British Geological Survey

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Department For International Development

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Overseas Geology Series

GEOLOGICAL SURVEYS IN DEVELOPING COUNTRIES: STRATEGIES FOR ASSISTANCE

PROJECT SUMMARY REPORT

A J Reedman, R C Calow and C Mortimer

BGS International

Natural Environment Research Council

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1 INTRODUCTION

Much effort is made by donors of technical and financial aid to developing countries in helping to create a sound physical infrastructure for economic development within the recipient countries. In many sectors, such development aid results in highly visible deliverables such as roads railways, ports, power stations, hospitals, schools and housing. Much less visible is a layer of infrastructure comprising the scientific and technical knowledge essential to sound national development planning. Much of this knowledge may be universal in its application but some is based on data which is country specific: it can only be collected locally and comprises a unique national knowledge-base or information infrastructure. Such data is usually collected, stored, processed and delivered to users by a wide range of public institutions.

A national geoscience database forms an important element of a nation's information infrastructure. It reflects the fact that all countries 'own' a unique sector of the earth's crust which forms its land mass and, for maritime nations, its adjacent sea floor. This crustal sector is both literally and metaphorically the foundation upon which the nation's development is based, it is fundamental to the nation's existence and individuality and provides space on its surface for life, growth of food and accumulation of water, while below the surface it hosts mineral, water and energy resources. In most countries a national public sector Geological Survey Organisation (GSO) has the responsibility for both populating and managing the national geoscience databases that describe the geological foundations of the country, and for providing a national geoscience information system derived from these databases.

The purpose of the recently completed study, summarised in this report, was firstly to define an appropriate programme of core activities for developing country GSOs which will fulfil the requirement to provide a national geoscience information system, secondly to assess the extent to which GSOs are meeting that requirement and finally to suggest a strategy that focuses technical assistance to developing countries on key activities within that core programme. The methodology adopted has been to test a 'model' core programme against the current programme of activities of over fifty GSOs and, further, to assess the current status of some of their important national geoscience databases. In addition we have examined the resource base of the GSOs for fulfilling their national role and their priorities for technical assistance for these activities. We have also examined recent trends in geoscience technical assistance from a variety of major donors and the degree to which current geoscience programmes in the 'aid sector' are directed toward assistance to the various core programme activities of developing country GSOs. Based on our findings we have suggested some guidelines for technical assistance directed toward GSOs in developing countries.

Many GSOs have contributed information during the course of our project. Detailed questionnaires were returned

A Nation's Geological Environment

Every country is the guardian of a unique sector of the earth's crust. This crustal sector is both literally and metaphorically one of the foundations on which the countries development is constructed and knowledge of its constitution is thus a vital national asset.

by the GSOs of Angola, Bangladesh, Botswana, Cambodia, Colombia, Cyprus, Ecuador, Egypt, Ethiopia, Gambia, Guyana, Indonesia, Jordan, Republic of Korea, Lithuania, Malawi, Malaysia, Mongolia, Namibia, Papua New Guinea, Paraguay, People's Republic of China, Peru, The Philippines, Romania, Solomon Islands, Sri Lanka, Thailand, Vanuatu, Zambia and Zimbabwe. Information on a further nine Latin American GSOs was provided by the Asociacíon de Servicios de Geología y Minería Iberoamericanos and on sixteen GSOs, by the Forum of European Geological Surveys. Other organisations which have facilitated the study are the Coordinating Committee for Offshore and Coastal Geoscience Programmes in South-East Asia (CCOP), The Association of Geological Surveys of the European Union (EuroGeoSurveys), The International Consortium of Geological Surveys (ICOGS) and the World Bank. The conclusions reached, however, as a result of considering all the data supplied, are those of the authors alone and no endorsement of these conclusions has been sought or is implied prior to the publication of this report.

2 THE ROLE OF GEOLOGICAL SURVEY ORGANISATIONS

Geoscience, comprising geology, geophysics and geochemistry, is the study of the solid earth (the geosphere), of its materials and its morphology and the physical and chemical processes which have acted, and continue to act, upon it to affect its historic and present composition and surface morphology. The spatial distribution of the various physical and chemical characteristics of that part of the earth occupied by a particular nation is unique and is reflected in the nation's mineral, energy and groundwater resources. The interaction of the geosphere with the biosphere, hydrosphere and atmosphere determine the character of the nation's soils and their content of both essential and toxic trace elements. Its internal structure, dynamics and morphology govern the distribution of natural geohazards such as volcanoes, earthquakes and landslides. Data which collectively contribute to our knowledge of the above features comprise the national geoscience knowledge base and information from this knowledge base is vital to national development.

A national geological survey organisation (GSO) is the provider of a geoscience information service. As such, it collects, on a systematic and nationwide basis, data concerning the nature of the underlying earth and it curates, processes, interprets and presents such data according to user requirements. At a basic level most GSOs generate collections of geographically located data which may be summarised either in regional geological, geochemical, geophysical or hydrogeological maps and models, or more specialised combinations or derivations of these, together with explanatory reports. The underpinning data collections upon which these products are based, comprising such material as rock, soil and water samples, analytical results of various kinds, field notes and maps, borehole logs and geophysical measurements, are a vital part of the national geoscience information infrastructure. Increasingly, electronic and digital systems of data storage, sorting, processing, modelling and display, allow the delivery of products customised to the particular needs of users.

Most GSOs are publicly funded and are deemed to be carrying out 'national interest' programmes. Some GSOs also derive income by the provision of services commissioned by individual customers. These customers may be in either the public or the private sector and the nature of the services and products are dictated by the specific needs of the customer and will often be provided on an exclusive basis. The extent to which GSOs should be funded by central government in the national interest on the one hand and operate commercially by drawing income from a variety of individual customers on the other, has been a matter for considerable debate in many countries. While wholesale privatisation has generally been rejected, some GSOs have been encouraged by their governments to operate in a duality of 'national interest' and 'commercial' roles (eg see Findlay, 1997). To clarify these two operational modes, the British Geological Survey

Purpose of a Geological Survey as defined by The Forum of European Geological Surveys

A Geological Survey is a governmental organization serving the changing needs of society for earth science information and expertise. It advises governments, institutions, industry and the public at large in such matters.

To fulfil this mandate, a Geological Survey undertakes mapping, monitoring and scientific research and development, maintains comprehensive data banks of geoscientific data and interprets geological information as a basis for decisions relevant to natural resources and the environment.

has developed the concept of a national Core Programme and a Commissioned Programme respectively. There is deemed to be a symbiotic relationship between these two elements (see Figure 1) with the Core Programme providing knowledge and expertise to the Commissioned Programme and the latter providing data and funding to the Core Programme. The Core Programme, however, is fundamental to the GSO's existence in the public sector where it represents the public interest and it is with the Core Programme of GSOs that we are concerned in this report.

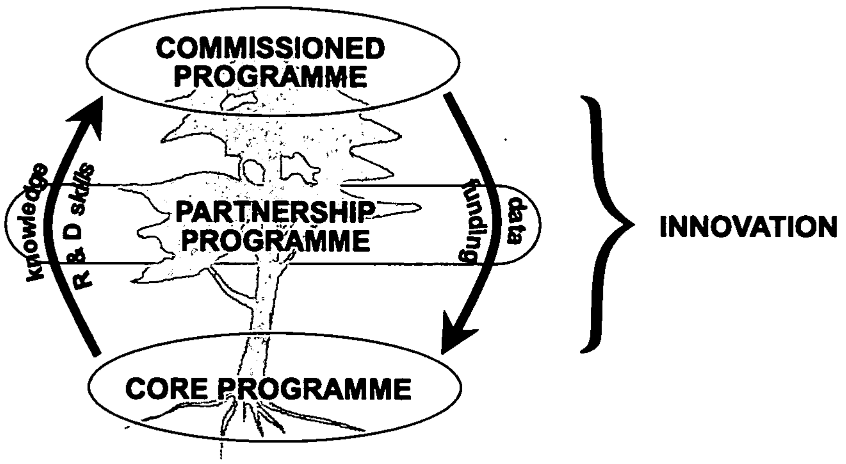


Figure 1 The relationship between a 'core programme' of activities performed in the national interest and publicly funded by government grant and a 'commissioned' programme of activities funded by individual customers some of which may be other government departments and agencies.

3 A CORE PROGRAMME FOR GSOs

The geological diversity of the earth's crust dictates that nations are variably endowed with geological resources and vulnerability to geohazards. This natural variation in a nation's geological environment will influence the priorities accorded to different activities within a GSO's Core Programme. Furthermore, governments' response to their sectorial responsibility is determined by a number of factors which include, as well as their perception of the national economic and social relevance of the geo-sector, their assessment of the national priority to be accorded to geological resource and geohazard assessment. This in turn will influence the amount of funding to be directly allocated to their national GSO. Other resource constraints, including lack of expertise, may also affect the scope of the GSO's activities but all GSOs attempt to carry out many or all of the activities defined in the sections below which collectively constitute a 'model' Core Programme as defined for the purpose of this report.

3.1 Systematic Geoscience Surveys of National Territory

Virtually all national GSOs were founded with the prime objective of carrying out systematic, nationwide surveys of the geology of the nation in order to determine the national potential for wealth creation through the exploitation of georesources. With advancing knowledge in the geosciences, both the techniques and the applications of such surveys have become much more diverse. They involve the systematic recording and interpretation of a variety of geoscience parameters across a national territory which form the fundamental basis of the geoscience information infrastructure. Such surveys are not a 'one off' activity but are subject to continual revision and updating as new data, techniques and interpretative skills become available and new applications are developed. The surveys can be divided into a number of different types and embrace both the onshore, and where applicable, the nation's coastal and offshore territory.

3.1.1 Geological Mapping

Activities

Geological mapping involves the observation and recording of data concerning the geological features of the land or seafloor of the national territory, the classification of the geological units present, projection of information to depth to deduce deeper structure together with examination of all supplementary geoscience information pertaining to the area. Primary surveys should be as detailed as realistically possible within the constraints of available resources and the necessity to cover at least the highest priority areas of the national territory within a reasonable timescale.

Products

The primary deliverables are geological maps and models at various scales, including individual detailed map sheets, and regional and national compilations together with the construction of an appropriate geological classification of units to internationally agreed convention. Maps are normally accompanied by an explanatory text on the map sheet and/or a complementary report series which describes the geology and resources of each area surveyed. Maps may be compiled to incorporate all classes of data collected or may be 'thematic', showing for example, the distribution of particular geological units suitable for use as aggregates, the distribution of superficial deposits, or of geohazards such as landslips. The use of digital cartography in the production of geological maps has greatly facilitated the ability to produce thematic maps and produce maps of varying scales upon demand.

3.1.2 Geochemical Surveys

Geological materials display wide variations in chemical composition. Individual elements may be present only in trace amounts or be concentrated to the point where they constitute a valuable and exploitable resource. Geochemical surveys record the spatial distribution of a wide spectrum of elements in various geological media such as soils, rocks, stream sediments and surface waters. Though traditionally developed as a means of exploring for mineral deposits, such surveys are now also used in human and animal health studies and as baseline data for monitoring contamination and pollution due to anthropogenic activity.

Activities

The main activity involves the systematic collection and analysis of various geological media at a predetermined average spatial distribution. Regional geochemical surveys leading to eventual nationwide coverage most commonly involve the collection of stream sediment samples at a density of between one sample per one square kilometre to one sample per five square kilometres.

Products

Output of regional surveys are normally in the form of digital datasets and folios/atlases depicting the spatial distribution and concentration of individual elements or combinations of elements accompanied by information on the relationship of element distribution to the known geology, the methodology employed in the survey and significant interpretative deductions.

3.1.3 Geophysical Surveys and Geophysical Monitoring

The determination of spatial variations in certain geophysical parameters, such as the earth's gravitational and magnetic fields, its electrical conductivity and its natural radioactivity can be important for understanding the earth's deep structure and composition, the location of mineral deposits and for assessment of potential geohazards.

Activities

Most geophysical surveys involve instrumental measurements in the field. Rapid, broad cover of the national terrain normally requires instruments mounted in vehicles or in either fixed-wing aircraft or helicopters. To be efficient, such airborne surveys require relatively large financial inputs over a fairly short period of time and, accordingly, though important, these types of geophysical survey form a component of the Core Programme in only a relatively few developing country GSOs.

A further desirable activity in countries susceptible to earthquakes and volcanic eruptions is the continuous instrumental monitoring of seismic activity via strategically located seismic monitoring networks.

Products

Output is usually as systematic maps showing contoured values of a specific parameter (eg. gravitational field) at regional and national scales and as digital datasets or catalogues of measurements.

3.1.4 Development of Survey Techniques

Adequate funding should be available for the development of equipment and of improved techniques to continually enhance the quality of geoscience surveys. The advantages offered by digital cartography and GIS systems need to be employed where appropriate, progressively leading to the integration of varied datasets to produce customised, thematic maps and models. In the future, output and dissemination will become largely electronic rather than paper-based, taking advantage of technology such as global electronic information networks and CD-ROMs.

3.2 The National Geological Resource Inventory

Within a GSO's Core Programme should lie the responsibility for collating information about the nation's overall geological resources (including fossil fuels, minerals and groundwater). This will involve details of their special distribution, quantity, quality (grade) and their suitability for certain end-uses. A GSO may also have the responsibility for gathering information on the production and trade in resources; information that is needed at a national level to ensure sensible management of finite resources and the provision of impartial advice on the regulation of industry and the requisite legislation dealing with the extraction and environmentally safe utilisation of the commodity.

3.2.1 Groundwater

The occurrence of groundwater, an important and sometimes critical source of potable water, particularly in arid countries, is largely controlled by geological factors and the national assessment of groundwater reserves may legitimately form a significant part of a GSO's Core Programme. However, it is recognised that in many developing countries responsibility for groundwater resource assessment rests with national institutes or departments independent from the GSO.

Activities

The key tasks of national importance are the monitoring of groundwater resources to ensure a continuity of supply through sensible abstraction policies, the provision of information on the surface and sub-surface distribution and hydraulic properties of aquifers and the monitoring of water quality.

Products

The output from such activities is likely to include hydrogeological maps illustrating the distribution and key hydrogeological properties of aquifers, catalogues of observation wells with details of water levels and quality, together with modelling studies of the water balance of individual aquifers and the effects of contamination and pollution.

3.2.2 Minerals

Activities

Within a Core Programme should lie responsibility for assessing regional mineral resource potential, monitoring the nation's proven mineral resources, maintaining statistical information on their production and providing advice on regulations and legislation in particular with regard to exploration, minerals planning and the environmental impact of mining. In many developing countries technical advice to small scale entrepreneurs and artisanal miners may also form part of a Core Programme.

In some countries where an active private sector mineral exploration capability does not exist, the GSOs may be required to conduct more detailed, localised mineral resource evaluations and mineral exploration programmes. In general however, the role of the GSO, within its Core Programme, is to make available regional geoscience data and exploration criteria in order to promote private sector investment in detailed exploration. The GSO may be commissioned by the private sector to undertake more detailed and site specific aspects of the latter outwith its Core Programme.

Products

In addition to the provision of advice and information on regional prospectivity, the output is likely to comprise published mineral statistics for the nation, perhaps including an analysis of wider international markets of particular importance to the domestic economy. Broad mineral distribution maps and databases of known mineral occurrences are also useful in guiding the development of the mineral industry.

Maintenance of prospection records and publication of progress maps and reports is a function of government vested in the Core Programme of many developing country GSOs and revenue accruing from the operation of minerals exploration concessions may also be administered by GSOs. In some cases revenue from licences may contribute to the funding of the GSO.

3.2.3 Hydrocarbons and Other Energy Resources

Activities

Exploration and assessment of fossil fuels, such as coal, oil and gas, is usually carried out by the private sector or by government-owned corporations, though they will normally use many of the products of the GSO's Core Programme activities, such as geological maps, to underpin their exploration activities. A considerable amount of new geological information, however, is produced during hydrocarbon exploration and this should be supplied, if necessary as 'commercial in confidence' to the GSO to be added to the national geoscience database as a statutory requirement.

GSOs in countries with significant alternative energy sources such as coal-bed methane, geothermal energy and hydropower will also act as providers of information and advice on background geological facts relevant for exploration and exploitation. Government may additionally commission specific studies of these possible energy sources.

A national programme may also require a GSO to be responsible for monitoring of hydrocarbon exploration, granting of exploration licences, and regulating the industry. In many countries, however, these functions have been passed to national corporations set up specifically to deal with oil, coal or gas.

Products

Gathering and assessing detailed exploration data enables government to prepare improved general accounts and maps of the geology of the oil, gas or coalfields whilst retaining the confidentiality of the specific proprietary company information. Such products commonly spur additional exploration activity as an overall geological picture of a region emerges which would otherwise be unavailable to individual operators. They also enable the provision of soundly-based advice to government to assist future licensing rounds.

3.3 Geohazards

Geohazards, including geological, geotechnical and geochemical hazards, can impose very considerable economic and social costs on a nation. Hazard, risk and vulnerability assessments should be an important part of national, regional and local development planning. Some of the principal geohazards, such as volcanic activity and earthquakes are related to geological-tectonic setting. For others such as landslips and mudflows, geographic factors may be important. For these reasons the relative importance of these hazards will vary widely from country to country. Other hazards, such a geochemical hazards may arise from anthropogenic activity giving rise to chemical pollution or from natural deficiencies or excesses of trace elements at or near the earth's surface and natural radioactive emissions. Ground subsidence due to over-extraction of groundwater or to mining may also be significant.

Activities

Within their Core Programmes, national GSOs should assume responsibility for the identification of geohazards, continuously monitoring their occurrence, and, if possible, predicting future trends and dangers. GSOs should also provide information and advice to the general public and to local disaster management authorities and, where possible, recommend remedial action and/or appropriate protective and mitigation measures.

Products

Output expected from the function is likely to include national, regional and site-specific reports identifying areas of high risk/vulnerability in order to enable national and local authorities to plan accordingly. Databases of past events, which are useful in prediction, are another important product. The provision of general literature and information to educate and increase public awareness, and advice to the general public on minimizing and avoiding risks may also be undertaken.

3.4 National Geoscience Data Centre

The data acquired by a GSO, either through its own activities, or by donation or lodgement due to statutory obligation by other entities, is a valuable national asset that must be preserved, properly indexed and made available to potential users as required and controlled by government regulation. The operation of a national geoscience data centre is one of the most important tasks of a national GSO.

Activities

The basic activity is the curation of all data of national significance acquired throughout the GSO's existence. This will require the safe storage and indexing of a great diversity of materials and data, including such items as rock, mineral and palaeontological specimens, geochemical samples, borehole cores and geological, geochemical, geophysical and hydrogeological records, analytical data, field notebooks, maps, reports and publications. Much of the material must be physically stored, but increasingly data can be stored electronically in either analogue or digital form. Systems must be in place for locating and retrieving data quickly for either internal or external usage.

Products

The products will be collections, databases and indexes, some of which may require confidentiality, which must be rigorously protected.

4 THE CURRENT STATUS OF NATIONAL GEOLOGICAL SURVEY ORGANISATIONS AND THEIR CORE PROGRAMMES

In this section of the report we review the current ability of GSOs in developing countries to carry out their core missions, the progress they have made to date in establishing nationwide geoscience data collections and their ability to deliver interpreted data to their governments and other customers. Information has been gathered from questionnaires completed by GSOs in thirty one developing countries with additional data, relevant to their members in Latin America, provided by Asociacíon de Servicios de Geología y Minería Iberoamericanos. Data provided by the Forum of European Geological Surveys has enabled comparisons to be made between GSOs in developing countries and those in developed countries.

4.1 The scope of GSO's core programme activities

As stated previously, few GSOs will carry out all the activities described in the 'model' core programme outlined in Section 2 of this report. The scope of the core programme of each GSO and the priority given to the different activities will vary according to natural variations in a nation's geology and geography as well as its economic system and its state of social and economic development. Not least, a shortage of both financial resources and specialist skills may severely limit a GSO's ability to carry out some or even most of their planned core activities and while an activity may remain on their stated core programme agenda it may, in fact, be essentially moribund.

In a survey of thirty one developing country GSOs (*in Table 1) all respondents stated that they have core programmes embracing the majority of activities defined in our model core programme (Figure 2). For example, all GSOs surveyed claimed to carry out programmes of onshore geological mapping, the fundamental purpose for which most were originally established, though it is of interest to note that less than fifty per cent have facilities for processing remotely sensed data such as satellite imagery or air photographs which in many cases would significantly aid their geological mapping programmes. A majority of over seventy five per cent, claim to have the capacity to carry out systematic geochemical or geophysical surveys but less than fifty per cent of maritime nations claim to carry out programmes of offshore geological mapping, a relatively expensive activity.

Less than half the GSOs in our survey carry out programmes concerned with groundwater, indicating that in many countries, groundwater resource surveys are the responsibility of a separate institution. Mineral resource surveys and assessment are undertaken by eighty per cent of the GSOs with slightly less than fifty per cent also being responsible for the issue of exploration licences and fifty per cent also being responsible for the compilation of production statistics. Fifty per cent of the

Scope of GSO Core Programmes

The scope of the core programme of a national GSO and the priorities placed on different activities within the programme will vary according to the nation's geological and geographical character and its state of economic and social development.

INCOME GROUP	AFRICA AND MIDDLE EAST	ASIA AND SOUTH PACIFIC	SOUTH AND CEN-TRAL AMERICA	EUROPE
Low Income Per Capita GNP $675 or less	*Egypt *Ethiopia *The Gambia *Ghana *Malawi *Zambia *Zimbabwe	*Bangladesh *Cambodia *China *Indonesia *Sri Lanka	*Guyana	
Lower-Middle Income Per Capita GNP $676–$2695	*Angola *Nambia *Jordan	*Mongolia *Papua New Guinea *Philippines *Solomon Islands *Thailand *Vanuatu	Bolivia Chile *Colombia Dominican Republic *Ecuador *Paraguay *Peru	Czech Republic *Lithuania Poland Romania Turkey
Upper-Middle Income Per Capita GNP $2696–$8355	*Botswana	*Korea, Republic of *Malaysia	Argentina Brazil Mexico *Suriname Uruguay Venezuela	Greece Slovenia
High Income Per Capita GNP $8356 or more				Austria Belgium *Cyprus Finland Ireland Netherlands Norway Spain Sweden Switzerland United Kingdom

Table 1 Classification, according to income group, of GSOs from which data have been used in the current project. The classification is that of the World Bank for 1994 and is based on the per capita GNP according to the limits as shown. Countries marked * are those which returned detailed questionnaires.

respondents carry out programmes specifically targeted at hydrocarbon exploration and assessment and a greater proportion, over eighty per cent, claim to undertake some work related to other energy sources of one kind or another.

Virtually all GSOs have stated programmes concerned with one or more geohazards, the scale and nature of the programmes depending on the vulnerability of the country to the various hazards.

All the GSOs hold geoscience data and therefore are 'Geoscience Data Centres'. However, there is a wide variation in the types and amount of data held, the degree to which the activity is systematically organised and managed and the accessibility of data.

The above figures only give a measure of the stated ability of a sample of developing country GSOs to carry out various core activities. It does not indicate either the current quality or quantity of output from the various activities. Personal experience of many developing country GSOs tells us that though they have objectives entrenched in their core programmes that should largely satisfy national needs, their ability to carry out the necessary programme activities is frequently severely limited by a lack of both human and financial resources, a fact that we explore below.

4.2 Funding and staff resources available for GSO Core Programme Activities

We have assembled data on the budgets and staff resources of fifty five GSOs. Among these, eleven represent

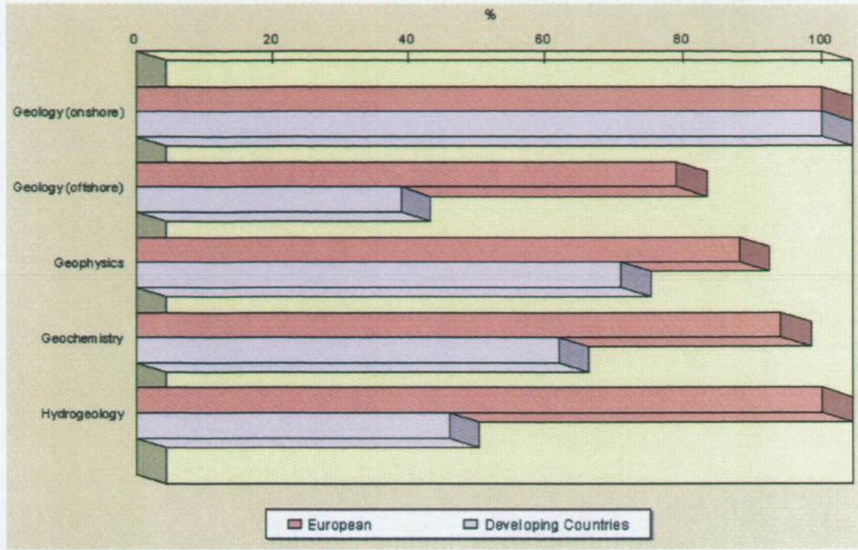


Figure 2 Percentage of European Union and developing country GSOs (*in Table 1) carrying out various core programme activities.

AFRICA

A	Angola
B	Botswana
Eg	Egypt
Et	Ethiopia
Ga	Gambia
Gh	Ghana
J	Jordan
M	Malawi
N	Namibia
Za	Zambia
Zi	Zimbabwe

C. & S. AMERICA

A	Argentina
Bo	Bolivia
Br	Brazil
Ch	Chile
Co	Colombia
D	Dominican Rep
E	Ecuador
G	Guyana
M	Mexico
Pa	Paraguay
Pe	Peru
S	Suriname
U	Uruguay
V	Venezuela

ASIA & S. PACIFIC

Ca	Cambodia
B	Bangladesh
I	Indonesia
SK	Korea, S.
Ma	Malaysia
Mo	Mongolia
PNG	Papua New Guinea
P	Philippines
SI	Solomon Is.
SL	Sri Lanka
T	Thailand
V	Vanuatu

EUROPE

A	Austria
B	Belgium
C	Cyprus
CR	Czech Rep.
F	Finland
G	Greece
I	Ireland
L	Lithuania
Ne	Netherlands
No	Norway
P	Poland
R	Romania
Sl	Slovenia
Sp	Spain
Swe	Sweden
Swi	Switzerland
T	Turkey
UK	UK

Figure 3 Key to GSOs plotted in Figures 4, 5 and 6.

countries with a per capita GNP in 1993 of greater than US$8256 and therefore were classified as 'high income countries' (Table 1). These latter GSOs have been included for comparative purposes. The data have been analysed in a number of diagrams (Figures 3 to 6) by relating GSO budgets and staff resources to the size, and 'wealth' of the nation. In order to

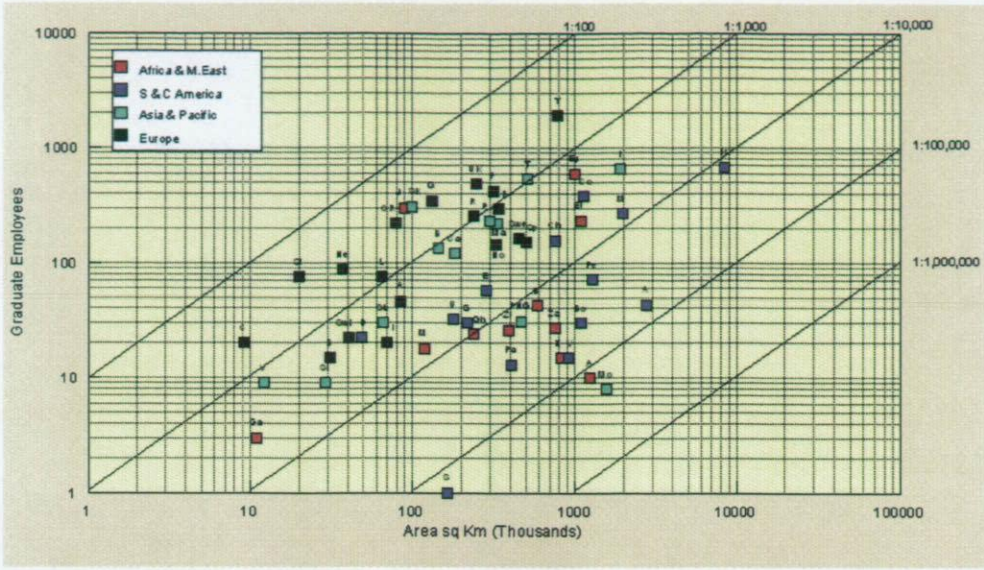


Figure 4 The number of graduate staff in each of fifty five national GSOs plotted against their nation's land area. For key to countries see Figure 3

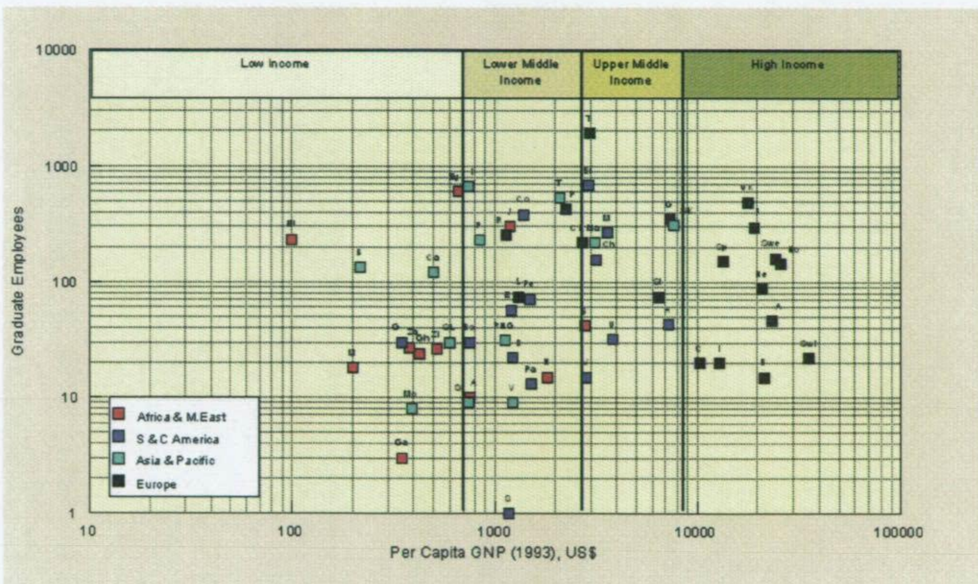


Figure 5 The number of graduate staff in each of fifty five national GSOs plotted against the per capita GNP of their country. The national income groups are according to World Bank definitions for 1994 (see also Table 1, this report). For key to countries see Figure 3.

make reasonable comparisons, only that amount of each GSO's budget that they receive from their respective governments for their core activities is included and commercial income or income from bilateral or multilateral aid programmes is excluded where the relevant information is available.

There are many factors that might determine the optimum size, in terms of staffing levels, of a national GSO, but one of the most important will be the area of national territory; the larger the country the greater the amount of data required to understand all aspects of its geology and hence the more resources, including staff resources, a GSO will require to collect, store and process data and deliver information on a national basis.

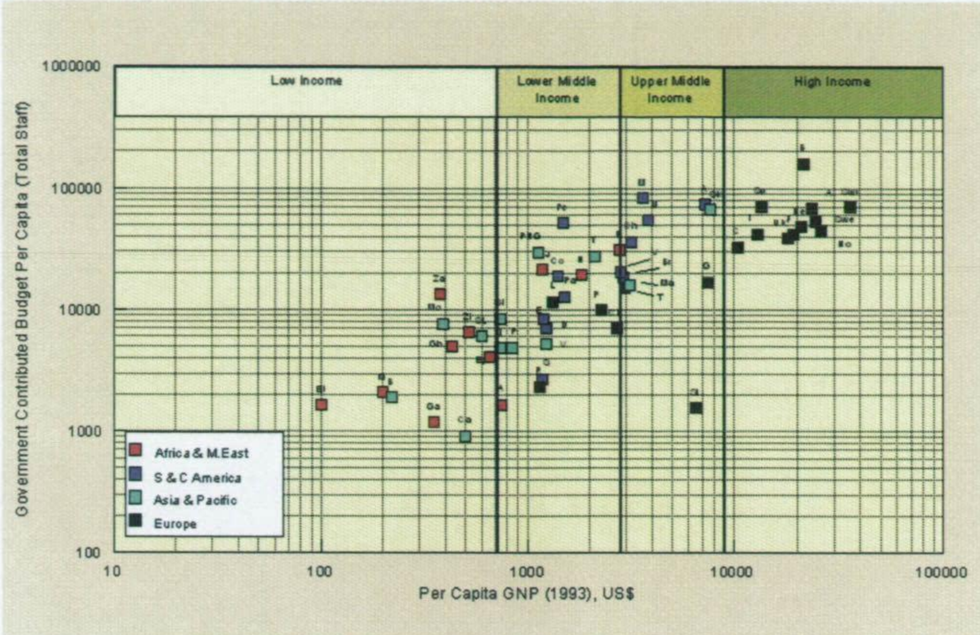


Figure 6 Per capita budgets in US$ of fifty five GSOs (total staff complement) plotted against the per capita GNP of their countries. NB: the per capita budgets of the GSOs are calculated on that part of their income they receive from their central governments as grant in aid for their core programmes. Key to countries in Figure 3.

For the purpose of comparing the professional staff resources available to the fifty five GSOs with the size of the geoscience surveying task with which they are confronted, we have plotted each GSO's complement of graduate staff against the onshore area of their national territories (Figure 4). A broad positive correlation between the two variables is seen to exist but very wide variations in area of national territory per graduate member of staff is indicated amongst the GSOs. Twenty four per cent have a graduate staff resource of better than 1 per 1000 km^2, forty nine per cent between 1 per 1000 km^2 and 1 per 10 000 km^2 , while twenty seven per cent have areas exceeding 10 000 km^2 per graduate member of staff. In comparative terms the twenty seven per cent of the GSOs that have less than one graduate member of staff per 10 000 km^2 of national territory can be considered as under-resourced in terms of scientific expertise. All the GSOs in the latter class are from developing country GSOs. The fifteen per cent of GSOs, all from developing countries, which have between 5000 and 10 000 km^2 of territory per graduate staff member may be regarded as barely adequately resourced.

An interesting comparison can be made between the ratio of the total graduate staff resources available to the African GSOs of our sample as compared to their total land area, and the same ratio for the GSOs of the European Union. Whereas the ten African GSOs had, in 1995, a total of 995 graduates available and a land area of 6.25 million km^2, fifty four per cent of which remained to be mapped, the fifteen GSOs of the European Union had available 3782 graduates for 3.6 million km^2, only fifteen per cent of which remained to be surveyed at scales larger than, or equal to, 1:250 000. The ratio for the African and European Union GSOs are 1 graduate per 6294 km^2 and 1 graduate per 995 km^2 respectively, though the remaining surveying task in Africa, at the scales indicated, is six times larger in Africa than in Europe.

Comparative Staff Resources

The total graduate staff resource of the ten African GSOs in our sample is only 26% of that available to the combined GSOs of the European Union, but the land area they are responsible for surveying is almost twice as large as that of the European Union.

As might be expected, the comparative wealth of a country alone will not be reflected in any systematic way in the size of the scientific staff resource of its GSO. This is illustrated in Figure 5 which indicates wide variations in graduate staff numbers between individual GSOs in each of the four income categories. The only systematic variation seen is an increase in the average graduate staff complement of GSOs from low income to lower middle and upper middle income categories and then a modest decrease in the upper income GSOs to approximately the level of the lower middle income GSOs. This latter trend reflects recent 'down sizing' in many GSOs in the upper income group largely resulting from reductions in government funding for core programmes. However, such downsizing has not necessarily resulted in a reduction of output as efficiency gains due to the increased application of information technology have often resulted in an increased flow of geoscience information. For example, in the British Geological Survey, emphasis on digital cartography has resulted in a productivity increase, in terms of new maps published per annum, of over one hundred per cent in the period 1995–7 as compared to the previous five years.

We make no attempt here to define the optimum ratio of professionally qualified (graduate) staff to total staff complement of GSOs. This will depend on the priorities accorded to various parts of the GSO's programme of activities. We have, however, focused our analysis of staff resources on graduate staff because as geoscience surveying is not a purely mechanistic technical operation it requires highly developed professional skills in the interpretation and presentation of data and the provision of information thus acquired. Amongst the technically advanced GSOs of the high income group of countries, graduate employees comprise between thirty one per cent and sixty eight per cent of total staff complements with a median of fifty one per cent (Table 2). Comparable figures for the GSOs of the low and lower middle income countries are also given in table 2 and generally indicate a relative deficiency in graduate employees in the GSOs of the low and lower-middle income countries with the overall situation being worst in Africa and the greatest variation being seen in Asia and the Pacific.

The financial support given by governments to their national GSOs, expressed in terms of budget per member of staff, is plotted against national wealth (per capita GNP) in Figure 6. While the average government grant per capita rises systematically from the lower income group to that of the higher income group, Figure 6 indicates the very large variations that exist between the individual GSOs from countries of comparable 'wealth'. This comparison, however, does not take into account the large variation in ratios of graduate to support staff in the total staff complement of the GSOs used to calculate their per capita budgets.

Any attempt to make overall comparisons of the adequacy of total resources, both human and financial, available to our sample of GSOs poses considerable problems. Nevertheless, even a cursory examination of Figures 4 to 6 indicates that many of the GSOs of the less developed countries are much more poorly resourced than their peers from countries of comparable national wealth. The financial situation of many of the most poorly resourced surveys is such that they not only have insufficient experienced graduate staff but they

Geological Survey Organisations by Income Group and Region	Graduate Employees as % of total staff complement	
	Range	**Median Value**
High Income Countries	31%–68%	51%
Low and Lower-Middle Income Countries — Africa and Middle East	3%–35%	22%
Low and Lower-Middle Income Countries — South and Central America	5%–54%	37%
Low and Lower-Middle Income Countries — Asia and Pacific	3%–77%	28%

Table 2 Graduate employees as percentage of total staff complement of fifty five national GSOs

often cannot retain those they may possess in the face of competition from the private sector. Furthermore, money available for operational costs, over and above salary costs, is often negligible and consequently their core 'programme' exists largely as a wish list in an environment of frustration and stagnation. This is a situation which brings with it particularly difficult challenges for potential donors of technical assistance.

4.3 Attainment of Core Programme Objectives

A detailed assessment, on a country by country basis, of the progress that national GSOs have made in meeting core programme objectives is beyond the scope of this summary report. However, there are some indicators that can be used to make a general, overall assessment of the ability of developing country GSOs to fulfil their obligations as national geoscience data centres and providers of a national geoscience information service.

The proportion of a country's surface area that has been covered by systematic geoscience survey is one measure of a GSO's success in collecting information vital to the nation's geoscience knowledge base. Geoscience surveys such as geological, geophysical and geochemical mapping, are carried out and published at a variety of scales depending on the time and resources available and the objectives of the survey programme.

The information gathered from thirty one developing country GSOs indicates that most systematic geological mapping programmes, ultimately aimed at nationwide coverage, are carried out on base scales between 1:25 000 and 1:250 000 with publication of individual geological map sheets most commonly at scales of 1:50 000, 1:100 000 and 1:250 000. Geochemical maps have less commonly been published in developing countries as part of a systematic series as the surveys so far undertaken have generally had specific local mineral exploration objectives rather than the long-term aim of uniform national coverage. As for geophysical surveys, in general only those countries where airborne surveys have been carried out have extensive geophysical map coverage. With the increasing ability to capture more and more geoscience survey data in digital form it is possible to produce maps on

Geological Mapping in Africa

An estimate of the current status of geological mapping in Africa indicates that less than half (46%) of the continent has been geologically surveyed at scales of 1:250 000 or larger and less than one quarter (24%) is covered by published maps of similar scales. This compares with the land area of the European Union where over three quarters (85%) has been geologically surveyed at scales equal to or larger than 1:250 000 and substantially more than half the land area (70%) is covered by published maps of similar scales.

demand at whatever scale is appropriate to a particular user requirement though the detail addressed in the field survey will ultimately control the usefulness of an interpretative 'map' at any particular scale. In this study we have assessed progress in developing countries in terms of area surveyed in sufficient detail to produce maps at scales of 1:250 000 or larger.

Based on the above criteria, there is a very wide variation in developing country GSO status with respect to onshore area geologically surveyed and area published. A few GSOs have surveyed and published geological maps of virtually all their national territory at scales considerably larger than 1:250 000 (eg Malawi 100% and Republic of Korea 87%, both at 1:50 000 scale) others have surveyed less than 20% even at the smallest scale of 1:250 000. Map coverage is particularly sparse in parts of Africa; taking the ten countries for which we have details from our survey and which together represent twenty per cent of the total surface area of Africa, less than half (46%) of the area has been geologically mapped at scales equal to or greater than 1:250 000 and less than a quarter (24%) has published maps at similar scales. A general investigation of published geological maps at scales equal to or greater than 1:250 000 in Africa suggests that the overall average may be even worse than that suggested above, though coverage varies greatly from country to country. The fact that at least seventy five per cent of one of the world's great continents lacks published geological maps at scales suitable for application to developmental projects must be a cause for great concern. Our data for Asia and Latin America are insufficient to allow overall estimates of map coverage for those continents but again marked variations from country to country are known to exist, and most have inadequate coverage.

For comparison we can examine the status of geological mapping in the fifteen countries of the European Union. Here, approximately 85% of the total land area of 3.6 million km^2 has been geologically surveyed and almost 70% is covered by published maps at scales of 1:250 000 or better. In many of the countries there is extensive publicly available coverage at scales of 1:50 000 (eg France 88%, UK 90%, Greece 98%, Spain 93%, Portugal 65%) whilst some 88% of the United Kingdom has been surveyed at scales as large as either 1:10 000 or 1:10 560.

In comparison with systematic geological surveys, geochemical surveys cover much smaller areas of most of the developing countries that have provided us with data. Of the twenty six countries which indicated that they carried out systematic geochemical surveys, most commonly by the collection and analysis of either stream sediment or soil samples, and stated the percentage of their country's area they had covered, fourteen had covered less than ten per cent, and only five more than thirty per cent of their country. Of these data held by the GSOs, a generally much smaller proportion have been published as systematic map series than is the case for geological survey data.

The amount of coverage by geophysical surveys in a particular country generally depends on whether airborne geophysical surveys have been carried out, usually as part of a technical assistance programme. Surveys carried out by mining or oil companies may also, eventually, be made available to national GSOs. Of the thirty two developing country GSOs that provided us with information, six countries had complete cover of their entire national territory, eight had more than fifty per cent coverage, six had between twenty five and fifty per cent and twelve had less than twenty five per cent. Many countries had published all the data as maps but a few had published none. Possibly, in the latter case, the data were supplied to the GSO by the private sector on a 'commercial in confidence' basis.

Other elements of developing country GSOs' core programmes cannot be assessed quantitatively on the basis of the information supplied to us. We are aware, however, from personal knowledge and experience, that levels of activity vary widely due to variations in available funding, expertise and the priority afforded the activity in the GSO concerned. In particular, the application of modern information technology varies from virtually nil in some GSOs to wide application affecting virtually all sectors in others.

5 TECHNICAL ASSISTANCE TO DEVELOPING COUNTRY GSOs

There has been a considerable amount of technical assistance to developing country GSOs, delivered through both bilateral and multilateral aid programmes, during the last few decades.

The total amount invested to date in such programmes is not known to us but an indication is given from a survey of the value of technical assistance projects being implemented by the Geological Surveys of the European Union, together with Norway, in 1996 involving 48 developing country GSOs. The total value of the projects involving developing country GSOs was over $60 million and the funding sources included the European Union, the World Bank and regional international development banks, UN development funds and the individual governments of the member nations of the European Union. Many of the GSOs of the European Union currently carrying out technical assistance programmes in cooperation with developing country GSOs have operated on a similar scale for at least three decades. Taking into account the projects implemented by non GSO consultants and by GSOs outwith the European Union, it is clear that to date technical assistance to the developing country GSOs is likely to have attained a total value of almost one billion dollars.

In the face of this huge investment, the question arises as to how well targeted the funded projects have been on the essential core requirements of the developing country GSOs.

Priorities for Technical Assistance

Our survey of developing country GSOs indicated that their highest priority for technical assistance projects is currently in the area of basic geological surveying and geological map production.

5.1 Technical Assistance Priorities: A view from the Developing Country GSOs

As part of our survey of developing country GSOs we asked them to prioritise their requirements for new programmes of technical assistance in terms of major elements of their core programme objectives. Their response, taking the top three priorities named by each of twenty nine GSOs who responded, is summarised in Figure 7. The highest priority was for basic geological surveying and geological map publication. Taken together the 'geoscience surveys' element of the core programme, including regional geological, geophysical and geochemical surveys, accounted for almost fifty per cent of priority activities listed. Topics specifically related to the 'national geological resource' element (minerals, water and energy resources) accounted for seventeen per cent. It should be noted, however, in making these comparisons, many of the priority activities listed in Figure 7 have applications that extend across the somewhat artificial sectorial boundaries within the model core programme.

The response of the GSOs on the question of core programme priorities quoted above refers specifically to technical assistance requirements and reflects the need for inputs of external expertise and training, not merely an increased budget. We asked the GSOs to give a similar list of priorities should they receive additional funding for their core programmes from their own govern-

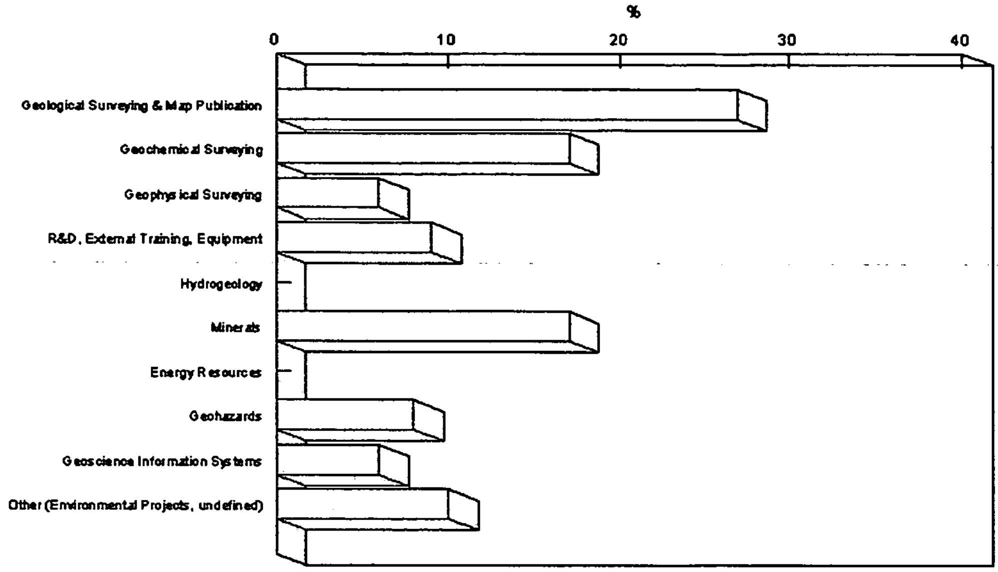


Figure 7 Priorities expressed by thirty one developing country GSOs for further technical assistance according to core programme activities. Priorities are expressed as a percentage of the total of the top three priorities expressed by each country.

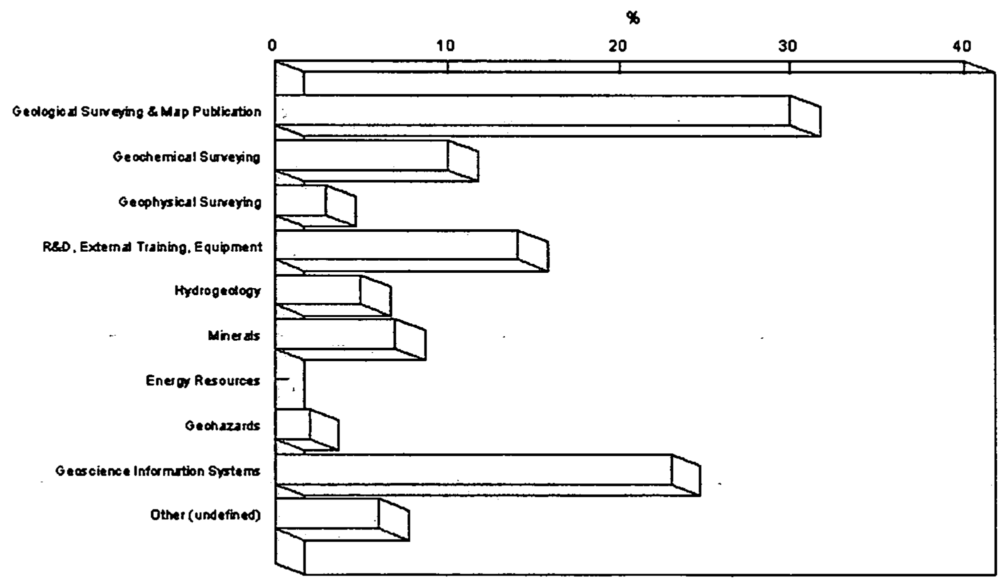


Figure 8 Priorities expressed by thirty one developing country GSOs for expenditure of additional funds from their governments for core programme activities. Priorities are expressed as a percentage of the total of the top three priorities expressed by each country.

ments. Geological surveying and map publication again topped the list of priorities (Figure 8) and the 'geoscience surveys' sector of the core programme again accounted for over forty per cent of the priorities listed. The geological resource sector accounted for about twelve per cent of priorities but, significantly, was overtaken in second place by 'geoscience information systems' which represented over twenty per cent of the priorities listed.

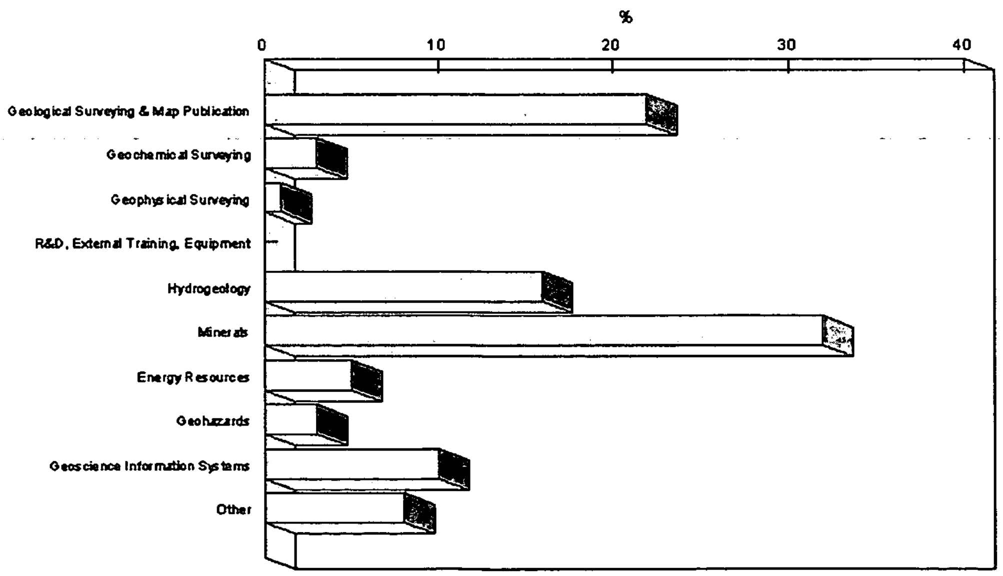
In a survey conducted by Otto (1994), in which forty three GSOs worldwide participated, including twelve developing country GSOs not included in our survey, similar priorities were found to emerge. The participating GSOs identified their three most important activities amongst which sixty seven per cent mentioned systematic mapping activities together with twenty six per cent which separately listed acquisition, processing and dissemination of geoscience information. Forty seven per cent listed mineral exploration and twenty three per cent the regulation of private sector exploration and nineteen per cent the study of groundwater resources. The participating GSOs included both developed and developing country GSOs and the priorities listed reflected their view of their most important activities rather than specific sectors where the developing country GSOs stated their needs for more assistance.

5.2 Technical Assistance Provision: Relation to Core Programme Priorities

Though all the developing country GSOs that took part in our survey had received some technical assistance in the last ten years, under either bilateral or multilateral aid programmes, it should be stressed that not all geoscience related technical assistance to developing countries is directed to their GSOs. For example, of the one hundred and fourteen technical assistance projects being implemented by the GSOs of the European Union in 1996, only just over half were being conducted in partnership with one or more developing country GSOs. Particularly in the fields of hydrogeology, hydrocarbons and, to an extent, mineral resources, projects were being carried out in collaboration with other organisations. This arises either because the national GSO is not the responsible state body for the sector concerned or because projects focused on downstream activities, such as mineral production and processing, which are primarily private sector activities.

Amongst those projects being implemented in partnership with developing country GSOs, a breakdown of activities is shown in Figure 9. The classifi-

Figure 9 Percentage of total number of technical assistance projects being implemented in developing country GSOs by the GSOs of the European Union in 1996 supporting the various categories of core programme activity.



cation used is the same for that of figures 7 and 8, which show the priorities expressed by developing country GSOs for increased assistance to their core programmes. Here, this classification has some limitations as some projects span several activities. Nevertheless, some useful comparisons can be made in terms of recent technical assistance provision as compared to the developing countries GSOs' assessment of their needs. For example, the core programme sector attracting the most attention from donors was the national geological resource (groundwater, minerals, energy resources) sector with 53% of the projects specifically focused on this sector and a particularly high proportion (32%) on minerals alone. By comparison only 21% of projects were concerned with regional geoscience surveys. These figures represent an almost exact reversal of the sectorial priorities for technical assistance expressed by the developing country GSOs themselves in our current survey.

The figures given for projects being implemented by the GSOs of the European Union are a snapshot of projects active in 1996. In an attempt to identify any significant trends in the nature of technical assistance provision in relation to core activities we asked the developing country GSOs involved in our survey to provide information on all the technical assistance projects they had hosted in the period 1975 to 1995. Seventeen GSOs provided details of 113 projects. The results indicate a very similar emphasis on the resource sector (52% of projects) to that apparent in 1996 survey of technical assistance projects being implemented by the GSOs of the European Union (53%, Figure 9). Twenty seven per cent of projects were primarily concerned with the systematic geoscience surveys, slightly higher than in the 1996 survey of technical assistance projects being implemented by the GSOs of the European Union.

Looking more closely at the comparative figures, in the 'systematic geoscience surveys' sector, geochemical surveying was stated as a much higher priority by the developing country GSOs in 1996 than the attention it was receiving from donors in that year (10% of technical assistance projects being carried out by the GSOs of the European Union, Figures 7 and 9). In other sectors, work on information systems appears to mirror quite closely the perceived developing country GSO priorities for technical assistance but that on geohazards is under represented. In the classification adopted in Figure 9, no separate designation could be included for training and equipment which, however, formed an element of many projects allocated to other activity sectors.

The variations displayed in Figures 7 to 9, illustrating the discrepancies between priorities for core programme assistance expressed by the developing country GSOs in 1996 and the record of technical assistance delivery over the last twenty years, probably results from a marked recent change in GSO priorities with changing perceptions of their national role. How quickly this will change the balance of activities in donor programmes remains to be seen.

Although it has not been possible within the scope of the present review to make a universal assessment of technical assistance to developing country GSOs, either in terms of total expenditure or in proportion of different types of sectorial activity, nevertheless examination of some important donor programmes does indicate some significant recent trends. In particular, though regional resource assessment remains a high priority, there is a definite move away from funding programmes of site specific mineral exploration, particularly those involving the proving of ore reserves and actual mine development. This in itself mirrors a trend in many developing country GSOs which are becoming less involved in such activities as their hitherto centralised economies are liberalised, and the role of the state as a producer of minerals is devolved to the private sector. At the same time there has been a realisation that GSOs, many of which have been required by their governments to act as virtual state mineral exploration companies, must return to the basic function of carrying out systematic national geoscience surveying (see Figures 7 and 8) in order to provide the information upon which the private sector can base investment decisions concerning detailed mineral exploration projects. Both the World Bank (Industry and Mineral Division) and the European Union (SYSMIN programme) have invested heavily in mining development related programmes over the last two decades but in both cases, during the last five years, a significant proportion of their investment has been focused on increasing the amount of systematic geoscience survey information available within developing countries. As stated by the World Bank (1996, p35), 'the reform of a GSO aims at transforming an exploration oriented organisation into one that gathers, orders and provides nationwide earth science information'.

From the above it does appear that the developing country GSO core programme priorities and donor action in terms of the nature of geoscience technical assistance may be starting to converge. Whilst this will help in addressing the huge deficiencies in systematic geological survey information identified in section 4.3, above, only GSOs with sensibly planned core programmes and the resources to sustain the programmes over the long-term will satisfactorily provide the national geoscience information services needed to underpin national development.

5.3 Technical Assistance and Sustainable GSOs

In section 4 we showed that while most of the GSOs surveyed declared core programmes covering a very wide variety of activities, the funding provided by their governments and their available human resources varied very widely between GSOs of countries of comparable size and wealth. Many would regard their resources as inadequate to carry out their national role and some are undoubtedly so poorly resourced as to be virtually moribund, particularly in so far as adding new data to national geoscience databases is concerned. At worst, in a few cases, even pre-existing databases have either been dissipated through lack of maintenance or physically destroyed during periods of warfare or civil disturbance.

Most technical assistance projects have a limited life, generally of one to five years. Concurrent and successive projects from one or several donors may continue in a particular developing country GSO for many years. Sooner or later, however, technical assistance for a particular core activity will cease and the question of whether the activity is sustainable without external assistance arises. No matter how effective training of local staff has been during the period of technical assistance or how adequate the equipment provided to the host GSO, the activity will eventually founder if the national government does not provide the resources to sustain the activity. Unfortunately this seems to be the fate of many donor initiated activities, particularly so in those developing countries whose economies have shown little or no growth over long periods. By comparison, those developing countries whose economies have shown strong growth over the last few decades have, with the help of technical assistance, developed GSOs with strong sustainable core programmes. Particularly good examples are seen in SE Asia (eg Republic of Korea, Malaysia, Thailand, Philippines and Indonesia).

Technical assistance programmes involving 'institutional twinning' or 'professional linkages' have often proved effective in fostering sustainability of core activities. Here the GSO of the donor country is linked with a developing country GSO in order to carry out a long-term but relatively low level of technical assistance in a particular core activity. The assistance will usually involve periods of training interspersed with periods of project work by the trainees aimed at completing specific core programme projects. A good example is seen in the long-term development of geological mapping teams in Egypt in a professional linkage between the Egyptian Geological Survey and Mining Authority and the British Geological Survey which during its course has not only established a fully trained mapping capacity but has produced published geological maps covering 135 000 km^2 of country (O'Connor, 1996).

Fozzard (1993) has argued that even where the GSOs of particular countries are so weak that they cannot perform any meaningful work and are basically unsustainable, there may still be a case for technical assistance on a one-off consultancy basis targeted on products that are likely to have a positive economic impact. Such work might include 'evaluation of mineral potential; evaluation of specific environmental problems; collation, integration and evaluation of data; publishing maps etc.' We support this view but would also observe that, paradoxically, some developing country GSO's core programmes are potentially unsustainable because governments have relied too heavily on technical assistance projects to fulfil the ongoing core mission of their national GSO. We have identified a few countries which have disproportionally low levels of government funding compared with their staff resources, many of their staff being supported through donor funding, usually via soft loans or grants for specific projects.

Developing country GSOs will be funded by their governments at levels that guarantee a degree of sustainability to their highest priority core programme activities only if the governments fully appreciate the relevance of those activities to either the creation of wealth or the quality of their citizen's lives. It is curious that, as careful examination of Figure 6 will show, even governments of some countries who either rely heavily on mineral exports as major foreign currency earners, or who are especially vulnerable to geohazards or rely almost entirely on groundwater to sustain their populations, fail to provide funding for a viable national core programme within their GSOs. This strongly suggests that GSOs have to develop better methods of drawing attention to the value of their work and particularly be able to demonstrate this quantitatively by cost-benefit analysis of their various core activities. While some research has been undertaken, for example, on the cost-benefit analysis of geological mapping, this has been mainly in developed countries. We now consider this a vital topic to be addressed in developing country GSOs. Further discussion of this theme is presented in an appendix to this report.

6 STRATEGIES FOR TECHNICAL ASSISTANCE TO DEVELOPING COUNTRY GSOs

Experience shows us that most of the world's poorest countries, though most in need of technical assistance to develop their national GSOs, are least able to sustain and build on the activities supported by the assistance after the external intervention is ended unless the country is experiencing economic growth and their governments are prepared to invest some of the increasing national wealth in their GSOs. Where this has happened, and there are some notable successes amongst countries which have progressed into the lower- and upper-middle income groups, active GSOs with well balanced, viable core programmes have emerged.

Whilst examination of Figure 6 gives us a particular snapshot of the wide range of GSO per capita budgets as compared to national wealth, and could be construed as a crude indicator of government commitments to their GSOs, only careful examination of the recent performance of a GSO will indicate if, perhaps with some restructuring and internal redirection of resources, it is capable of maintaining a modest level of core activity. For many donors this sort of evaluation is an essential precursor to granting technical assistance. Similarly the balance of the core programme in relation to the geological character of national territory requires evaluation; there is plenty of evidence that the senior staff of GSOs are well placed to advise on the latter even though they may in some cases have previously been directed by their governments into expending resources on high risk exploration programmes.

For GSOs which are under-resourced to the point where a sustainable core programme comprising even the most basic activities of data collection, archiving and supply of national geoscience information cannot be guaranteed, technical assistance in the form of one-off consultancies to bring into the public domain geoscience information previously collected but never published may still be merited. The discrepancy seen (section 4.3) in our sample of African GSOs between total land area geologically surveyed at 1:250 000 scale or better (46%) and area published as maps (26%), demonstrates the huge task remaining in this single important area of delivery of systematic geoscience information. This discrepancy between information collected, often in the colonial era, and information readily available in the public domain arose in many countries because their GSOs were diverted from the core activities of systematic surveying and information services into high risk and detailed mineral exploration activities. A recent example of technical assistance to correct this tendency and to bring information into the public domain is provided by projects funded by the World Bank and the European Union (SYSMIN) in the Geological Survey Department of Zambia which will result in the publication of approximately one hundred geological map sheets from information hitherto lying dormant in the Department's archives. In the case of Zambia, these projects are being followed by additional technical assistance involving further field survey and training in data collection in the field in order to revitalise these core activities within the Geological Survey Department. Whether these latter activities will prove sustainable in the long-term, only time will tell, but the current donor's assumption is that the Zambian Government will have the commitment to provide the necessary resources to its GSO for a modest but balanced programme of core activities to continue into the future.

For GSOs whose support from their governments has allowed a more varied selection of core activities to proceed with reasonable continuity for a number of years, technical assistance projects may, according to the particular needs of the GSO, address a wider range of core activities. Nevertheless, both GSOs and donors should be careful that technical assistance inputs into a particular core activity do not make such demands on the GSO's limited resources that the core programme is distorted and parallel activities are damaged. Governments of developing countries have in the past sometimes been tempted, particularly with respect to bilateral aid programmes, to take what was on offer rather than insist on what was most needed and most appropriate. A number of GSOs have seen their core programmes damaged by such actions, particularly where their governments did not carry out any meaningful consultation with the GSOs before decisions were made.

There are many ways of carrying out technical assistance projects, or more accurately technical cooperation projects, with a developing country GSO which is operating a viable core programme of activities. The initiation of new activities, strengthening of current activities or the introduction of new technology may all be involved. Similarly, training will have an important role. Again the requirement for a new activity must be carefully appraised and assurances gained, by both sides, that it will not remove resources from another core activity of equal or greater priority. Seen overall, our survey indicates that priorities remain with the strengthening of the basic core activities of systematic geoscience surveying, improving national natural resource inventories and providing an efficient geoscience information service. The strengthening of these activities will also contribute to the ability of GSOs to actively contribute to addressing environmental issues. Priorities will differ from country to country, mainly dependent on geological and geographical factors, and as countries develop economically, the demands on the core programmes of their GSOs will become more diverse and demanding. Furthermore, any technical assistance is likely, but not inevitably, to be more sustainable.

Some studies aimed at identifying the areas in which developing country GSOs are likely to require technical assistance have proposed single schemes of categorization of GSOs against which likely technical assistance needs are listed. For example, in developing a mining strategy for Latin America and the Caribbean (World Bank, 1996) it was suggested that countries could be plotted on a graph of institutional and professional capability against the presence of a mining tradition. In this way, four broad categories of country could then be recognised; countries with a mining tradition and strongly developed professional and institutional capability; countries with a mining tradition but poorly developed professional and institutional capability; countries where mining is non-traditional but with a well developed professional and institutional capability; and countries where mining is non-traditional and with a poorly developed professional capability. Such classifications, though necessarily somewhat arbitrary and subjective, can be useful in discussing priority areas for technical assistance for GSOs in the context of activities within GSO's core programmes which provide information relevant to a particular customer sector. We have not attempted to use such a classification in our discussion as it has not been our objective to look in detail at core programme activities and technical assistance requirements in terms of their relevance to specific industrial, or other, sectors.

7 CONCLUSION

Most national GSOs aspire to a core programme of activities displaying broadly common features though the priority given to the various activities will vary according to geological, geographical and socio-economic factors.

The resources available to GSOs, both in terms of expertise and finance, are highly variable and display only a weak correlation with either the wealth or size of nations. Many GSOs, particularly in the low and lower-middle income countries, cannot operate adequate core programmes, and in extreme cases are virtually moribund, because of lack of resources.

The highest priority for technical assistance, as expressed by the majority of GSOs from the low or lower-middle income developing countries, is in the area of geoscience surveying with both basic geological mapping and map publication and systematic geochemical surveys being particularly emphasised. Mineral and other natural resource assessment programmes are also in demand but many GSOs now regard detailed and localised exploration programmes as primarily private sector activities.

Our study suggests that the supply of technical assistance is adjusting to the changed priorities expressed by the developing country GSOs but there is necessarily a lag of 'supply' priorities behind 'demand' priorities.

In the provision of technical assistance to the core programmes of developing country GSOs, the question of sustainability of the activity following completion of the technical assistance should be carefully considered. While certain one-off programmes, such as some basic data acquisition and delivery into the public domain, may be merited in countries where the GSO is so poorly resourced as to be virtually moribund, experience indicates that assistance to core programme activities generally takes root most successfully in GSOs in countries with a growing economy.

In order to increase investment by their governments in their core programmes, GSOs in developing countries need to be able to demonstrate the economic and social benefits that accrue from geoscience surveying and the information it provides. To this end methods for the cost- benefit analysis of such programmes need to be developed.

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9 APPENDIX

THE ECONOMIC VALUE OF GEOLOGICAL MAPPING

"Detailed publicly available information concerning the nature and origin of the geology of an area is essential for informed public-policy decision-making and for economic development" (USGS, 1993).

1 Background

One of main functions of a geological survey is to produce national and regional geological maps. These have been considered of strategic importance, and have thus formed part of the core programmes of most geological surveys. A fundamental assumption underpinning the funding of such work is that geological mapping programmes realise diverse economic and social benefits, and that these benefits far outweigh mapping costs.

While there is no doubt that geological mapping does produce benefits, few attempts have been made to actually quantify them. There are good reasons for this: firstly, there are major methodological difficulties associated with the measurement of benefits and, secondly, few scientists or public institutions have had to justify their work in cost-benefit terms. This situation is changing however, with those in charge of public finances increasingly keen to ensure spend efficiency. In developing countries, where competition for public money is arguably more acute, the need to demonstrate the cost-effectiveness of survey programmes is particularly great.

In this section of the report, an attempt is made to show how some of the principles of cost-benefit analysis (CBA) might be applied to the valuation of geological mapping programmes. We begin with an overview of the typical uses and users of geological maps (Section 2). The range of uses and users is large, and it is suggested that benefits - both tangible and intangible - may be equally diverse. This is followed in Section 3 by a more detailed examination of costs and benefits, with particular emphasis on the nature of benefits and potential valuation approaches. Reference is made to previous valuation studies undertaken in the US and UK which have attempted to 'capture' certain benefits in quantifiable, economic terms. Finally in Section 4, some of the advantages and pitfalls of this type of analysis are discussed, and tentative conclusions are drawn.

Box 1 What do we mean by geological mapping?

Geological maps are the most obvious end product of a mapping programme. However, mapping programmes deliver other important outputs, both tangible and intangible.

In this review, the production of geological maps is interpreted broadly to include underpinning databases, the three dimensional model derived from mapping and the intellectual knowledge and understanding of the scientists involved.

2 Users and uses of geological mapping

Geological maps form a fundamental database for many different types of environmental decision requiring a predictive capability (USGS, 1993). Because of their comprehensive information content, they have applications in a wide range of societal and scientific applications.

Some of the more obvious applications of the information on geological maps include mineral, groundwater and energy assessment, geohazard evaluation, environmental analysis and land use planning. Within these broad categories, however, there are many more specialised uses which draw on particular classes of data. In this way, the general map is used as a source for the production of many special purpose derivative or 'thematic' maps. Table 1 presents a list of applications and indicates how elements of the general map are used in different disciplines and sectors.

Table 1 draws a simple distinction between economic, environmental, health, educational and security benefits arising from the use of geological maps within different sectors. Thus, use of information in the construction industry may realise economic and environmental benefits through lower site investigation costs and geohazard avoidance, respectively. However, health and/or educational benefits may be minimal or non-existent. Conversely, use of survey information in schools and colleges may yield educational benefits, but few tangible economic or other benefits. As with different sector uses, distinctions are not always clear cut. For example, uses which register health benefits are also likely to generate economic benefits through greater productivity and reduced health care costs. However, unambiguously assigning health improvements to the use of survey information is extremely difficult, as is quantification of health effects. The issue of benefit estimation, and nature of benefits (direct and indirect) is discussed in more detail in the sections below.

3. Empirical evaluation

The benefits of geological mapping programmes are largely in the form of costs, or losses, avoided. However, costs and benefits go beyond the immediate monetary amounts spent on conducting the mapping work or in avoiding future costs. Society pays for and profits from publicly financed mapping programmes in ways which are not amenable to immediate quantification. These social costs and benefits must also be taken into account in decision-making (ISGS, 1991).

Valuation framework

Cost-benefit analysis is used as a decision-making method in project appraisal, and its principles can be applied to the valuation of mapping programmes. In essence, cost-benefit analysis is a simple method for comparing, over time, the predicted costs with the predicted benefits of a line of action, such as the adoption of a particular policy or project. To assess the worth of a course of action, two scenarios are compared: one 'with' the project, and one 'without'. The 'without' scenario is used as a baseline, or benchmark, against which the effects of a project or policy are measured. The present value of cost and benefit streams is then determined by a process known as discounting, in which future amounts are multiplied by a discount factor to calculate the value today of amounts received or paid out in the future. Benefit cost ratios can then be calculated or, more typically, the net present value (NPV) of an investment is determined by discounting the incremental net benefit (the difference between costs and benefits). Decisions can then be made on the basis of whether a positive or negative value is obtained. Mathematically, the discounting occurs as follows:

$$NB_{pv} = \sum_{i=1}^{n} \frac{NB_i}{(1+r)^i}$$

NB_{pv}	present value of net benefits
NB_i	net benefits in year I
r	annual discount rate (eg r=0.1 for a 10% discount rate)
n	number of years

In terms of mapping evaluation, the 'with' and 'without' project scenarios

Table 1 Principal users of geological maps

PRINCIPAL ACTIVITY SECTORS REQUIRING GEOLOGICAL STUDIES (WHICH SUPPORT THE FOLLOWING:)	UNIVERSAL BENEFITS				DATA DERIVED THROUGH THE APPLICATION AND INTERPRETATION OF THE INDICATED GEOSCIENCE DISCIPLINE														
	1a Health	2a Environmental	3a Financial	4a Security	5a Geological Mapping	6a Geomorphology (Bathymetry)	7a Geochemistry	8a Geophysics	9a Hydrogeology	10a Metallic Minerals genesis	11a Non-Metallic Minerals genesis	12a Gem & Precious Metals Exploration	13a Petroleum Geology	14a Geothermal Studies	15a Nuclear Geology	16a Marine Geology	17a Geotechnical Engineering	18a Remote Sensing	19a GIS/IT
1 Minerals Aggregates Extraction		0	0		x	x			x		x					x	x	x	x
2 Minerals Industrial Extraction		0	0		x		x	x		x	x	x				x	x		x
3 Waste Management	0	0			x	x	x		x						x	x	x		x
4 Environmental Assessment	0	0			x	x	x		x					x	x	x	x	x	x
5 Planning (Old Workings, Caverns, Landslips)					x	x			x						x	x	x	x	x
6 Coastal Management (Erosion, Sedimentation)		0			x	x	x		x						x	x	x	x	x
7 Water Management Resources (Groundwater)		0			x	x	x	x	x					x	x			x	x
8 Water Management Protection	0	0			x		x		x					x	x				x
9 Construction Industry, (Building Foundations etc.)		0	0		x										x		x		x
10 Road, Rail, Canal, Airport, Dock, (Transport) Construction		0	0		x				x							x	x	x	x
11 Insurance Industry (Subsidence, Earthquake etc.)			0		x												x	x	x
12 Education Requirements			0		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13 Academic Research Areas			0		x	x	x	x	x	x	x	x	x	x	x	x		x	x
14 Hydrocarbons Offshore Industry			0		x		x	x					x			x	x	x	x
15 Hydrocarbons Onshore Industry			0		x		x	x	x				x				x	x	x
16 Coal Mining			0		x			x	x								x	x	x
17 Health	0				x		x		x	x	x				x				x
18 Conservation		0			x	x			x								x	x	x
19 Tourism & Recreation & Adornment			0		x	x						x					x	x	x
20 Agriculture		0	0		x				x									x	x
21 Forestry		0	0		x				x									x	x
22 Military (Onshore)				0	x	x		x	x				x		x	x	x	x	x
23 Military (Offshore)				0	x	x		x					x		x	x	x	x	x
24 Communications (eg Seafloor Cables, Power Lines, Tunnels)			0	0	x	x		x								x	x		x
25 Geothermal Power		0	0		x			x	x	x	x			x			x	x	x
26 Nuclear Minerals Industry & Radioactivity Considerations)	0	0	0	0	x	x	x	x	x	x					x		x	x	x
27 Metallic Minerals Industry		0	0		x	x	x	x	x	x		x			x	x	x	x	x
28 Gemstones			0		x	x	x	x				x					x	x	x
29 Equipment Manufacture, Survey & Mining			0					x	x	x			x	x	x	x			x
30 Offshore Equipment			0					x					x			x	x		x
31 Global Environment, Relative S/L Change		0		0		x			x	x				x	x	x	x	x	x
32 Minerals & Petroleum Law Administration		0	0							x	x		x	x	x	x	x	x	x

can be viewed in a number of different ways, depending on project perspective and the nature of benefits to be valued. Important considerations include:

- *Time frame:* there is often a considerable time lag between mapping and the application of information in, for example, land use planning. In addition, the life span of a geological map may be considerable before remapping occurs. Both considerations indicate the need for a long time frame in any valuation study.

- *Analytical perspective:* 'with' and 'without' mapping scenarios can be compared to evaluate both existing and proposed programmes. For example, an *ex post* analysis would look back in time to consider benefits that have actually accrued through the use of mapping information; an *ex ante* approach would consider future (expected) benefits from a proposed programme.

- *Nature of benefits:* in those areas where geological mapping has led, or is expected to lead to, the identification of 'new' resources (eg through identification of new mineral deposits), new wealth is created and a stream of *direct benefits* may be identified. This would seem more likely to occur where hitherto unmapped areas are mapped (primary mapping), a situation more typically found in developing countries. In the industrialised world where remapping is the norm, the identification of 'new' resources is unlikely, and most benefits are likely to be in the form of costs, or losses, avoided through provision of more detailed information. These can be termed *indirect benefits.* In these cases, the net economic benefit of any geological mapping programme can be described in terms of costs avoided from using the geological map, minus the costs of producing and disseminating the map.

Estimating costs

The direct costs of geological mapping are relatively straightforward to estimate. In most industrialised countries, costs are associated with *remapping* areas that have already been mapped. In these instances, the new mapping exercise will make use of the existing geological database, the costs of which will have already been underwritten by earlier funding initiatives. Where the available data already consist of modern, inter-disciplinary, high resolution information, it follows that existing maps and databases may only require slight revision, perhaps in the context of new interpretive models. In such cases, map production costs will be relatively low. In developing countries, however, geological maps might not exist at all, or may be very old. In these cases, the acquisition of new information of greater density and accuracy is likely to be more costly. In both cases, however, the broad cost sources are much the same (see Box 2).

While the costs of producing a new map, or of remapping, may mean that most costs are incurred at the beginning of a project, it is important to note that maintenance of databases, map production and distribution will result in other costs being spread out over the lifetime of a project. Thus in areas where remapping forms the basis of the 'with' project scenario, it is important to remember that maintenance of old maps in the 'without' project scenario may also incur costs.

Box 2 The cost of geological mapping

Typical costs include:

- data collection in the field;
- data compilation and interpretation;
- data presentation, including digitising maps and database development
- printing and publication; and
- map distribution

Box 3 Direct vs indirect benefits of geological mapping

Indirect benefits in terms of avoided costs are likely to be most significant type of benefit in remapping projects in industrialised countries. In developing countries, the principal of avoided cost may be less obvious. Primary mapping may identify 'new' mineral deposits, leading to commercial exploitation and direct wealth creation, though much will depend on the presence of an enabling legislative and economic environment. Even here, however, cost avoidance is significant. In the absence of basic geological maps, each competitor in the extraction business would generate proprietary information not available to others, leading to significant duplication costs.

The indirect benefits of avoided costs would be thought of as somehow inferior to direct benefits. Wherever costs are avoided, be it in infrastructure planning, non-duplication of information or site clean-ups, savings can be invested in other projects of benefits to society and the economy

Estimating benefits

As noted above, a simple distinction can be made between the direct and indirect benefits of geological mapping. However, while mapping costs are relatively straightforward to estimate, measuring benefits presents major difficulties. In the absence of market prices which reflect the value of public goods such as maps, indirect means of estimating value have to be sought.

Attempting to capture the full range of benefits accruing from the use of geological maps is clearly impossible. For this reason, previous valuation studies have focused instead on discrete, more readily quantifiable aspects of use. Table 2 presents a summary of published and unpublished work in this area. Three out of the four studies listed have been undertaken in industrialised countries (The US and UK) and therefore deal with remapping rather than primary mapping. Not surprisingly, benefits identified and valued in each case are in the form of costs avoided (see Box 3), though methodological approaches and the nature of cost savings identified vary. The Kenyan (ODA) study (Table 2) focuses on primary mapping carried out in the 1980s by the British Geological Survey (BGS). Benefits again take the form of costs avoided, though alternative analyses focusing on direct commercial benefits would have been possible.

By far the most comprehensive study published was by the United States Geological Survey (USGS, 1993). In this study, an *ex ante* analysis was undertaken to evaluate cost savings that could be directly attributed to the use of a new map for two planned developments: (a) selection of a road corridor; and (b) selection of a landfill site. In each case, hypothetical land use decisions made with and without the benefit of new mapping information were compared. The aim was to see if the new information would be compelling enough to alter land use decisions and then to determine the economic impact of such decisions. Although only two of many possible mapping applications within one County were evaluated, net benefit estimates of between $1.28 and $3.5 million were obtained.

The Idaho State Geological Survey (ISGS, 1991) study also focused on the environmental hazards of waste disposal. In this study, however, an ex *post* approach was adopted which looked at the costs that could potentially have been avoided in terms of the investigation and clean-up of *existing* waste disposal and industrial sites. The underlying contention here - supported by subsequent cost benefit analysis - was that if sufficient geological information had been available at the time siting decisions were made, all or part of the clean-up costs within the area could have been avoided. In this study, the net benefit of geological mapping, projected from county level to the entire state (but still for only one application), was estimated at roughly $21 million.

In the much smaller (unpublished) BGS study, two contrasting approaches were taken. The first involved the compilation of national, baseline information on policy, guidance, best practice and government research recommending the use of geological mapping for different activities. The value of mapping to each of the 20 sectors identified was then estimated based on assumptions about how frequently information was used and the proportion of output value that might reasonably be attributed to having the information. The outcome of these calculations was a subjective

Table 2 Summary of map valuation studies.

	Map Valuation Study			
	USGS (1993)	**ISGS (1991)**	**BGS (1996, unpublished)**	**ODA (1992)**
Study	Loudoun County, Virginia, Washington D C Metropolitan Region, US	Boone and Winnebago Counties, Illinois State, US	National and local (see below)	National Kenya
Mapping programme evaluated	Remapping of Loudoun County - 1:500,000 to 1:100,000	Remapping of Boone and Winnebago Counties	(a) national remapping programme and (b) remapping of one local sheet	National geological mapping programme (primary mapping)
Comparisons made	Future land use decisions made with and without benefit of updated geological information	No specific comparisons made (see below)	No specific comparisons made in (a) above. In (b), comparison of land subsidence costs with and without incorporation of new geohazard information into planning guidelines	*Ex post* evaluation of geological data collection costs avoided by different enterprises extrapolated over future lifetime of map
Case studies	Proposed siting of (a) interstate road corridor; and (b) waste disposal facility	General siting of waste disposal sites within the county. Assumed that 'better siting' generally would have led to avoidable losses	In (b), two housing development scenarios evaluated within area vulnerable to land subsidence	No specific case studies. Questionnaires sent out to number of geological map users to determine costs saved with mapping
Nature of mapping benefits quantified	Environmental hazard costs which could be avoided through remapping. For (a) above, in terms of engineering mitigation costs avoided; for (b) in terms of property value losses avoided	Environmental hazard costs which could have been avoided through remapping, in terms of investigation and clean-up costs at existing industrial and waste disposal sites	In (a), contribution of mapping programme to sector output values based on 'reasonable assumptions'. In (b), benefits as house damage costs which could be avoided through changes in house building regulations following uptake of improved geological information	Geological data collection costs that would have been incurred by map users had national, public mapping data not been available
Net benefit of mapping application(s) examined	For (a) and (b) above, combined NPV estimated at US$1.28-$3.5 million at 10% discount rate (1993 prices)	Benefit-cost ratios, projected to entire state, estimated at 3:1. NPV for entire state estimated at US$ 21 million at 10% discount rate (1990 prices)	Baseline net value for (a) estimated at £15.7 million (1996 figures). NPV for (b) estimated at £540,000 at 10% discount rate (1995 prices)	Net benefit of over £200,000/year (early 1990s prices)
Assumptions/caveats	Model assumes strong regulatory framework for enforcing 'better' decisions	Weaker methodological basis than USGS study; assumes strong regulatory framework for enforcing decisions	First approach (a) less rigorous; assumes national baseline statistics available. Second approach (b) more empirically rigorous, but assumes strong regulatory framework for enforcing decisions	Rapid study.

Note: NPV = net present value (see Section 2) gross value of £18.9 million/year, which compares with a geological mapping budget of roughly £3.2 million for 1996/97. The second approach was based on a more objective quantification of remapping (one sheet) benefits within a small town, where gypsum dissolution has led to significant land subsidence and damage costs. For this approach, a spreadsheet model was set up to estimate land subsidence costs that could be avoided through remapping and better characterisation of vulnerable areas. In this case, it was assumed that land use decisions would remain the same, but that better information would ensure that buildings were constructed in such a way as to minimise the risk of costly structural damage in sensitive areas. For this small area, and for this single application, net benefits were estimated at roughly £540 000.

The Kenyan study was undertaken as part of an ODA evaluation of a Kenyan mapping project. This ODA-funded geological mapping project was carried out by BGS between 1980 and 1987, and details on the economic evaluation are drawn from an ODA evaluation report of this and two other geological survey projects (ODA, 1992). Details are sketchy, and it is apparent that the study was small in scope. However, an empirical estimate of value was made, based on questionnaire responses from map users. Users were asked to place a value on costs which would have been incurred by their operations had the maps and reports not been available. Assuming a mapping lifespan "in excess of 40 years", net benefits of over £200 000/year were calculated, and it was concluded that the mapping project had made, and would continue to make, significant beneficial impacts in a number of different sectors.

5. Conclusions

Several important conclusions can be drawn from the above:

- Geological surveys and other public bodies are increasingly having to demonstrate the cost-effectiveness of their work. Geological maps are used by a wide range of users and undoubtedly realise significant societal benefits, some of which are more amenable to quantification than others. Quantifying benefits is difficult, but by focusing on particular aspects of mapping use and benefit streams, progress can be made.

- Few studies have attempted to evaluate mapping programmes in cost-benefit terms. However, those that have been carried out indicate that the net benefits of geological mapping are considerable. While there may be significant caveats concerning assumptions and methodologies used, these tend to be counterbalanced by the fact that most studies only focus on single benefit streams, such as land clean-up costs avoided. In reality, geological maps have numerous applications producing many different benefit streams.

- The majority of studies have been undertaken in industrialised countries where remapping is the norm. In developing countries where primary mapping is more likely, returns may be considerably greater. This is because primary mapping programmes provide 'new' information (including strategic data on resources such as minerals, energy and water) rather than merely updated information. However, uptake and application of mapping data cannot be assumed. Commercial investment in the minerals sector, for example, requires a positive minerals development policy and an enabling legislative and economic framework. This may entail a clear and well organised system for granting licenses for prospecting and exploitation.

- The methodological approaches adopted in US and UK studies have assumed that improved planning decisions made with new geological information are supported and enforced through a strong regulatory environment. In this way, environmental hazards are avoided through better decision making. These assumptions are less applicable in developing countries where administrative and institutional capacity is weaker. In developing countries, valuation studies could focus more on direct commercial returns from mapping, though no such work is known to the authors. As noted above, however, commercial investment also requires a sympathetic regulatory and economic environment.

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