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ENGINEERING GEOLOGY – PAST, PRESENT AND FUTURE

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ABSTRACT

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Engineering geology forms the bridge between geology and engineering. It is taught and practised throughout the world and fulfills all the criteria that serve to identify a separate discipline. Its strength lies in the wide range of earth sciences it encompasses while remaining firmly rooted in geology, but its diversity of interest gives rise to uncertainty over its purpose and limitations. The author briefly traces the development of the subject, attempts to define its present state relative to purpose, scope, training and practice and speculates as to further developments.

INTRODUCTION

Many engineering geologists have arrived at meetings with engineers, architects, planners and others concerned with engineering developments to be greeted with the questions "What do you do?", "What is Engineering Geology?" and have had difficulty in framing an answer. Often the engineering geologist wonders himself what there is that he is not expected to be able to do and where his limits should lie. In practice, much depends upon the capacity of the individual, his experience and the special techniques that may be offered by the organisation for which he works. In training, courses are often compounded as much from what is available as they are from that which is desirable.

It may be that the discipline is as yet too young to set its boundaries, but the author feels that some attempt should be made in this direction so that engineering geologists may perhaps see what they have to give to the world and others realise what engineering geology has to offer them. In this paper the author presents his own views on these matters, fully recognising that they are subjective and biased by his own limitations and experience.

DEVELOPMENT OF ENGINEERING GEOLOGY

The success that civilisations have achieved in mastering their environment may be judged by the magnitude and design of their civil engineering works. There are few, if any, parts of the world where nature has provided an environment that is suitable, without modification, for the development of a civilised society. Such modifications, which are undertaken to ensure a continuing supply of food and water and give protection against weather, flood and sea are provided by civil engineering. These works are built in contact with the ground, often from materials won from the ground and may involve some remodelling of the shape and properties of the ground. Thus some understanding of the nature of the ground, that is, its geology, is fundemental to engineering success.

Considerable, though presumably disorganised and empirical knowledge of geological phenomena must have existed since the earliest times but the development of geology as a science may be considered tentatively to have been initiated during the period of the Industrial Revolutions of the seventeenth and eighteenth centuries. The demands of new industries during these times for increased supplies of raw materials, fuel and for improved communications brought about the requirement for more sophisticated mining and civil engineering techniques. In particular the development of large quarries for building materials and of the cuttings and tunnels associated with canal and railway construction, brought civil engineers into contact with large continuous and fresh exposures of soil and rock. It is not surprising, therefore, that in their efforts to understand the engineering problems of working with ground materials, engineers began to speculate over the origin of these materials and the reasons behind their distribution. Men with an engineering responsibility and background such as Lewis Evans (1700-1756) in America, William Smith (1769-1839) in England and Pierre Cordier (1777-1862) in France, were active in the development of geology as a pure science, following the observations they made in their engineering practice.

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The sciences of engineering and geology developed greatly during the eighteenth and nineteenth centuries; engineering to succesfully construct increasingly complex works and geology to uncover greater detail of, and propose more complex theories for, the origin and structure of the earth. Engineering is based on mathematical principles and to allow mathematical analysis of ground conditions it was (and still is to this day) necessary to simplify ground geology. As this was happening, geologists, many now working without association with other disciplines, were discovering greater complexities in geology. Inevitably, as geology and engineering separately developed, rapport between geologists and engineers dwindled until in the early twentieth century many engineers had but little knowledge of geology and few geologists any interest in engineering.

There were, of course exceptions to this condition. L e g g e t (1972) gives examples of engineers who clearly understood and advocated the value of geology in their work and of geologists who appreciated the importance of their science to engineering. Legget mentions the publication of a book entitled "Engineering Geology" (P e n n i n g, 1880) in the late ninteenth century, which must be one of the earliest, if not the earliest, uses of the term signifying the link between the two sciences.

The civil engineers' understanding of the ground is expressed mainly in the discipline of soil mechanics. In the eighteenth and nineteenth centuries engineers such as Colomb and Rankine developed methods of analysing the deformation of earth masses under the stresses imposed by civil engineering works. The great leap forward in soil mechanics is usually considered to have been the publication of "Erdbaumechanik" by K a r l T e r s a g h i in 1925, which fully established soil mechanics as a new discipline in the field of engineering. Subsequent publications (particularly those by Tersaghi) revealed a clear understanding of the significance of geology in soil mechanics.

The need for the engineer to understand geology was occasionally and dramatically emphasised by failures of major engineering works, such as the dams at Austin in Texas in 1900 (T a y l o r, 1900), the St. Francis Dam in California in 1928 (H i l l *et al.*, 1929) and the Lake Gleno Dam in Italy in 1923, all of which were due (at least in part) to a lack of appreciation of the geology of the site and, as a consequence, the reaction of the ground to the engineering work.

On the reverse side of the coin, certain gifted geologists such as Zaruba in Czechoslovakia and Berkey in the United States gave clear testimony in their work to the value of geology and geologists in engineering projects. Because of these contrasted factors there was, by the 1940's, a tendancy for engineers to employ geologists to give advice on site geology. This liason was not always successful for engineers often had insufficient knowledge of geology to pose the right questions to the geologist, while geologists had too little knowledge of engineering to frame answers that might be useful to the engineer. There circulate today stories, stemming from this period, of eminent (but un-named) geologists who, when asked to produce plans of site geology, produced these with great attention to stratigraphic zones and fossil content but containing little information of direct value to the engineer. If such events ever occurred, they serve not only to demonstrate the inadequacy of the geologists but also the inability of the engineers to communicate their requirements in geological matters.

The initiative to resolve such problems of communication between engineer and geologist came generally from geologists. Those employed by engineers found themselves, by self-tuition and association with engineers, learning something of engineering in order to blend into, and make their career in, engineering organisations. Much of their work was in the field of site investigation. With increasing skill and experience many geologists found themselves designing, conducting and evaluating the results of site investigations and writing reports which included engineering recommendations. Such geologists considered themselves as engineering geologists to indicate their committment to and special abilities in the realm of engineering.

The recognition that there was a new specialisation in apllied geology which was as significant as, say, petroleum or mining geology lead to the development of training courses in the subject and opportunities for students to obtain qualifications (usually post-graduate) in Engineering Geology. Courses started to develop in many countries, mostly European or North American, in the late 1950's or early 1960's.

In California there were, in the early 1960's, sufficient practising engineering geologists for them to band together into a professional association. In 1963 this expanded to become the Association of Engineering Geologists (AEG), an organisation covering the whole of the United States and now with sections in Canada, Britain and South Africa. Entry into full membership of this organisation is limited to those with appropriate qualifications who are practising and experienced in the field of Engineering Geology and membership may thus be considered as a professional qualification.

The learned societies have developed specialist groups dealing with engineering geology. Thus the Geological Society of America established an Engineering Geology Division in 1947, the Engineering Group of the Geological Society of London was initiated in 1964 and the Ingenieurs-Geologische Kring of the Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap was formed in 1974. On the international scene the International Societies for Soil Mechanics and Foundation Engineering and for Rock Mechanics were complemented in 1967 by the International Association of Engineering Geology (IAEG), which has now held two international conferences and has national bodies in many countries of the world. The International Geological Congresses now usually include a special section for engineering geology in their four-yearly meetings.

The Association of Engineering Geologists published its first Bulletin (now published quarterly) in 1964. The Geological Society of London published the first issue of the "Quarterly Journal of Engineering Geology" in 1967, while the

International Association of Engineering Geology commenced publication of its Bulletin in 1970. In addition to these journals an excellent vehicle for publication is afforded by "Engineering Geology", an independent journal for engineering geological papers which is published by Elsevier of Amsterdam.

It seems clear therefore, that engineering geology has fullfilled all the criteria which generally serve for recognition of a discipline. It is taught in universities, has professional and learned societies devoted to its interest on both national and international platforms and has its own publications in which to demonstrate its applications and philosophy.

However, despite this there is still some uncertainty in the minds of those who are not engineering geologists as to the purpose, content and limits of engineering geology. A definition will not necessarily be achieved by a study of the literature. Journals ostensibly devoted to engineering geology often contain papers on other earth science topics. These may be, for example, on topics in soil mechanics, rock mechanics or hydrogeology and many papers written by engineering geologists tend to show their special rather than their general interests. Because of this, some have the impression that engineering geology is concerned mostly with, say, rock mechanics, while in fact this is but one of the many interests of the engineering geologist. The content, purpose and limits of engineering geology thus merit definition.

NATURE AND PURPOSE OF ENGINEERING GEOLOGY

The Association of Engineering Geologists (AEG) publishes the following statement in its Yearbook:

' "Engineering Geology" as defined by the Association includes the discipline of applying geologic data, techniques and principles to the study of naturally occurring rock and soil materials or subsurface fluids. The purpose is to assure that geologic factors affecting the planning, design, construction, operation and maintenance of engineering structures and the development of groundwater resources are recognised, adequately interpreted and presented for use in engineering practice'.

The International Association of Engineering Geology (IAEG) says:

'The scope of Engineering Geology is defined as the science which determines the physico-chemical and mechanical properties of the earth's crust, both in rock samples and in situ bed-rock, as exactly as possible; which makes these geological findings available for utilisation of the earth with special regard to the needs of all branches of engineering, for the safety and greatest benefit of mankind.

Thus the scope of Engineering Geology also covers the applications of Earth Sciences to engineering, planning, construction, prospecting, testing and processing of related materials'.

The "study" in the AEG definition and the determination of the "physico-chemical and mechanical properties" of the IAEG statement are undertaken in practice in the context of "site investigations". Site investigations for engineering works are undertaken to obtain sufficient knowledge of ground conditions to allow the engineering works to be planned, designed, constructed and subsequently to operate with maximum economy and safety.

Site investigations are still too often thought of as a phase in the engineering programme, to be squeezed between design and construction, in which it is hoped that the ground conditions will be revealed to be adequate for the proposed engineering design. This procedure may, if the investigation is adequate, ensure that no disaster occurs because of lack of knowledge of ground conditions. However, if the ground conditions are not demonstrated to be adequate there may be considerable additional expense incurred in redesign and construction programme delay. It must always be remembered that engineering failure is not only signified by the collapse of the construction; excessive construction cost, perhaps resulting from inadequate knowledge of ground conditions, may be an equal calamity. Worst of all, perhaps, a social or political committment may have been made to develop a site which is later proved to be unsuitable because of its ground conditions.

Fortunately it is now becoming common to undertake ground investigations throughout all phases of engineering projects, including that of the earliest concept planning. These early investigations, generally intended to establish project feasibility may be very simple in character, consisting perhaps of little more than a study of available geological and other information on ground conditions and a site examination by an engineering geologist (C h a p l o w, 1975). As the result of this work the engineering geologist should be able to outline to the engineer the constraints that the ground conditions may impose on engineering. This is often the most important stage in the whole investigation process for the data recovered could influence all subsequent engineering design. Thus, for example, if a tourism project is found to be situated in a seismic zone having a particular level of earthquake activity, this will have not only an effect on the structural design of buildings but also on such diverse features as sewer pipe joint design, cut slope design and water supply. Special provision in layout design for emergency relief services and so forth might also be required. If these early appreciations are good, then such engineering planning and design as must go forward prior to the main site investigation should not require major revision when the ground conditions are known in detail. This recognition of the significance of the geological features of the site on all aspects of the engineering project requires a very wide breadth of earth science knowledge on the part of the engineering geologist, who must be able to forsee all the possible inter-reactions between geology and project.

Such apprecations often seem to have pointed out what seems obvious and commonplace when viewed in retrospect, but the correct recognition of problems to give the opportunity to avoid them or time to consider their solution is

perhaps the greatest professional triumph that the engineering geologist can enjoy. Arranging the layout of, for example, a new town to reduce construction costs is a much more worthwhile activity than resolving the foundation problems caused by an incorrect layout; unfortunately the former, the typical work of the engineering geologist, is not often recorded by the publication that may enhance the triumph of the latter.

Preliminary appreciations warn of problems and should also suggest the best method for their further investigation. This main investigation, which should obtain such parameters of ground conditions as are necessary for engineering design, must itself be designed in order to retrieve the information required using the most appropriate methods, employed at the correct intensity of application (P r i c e, 1975). There are very many ways of examining the ground and the engineering geologist must be aware of them all, their usefulness and their limitations. Thus, for example, while an engineering geologist would not be expected to undertake a seismic geophysical survey with the expertise of a specialist engineering geophysicist, he should be able to appreciate the limits of the technique so that he may know when to ask for it, to understand the difficulties of interpretation of the results and to generally be aware of the geophysicists problems. With such knowledge of site investigation methods and also in the organisation of these activities, the engineering geologist is the ideal person for the design of investigations and their supervision in the field. In the case of large investigations where varied methods are employed and there is a high daily volume of data output he may be the only person on site capable of appreciating the significance and interrelationship of results as they become available, so that problems may be reported as they are revealed and the investigation modified to deal with them.

The main investigation, which may be in several phases (F o o k e s, 1967) is usually followed by the construction of the civil engineering work. Further investigation may be planned for the construction phase because, perhaps, access difficulties limited the scope of the main investigation beforehand. Other investigations may have to be undertaken as the result of unforeseen conditions revealed by the construction works. It must always be recognised that no site investigation can reveal the ground conditions as accurately as can the construction itself. There are limits to the accuracy that investigations can achieve (P r i c e, 1971) which are not always related to the amount of effort or finance put into the work but to the complexity of ground conditions in contrast to the investigation methods available. Variations between the ground conditions encountered and those forecast by the investigation may be important not only for themselves but because of the differences they may suggest in the understanding of the conditions on other parts of the site. In tunnelling, for example, an unexpected fault found in the early section of a tunnel drive may be an unimportant feature itself, but could necessitate a major, and much more important, revision of the anticipated geological conditions further ahead in the drive. Accordingly the ground conditions revealed during construction should be recorded as they are found and the significance of any variations from anticipated conditions assessed. Many consulting engineers and contractors now employ engineering geologists for this task. They may also be involved in assessing the behaviour of works, such as cut slopes in rock or soil, after construction to assure that their performance it as anticipated.

Much of the knowledge utilised by the engineering geologist in his work stems from geology and from engineering based earth sciences such as soil mechanics or rock mechanics. The dicipline of engineering geology may perhaps present to some the aspect of a collage of assorted earth sciences assembled on a canvas of geology. There is an element of truth in this view but this combination of sciences has produced an attitude that is uniquely engineering geological. This is evidenced perhaps most in the attitude of the engineering geologist to geology.

The geology with which the engineering geologist is mostly concerned is distinguished by two main factors, namely that it is commonly examined in much more detail than is usual for most geological purposes and that it is presented with reference to engineering use. Regarding the former engineering geologists may be concerned, for example, with the examination of valleyside bridge foundations no more than 15 m square but that examination must be sufficiently accurate and detailed to ensure that not one shear plane that would allow sliding failure of the foundation is present. Presentation with regard to engineering use may, for example, be found in the ways with which natural materials are described. Thus a conventional geologist describing cores of granite taken from a rotary cored borehole might write "GRANITE, hornblende, coarse, grey" as his description for general purposes. The engineering geologist would see the same core as "Slightly weathered, isotropic, grey, coarse, very strong hornblende GRANITE with medium spaced joints", adding to the conventional geologists' description comments on such features as weathered state, material fabric and strength and spacing of discontinuities, for these are of considerable engineering significance. Indeed, it has been argued that for engineering geological pruposes the geological name of a rock is the least important part of its description unless it serves for purposes of correlation or implies the presence of other geological features of engineering significance.

While in the early days of engineering geology its practitioners were distinguished from their fellow geologists perhaps only by such attitudes, engineering geologists have now developed descriptive methods and field mapping techniques that are special to engineering geology. Much attention has been given to the logging of rock cores for engineering purposes. A Working Party of the Engineering Group of the Geological Society of London reported on this subject in 1971 (A n o n y m o u s, 1970). A committee initiated by the American Institute of Professional Geologists now works toward a similar goal as does a Working Party set up by the

South African Section of the AEG. Perhaps the most significant development has been in the field of engineering geological maps and plans. Essentially these display geology in engineering terms and are most useful in planning engineering works, such as new towns, tourism resorts, new transportation routes and other developments that cover large areas. Attention has been given to the production of such maps for many years, some of the earliest being produced before the Second World War. The early maps largely recorded information available from borings in urban areas giving such geological data as was especially important for engineering purposes in that area. This could be, for example, contours of rockhead, the groundwater table level or the limits of strata with particularly poor engineering properties. A number of working parties have reported on methods of producing engineering geological maps and plans. The Engineering Group of the Geological Society of London produced a report in 1972 (A n o n y m o u s, 1972) and a UNESCO report was published in 1976 (A n o n y m o u s, 1976). Much use of aerial photographs and techniques of terrain evaluation is being made to produce large scale engineering geological maps in little developed areas (E d w a r d s 1976).

Such mapping is exclusively the province of the engineering geologist for only he has sufficient breadth of knowledge to undertake both the geological mapping and the engineering appreciation. This breadth of earth science knowledge is the strength of engineering geology but in terms of training imposes problems as to the depth to which any particular earth science topic may be studied within a given length of training course. In general terms each topic should be studied to a standard but not a specialist level. Thus the engineering geologist might study rock mechanics to the level of the mining and civil engineer, but not to that of the specialist rock mechanician. However, teaching of engineering geology is still sufficiently new for there seem to be some considerable variations of opinion as to course content.

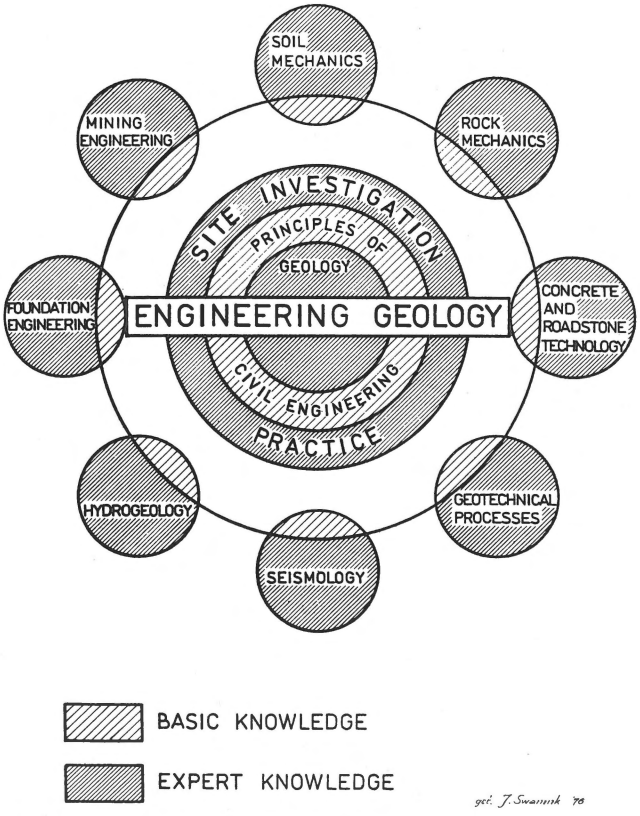

Fig. 1.
The content of engineering geology.

TRAINING IN ENGINEERING GEOLOGY

The wide variety of ideas over the teaching of engineering geology is well displayed to the interested reader by the papers published in Theme 1, "Teaching and Training in Engineering Geology" in the Proceedings of the Second International Congress of the International Association of Engineering Geology held in Sao Paulo, Brazil in 1974. The papers published reflected attitudes in the U.S.S.R., Belgium, Brazil, Great Britain, Poland, F.R. Germany, Canada, Spain, U.S.A. France, Portugal, Australia, Turkey and India. The views given show differing national attitudes to education generally and in some cases the endeavour to train engineering geologists to deal with specific national problems. However, they generally agree on basic content of courses.

The authors own views are expressed in fig. 1 which endeavours, in diagrammatic form, to show the topics in which the graduate engineering geologist must have basic and expert knowledge. Basic knowledge is required of soil mechanics, rock mechanics, hydrogeology, foundation engineering, concrete and roadstone technology, geotechnical process geology, aspects of mining engineering and applied seismology. Some insight into the general principles of civil engineering practice is also desirable. A much greater knowledge is required of site investigation practice such as methods of boring, sampling, laboratory and in situ testing, engineering geophysics, applied photogeology, techniques of material and mass description and engineering geological mapping. In these topics the graduate should be as expert as he can be made within the limits of a training course.

This knowledge is imprinted on a background of geology which, ideally, should be relatively unspecialised. However, if the geology courses available require the student to specialise, this should best be in topics such as structural geology, geomorphology or sedimentology rather than, say, palaeontology or mineralogy. The student should also have a good background in the natural sciences, especially mathematics and physics and also chemistry.

Engineering geologists are essentially practical men, so training courses must be practical rather than theoretical and include laboratory and field exercises. The graduate engineering geologists' tasks in his first employment will be most probably in the field, assisting in or supervising site investigations. One of the duties that a training establishment has to

potential employers of its graduates is to train them to be able to perform their first tasks adequately and to be of immediate value to their employer. Accordingly such establishments must have such standard field and laboratory equipment that engineering geologists employ and must instruct students in its use.

The design of site investigations to achieve the required information on ground conditions is based on a combination of geological environment and particular types of engineering works. Thus there are different engineering geological problems associated with the construction of dams, of harbours, of bridges and so forth and different styles of investigation and analysis appropriate to each. Discussions of such problems should form part of the course in engineering geology proper.

There are few engineering geologists who spend their whole professional life in working in their home country. Even if they are employed by organisations based in their own country, they must expect to be engaged in engineering works overseas. Accordingly, an engineering geology course must be international in character and seek to instruct students to deal with situations that, because of geology and climate, cannot be found in their homeland. Courses should contain instruction on engineering geological problems that might be found in extreme environments such as the arctic regions, equatorial areas or in deserts. Nevertheless, courses should be constructed on a firm background of the particular techniques and expertise that has been developed in their own country.

Contact with industry is necessary throughout such training courses. This is clearly a part of engineering geological education, for there is no better way for the student to gain an insight into engineering than to see engineering works in progress and to discuss engineering problems with engineers. While in the short term this benefits the students most, in the long term it also benefits their national industry itself. Engineering geologists tend to operate as single individuals or small groups within larger organisations and are often asked to recommend contractors for specialist processes or to supply specialist equipment. Most recommend what they know and trust as the result of past contacts, which are generally with the industries of their home countries.

The universities at which engineering geology is taught are generally industrially based. Specialist subjects such as soil and rock mechanics should be taught, if they are to be taught well, by specialists in these fields. Accordingly, most universities that offer engineering geology have departments of geology, civil and mining engineering together with their specialist sub-departments. Students benefit not only from courses given by these departments, but also from the general atmosphere of industrial science and from contact with engineering students.

While close association with engineering is vital, this does not imply that engineering geology should be divorced from "pure" geology. It must always be remembered that engineering geology is rooted in geology. Thus as new theories and techniques in geology develop, the pure geologist will seek to evaluate their validity and utility in scientific terms while the engineering geologist seeks to assess their significance to engineering. The exchange is mutual. There is no doubt, for example, that engineering geological mapping draws much on the techniques developed by geomorphologists while the work of geomorphologists on landslip phenomena has gained much from soil mechanics and engineering geology.

EMPLOYMENT OF ENGINEERING GEOLOGISTS

Employment for engineering geologists may be found within a wide range of opportunities. Their likely employers will be mainly within the field of civil engineering, either as consultants or contractors. In either case their work will lie mostly in the field of site investigation. If employed by consulting engineers, they may be called upon to design investigations, supervise them and thence follow through to aid engineering design and record and evaluate conditions found during construction. If employed by a contractor, they may be asked to evaluate information provided in tender documents, perhaps conduct additional investigations and offer advice during construction. Since many consultants and contractors tend to specialize in particular types of construction the engineering geologists they employ may find themselves dealing exclusively with one kind of engineering work, such as dams, tunnels, dredging works, bridges or motorways.

Employment may also be gained within the specialized world of the site investigation contractor or consultant, in which the engineering geologist may be called upon to devise, execute and comment on the results of investigations for a wide variety of civil engineering works. Specialist contractors, such as those which deal only with piling, anchoring or grouting have need of engineering geologists to evaluate projects and supervise work. In the field of the supply of construction materials, such as concrete aggregate, roadstone, rip-rap and mass fill the engineering geologist is particularly useful, for he is equipped not only to search as a geologist for such deposits and determine quantity and quality, but also to appreciate as an engineer the problems of excavation and ground water control that may arise in winning the material. Engineering geologists are active also in mining, largely in the field of mining subsidence problems, slope stability in opencast mines and spoil tip stability.

A further source of employment is in government service. Many national and state surveys now have engineering geology divisions. Their task is generally to consider the engineering geological aspects of the planning of new highways, new towns and other massive engineering projects of national significance. In city and town administrations engineering geologists may be employed to conduct investigations, record ground conditions found in civil engineering works, build up data banks and produce such engineering geological maps and plans as may aid future developments.

Within each of the types of employment described above, the newly graduated engineering geologist must be prepared for further self-education to allow himself to operate most effectively within a specialized engineering field. However, much of his value to a specialist organisation is that he has a background to build upon such knowledge while still retaining the ability to recognise other factors that may occasionally, but then perhaps critically, affect the success of the specialists work.

For grammatical simplicity the paragraphs above have been written assuming that the engineering geologist is male. While most are, there is a significant proportion of women engineering geologists. There are few organisations that do not, will not or have not employed women engineering geologists. It may be that, for reasons of local custom, there are certain overseas countries to which it is unwise to send women engineering geologists, but in general there are no objections to their entering the profession.

FUTURE OF ENGINEERING GEOLOGY

The position of engineering geologists within the engineering world is now well established. Their employment is likely to remain largely within the field of site investigations. Many organisations presently employ engineering geologists for such work but often in a subordinate rather than an equal position to civil engineers. However, the author anticipates that in time engineering geology will become the principal discipline concerned in site investigation work, partly because by training engineering geologists span the whole range of disciplines that may be concerned in this work and also because of their concern with the design of investigation programmes.

A subject of much past debate has been whether engineering geologists should take engineering decisions since they are not engineers. They do now take such decisions, often independantly of any advice from engineers, and in general recognition of this is increasing. The Institution of Civil Engineers in Great Britain, for example, has accepted certain approved qualifications in engineering geology as one of the bases for entry to the examination for Membership of the Institution. However, it is equally important for the engineering geologist to recognize that he is not an engineer and to limit his engineering activities to those fields in which he knows himself to be competent.

There are many organisations in engineering who are too small, or whose activities are too specialized, to warrant inclusion of a full-time engineering geologist on their staff. Currently they employ services of consultants, often university based, to offer engineering geological advice. Over the last few years a number of consultant engineering geology organisations have emerged. These may well increase in number and size and should offer a further field for employment to engineering geologists.

The author anticipates that more use will be made of engineering geologists in the field of environmental planning in its widest sense. In urban areas in particular there is a general need to appreciate the engineering geology involved in new town developments and old town reconstruction. It is to be hoped that one day "City Engineering Geologist" will be as coveted and significant a title as "City Architect" of "City Engineer".

In future engineering geologists will continue to develop their own special techniques, skills and philosophies that will become exclusively their preserve. This is an entirely natural development but may hold within it the seeds of a future problem. Engineering geologists must communicate with engineers and however well an engineering geologist may express himself, however subordinated pure geology may be to engineering in a report, the engineer must have the fundemental of geology to appreciate what he is being told. Regrettably, geological training for engineers varies greatly in its adequacy as taught in training centres about the world, sometimes being barely sufficient for cummunication. If engineering geology becomes too exclusive in its language, a rift in mutual comprehension may open. While the essential practicality of engineering geology gives assurance that the rift will be no greater than can be helped, it may well be desirable to modify geological training of engineers to teach "Engineering Geology for Engineers". Engineering geology has built the bridge that unites geology to engineering; both engineering geology and engineering must take measures to ensure that they remain closely linked in mutual understanding.

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