The place of geology in government scientific research

FREDERICK HENRY STEWART

Introduction

'There is no science whose value can be adequately estimated by economists and utilitarians of the lower order'

HUGH MILLER 1841

'It is most important that the opportunity afforded by the appointment of a new Director of the Museum of Practical Geology should not be lost for furthering the general scheme for bringing science and art to bear upon the productive industry of the Country . . .

. . . as it so often happens that the person who through great difficulties, and by his own exertions has succeeded in realizing one idea, does not readily merge this in a larger one, so Mr H. De la Beche cannot be said to have extended the usefulness of his Department, but has rather counteracted the plans of the Commissioners by confining his attention to simple Geology.

It becomes of the utmost importance that whoever is appointed now should be made thoroughly aware of the views of Government and accept the office with a clear understanding that he will be counted upon to work them out. He should further consider himself not in the light of a simple Geologist, but as the head of a Government educational establishment for the diffusion of Science generally as applied to productive industry.'

('Copy of a letter of Prince Albert to Lord Palmerston when my good friend the latter appointed me Director General of the Geological Survey May 1855.

R. I. MURCHISON')

Perhaps the range of attitudes has not changed all that much in the last hundred years or so; organization and spending certainly have. Even as recently as thirty years ago the Government spent only about 1.2% of the present amount devoted to Civil Science.

Organization and finance of scientific research and development in the U.K.

The money for scientific research and development comes from taxes and profits, and is provided by the Government, private industry, public corporations, trusts, foundations, benefactions and learned societies. The amount spent has increased greatly over the past two decades or so—for example from about £300 million in 1955-6 to about £883 million in 1966-7. It cannot be far off £1,000 million today. About 40% is spent through non-Government sources, mainly private industry, and about 60% through departments of Central Government.

Industrial research is done in the laboratories of industrial firms, in research associations (partly financed by Government) and, through contracts and consultancies, in government laboratories, independent institutes, universities and technical colleges. In the geological and geophysical fields, the oil and mining companies do a considerable amount of research and development, but the quantity done in the fields of engineering and chemical industries is surprisingly small.

Figure 1 shows the structure of Government scientific R. and D. in 1968-9, with the net expenditure in that year (just over £545 million). Table 1 shows the percentage distribution among the principal spenders. The Central Advisory Council gave advice to the Government on the most effective national strategy for the use and development of scientific and technological resources. The Ministry of Defence has a large budget, and, in the field of the environmental sciences, includes the Meteorological Office. Most of the rest of the money went through the Ministry of Technology and the Department of Education and Science.

Some of the Ministry of Technology establishments had some concern with the earth sciences, such as the Hydraulics Research Station, the Water Pollution Research Laboratory and the Atomic Energy Authority's establishment at Harwell. However, by far the greatest part of the Government money for scientific research in the earth sciences comes through the Department of Education and Science, which spent nearly £130 million on scientific R. and D. in 1968-9. This money was allocated through two main channels, the University Grants Committee and the 'Science Vote.'

The U.G.C. allocates funds to the Universities on a quinquennial basis in the form of capital grants for buildings, block grants for equipment, and block grants

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**TABLE 1.** Percentage Distribution of Government R. and D. Expenditure in 1968-9

<table>
<thead>
<tr>
<th>Department/Institute</th>
<th>Expenditure (£ million)</th>
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<tbody>
<tr>
<td>Central Advisory Council for Science and Technology</td>
<td>£52.4</td>
</tr>
<tr>
<td>Agricultural Research Council</td>
<td>£13.4</td>
</tr>
<tr>
<td>Medical Research Council</td>
<td>£14.8</td>
</tr>
<tr>
<td>Natural Environment Research Council</td>
<td>£8.8</td>
</tr>
<tr>
<td>Science Research Council</td>
<td>£37.4</td>
</tr>
<tr>
<td>Royal Society of London</td>
<td></td>
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<tr>
<td>Royal Society of Edinburgh</td>
<td></td>
</tr>
<tr>
<td>Office of Scientific and Technical Information</td>
<td>£2.1</td>
</tr>
<tr>
<td>Natural History Museum</td>
<td></td>
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</tbody>
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**FIG. 1.** Structure of Government Scientific Research and Development in 1968-9, showing the net expenditure (in £ million) for that year.

C.A.C. = Central Advisory Council for Science and Technology.
G.S.P. = Council for Scientific Policy.
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Table 1: Net Government expenditure on Scientific research and development
Percentage distribution in 1968-9

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<table>
<thead>
<tr>
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<tr>
<td>Defence:</td>
<td>43.3%</td>
</tr>
<tr>
<td>Technology:</td>
<td></td>
</tr>
<tr>
<td>Atomic Energy</td>
<td>8.8%</td>
</tr>
<tr>
<td>Aerospace</td>
<td>16.2%</td>
</tr>
<tr>
<td>Universities</td>
<td>9.6%</td>
</tr>
<tr>
<td>A.R.C.</td>
<td>2.5%</td>
</tr>
<tr>
<td>M.R.C.</td>
<td>2.7%</td>
</tr>
<tr>
<td>N.E.R.C.</td>
<td>1.6%</td>
</tr>
<tr>
<td>S.R.C.</td>
<td>6.8%</td>
</tr>
<tr>
<td>Other Science Grants</td>
<td>0.4%</td>
</tr>
<tr>
<td>Agriculture, Fisheries and Forestry</td>
<td>1.6%</td>
</tr>
<tr>
<td>Other (including External Relations)</td>
<td>3.6%</td>
</tr>
<tr>
<td>Roads and Transport</td>
<td></td>
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<tr>
<td>Housing</td>
<td></td>
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<tr>
<td>Law and Order</td>
<td></td>
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<tr>
<td>Health and Welfare</td>
<td></td>
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<tr>
<td>Financial Administration</td>
<td></td>
</tr>
<tr>
<td>and Common services, etc.</td>
<td></td>
</tr>
</tbody>
</table>

for recurrent expenses including salaries, departmental and library expenses, maintenance of buildings, etc. The building grants are earmarked, but the Universities (broadly speaking) may use their discretion in the spending of the other funds, with some general guidance from the U.G.C. It is difficult to find the proportions spent on science-based relative to arts-based subjects, and the relative amounts spent on teaching and on research, but an approximate estimate gives about a quarter of the total funds (£52 million in 1968-9) to research in science-based subjects. In the earth sciences the U.G.C. covers the salaries of about 47% academic staff, together with supporting technical and secretarial staff, and equipment and running expenses for teaching and some research.

The 'Science Vote' is independent of the U.G.C. and is mainly distributed between the Agricultural, Medical, Natural Environment and Science Research Councils, the Royal Societies, the Office of Scientific and Technical Information, and the Natural History Museum. The Council for Scientific Policy advises the Secretary of State for Education and Science on the size and distribution of the Science Vote among these various agencies, after examining their 'Forward Looks,' on a rolling quinquennial basis. The amounts allocated for 1969-70 and the estimates for 1970-1 are given in Table 2.

The Royal Society of London plays a substantial part in fostering international scientific co-operation and exchange. Its grants-in-aid assist other learned societies and provide money to individuals for specific research projects. O.S.T.I. gives grants to university workers in the field of information science, including the earth sciences. The Natural History Museum has a key role in public education, and has its own body of research scientists.
TABLE 2: Budgets in £ million of the 'Science Vote'

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<tbody>
<tr>
<td>Agricultural Research Council</td>
<td>14·7</td>
<td>16·2</td>
</tr>
<tr>
<td>Medical Research Council</td>
<td>17·1</td>
<td>19·7</td>
</tr>
<tr>
<td>Natural Environment Research Council</td>
<td>11·7</td>
<td>13·9</td>
</tr>
<tr>
<td>Science Research Council</td>
<td>45·8</td>
<td>49·6</td>
</tr>
<tr>
<td>Natural History Museum</td>
<td>1·1</td>
<td>1·8</td>
</tr>
<tr>
<td>Royal Society of London</td>
<td>0·9</td>
<td>1·0</td>
</tr>
<tr>
<td>Others</td>
<td>1·0</td>
<td>1·0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>92·3</td>
<td>103·2</td>
</tr>
</tbody>
</table>

About 96% of the Science Vote is shared by the four Research Councils, which are autonomous bodies established by Royal Charter. Their terms of reference are very different from those of the U.G.C. They are not primarily concerned with undergraduate training. They have the task of encouraging and supporting scientific research in their various fields in the ways which they believe to be most effective. They therefore support research in universities, where there is a large force of expert manpower, by grants (normally short-term but sometimes long-term), by groups and units attached to University departments, and by postgraduate training awards with their attendant research training support grants. Where there is a need for greater continuity, or for substantial advisory service, or for a concentration of specialised research workers, they maintain their own institutes and units such as the Institute of Geological Sciences and the National Institute of Oceanography, and they grant-in-aid some partially independent establishments such as the Marine Biological Associations. They also maintain central facilities for the use of workers from their own institutes and from Universities, such as the Rutherford Laboratory of S.R.C., and the Research Vessel Unit of N.E.R.C., and they contribute to international facilities such as the European Space Research Organisation and the Centre for European Nuclear Research. In fact, they provide a most important link between the Executive Departments of Government and industry on the one hand and the educational system on the other, ensuring that the activities of the executive departments are underpinned by a large body of fundamental knowledge, and that students in Universities receive up-to-date training to fit them for various types of specialised employment.

So far as the Universities are concerned, there is, broadly speaking, a dual support system for research in science-based subjects. The U.G.C. provides a floor of support which covers buildings and unearmarked money, which is allocated to 44 universities in approximate proportion to the number of students in different subject groups, making allowance for special responsibilities. This money is allocated to departments after internal argument. The Research Councils give earmarked money to individuals or groups for projects which fit the criteria of timeliness and promise, and have been approved by committees of experts in special fields of science. This dual system helps to maintain a reasonable level of research on a broad front, while allowing the Research Councils to stimulate new
activities and new inter-disciplinary fields and to support the exceptional workers on whom much of the best progress depends.

The activities of the Natural Environment Research Council

After the report of the Trend Committee, the functions of the Department of Scientific and Industrial Research were split, and two new Research Councils, N.E.R.C. and S.R.C., were established in 1965. The terms of reference in the Charter of N.E.R.C. are 'to encourage and support by any means research by any person or body in the earth sciences and ecology and in particular (but without prejudice to the foregoing) in geology, meteorology, seismology, geomagnetism, hydrology, oceanography, forestry, nature conservation, fisheries or marine and freshwater biology.' N.E.R.C. is by far the largest of the non-U.G.C. sources of government support for research in the earth sciences in this country. The contributions of the other Research Councils in these fields are relatively small (e.g. soil science—A.R.C.).

In 1965 some of the environmental sciences were obviously underdeveloped and undersupported in this country, but they have been becoming increasingly important to the economy and social health of the nation, and the Research Council has therefore grown at a considerable rate from a budget of £4.02 million in 1965-6 to nearly £14 million in 1970-1. The percentage growth rates in real money terms have been:


This growth has been accompanied by, and includes funding of, increased responsibilities, such as the take-over of the British Antarctic Survey from the Colonial Office in 1967, and of the Institute of Coastal Oceanography and Tides from Liverpool University in 1969.

The growth has also been accompanied by a marked change in attitude towards the value of the environmental sciences. Many departments of central government, local authorities and industries are making greatly increased use of the work supported by N.E.R.C.; the universities are becoming more conscious than before of the economic and social relevance of their teaching and research; and the public are becoming increasingly concerned about the problems connected with the management of the environment and of its resources. At the same time, the rapid improvement of techniques and instrumentation has opened the way for revolutionary advances in the study of the earth's interior, the oceans and the atmosphere.

Figure 2 shows the principal fields of N.E.R.C. and the proportions of money spent on them in 1969-70, and Fig. 3 gives the net expenditure on the principal establishments and on university support during the first five years of the Council's existence with provisional estimates for the present year. The figures should be interpreted with caution, because they include both capital and recurrent expenditure, and the shapes of some of the curves in Fig. 3 depend partly on costly capital items such as ships and buildings.
The geological sciences (including geophysics) come into the divisions of terrestrial earth sciences, sea floor and Antarctica in Fig. 2. A further breakdown of these made recently by N.E.R.C. gives the approximate estimates of expenditure for 1970–1, as percentages of a total of about £6·4 million, as follows:

- Structure and composition of the U.K. land mass: 22·0%
- Structure and composition of the U.K. continental shelf: 19·5%
- Mineral resources (U.K. land, continental shelf, and overseas): 18·9%
- Physical properties of rocks and soils: 3·6%
- Underground water: 5·4%
- General structure and properties of earth's interior and continental crust and mantle: 20·0%
- Structure and composition of the oceanic crust and mantle: 4·1%
- Earth's magnetism: 4·5%
- Glaciology: 2·0%

These subjects, of course, form an intricate network, so that the percentages can only be considered as estimates. The first category includes the terrestrial geological survey of the I.G.S. in the U.K. and a considerable amount of university work. The second includes the continental shelf studies of the I.G.S., the N.I.O. and the universities, with the facilities of the Research Vessel Unit, and involves geophysical reconnaissance, shallow drilling and sampling, and the compilation...
B.A.S. = British Antarctic Survey
G.A.L. = Grant-aided Laboratories and Units
I.C.O.T. = Institute of Coastal Oceanography and Tides
I.G.S. = Institute of Geological Sciences
I.H. = Institute of Hydrology
N.I.O. = National Institute of Oceanography
N.C. = Nature Conservancy
R.V.U. = Research Vessel Unit
T.A. = Training Awards
U.C.S. = Unit of Coastal Sedimentation
U.G. = Grants to Universities, Colleges and similar Institutions.

**FIG. 3.** Net expenditure in £1000 in the principal activities of the Natural Environment Research Council during the period 1965-70, with estimates of expenditure in 1970-1.
of data from commercial operators. A substantial part of the work of the I.G.S. is related to the third, with local and regional geophysical studies, geological and geochemical survey, and mineral assessment at home and abroad. The last four categories include much of the fundamental research being done on geological processes and on the structure and properties of the solid earth, in which the universities, the I.G.S., the N.I.O. and the Antarctic Survey all play their parts.

In his Presidential addresses to the Geological Society of London (1967, 1969), Dr Dunham gave an eloquent account of the useful aspects of the earth sciences and stated that 'The applications of geology and geophysics to the day-to-day conquest of the human environment are numerous and impressive, and compare favourably with those of any of the other scientific disciplines.' This has become increasingly true as links with user bodies have been built up. Those whose functions are underpinned by N.E.R.C. research in the geological fields include at least seven Government Departments, Local Authorities, Water Boards, River Authorities, Post Office, New Town Development Corporation, and nationalized and private industries. The applications range from such short-term things as advice on civil engineering and constructional schemes, land use, mineral potential, underground water resources, routing of submarine cables, deep sea waste disposal, etc., to longer-term possibilities such as prediction and possible control of earthquakes, prediction of volcanic eruptions, and continued improvement of the broad basis for search for useful geological materials.

In fact, although the work supported by N.E.R.C. is typically long-term in nature, and aimed at a fundamental understanding of the natural systems of the earth, most of it gives knowledge with practical benefits and much of it contributes to short and medium term economic and social goals.

Some problems of policy

For many years past the amount of money spent on science has increased at a rate much greater than that of the Gross National Product. Dunham (1967) shows the remarkable increase in money and manpower devoted to geology and geophysics up to 1966. During the past ten years the number of university staff in geology and geophysics has increased from about 300 to about 470, and the number of scientific staff of the I.G.S. (formerly Geological Surveys of Great Britain and Overseas) from 244 to 457. The number of N.E.R.C. postgraduate awards taken up has increased by about 50% in the last seven years. This sort of expansion has been taking place in many parts of Government science.

If anything continues to increase at a rate greater than the Gross National Product, it must come to equal the G.N.P. in time. Therefore such an expansion cannot continue, and in fact the rate of growth of the Science Vote has been decreasing, and is likely to fall rapidly within the next few years to about 2% in 1974–5 in real terms. Such a growth rate cannot keep pace with the sophistication factor, estimated at about 5% per annum (although this figure is a mere estimate), which relates to the improvement in type of equipment and to other costs which do not include inflation, and it cannot cover additional research associated with...
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the major increase in student numbers in universities which has been predicted for
the next five years.

These considerations raise, in a more acute form than ever, the problems of
priorities in research. With an infinite number of things to do, which do we
choose? What should be the balance of basic and applied research? Which old
activities do we stop so that new ones can be supported? How can we reorientate
peoples' interests and types of work? How much should we support individual
excellence? To what extent should we build up central facilities for equipment—or
concentrate manpower in certain places in certain fields? What should be done
in institutes and what in universities? Should there be international centres for
certain types of research? Should every member of staff of a university do research?
How many postgraduate students should we produce in the national interest?
The questions are legion, and very difficult, but they will have to be faced.

It is possible to identify some of the criteria which must be taken into account
in making decisions. The internal criteria, related to the quality of scientific
research as an end in itself, include such things as excellence of the field or topic
(intellectual promise and timeliness), excellence of the available workers, per-
vasiveness (the stimulus given to other parts of science) and cultural value. The
external criteria include economic, social, industrial, political and educational
benefits to mankind. Other criteria include the resource implications—demand on
capital and manpower, availability of manpower and production of trained men
for industry and other employment. And there is the need to keep the right
general balance of scientific activity and to ensure that we have enough specialists
in this country to recognise and make use of advances from abroad.

All these things must be taken into account in deciding priorities, and it is not
much use listing the criteria, marking out of ten for each and making decisions on
the results. For example, although work on plate tectonics and continental drift
would at present score very high marks for the internal criteria it would get low
marks for external criteria and for demands on money and manpower. Yet it
would be ridiculous not to support work in what is one of the most exciting fields
of our science. The same applies to the greatly more expensive fields of nuclear
physics and radioastronomy, where we have a very high international reputation.
One of the important factors in Antarctic research is the political one of main-
taining a British interest in that part of the world. Much of the work of the I.G.S.
scores high marks for the external criteria, and some, such as global seismology,
comes into the field of fundamental research. Social and educational benefits are
important in the pollution and conservation aspects of N.E.R.C.

The balancing of these various things is really a matter of value judgment,
made especially difficult by the unpredictability of scientific research. The earth
sciences are at a stage of development where they are being used more and more
for short-term benefits and at the same time the fundamental aspects are in a state
of major change because of the recent advances in marine science and geophysical
method. There must be few who read the Journal of the Geological Society who
would not say that these sciences were deserving of high priority at present!

The questions which I have mentioned above are far too complex for any easy
answers, and in any case the answers of today will not always be right in a few
years time. Perhaps one of the most important things is to have the right organization for making judgments—the right committees, with representatives from academic, industrial and governmental interests, taking advice from as wide a clientele as practicable. Let us hope that the recent establishment of eleven working parties by N.E.R.C., to consider the state of research in the various parts of the geological sciences will stimulate us into thinking more clearly why we do what we do, what we ought to do that we don’t, and perhaps some of what we should not do that we do from force of habit. Let us hope that the reports of these working parties will lead to rational discussion and better decisions by the standing committees of N.E.R.C., and to a more coherent policy for the earth sciences. And let us also hope that this will lead to sensible support from the powers that be, and to greater benefits to man.

ACKNOWLEDGMENTS. I am grateful to the following for help with the factual material: Mr R. H. Beverton, Mr J. D. D. Smith and Dr B. G. Jamieson of N.E.R.C. and Mr M. B. Baker of D.E.S. Further information is contained in the following publications of H.M. Stationery Office:


References


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