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Report of the Joint Study Group on

GEOLOGICAL TRAINING AND RESEARCH IN THE REPUBLIC OF ZAIRE

Kinshasa, Republic of Zaire

20 July - 1 August, 1972

Jointly Sponsored by the
National Office for Research and Development
Kinshasa, Republic of Zaire

and

The National Academy of Sciences
United States of America

This report summarizes the discussions held and recommendations formulated by the NAS-ONRD Joint Study Group on Geological Training and Research in the Republic of Zaire. The meeting was held 20 July - 1 August 1972 in Zaire under the auspices of the Board on Science and Technology for International Development, Office of the Foreign Secretary of the National Academy of Sciences (NAS), and the National Office for Research and Development (ONRD) of the Republic of Zaire. The report is submitted to the Agency for International Development under contract AID/csd-2584, Task Order 1.

The proceedings in French will be issued by the ONRD.

NOTICE

The study reported herein was undertaken under the aegis of the National Academy of Sciences with the express approval of the Governing Board of the National Academy of Sciences - National Research Council. Such approval indicated that the Board considered that the problem is of national significance; that elucidation or solution of the problem required scientific or technical competence and that the resources of the NAS were particularly suitable to the conduct of the project. The institutional responsibilities of the Academy were then discharged in the following manner:

The members of the study committee were selected for their individual scholarly competence and judgment with due consideration for the balance and breadth or disciplines. Responsibility for all aspects of this report rests with the study committee, to whom we express our sincere appreciation.

Although the reports of our study committees are not submitted for approval to the Academy membership nor to the Council, each report is reviewed by a second group of appropriately qualified individuals according to procedures established and monitored by the Academy's Report Review Committee. Such reviews are intended to determine, inter alia, whether the major questions and relevant points of view have been addressed and whether the reported findings, conclusions, and recommendations arose from the available data and information. Distribution of the report is approved, by the President, only after satisfactory completion of this review process.

PREFACE

The formation of the Joint Study Group on Geological Training and Research in the Republic of Zaire resulted from recommendations made at the Joint Workshop on "The Role of Science and Technology in the Economic Development of the Democratic Republic of the Congo (Zaire) during the 1970's." Held in Kinshasa, June, 1971 this workshop was jointly sponsored by Zaire's National Office for Research and Development (ONRD) and the National Academy of Sciences (NAS). The Workshop recommended that a joint ONRD - NAS working group be convened to formulate plans and make recommendations for the development and the strengthening of the geological services of the Congolese Government and of institutions capable of training, within the Congo, the necessary scientific personnel in the earth sciences, as well as technical personnel for the mineral extracting and processing industries.

Detailed preparations for the work of the joint study group were made by Dr. John C. Maxwell, University of Texas at Austin, and Chairman of the NAS panel, during a visit to Kinshasa in December 1971, in concert with ONRD officials.

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I

INTRODUCTION

In May, 1971, a statement of Zaire's national objectives, "Policy, Prospects, and Means of Development," was prepared for the first meeting of the consultive group organized under the auspices of the World Bank. The following excerpt defines one of two aspects of the economic development policy:

> To exploit the available national resources in such a way as to obtain the internal revenue, tax receipts and foreign exchange which are indispensable if development is to be subsequently directed into the priority sectors, in particular, those of agriculture and the industries which produce for the local market.

The mining industry accounts for some 55 percent of the country's gross national product. Thus, the success of Zaire's economic development program depends largely on a continuing and growing exploitation of its mineral resources, but the scarcity of well-trained Zairian geologists and mining engineers has forced the country to rely on exploration and development programs conducted under contract by foreign technical personnel. The joint study group does not impugn the actions of the personnel or their companies, but the Zairian people would obviously benefit by gaining and maintaining a controlling position in the exploration, evaluation, and development of the country's mineral resources. This report, therefore, considers the present state of the geological and mining professions in Zaire, makes recommendations for increasing the numbers and quality of professionals, and suggests mechanisms for increasing the effectiveness of geological work, especially in the minerals industry.

II

ON THE FORMULATION AND IMPLEMENTATION OF A COMPREHENSIVE PLAN

To assure Zaire a continued and increased income from its mineral and energy resources, long-range plans for their systematic discovery and development are needed. Such plans should include a coordinated program of topographic, geologic, and hydrologic mapping. In conjunction with the mapping, research studies should be designed to accumulate the basic scientific data needed by government and industry to effectively find and exploit mineral, water, and energy resources and collect the type of geologic and hydrologic data necessary for the construction and engineering groups engaged in developing the country.

President Ileo of the National Office for Research and Development (ONRD) has indicated the urgent need for a short-term program of prospecting for and evaluating the mineral deposits in the Kasai and Equateur Regions especially directed toward the investigation of reported occurrences of iron, gold, diamonds, platinum, chromite, limestone, and other minerals. He has asked for assistance, both men and money, so that these possible sources of minerals can be evaluated in terms of near-future commercial exploitation.

Although an immediate start of this short-term program is desirable, it should be carried out as part of a comprehensive, long-term mineral exploration program, because the likelihood of finding additional significant mineral deposits is slight until the geologic framework of the country is known. For example, some 300 U.S. geologists and numerous prospectors in a similarly urgent prospecting and evaluation program

required 7 years to find significant uranium deposits, and these deposits were found only after geologic mapping was well advanced in the favorable areas. Examination and evaluation of mineral occurrences should proceed concurrently with geologic mapping; the joint study group strongly recommends that these preliminary short-term steps be part of a comprehensive mineral, water, and energy prospecting and evaluation program.

To implement a comprehensive program of mineral prospection, evaluation, and exploitation, the joint study group recommends the formation of a national company comprised of the best qualified Zairian geologists, mining engineers, and metallurgists to plan and oversee a program for developing the country's mineral, water, and energy resources. An example of this type of company is PETROBRAS, in Brazil. For the first 5 years the Zairian company might be directed by an experienced foreign exploration geologist, who, with assistants as needed, would organize and operate the program and train Zairians to take over the supervisory and operational duties by the end of the contract period.

The suggested organization chart of the company (at the end of this chapter) is designed so that the mineral prospecting and evaluation program could serve as the nucleus of the company's economic geology and areal geology programs. Other functions can be added as necessary and as funds become available.

Should this mechanism not prove feasible, a small commission of the most qualified earth scientists from the government, industry, and the university should be charged with making long-range projections of the

country's needs and formulating a definitive plan of action for the next 20 years. The plan should be divided into segments based upon the priorities dictated by existing and future needs, taking into account the projected availability of funds and personnel.

A 20-year plan should provide for the following items:

1. The systematic topographic, geologic, and hydrologic, geophysical, and geochemical mapping of the entire country on a scale of 1:200,000 and the systematic mapping of the more critical areas on scales of 1:25,000 or 1:50,000. More detailed scales should be the responsibility of the mining industry or engineering groups.

2. The search for, and evaluation of, new mineral, water, and energy resources. Present concessions are under detailed study; therefore, primary effort should be in adjacent areas or new areas of promise.

3. The continuous inventory of mineral, water, and energy resources.

4. Applied research on new mapping techniques that will allow a geologic evaluation to be made of the equatorial and other inaccessible areas, for use in the mining and construction industries.

5. The hiring of the technical personnel and equipping of the laboratories needed to support the field programs.

6. The preparation and publication of maps and reports.

7. The development of usable geologic libraries in the government and university.

8. On-the-job training programs for undergraduate and graduate university students during summers, holidays, and periods of research (perhaps a cooperative work-study program patterned after the program at

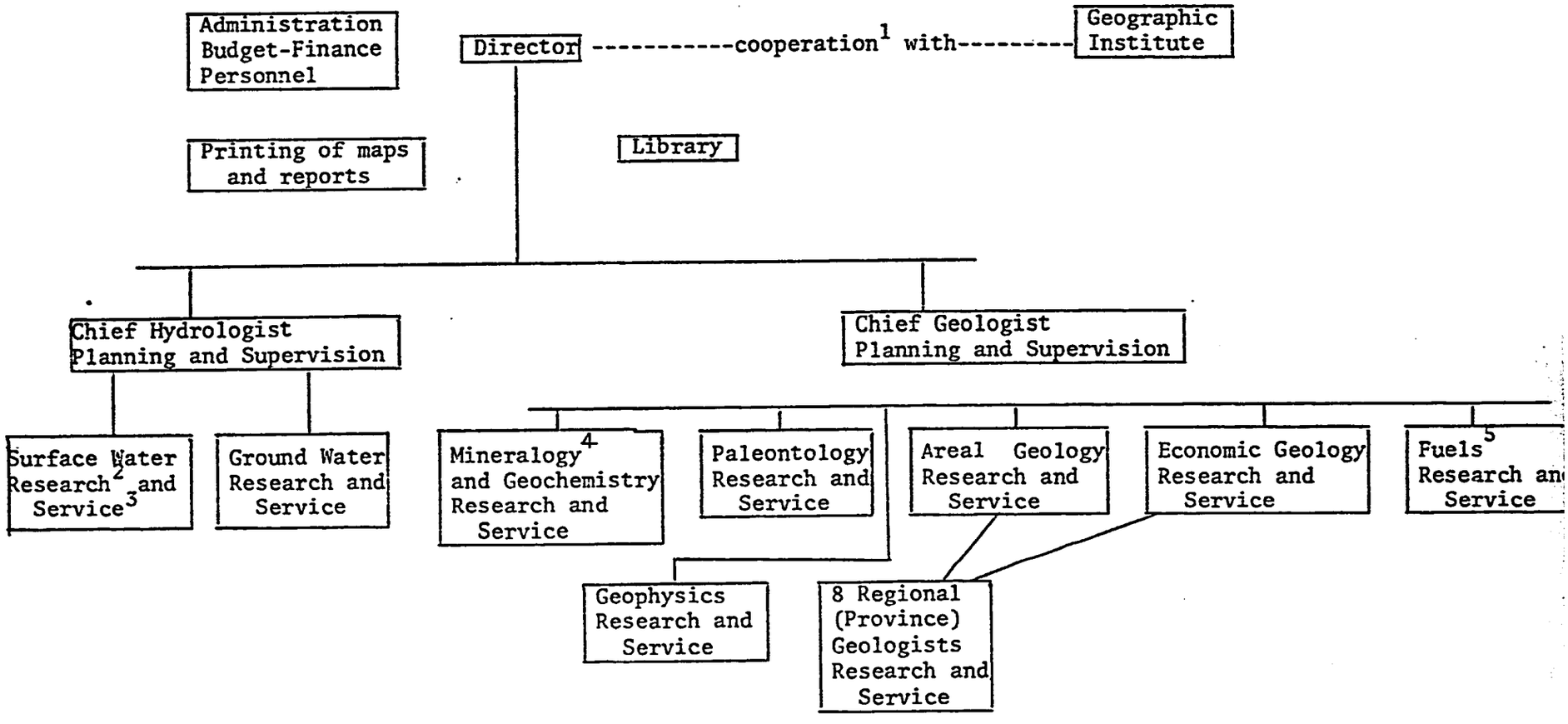
Northeastern University in Boston, Massachusetts); the permanent employment of qualified graduates; recommendations of personnel for training abroad to obtain the specialized manpower necessary to organize the geological infrastructure.

9. Criteria for determining the potential effectiveness of proposed foreign aid programs in the earth sciences in terms of the long-range program and the country's immediate needs.

10. Reactivation of the Geological Society of Zaire (1959 - 1960) with provisions for student membership. The Society, at this time, might include mining and metallurgical engineers, and might be affiliated with the newly formed Geological Society of Africa.

With the construction and planned development of a steel plant near Kinshasa, there is now a pressing need for the immediate location of iron deposits. As will be discussed later, aeromagnetic surveying is the most advanced method throughout the world for rapid exploration of iron ore. For example, the last two major iron ore deposits now being exploited in the United States and all of the recently discovered major iron ore deposits in the Republic of Liberia were located by aeromagnetic surveys. Furthermore, an aeromagnetic survey in a carefully selected area could start a regional geophysical exploration program in Zaire to locate minerals of economic importance other than iron.

CHART 1. UNIT PLAN FOR GEOLOGICAL MAPPING AND PROSPECTING



[1]Cooperation means authority to request the preparation of topographic maps for critical areas

[2]Research = independent studies by professional personnel

[3]Service = work performed at the request of other parts of unit or other government agencies

[4]Includes all chemical and mineralogy laboratories

[5]Includes coal, oil, gas, and perhaps uranium, etc.

III

ASSESSMENT OF MINERAL WEALTH

Geological Mapping

Geological mapping is carried out to establish the pattern of distributions of various rocks in a given region in order to obtain the basic data to solve problems related to the development of a country.

Many minerals and mineral fuels are known to occur in specific types of rocks. The search for potential mineral resources and in particular the localizing of favorable areas for prospecting, therefore, depends, largely, on a knowledge of rock type and distribution and, therefore, on the availability and quality of geological mapping in a given region. Geological maps also have other important practical uses in (1) estimating hydrological problems and potential for both surface and groundwater; (2) planning the locations of transport routes; (3) estimating the availability of construction materials; and (4) anticipating construction problems involving rock and soil types and water for roads, dams, reservoirs, airports, and large buildings.

Geological mapping is a continuing process, with repeated field work by geologists and the application of photogrammetric, geophysical, and geochemical techniques to provide information on rock types and their distribution. As in other sciences, understanding of geological phenomena changes and improves with continuing research. Long-range planning for the development of Zaire, therefore, should include provisions for active and continuing geological mapping and research.

At the present stage of geological knowledge in Zaire, the most urgent need is for regional geological maps, i.e., maps on the scale of 1:200,000, or locally 1:25,000 or 1:50,000, to guide mineral exploration and evaluation. Concurrently, however, more detailed mapping should be carried out in areas of known mineral potential. Once prepared, the geological maps and accompanying explanatory material should be printed and made readily available to all interested persons in government and industry, if the ultimate needs of the nation are to be served.

Geological mapping requires base maps or aerial photographs on which the geological data can be precisely located. Because occurrences of rocks are three-dimensional, the most information can be conveyed by plotting the geology on topographic maps. It is, therefore, imperative that the organization entrusted with geological mapping also have the authority, or the capacity, to obtain the necessary topographic maps before beginning field work in specific areas.

Satisfactory air photographs or maps are not available for a large part of the interior of Zaire because of nearly continuous cloud cover. Now, however, aircraft equipped with side-looking radar (SLAR) can be used to map such areas. The priority assigned an SLAR mapping program should be based on the promise of useful mineral occurrences indicated by scattered data on rock types present in a region.

Three U.S. companies (Grumman Aircraft, Westinghouse Electric, and Goodyear Rubber Company) have SLAR equipment commercially available and capable of making a map of equatorial and other inaccessible parts of the

Republic of Zaire. Such maps can be made at various scales; those at small scales (1:200,000 to 1:1 million) allow an overview of the entire area that emphasizes the details of topography. Maps made in Panama, Massachusetts, U.S.A., Venezuela, Brazil, and New Guinea attest to the usefulness of the SLAR method.

SLAR produces a pseudophotographic picture of the terrain, useful for planning transportation and electric-line routes. The lineations of the topography allow the interpretation of faults, folds, beds, and other linear structures; recognition of areas of uniform rock type; and areas affected by recent stream action. A useful reconnaisance geological map can be produced from this data with a minimum of geologic and geophysical information about the region.

Another method of making useful reconnaissance geologic maps quickly is the combined aeromagnetic and radiometric survey. The aeromagnetic method measures from an aircraft the variations in the earth's magnetic field. This variation is primarily a reflection of the varying amounts of magnetite in the rock and to a lesser degree the anomalous remnant magnetization in other iron-bearing minerals. Variations in the aeromagnetic anomaly patterns displayed on magnetic contour maps allow various distinct magnetic lithologies to be defined. The variations of these anomaly patterns also show by changes in the rock structure. Consequently, an area defined on the magnetic contour maps by a distinctive magnetic anomaly pattern can be mapped by a geologist using samples from a few scattered localities, because the rock type can be assigned to the entire area of that particular distinct anomaly pattern. Experience has

shown that abrupt changes in magnetic anomaly patterns are good indicators of geological contacts and can save months and even years of ground geological work.

In addition, within the zone of a particular magnetic anomaly pattern, individual anomalies can be analyzed, using slightly more rigorous analytical methods to determine (1) lineation, (2) dip, (3) shape, (4) depth of burial, (5) plunge, and (6) magnetite content. Although the figures determined for these parameters will be only approximate, they can be extremely useful in areas where no data exist and even more useful in areas where some geological information is available.

Therefore, in addition to directly locating large anomalous concentrations of magnetite such as magnetite iron deposits, the aeromagnetic method can be useful in locating other valuable minerals that are directly associated with magnetite, and also nonferrous minerals that may be associated with geological map units that can be delimited indirectly by the magnetite anomaly patterns.

When combined with radiometric (gamma ray radiation) surveys, the aeromagnetic method is a rapid and relatively inexpensive tool for evaluating mineral possibilities and for constructing reconnaissance-type geological maps of areas of potential economic interest.

Most airborne radioactivity surveys measure variations in the total amount of potassium, thorium, and uranium in the rocks and soils. This method, when accompanied by an aeromagnetic survey, is useful in defining varying types of granites and other rocks containing little or no magnetic mineral. These rocks, however, may have significant differences

in the amounts of radioactive elements such as potassium, thorium, and uranium and, thereby, show contrasting levels of radioactivity. Newer instrumentation methods, based on the differing energy levels of potassium, thorium, and uranium, can yield data that can be compiled separately into three contour maps showing variations in the levels of these three types of radioactivity, and from these data, variations in rock types can be inferred. As in the aeromagnetic method, the field geologist can locate rock samples from scattered points within an area defined by a distinct level of radioactivity and thereby define the rock type contained within a particular mapped radioactive unit.

However, many rock types do not display distinct magnetic or radioactivity patterns and require conventional methods of geological mapping. Nevertheless, experience in Liberia has shown that a reasonably accurate and detailed regional geological map of a large area can be produced in a few years using airborne geophysical methods, whereas conventional geological mapping methods would have required decades.

The type of aeromagnetic and radiometric geophysical survey proposed would require flying at an altitude of 500 feet (150 meters) above the ground along traverses placed 0.5 mile apart (0.9 Km). Flying can be accomplished only when the weather permits, usually near the end of the rainy season. Doppler navigation and a continuously recording radar altimeter is proposed for navigational control. A backup 35mm, continuous strip camera would provide a visual flight-path record. In low latitudes, the flight lines would be oriented north-south.

The Republic of Zaire covers approximately 905,000 square miles and

would require 1,800,000 miles of airborne traverses. Based on the experience in Liberia 6 years ago, this would require at least 30 months of flying time for two aircraft and cost approximately U.S.$18,000,000.* The cost estimate is based on a bid for an area 20 times smaller and, therefore, the actual contract figure for the whole of Zaire would probably be somewhat less. Mapping of selected mineralized regions could, or course, be accomplished at a much lower total cost, but at a somewhat greater line-mile cost.

The most feasible method to obtain airborne geophysical maps is to contract with a private company or companies for the data acquisition (preferably digital format), data reduction (compiled to planimetric or topographic base maps showing contained data), and follow up of more sophisticated data analyses. Details on the necessary steps and an example of contract specifications can be obtained from the Republic of Liberia or the U.S. Department of State/U.S. AID, who followed these procedures in 1966.

Prospecting and Evaluation

The prospecting and evaluation of mineral deposits requires detailed geochemical, geologic, and ground geophysical studies. To select areas for detailed investigations by geochemical, geologic, or ground geophysical studies requires a thorough review of all available geological mapping, to locate areas where there has been some past prospecting and

*Based on 1966 cost figure and a per line-mile cost for a smaller area (43,000 square miles).

where mineralized rocks are known--as well as to identify rocks and structural zones in which other mineral deposits might be found. Any regional aeromagnetic maps should be scrutinized with particular care, because they are likely to reveal many promising areas for the occurrence of mineral deposits worthy of study by detailed geochemical and ground geophysical studies.

The discovery of anomalies or mineral "shows" by detailed geological, geochemical, or geophysical surveys does not necessarily mean that an ore body of commercial value is present. Many parameters control the formation and strength of geochemical and geophysical anomalies besides the grade of the underlying mineralized rock. Only a small percentage of anomalies recognized during an extensive exploration program will eventually result in the discovery of important mineral deposits, but all anomalies discovered that appear to offer some promise in terms of their strength and size should be further evaluated by systematic exploration. Test pitting would be a logical first step, and additional samples of the overburden should be collected in the walls of such pits and analyzed to see if the metal values increase with depth. Because of the possible lateral migration of metal during the past, mineralized rock may not necessarily be directly under the strongest part of the anomaly. This is particularly true in areas of uneven topography. Geochemical analysis of profile samples collected in the walls of test pits will provide important data that can be used to help select drill sites. If, after this operation is completed, the anomalous patterns still appear to offer promise, the next step would be to start a program of drilling to test the area in depth.

Any program for developing and exploring Zaire's mineral resources should include the use of exploration geochemistry and geophysics. Geochemical exploration is a method of mineral exploration based on the chemical analysis of geologic materials for one or more metals or other chemical properties. The objective of this method is to locate geochemical anomalies, which are areas where the metal content of the geologic material (e.g., soil, sock, stream sediment) is higher than average, and which usually indicate the presence of nearly concealed mineral deposits. The method is quite similar to the age-old prospecting technique of panning a sample of soil or stream gravel for fragments of ore minerals, e.g., gold, and then proceeding in the direction of increasing concentrations until the source is found. In the panning method the eye is the analytical tool; in geochemical exploration, modern methods of trace-element analysis are used to ascertain whether a sample contains more than normal amounts of one or more metals. There are a number of geochemical sampling techniques in common use today: soil surveys, wherein systematically collected samples of soil are taken and analyzed; stream sediment surveys, wherein samples of stream sediment or water are collected, including the collection of panned heavy mineral concentrates; biogeochemical prospecting, using systematically collected samples of vegetation as the sample media; and rock sampling, wherein samples of bedrock are taken on a systematic basis.

In tropical areas like Zaire, the surface rocks are usually extensively weathered and bedrock exposures few. Thus, it appears that soil sampling for concealed mineral deposits would be a most effective method of exploration. This technique is now well proved, has been widely used

in a variety of geologic environments, is dependable, rapid, and quite simple. Plant sampling, on the other hand, has a number of drawbacks and normally should only be considered when it can be ascertained that soil sampling offers little hope of success, as when the surface is extensively covered by a thin layer of surface sand or other transported overburden. Stream sediment sampling can also be an effective reconnaissance method, especially in areas of appreciable topographic relief. Either samples of the silt and sand fraction or of the heavy mineral fraction or both can be taken depending on the object of the search. In general, in areas like Zaire, anomalies of the chemically mobile elements like copper, zinc, cobalt, etc., would be sought in the silt and sand fraction, whereas anomalies of the more immobile elements like lead, tin, gold, etc., would be looked for in the panned concentrates. Water sampling, while possibly useful in a few specialized situations, is not generally applicable in areas of high rainfall and deep weathering.

Geochemical prospecting surveys produce large numbers of samples; and for efficient operations, these must be analyzed for one or more trace metals as rapidly as possible. Thus, the use of geochemical techniques in Zaire would require the establishment of a specialized geochemical analytical laboratory. A large number of analytical techniques especially designed for the analysis of geochemical samples are available. Because of the lack of maintenance facilities in Zaire for the complex instruments used today in many geochemical laboratories, it would be best, at least initially, to use the colorimetric techniques which require only ordinary chemical glassware and equipment. In such techniques,

a sample is first decomposed by fluxes or acids, and then, after certain chemical manipulations, an organic compound is added that forms a colored compound with the metal being determined; the intensity of the color is proportional to the amount of metal present and can be estimated by comparing the color with solutions of known metal content. These colorimetric methods are fast, relatively simple, and can be carried out by technicians. With many of the methods, one man can analyze 100 or more samples per day. Such a laboratory should, of course, be under the supervision of a professional chemist, but most of its staff can be trained, nonprofessional personnel.

Eventually, it would be desirable to include an emission spectograph in the geochemical prospecting analytical laboratory. With such an instrument it is possible to determine 30 or more trace constituents at the same time. The use of such an instrument is particularly recommended in the early stages of a geochemical sampling program when one is not certain what the most diagnostic elements may be. For the analysis of only a few constituents in a sample, however, it is usually best and cheaper to use the wet chemical procedures. The operation of an emission spectographic laboratory must be supervised by a trained professional, but many of the operations can be performed by technicians.

To establish a geochemical prospecting laboratory in Zaire, it would be helpful if the chemist in charge could spend some time in a geochemical prospecting laboratory abroad to learn the analytical methods and study the overall operations of a geochemical laboratory. This might be done at the Denver, Colorado, center of the U.S. Geological Survey. Alterna-

tively, a specialist from abroad could be brought to Zaire for a few months to assist in the establishment of the laboratory.

Finally, interpretation of geochemical prospecting data in mineral evaluation and exploratory work is a geologic problem; the data must be interpreted in the light of other available information, e.g., data from the geophysical and geological surveys. Thus, geochemical prospecting surveys should be under the direction of an experienced economic geologist who has had some training in exploration geochemistry.

IV

TRAINING OF GEOLOGISTS

General Observations and Recommendations

In order that the citizens of the Republic of Zaire assume their rightful positions at the decision-making levels in their industries and universities, programs for training young people must be planned and implemented at the university level. Academic curricula must be designed to serve the specific needs of the Republic in this developmental phase of its history and at the same time to guarantee each graduate a strong and viable intellectual base in government. Toward these goals, we offer these observations and recommendations.

At the visit with the faculty at the School of Mines at Bukavu, we learned that their program was hampered by isolation from mining centers and from other faculties (science and polytechnic) and by serious equipment and staff shortages in some areas. The planned move of the School of Mines to Lubumbashi will rectify some of these shortcomings, and a commitment from the government to fund the equipment needs and to replace the support now offered on a diminishing basis by the United Nations would satisfy the other major problems.

The competence and dedication of the faculty we met at the University at Lubumbashi is heartening indeed. It seemed to us, however, that there was a need for (1) a better coordination of the curricula of the various institutes; (2) a greater flexibility for the student within his individual academic program (for example, a student in a program directed by the

science faculty should be able to take one or more courses in the polytechnical program as approved substitutes); (3) a better use of existing manpower (for example, required instruction in mathematics and in the geology curriculum could be taught by a polytechnical faculty member); and (4) a closer coordination of the present academic time schedules (for example, courses in both the science and polytechnical faculties should begin and end at the same times on both a daily and semester basis, especially for the lower-level, basic courses in mathematics, physics, and chemistry).

To broaden a student's educational program further and to motivate and stimulate professionalism in his chosen field, opportunities should be provided for on-the-job training in government service and in private mining and petroleum industries. Other industries and areas of government service to be considered for on-the-job training programs for students in the geological sciences are those involved in the planning or construction of roads, dams, reservoirs, and major buildings or building complexes, such as airports and factories.

Fundamental to the revitalization and development of geological exploration and research is the mutual cooperation of all persons and organizations concerned. A necessary and essential part of the overall efforts toward revitalization and development is a strong program for the practical training of young Zairians in the various branches of the geological sciences. The following scheme is proposed:

1. The government should institute a program involving organizations participating in geological exploration, mining, research, and natural

resources in general designed to train Zairians for management and operation of these services.

2. An educational program should be instituted, as resources permit, to acquaint young Zairians with the natural resources and economic potential of the country. This program could be set up and initiated by offering a course in earth science, or in the natural resources and economic potential of Zaire, in all secondary schools. To realize this aim, a program in the training of secondary school teachers of earth science should be established. Such a training program might be patterned, in part, on the current Earth Science Institute Programs for Secondary School Teachers sponsored by the National Science Foundation in the United States.

3. All mining companies, such as GECOMIN, should be required, or given government incentives, to establish on-the-job training programs for interested and promising students studying mining and the geological sciences. Paralleling and supplementing this effort should be a hiring program through which citizens of the Republic of Zaire who are qualified by company standards will be given preference.

4. To stimulate interest among prospective students, tours and field trips should be set up so that secondary school students can see the proper role of geologists and the relation of geology to the economy of Zaire.

This or a similar approach could inform the people of Zaire of the natural resources and economic potential of their country and facilitate the training of people capable of carrying forward geological exploration, mining, and beneficiation of the mineral wealth of Zaire.

Curriculum

Additional faculty is needed with expertise in geophysics, geochemistry, and hydrology to give students the broad basic training needed. Facility in these specialties is essential for exploration and discovery of ore bodies and fuels, as well as the study of hydrological problems. As a start, introductory courses in applied aspects of these subjects should be offered, to be followed later by more advanced theoretical courses, which will encourage the development of geochemical and geophysical techniques especially suited to the geography and geology of Zaire.

With known presence of offshore and onshore petroleum reserves, some course work in petroleum geology is advisable. The present faculty at the National University at Lubumbashi may be able to offer courses in this area; if not, this facet of instruction needs to be supplied by importation of foreign faculty.

As an integral part of the curriculum, a special program of symposia could utilize technical personnel from mining and petroleum companies, the ONRD, and the Institut Geographique, thereby greatly facilitating the training of students at little additional cost to the university. Some invited foreign specialists may be needed during the first few years of the program. The following courses should be developed through this program:

1. Courses in applied geophysics, geochemistry, hydrology, and petroleum geology.

2. Short courses for technicians in various aspects of the above-

listed subjects, possibly involving the operation of basic and special equipment in geophysics, geochemistry, hydrology, etc.

3. Seminars on special topics designed along the lines of the short courses.

An essential aspect of the curriculum should be a strong emphasis on practical and applied geology, coupled with on-the-job experiences early in the student's training. Some practical training could be obtained through cooperative programs with the Zairian National Geological Service, the Ministries of Transportation and Public Works, as well as with Gecomines and other mining and petroleum companies.

The undergraduate curriculum should be as flexible as possible. Once a student has completed the required basic courses, he should be permitted to adjust the program to suit his abilities and needs.

Urgent and Continuing Needs

The centralization of the geological and mining curricula in the National University at Lubumbashi may alleviate some of the problems resulting from the scarcity of teaching equipment by making it possible to pool some equipment, such as microscopes. Some excellent apparatus, including the proton magnetometer and the shallow refraction seismograph owned by the National Institute of Mines, will be available for teaching and research purposes. Some equipment deficiencies, however, are very apparent and serious: even the most basic instruction will require additional stereoscopes (large and small) and a large number of compasses, neither of which, fortunately, are costly items. The X-ray equipment at

Lubumbashi, the most important diagnostic apparatus for studying and identifying minerals, has been out of service for at least a year; it should be put in working condition, and, again fortunately, the cost will not be large. Other inexpensive items, such as maps and air photographs, for use in laboratory instruction are not now available in the quantities needed.

There are critical deficiencies in library facilities and transportation for field work; remedying these deficiencies will be more costly, but absolutely necessary, if geologists are to be trained. The National Institute of Mines at Bukavu has a reasonably good collection of recent textbooks and of some basic periodicals in geology and mining. The National University at Lubumbashi, on the other hand, has few textbooks and only a short run of periodicals, terminating in 1968. For both educational and research purposes, copies of the missing periodicals must be obtained, and, most important, a continuing budget for subcriptions to periodicals and for new text, bibliographic, and reference books must be provided.

The cost of past and current publications can be greatly decreased by subscribing to services that provide periodicals on microfiche cards, which have the added advantage of greatly reducing the required storage space. Use of microfiche cards requires "magnifying readers," but the readers are inexpensive compared to the costs of buying and storing publications.

The library of the Scientific Research Institute of Central Africa (IRSAC) at Bukavu contains much of the necessary basic geological and

geophysical publications. If microfilm facilities were installed at IRSAC and if magnifying readers were available at Lubumbashi, it would be possible for students and faculty at Lubumbashi to take advantage of the IRSAC library by requesting film copy (35mm) of the needed articles.

The teaching and the practice of geologic mapping requires transportation, for both access to and exploration within field areas. The absence of good roads and of adequate public transportation in much of the Republic multiplies the problem. At present, two old buses are available at Bukavu to take students to mining areas, but they cannot be used in rough terrain. At Lubumbashi there is one Land Rover, but no other transportation for field teaching and research.

It is strongly urged that field vehicles be purchased for exclusive use by the geological and mining faculties of the National University at Lubumbashi for the training of students and for geologic mapping by the faculty. For the present student enrollment and faculty, the goal should be to have six to eight field vehicles available.

Because the Government of Zaire intends to develop and maintain the capacity to train most of its geologists and mining engineers, it will be necessary to provide continuing budget support for the purchase of teaching and research equipment. Provision for repair and replacement parts for equipment and vehicles and for the gradual addition of new kinds of equipment must also be included.

V

SCHEDULE OF VISITS AND MEETINGS

Thursday, July 20, 1972

Morning

-Briefing of NAS Participants by ONRD President Ileo

Afternoon

-Open

Friday, July 21, 1972

Morning

-Fly to Bukavu

Afternoon

-Arrange for Local Visits

Saturday, July 22, 1972

Morning

-Visit the National Institute of Mines

-Visit the Scientific Research Institute of Central Africa (IRSAC)

Afternoon

-Fly to Lubumbashi

Sunday, July 23, 1972

Morning

-Visit the Polytechnical School and the Department of Earth Sciences, National University of Lubumbashi

Afternoon

-Discussions with the Faculty of the Polytechnical School and the Department of Earth Sciences

Monday, July 24, 1972

Morning

-Visit Likasi and the Kambore Mines of GECOMIN

Afternoon

-Discussion with GECOMIN Geologists

Tuesday, July 25, 1972

Morning

-Discussions on Geological Mapping with GECOMIN Geologists at Kipushi

Afternoon

-Visit the GECOMIN Mine at Kipushi

Wednesday, July 26, 1972

-Discussion with Faculty Members of the Polytechnical School and the Department of Earth Sciences

-Return to Kinshasa

Thursday, July 27, 1972

-Visit the National Geographical Institute

-Visit the National Geological Service

Friday, July 28, 1972

Morning

-Plenary Session at ONRD

Afternoon

-Working Session of the Joint Study Group

Saturday, July 29, 1972

-Working Sessions

Monday, July 31, 1972

-Working Sessions

Tuesday, August 1, 1972

Morning

-A Presentation by President Ileo to the Joint Study Group on the Immediate ONRD Needs

Afternoon

-Closing Plenary Session

-Visit to the Office of the Minister of Mines

VI

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