls are no more ludicrous a record of an era than are the average sediments and fossils on the basis of which we have to reconstruct a sea floor or a river bed hundreds of millions of years old.

My own work has been concentrated on the Mesozoic Era of earth history. I have worked mainly on certain regional studies of some of the better wine growing areas of Europe and on one group of fossils—the phylum Brachiopoda. The brachiopods, though still living today in a humble way, are sadly neglected by the zoologist. Here we are still in the descriptive stage of our science, for whereas at the present day there are perhaps some 200 species of brachiopods scattered around the world, in the Mesozoic era alone, which was by no means the heyday of the phylum, there were nearly 200 genera of just one of the constituent orders and certainly 200 named species for each of the thirty or so Ages into which the periods of the Mesozoic are divided.

It has been estimated that there are 1,500,000 living species of animals and plants on earth today. It has also been estimated, with even less validity, that a species survives on the average about half a million years (which means incidentally that *Homo sapiens* has already passed its allotted span). On that basis there may have been something like 1,800,000,000 species on earth since the beginning of life, all of them potential fossils. The immensity of the task of straight forward study and description is obvious.

The Mesozoic Brachiopoda are a comparatively well-studied group, yet it is still hardly possible to make an exhaustive collection at any good locality without finding undescribed species if not genera. Most of those that have been named have only been described in the most superficial way in terms of external appearance and we are only just starting on biometrics and the proper statistical evaluation of intraspecific variation. With serial sections and cellulose peels, almost every specimen has the excitement of a detective story. To quote one example from thousands, an undescribed species in a thin bed of Jurassic sediment in Dorset proved to belong to a genus which had at that time been described only from Sicily. This was the first clue in a whole trail of

evidence that revealed strong, but temporary, Mediterranean connections, and thereby gave fresh insight into contemporary geography and faunal provinces.

That brings me back to my main theme, for though there remains this immense task of morphological study and description, we are already in a position to make meaningful deductions about evolution, geographical distribution, fossil communities, ecological adaptation and functional morphology of species and groups long extinct. Certainly our conclusions in these fields have much more validity than they had a few years ago.

Thus within finely delimited time divisions of the Mesozoic Era we can recognise clear distributional zones of brachiopod genera and species. In some respects these seem to relate to ancient faunal provinces, notably in Mesozoic times the so called Tethyan province referring to an elongated ocean (called Tethys by classically educated geologists) which existed for many millions of years and of which the Mediterranean is the last remnant. From almost the beginning of the main fossil record, nearly 600 million years ago, through to the Alpine mountain building spasm a mere 25 million years ago, one can recognise this ocean and its faunas. Some Mesozoic brachiopods, for example, are virtually identical whether they come from Mexico, Morocco or India, whereas they are unknown in equivalent strata a short distance further north and south.

But it is always unwise to place too much reliance on the distribution of one organism or group of organisms. The *Yucca* palm, for example, is characteristic of the more arid parts of southern Europe and north Africa, but also flourishes on Mumbles Head. What is more, it is my purpose here to talk about the distribution of fossil organisms, not in relation to some vague indefinable thing called geography, but in relation to their contemporary environments.

The brachiopods are particularly suitable for such studies in that as sessile, benthonic, suspension feeders,

I think their distribution is controlled by the nature of the bottom to which they attach themselves. In this I differ somewhat from some of my coworkers, who see more significance in depth of water and geographical barriers than in the nature of the substratum. Thus the highly unusual Mesozoic brachiopod family, the Pygopidae, is particularly characteristic of the Mediterranean region and would be regarded by most geologists as typically Tethyan forms, but also turn up in a very similar sedimentary environment in eastern Greenland. I mention these things, however, not merely because the brachiopods are (after women) the most fascinating of living organisms, but to illustrate the point that we still have a vast amount of straight-forward work before us.

But the study of fossils in relation to their ancient environments is much more than this. We can now use most of the methods of the ecologist in studying our extinct organisms. Quantification and the shadow of the computer have now spread into all aspects of our subject. On the whole we can use the methods of the plant ecologist rather more than those of the animal ecologist for the simple reason that our fossils, like plants, stay in one place and do not have to be caught. Thus we now use quadrat studies widely in the study of rock bedding planes which seem to represent actual ancient sea floors. With the quantitative data so acquired we can use simple statistical methods such as the chi-square test to estimate the probability of associations being significant rather than random and we can build up whole constellation diagrams to show the natural groupings within a fossil assemblage. We can even reconstruct the distribution of different trees in an ancient forest or the distribution of sessile organisms on a sea floor. We are also beginning to carry out such exercises as mapping the diversity indices of fossil faunas, with fascinating results.

So far I have only mentioned the biological half of the story of ancient environments, since that is my own chief interest, but we can learn even more from the rocks

themselves, that is, from the ancient sediments in their various forms.

In the Jura mountains of south east France, my students and I worked in an area of repeated coral reef development of Jurassic and Cretaceous age, with associated shallow marine and lagoonal deposits. In the Dordogne area, west of the Massif Central, the reefs are algal rather than coral and are of potential economic importance as oil traps. In the English Cotswolds a former colleague and I have concluded that strata of about the same age were laid down in extremely shallow water comparable to the carbonate-depositing environments of the Trucial Coast at the present-day and with the interesting conclusion that Wales was mostly, if not entirely, flooded by the sea at that time.

On the other hand, in the Boulonnais region of northern France, we find a sandy rather than a limy coast-line of Jurassic age, with intensely burrowed subtidal sediments and even inter-tidal beach sediments at times. Finally in considering such field studies, I must mention the southern Celtiberic chain in eastern Spain where I have just started a project for Swansea students and where, besides the varieties of Mesozoic sediments I have already mentioned, we have river and flood-plain deposits of Triassic age magnificently exposed.

In western Canada, the main wealth of the Province of Alberta depends on the finding, at great depth, of ancient coral reefs which form reservoirs for oil and gas. This fact is so important in the economy that there is a monument in Calgary to the cavernous rock concerned. There are now said to be more geologists in Calgary than in the whole of Britain and they are nearly all primarily concerned with this business of interpreting the ages and environments of ancient rocks which are seen at the surface in the Rocky Mountains to the west, but are buried, with their oil, at great depths under the prairies.

In such circumstances the geologist has to depend on tiny chippings of rock brought up by exploratory borings.

A mistake may cost vast sums of money. Every possible character of the rock and its fossils has to be considered and the geophysicist lowers every kind of recording device down the boreholes to log the strata penetrated.

Where the strata reach the surface we are in a much better position to be scientific in reconstructing ancient environments. In South Wales, for example, a colleague has analysed statistically nearly two thousand observations on cross-bedding directions in the sandstones of the Coal Measures. As a result he has arrived at a picture of the river drainage pattern in this region some 300 million years ago which bears directly on the environment of deposition of the coal-seams and the economically important matter of their lateral variation. Such studies have been aided by flume experiments in the department and by studies on analogous modern river deposits.

Similarly our geochemists have studied the variation in the organic carbon content of the shales associated with the coal-seams. They have found a progressive increase in hydrocarbons which relates directly to the depth of water in which those sediments were deposited. At the same time, variations in fluorine and boron content can be related, with confidence, to variations in the salinity of those ancient seas.

Much of this is pure research, but in application it may bear directly on the finding of those concentrations of hydrocarbons which constitute the principal wealth of many nations in the world today. The study of ancient environments is not merely an academic exercise, not merely the satisfying of our curiosity about past worlds ; it has a direct and major bearing on the discovery of all the vital mineral resources which our modern world is devouring at such an alarming rate.

But another geochemical study currently being pursued in our laboratories illustrates environmental geology in a completely different sense. This study relates to the relatively high incidence of that heart-breaking juvenile deformity *Spina bifida*, in mining areas of South Wales and

elsewhere. Work is now going on in the Department to see if it can possibly be related to an abnormally high content of certain trace elements in the local coals which are burned in these areas. So geochemistry has led me from considering the geological environments of the past to considering geology as it bears on the human environment of today and of the future.

It is the most hackneyed and misused geological dogma that we interpret the past in the light of what we know of the present. But at times we can also reverse this uniformitarian principle and interpret the present in the light of what we know from the geological record.

> ' Time present and time past
> Are both perhaps present in time future
> And time future contained in time past '.

(T. S. Eliot like Tennyson is full of geological philosophy).

Considered in the broadest sense, geological science can give us clear indications of the future of man's environment on the earth's surface. The geologist is perhaps more aware than anyone else that, as Gogarty wrote in a delightful free translation from the Greek :

> ' Everything changes
> Time deranges
> Men and women and mountain ranges . . .'

But a geologist is also perhaps more aware than anyone else that ' Plus ça change, plus c'est la même chose ' for he sees constantly the phenomena of today's environments preserved for him in the rocks.

He can therefore forecast what major changes are likely to take place in the distant future. Thus it is likely, extrapolating from Voigt's interpretation of the history of north west Europe during the last 100 million years or so, that there will be a major uplift in the western part of the English Channel and in the Irish Sea at some time in the future. At the same time one may expect that Wales will once more disappear under the sea. I am fairly safe from contradiction in this, since it is hardly likely to happen during my tenure of the Chair at Swansea.

On a much more modest scale, we can now forecast, for example, with fair confidence, the probable locality and time of future earthquakes. Local authorities ignored, to their cost, the warnings by geologists which preceded the disastrous Alaskan earthquake of 1964. In fact there is a general, almost world-wide, neglect of geological advice in the field of major planning and development. I could easily give enough examples of this to convince my listeners that I have a persecution complex, so I will just mention a well-known South Wales clearway which was situated in a disastrous position from a geological point of view, contrary to advice, and at resultant great cost. I cannot resist adding, however, that, by all accounts, a considerable sum might have been saved in building the present Natural Sciences Building itself if sufficient notice had been taken of the advice of an engineering geologist.

It would also seem that Swansea might benefit at the present time of restrictions through consulting a geologist about her water supply.

That we have a large and flourishing department of geology at Swansea is in itself an illustration of my theme of environmental control. The coal industry and the iron and steel industry of South Wales both arose directly from the Carboniferous strata which underlie this College.

We are also particularly fortunate in that one of the major structural lines of Europe, the boundary between what Stille called ' Palaeo-Europe ' and ' Meso-Europe ' passes just below our feet. As a result we have to the north, the exploitable economic resources of comparatively gently folded strata, whereas to the south of the line we have the strongly folded and scenically exciting rocks of Gower and Pembrokeshire. And let us never hereafter forget that dry land is only half of Swansea's domain. We now have a vigorous and enthusiastic (if impecunious) Sub-department of Oceanography within the Geology Department. It is unique in Britain in being largely concerned with the all-important geological and environmental aspects of the sea and the sea-shore.

Just before Apollo XI landed on the moon in July, I was asked by the local press if our department was getting any of the moon rock. My reply was that, although we were naturally interested in these very expensive specimens, we were far more occupied with Swansea Bay, about which we know rather less than we know about the moon.

We seem to have been, and still to be, appallingly irresponsible over our natural environment through the neglect of seeking and taking proper scientific advice. As the Principal has reminded us, Walter Savage Landor called Swansea Bay ' that most beautiful coast in the universe ' and certainly at night, when darkness hides the despoilation and neglect, it compares favourably with the Bay of Naples or the Bassin d'Arcachon. Yet we have neglected its wonderful beaches. We allow intrusive *Spartina* grass to spread and to trap mud so that almost inevitably much of the bay will become a foul-smelling salt marsh. We extract sand and gravel both from the beach and offshore with no apparent control of the long-term effects ; we have despoiled great areas of the landward side of the bay without, until recently, any apparent planning for restoration, and we are currently pouring all sorts of horrifying effluent into the sea without seemingly caring about the long-term or even the short-term effects.

This is more than letting the nettles grow on our gravel court, it is making our own garden into a rubbish dump and putting filth into our own swimming-pool. Could anything be more idiotic and more shortsighted ?

Clearly a College such as this has a duty to its own region as well as to university education and research in general. We have a large geology department including our school of oceanography, both staffed with experts and with research students amply qualified to work on all the kinds of environmental problems I have mentioned. Have not the regional authorities themselves the duty to make use of these facilities in the service of the community ? Is it not, in fact, common sense for them to do so ?

We already have an arrangement with the Ministry of Agriculture, Fisheries and Food to carry out water sampling studies on the dispersion of radioactive waste contamination down the Bristol Channel from nuclear power stations on the Severn estuary. But the problems connected with untreated sewage and heavy metal pollution are potentially much more serious. We just do not know what we are doing to the natural environment of the sea and it is time that we did.

We are now actively at work in Swansea Bay and all along the South Wales coast, thanks to the University Grants Committee having provided us with a splendid research vessel—the ' Ocean Crest '—and in spite of the fact that no one has yet provided us with anything but pitifully small sums and temporary loans to run it ! We are unique in having this ship and three inshore boats in the equipment of a geology department. The resultant opportunities are immense. We can train our undergraduates and our research students properly in practical as well as theoretical oceanography. We have the vessel always available, with our equipment in position, for whenever the weather makes it possible to carry out our delicate sampling and testing operations. Pure minded geologists and geophysicists are equally involved and every voyage brings in a wealth of new information, not only about the sea-floor, but also about water and sediment movement, water composition and temperature, faunal and floral distributions, in fact every facet of the marine side of the Swansea environment as a dynamic, evolving system. We already know the form of the sea-floor over large areas and the thickness of unconsolidated sediment resting on it. We have recognised features such as channels cut down into the limestone of Swansea Bay and probably representing the ancient course of the River Tawe. That shows how close these matters are to classical geology, for soon after those channels were being cut out in the bay, the soil levels were probably being formed on land that we saw a few weeks ago just across

the Mumbles Road in the cutting for the new ' bus stop '. And on the beach just across there we can see the remains of a contemporary forest, now submerged at high tide, which has been dated from the decay of the radioactive carbon in the wood as some 8000 years old.

In all our oceanographic work there is a growing trend towards interdisciplinary co-operation. We have had a close association from the start with Zoology in our studies of the marine environment and are now working also with Genetics. To show the way in which this may work I would like to cite the example of fish farming, which is of great interest to the zoologists. In this subject the control of parasites is a vital consideration and our geneticists are considering work on the genetic control of resistance to parasitism. Bivalve molluscs act as secondary hosts to the parasites and these molluscs in turn are very much controlled by their sedimentary environment : bottom type, water turbidity and so on. These factors concern us very much as geologists and take us back once more to our research on ancient environments where the relationship between organisms and sediment are often better displayed and easier to study than they are today.

We are also actively engaged with our Electrical and Mechanical Engineering Departments in a totally different field. This is the design and construction of a remote-controlled oceanographic survey submersible. This vessel, which we have christened the ' Dolphin ' (for reasons that will become obvious later) should provide quickly and cheaply information about every aspect of the marine environment. It may well prove a major breakthrough in oceanographic research.

We are also very interested in the basic geological structure of the sea-floor, which potentially could be of great economic importance. Only last year, in a boring on Mochras Island, south of Harlech, there was made the most important discovery in Welsh geology since the heroic age of Sedgwick and Murchison. This was the finding of a tremendous thickness of geologically young

sediments in what has always been taken to be the centre of an upstanding dome of very old rocks indeed. Boreholes are very expensive and this one illustrates very well my point about the interdependence of all sciences within the realm of geology. The existence of a great sedimentary basin under the Irish Sea was deduced by good geological reasoning, was suggested by quantified geophysical observations and was proved in the subsequent borehole by the traditional systematic methods of stratigraphical palaeontology. Whether all these will lead to the economic boom of an Irish Sea oil or gas field still remains to be seen.

Though in other areas therefore, even as close as the Bristol Channel and Pembrokeshire, we are thinking of exploiting untapped mineral deposits, around Swansea geologists are thinking chiefly in terms of conservation and this is certainly the main potential practical application of our oceanographic programme locally.

Geologists are generally in a somewhat anomalous position over conservation. Most of them are what they are because they love the countryside and the open air, yet at the same time they are intimately concerned with the extension of quarries and gravel pits and mines and all the debris of the extraction industries. But is there not a strong flavour of hypocrisy in the criticisms of these things by a comfortable city civilisation which has used more minerals in the last fifteen years than in the whole previous history of man ? It is the same European hypocrisy which criticises Africans for killing off their indigenous predators without, at the same time, campaigning for the reintroduction of the wolf and the bear into our own domesticated scenery. We cannot eat our cake without using the cake knife, we cannot use our environment without changing it. But what we can do is to use the knife carefully without scattering crumbs all over the table and we can wash up the dishes properly afterwards.

I would not, however, wish it to be thought that I see

my function here solely as a kind of head gardener in our own back yard. Certainly ' il faut cultiver notre jardin ', but not having suffered all the horrifying vicissitudes of Candide, I have not yet reached his final placid state of mind. What is more, after the recent information from the moon and from Mars, I still believe with the great optimist that, for my kind of geologist at least, this is the best of possible worlds. That being so, we should make the best possible use of all parts of it, regardless of the colour of the flags or of the politics.

Whatever the merits of nationalism and provincialism, I will have none of them in geology. My predecessor established strong connections between our Department and North American universities. I too have many friends in that continent and intend to continue the tradition. But geologically, if not politically, Britain is part of Europe and it is in this continent that I see much of our future. The Welsh mountains are part of the great Caledonian chain which extends through Scotland up to the north of Norway, where Swansea has had a team working for several years on the complex structures and petrography of repeatedly folded ancient rocks. The folded rocks of Gower and south Pembrokeshire are part of the great Hercynian chain which extends southwards to the Spanish Meseta and eastwards through France and Bohemia to Dobrogea on the Black Sea. The folds and faults of the Mesozoic rocks of the Vale of Glamorgan are the outermost manifestations of the Alpine earth movements which reached their climax in building the great mountain chains which extend from the Betic Cordillera in southern Spain through the Alps, the Carpathians and the Balkan Mountains to the Caucasus in southern Russia. In all these regions I have mentioned, and in many others, we have active interests, direct or indirect.

Beyond Europe, in Asia, in Africa and in fact all over the world, we have connections of various kinds, either in research or in the employment of our students. One of

my colleagues, for example, participates in running summer schools in mining geology in Turkey, Iran and Pakistan under the auspices of the Central Treaty Organisation, training geologists from those countries in prospecting and exploiting ore minerals. The geologist's passport is always one of his most important pieces of equipment and is usually a rather battered document.

A century ago, in the midst of the industrial revolution which gave it birth, geology was taken very seriously by the British. Thus when the Prime Minister announced in Parliament the appointment of Sir Roderick Murchison as Director of the Geological Survey in 1855, both sides of the House rose to their feet and cheered.

Nowadays in Britain, in spite of its even greater impact on the world in which we live, geology tends to be regarded as a kind of harmless, but useless, amusement. In eastern Europe, on the other hand, where the state is much more directly involved in planning and using the human environment, geology is treated with much greater respect. Most countries there have a Minister of Geology and a great deal of money is poured into the state geological surveys. Bulgaria, for instance, with a total population less than that of Greater London, has a state survey larger than ours and a special rest home for geologists by the Black Sea ! In the Soviet Union nearly half a million geologists, other scientists, engineers and technicians are employed by the State Geological Committee. There are also large new geological, palaeontological and geophysical institutes in the various Academies of Science of eastern Europe, largely engaged in pure research, though the universities on the other hand are commonly old, poorly equipped and reduced in size and number. Thus in East Germany there are now only two universities teaching geology, compared with some thirty in Western Germany and nearly 750 in the U.S.A. and Canada. This is entirely a matter of employment and the East German geologists are particularly unfortunate in this, since unlike the Russians, the Czechs, the Hungarians,

etc., they cannot easily travel about the world providing a geological service to the developing countries.

In western continental Europe too, some countries seem to have recognised the vital role of geology far more than we have in Britain, and have made great efforts to provide geological services around the world. Thus the French, though their colonial record was certainly no better than ours, have continued to work on a big scale in their former colonies and elsewhere. What is more, their very active Bureau de Recherches géologiques et minières have entered into profitable agreements with a number of foreign governments, whereby they receive a fixed percentage of the proceeds from any valuable deposits they find. The German Federal Survey too, the Bundesanstalt für Bodenforschung, have gone into this business in a big way and have worked in some 30 different countries.

The British at last made an effort in this direction a few years ago. The old Geological Survey of Great Britain was fused with the Overseas Geological Survey to form the new Institute of Geological Sciences, which gave their joint staffs greater mobility and range of experience. It now has a staff of 700 including more than 400 scientists. But the geological pattern in most of our former colonies (with notable exceptions such as Ghana) seems to be generally one of retrenchment and decay. This cannot be a sound policy for countries desperately wanting to lift themselves out of an agrarian economy.

A former Cabinet Minister, and a Welshman, once said that Britain was made of coal and surrounded by fish. This was not very accurate geologically, but at least it showed a greater awareness of our geological and oceanographic environment than is generally apparent in the speeches of our politicians. So it is that British geologists tend to look abroad and to neglect, albeit unwillingly, the economic resources of our own islands.

As George Borrow said : ' There are no countries in the world less known by the British than these self-same British Islands '. Some years ago an independent report to the

Organisation for European Economic Co-operation commented : ' Britain, with its long history of mineral production and its very small present production would be one of the countries most likely to be rewarded by a thorough systematic re-appraisal of its mineral resources, but the stimulus seems to be lacking '.

But it is not the geologists who are at fault here. It is largely our forms of taxation and land ownership that make Britain almost an underdeveloped country in terms of metalliferous mining. Such mines as survive outside the coal industry are mainly at the two men and a donkey level and our economic geologists all go abroad to develop other people's resources.

Thus the whole world is our business and the whole world is also our employment bureau. It has been said in some quarters that there are too many geology students and too many geology departments in Britain at the present time. This is nonsense. It is as fallacious in argument and as unsupported by scientific observation as that even more widespread myth that the indulgence of university teachers in research is often to the detriment of their teaching.

There is still no shortage of jobs for suitably qualified honours geologists. In fact a higher proportion of geology students go into industry than in any other scientific discipline. What could be more in keeping with the spirit of the Swann Report ? Admittedly, as I have already implied, a large number go abroad for these jobs and in a sense are lost to the British taxpayer, but what better export investment could we have than the men who discover and develop the world's basic natural resources ? Patriotism has been called the fifth horseman of the Apocalypse and I sympathise with that view, but if we must think chauvinistically, then would we really prefer the Russians to develop the mineral resources of India and the Americans to develop all the oil resources of North Africa ?

But I do not wish it to be thought that I regard the

geology department at Swansea, in its industrial environment, as solely a training ground for technologists. In the first place, thanks largely I suspect to the leadership of our department, Wales has the highest level in the United Kingdom of geological education in schools. Though one can argue about its desirability at ' A level ', I can think of no subject more suitable than geology for arousing the interest and enthusiasm of children or for encouraging in them an awareness of the natural world about them and thence to acquire a broader and more enquiring state of mind. But it is our duty to ensure that those that teach them are essentially scientists who will pass on a scientific attitude rather than a dilettante ' Curiosities of Nature ' sort of approach.

This leads me, in effect, to twist my title yet again, for I am now talking about geological science itself as an environment. It is, I maintain, a very good environment for the university student, whether he intends to become a professional geologist or not. Whilst geology, like every other subject, requires and employs its specialists, it is an ideal discipline for the man who will not be a research scientist but who needs to be able to see for himself how the scientific attitude can explain and deal with the immediate problems of his environment.

Geology is unique as an undergraduate subject in tending to broaden rather than to restrict the scientific mind. Through geology, the student who is inclined towards chemistry is brought directly into contact with biological problems, and the biologist is made to think of the ways in which physics can be used in studying the structure of the earth. There is interchange in every direction.

But apart from its desirability as a mental training, a fully educated modern man should be aware of the geological fundamentals which underlie all political, economic and social problems. He should also realise the bearing on modern thought of the geological evidence of the nature of the world and its life. It would be quite

inadequate, for instance, to consider the history of science and the impact of science on society without considering the way in which the discoveries of geology changed the outlook of thinking men in the middle of the last century. When John William Burgon called Petra ' A rose-red city, half as old as time ' in 1845, he really meant it and his contemporaries would not have doubted his chronology.

What is more, geology is not a deep mystery studied with black boxes in laboratories and having an impersonal ' impact on society ' ; it has an immediate and direct bearing on every aspect of human activity and human endeavour. London and New York and Swansea are where they are because of geology. Beer is brewed at Burton-on-Trent because of geology, and for geological reasons, while the kings of Europe were building their Versailles, the British royal family was building its Brighton Pavilion. The one thing I regretted, in my prejudiced way, about Sir Kenneth Clark's recent brilliant series of television lectures on ' Civilisation ' was his omission of the underlying geological causes that control all human history. One might say, for example, that the transition from his age of ' Grandeur and Obedience ' to those of ' The Pursuit of Happiness ' and ' The Smile of Reason ' was brought about by the movement of wealth and therefore of intellectual opportunity from the sociological restrictions of city states in the orogenic zones of southern Europe to the greater opportunities of the newly-exploited large and stable sedimentary basins of the north. The zones of intense folding and metamorphism were ideal both intellectually and materially for producing the jewellery of Lorenzo the Magnificent and the statuary of Michelangelo, but the iron art of Brunel and the architecture of Le Corbusier needed the coal, the iron ore and the cement-producing limestones of the platform regions.

In military history too, the influence of geology was critical. The German armies failed against the French

in 1914 but succeeded in 1870 and 1940 for very simple geological reasons. The North succeeded against the South in the American Civil War for the same sort of reasons and incidentally employed some good geologists among its senior officers.

If one looks deeply enough one can see the fundamental geological reasons for every major human tragedy or success, whether it be on a national scale such as the bitter histories of Czechoslovakia and independent Nigeria or on a local scale such as the varied fortunes of Merthyr Tydfil and the Forest of Dean.

I see geology therefore as part of a general cultural education and worthy of a place in any university system. What is more, I am concerned not only with teaching our science students, but also with educating our future masters. No doubt I am prejudiced, but the environment of the geology department seems to me to provide the perfect discipline for an administrator, since it calls for accurate observation, scientific deduction, economic awareness and a generous helping of human judgment. I long to see one minister or magnate or magistrate with a geology degree for every fifty we have already with degrees in classics or law or (dare I say it ?) Welsh. This may be a forlorn hope, but I am a little optimistic in that while there is general regret in this country at the fall-off in the number of students opting for science in general, this is not true for geology, where numbers are everywhere rising. I think this is partly because students can see the direct bearing of geology on human life involving judgment and even emotion besides cold scientific logic. In fact I had thought of adapting a tragic phrase of 1968 and calling this address ' Science with a human face '.

In conclusion let me emphasise that I speak for a department and not just for myself. A wind of democratic change is sweeping through British universities, encouraged by some who wish it to blow away everything, and resisted by others who think the present system was established immutably on the eighth day of the Creation.

The British professor is now something between his continental equivalent (who has been called ' second only to God Almighty ') and his American equivalent, who is frequently just the only man in the department who does not want to do research.

In the Geology Department at Swansea we work very much as a team. We have a staff committee which discusses all important matters of departmental policy and makes many of the decisions. I have also established a staff/student committee which deals with all matters of mutual interest including the content of courses. In that connection I might add that staff/student relations in our Department, as in most geology departments, are excellent. It is difficult to be stuffy when one shares tents and stale sandwiches in the pouring rain on icy mountain tops. I also intend that technicians and administrative staff shall have their views heard, since they too have a considerable interest in the Department and its future.

At the same time, as the Chief of the Secret Service says of his job in one of the James Bond novels : ' Somebody's got to drive the bloody train '. I thank the Council for entrusting me with the controls of this particular locomotive. I cannot say that I hope it will stay on the rails, for I have a strong distaste for the steel lines of convention, but at least I hope that it will go in the right direction.

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