IAEA-TECDOC-583

Uranium exploration planning and practice

Report of an Advisory Group Meeting held in Vienna, 13–16 December 1988

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URANIUM EXPLORATION PLANNING AND PRACTICE
IAEA, VIENNA, 1991
IAEA-TECDOC-583
ISSN 1011–4289

Printed by the IAEA in Austria
February 1991

FOREWORD

The International Atomic Energy Agency has long had an interest in providing manuals and guidebooks to assist workers in the most effective use of uranium exploration methods and techniques. These have been widely used by the mineral industry around the world. Little has been done, however, to guide and assist senior levels of management of national Atomic Energy Commissions or Geological Surveys in planning for and managing their uranium exploration and development programmes. The nature of uranium, and its potential military use makes it a commodity requiring special consideration. On the other hand, the fact that it is a mineral fuel commodity that is explored for and mined like other mineral commodities presents management with problems of mineral economics unlike those normally faced by government scientific organizations.

In order to address these questions, the IAEA convened a Advisory Group meeting in December 1988, to discuss the requirements for uranium exploration planning and practice, from the point of view of national policy and strategy. The six advisors, three observers and four Agency staff members brought to the discussions a wealth of experience in government and in the minerals industry dealing with uranium. The present document, comprising formal papers as well as transcribed discussions on each, should be of interest and value to senior government planners charged with the task of regulating and controlling their country's uranium development. The Agency wishes to thank the Advisors and Observers for their presentations and discussions. The IAEA staff member responsible for the meeting and the preparation of the document was Arthur Y. Smith of the Division of Nuclear Fuel Cycle and Waste Management.

EDITORIAL NOTE

In preparing this material for the press, staff of the International Atomic Energy Agency have mounted and paginated the original manuscripts and given some attention to presentation.

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I. INTRODUCTION

PLANNING FOR URANIUM EXPLORATION

For some time a need has been felt for guidelines on the development of uranium exploration projects from the point of view of developing Member State organizations. In recent years the cost of mineral exploration has increased and, at the same time, has come to require more sophisticated and costly techniques. These factors have placed an increasing burden on Member State organizations, Atomic Energy Commissions and Geological Survey departments alike, that have sought to carry out uranium exploration themselves in the national interest. The concept of uranium as a "strategic" commodity has led to the formulation of special laws and regulations that are different from those applying to other mineral commodities.

The planning and carrying out of a uranium exploration project demands a number of important decisions on the part of governments. First and foremost, should the Government attempt to carry out its own exploration for uranium or should efforts be made to attract foreign exploration and mining groups? If the later, what conditions and controls should the government apply to these operations? What information and services can the government be expected to provide. Is it intended to use any uranium found in a national nuclear energy programme or is the uranium intended for external sale? What conditions will best attract the interest and participation of such mining companies, and to what degree should their activities be regulated and controlled? These and other questions require decisions before a uranium exploration and development policy is established and exploration is begun.

The Advisory Group meeting on Uranium Exploration Planning and Practice was convened to discuss these questions and to prepare a document in which various points of view on these questions are presented. A number of specialists from national Geological Surveys and mineral exploration companies and others responsible for supporting or carrying out uranium exploration were invited to present papers on various aspects of the question. These, together with the discussions on each paper form the material of this TECDOC.

The general topics for discussion presented to the Group members were as follows:

- Exploration Planning and Strategy

  The exploration programme; exploration strategy, the phases of exploration and their costs; organization and management of exploration; staffing and logistics; target evaluation and modelling; what types of uranium deposits are worth searching for in the present and foreseeable future?

- Contractual Arrangements

The legal and administrative aspects of a uranium exploration project; exploration permits and regulations; should uranium be treated as a special "strategic" commodity or as another mineral resource? Some typical national policies towards uranium.

- Role of National Geological Surveys

The role of government organizations in the search for uranium; the basic geological and uranium favourability information needed for effective uranium exploration, who should collect it and how should it be made available.

- Role of Outside Interests

Financing of projects; should governments do the exploration themselves or encourage private mining company interest and investment; how should the activities of private mining companies be controlled and regulated; health, safety and environmental considerations.

- Role of State Exploration Organizations

Examples of countries where uranium exploration is carried out entirely by state organizations without foreign participation, as a matter of national policy. How are the programmes planned and executed; at what costs; in what time scale; with what success? What are the requirements in terms of staffing, financial support, and infrastructure of national organizations responsible for uranium exploration?

The papers and discussions in this document are intended to serve as informational material for senior Government members and mineral resource planners faced with the task of developing policies and regulations for the exploration and development of the country's uranium resources. It was not the intention of the Group to make firm recommendations as to the model to be followed. Rather their intention was to present, from their varrying experience, the problems and questions that require consideration and solution.

Since the meeting was held in December 1988, there has been a remarkable movement away from central planning, and towards a free market orientation in many countries. Never-the-less there remain circumstances in which the vesting of exclusive jurisdiction over uranium exploration and mining in a state organization may be a valid choice. At the same time the rather special nature of uranium must be considered, as will be evident from the introductory discussion on the strategic nature of the element.

The Agency hopes that readers will find the topic as interesting and thought provoking as did the participants of the meeting. A list of participants is provided at the end of the document. The Agency wishes to thank these specialists for the time and thought they put into their presentations and discussions.

URANIUM: A STRATEGIC COMMODITY?
A GENERAL DISCUSSION

During the Advisory Group meeting upon which this document is based the discussion returned time and again to the question, "Is uranium a strategic material or is it a commodity like any other mineral or fuel commodity". To some extent the question revolves around the definition of the word "strategic". The Oxford dictionary defines strategic, when applied to materials as, "essential in war". This association of uranium with war and atomic bombs, in the minds of most people, has tended to confuse and obfuscate understanding of its mineral resource and fuel commodity aspect. These discussions illustrate the difficulty.

Darnley: I would like to comment on what I took to be a question at the beginning of your paper (Smith-Tauchid) as to whether uranium really is a strategic material now, a strategic mineral. I very strongly take the view that it is. People were first interested in uranium because of its military significance. But the world has changed quite a lot in the last decade or so. I think the world problems we have to focus on in the very near future, if not right now, is the whole matter of global change; the problem of deteriorating environment.

However, the majority of the world's population is still expecting an improvement in its standard of living. It still is looking for an increase in its possessions. There is absolutely no way that you can upgrade the quality of life of the majority of the world's population unless you can provide the population in general with an increasing amount of energy. It is very likely that the utilization of energy in the West is excessive, that there is a lot of energy wastage, and that it is possible to use energy much more economically than we are currently doing. But at the same time it is clear that 2/3 or 3/4 of the world's population definitely need to use more energy in order to achieve a satisfactory living standard.

It seems to be impossible to satisfy this increasing energy requirement unless there is an expansion in the use of nuclear energy. You can talk about solar and wind energy, gravitational and tidal energy, geothermal energy, and certainly they are going to contribute. In some parts of the world they are going to contribute quite significantly. But in terms of satisfying the base load of energy requirements of the world at large it is difficult to conceive how you can do this and, at the same time reduce the amount of hydrocarbon consumption, which has got to be done. How can you do this unless you introduce nuclear energy much more substantially than is presently the case. So for that reason I say that uranium is very much a strategic material and very much a commodity different from other commodities. There may be a temporary lull at the moment in the recognition of this fact.

In your presentation you pointed out that we have got to try to persuade the world's policy makers to be thinking of things of 10, 15, 20 years ahead. We have to emphasise the fact that in the next 10 or 15 years there have got to be some dramatic changes in the way energy is generated. And unless there is something done about the supply side of energy, more nuclear power, how else is it going to be done? Therefore, I would say it is a strategic commodity.

Chairman (Fuchs): I fully agree with you that uranium is a very important commodity but I wonder if we should use the word strategic for the future because strategic may have a different meaning. Most people relate the word with military material. A strategic mineral is a mineral for military use, and while we don't think this way a lot of people do. So maybe we should not use strategic any more but use important or whatever to avoid this military connotation of the word.

Müller-Kahle: I believe we should stress that uranium is a commodity like other commodities. We should get away from putting uranium into a special box. It is, as a matter of fact, an energy commodity like coal and oil and it is a mineral commodity like lead and zinc and copper and iron. I think we should stress that there should not be any difference in the treatment of uranium in any respect. In its legal and economic aspects it is a commodity and we see now in many other areas of mineral economy that commodities which we believed 10, 15, 20, 30 years ago to be of the utmost importance are now unimportant. I have to support what Dr. Darnley said as regards the development of human living standards and energy and electricity. It has been shown in recent studies that the electricity demand right now is increasing faster than GNP, while the use of other primary energy sources is falling below the curve of GNP growth. (this is to say that while electricity use is growing the use of other types of energy is falling as GNP increases) But this merely emphasises the importance of electricity generation in the future, its importance in the context of environmental problems, and the importance of nuclear energy generation.

Money: I would go further than Dr. Darnley. It is certainly true that the developing world is looking for a better quality of life than they have had until now. And in this context I feel there is need to indicate to the policy makers the role and relevance of uranium and nuclear energy. Far too often when we talk in terms of energy and electricity, most policy makers, certainly in Africa, think only in terms of petroleum and coal. And the moment you mention uranium, the first reaction they have is "atomic bomb". In this context I fully endorse the view that the use of the word strategic has other implications which ought to be taken out. Maybe we should emphasise that it has become an essential commodity like many other commodities. Equally I think energy is important and in that context I think uranium has an important contribution to make. This is certainly going to be the case in countries such as the densely populated countries in Southeast Asia and Asia.

Of course Africa has a sparse population but nevertheless the energy demand is increasing. Many countries are devoid of water resources for energy, devoid of gas and oil for energy. Without doubt nuclear energy is going to play a role in the energy scenario in the future. The policy makers should take cognisance of the development and role nuclear energy will play, perhaps in the next century.

Chairman: This is very interesting to hear this from you, a person from a developing country because we in Germany we have also discussions with our development agencies on the subject. As you know we have a ministry for technical cooperation. And these people just go the other way. They clearly define nuclear power as dangerous. We have done this in Europe, we have gone the wrong way and all our development aid organisations, at least in Germany, are absolutely against distributing any technology, anything concerned with nuclear energy to the developing countries. There is no support whatsoever, at least in my understanding, from the German development side to help developing countries to build up some nuclear energy capability for the purpose of generating electricity. So I think it is a very important policy for you (developing countries) to outline to the countries which support you in developing your country that nuclear energy is an important factor because people involved with development aid in the widest sense of technical cooperation, at least in Germany, are against it and don't even use the word nuclear energy.

Darnley: I would like to substantiate what you say: I think the people responsible for setting technical aid policies probably in the Western world in general are anti nuclear energy. I would be very surprised if the Canadian CIDA was not rather negative towards nuclear energy. But I think the facts of the changing environment, within 5 to 10 years are going to make it clear that it is in fact the lesser of several worse evils.

Müller-Kahle: We have to understand that it is not the objective of the foreign aid agencies to establish nuclear reactors in the developing countries. We have however, some indication that foreign aid is expanding for nuclear research. And I think this is much in line with the objectives of such agencies, certainly the IAEA. But to build a nuclear reactor is a billion dollar business and I believe it is outside the frame and the objective of a technical aid or a technical cooperation agency. If however, there is a commercial basis for such a project I am not sure if financing will be a problem. On the other hand, we see every day the man/machine problem, to be frank, the manpower problem, and this is something some people are afraid of even in our part of the world. Man is the weakest link in the chain. And this is an additional factor. People say, "Excuse me, are the developing countries ready for such an advanced technology as commercial nuclear power?". I think there is some hope, however, and maybe the next few years will show more and more the need for nuclear power generation in developing countries.

Verma: The perception about nuclear energy is obviously different in different parts of the world. We in India tend to agree with what Dr. Darnley said. Nuclear energy is inevitable. We have accepted this fact and we are going ahead with our programme and with uranium exploration to support that programme. I do agree that uranium should not be called a strategic material because it does frighten the public. And we in India also have this public acceptance problem for which we are taking action. Very recently we were setting up some reactors in the State of Kanataka. There has been some public opposition so a public debate is being organized there. Twenty scientists from our Department of Atomic Energy will be participating to throw light on the various aspects to dispel the apprehensions in the minds of the local population. Public men from the press and from parliament will be participating in the debates. So we have this programme of creating public acceptability there. Because we considered this inevitable. By the end of the century we envisage having installed a total electrical power generation capacity of 100 000 to 120 000 MW(e) and we hope to have 10% of it generated from nuclear power. We are going ahead with our reactor programme to install that capacity. Time is short and we have a long way to go. We have to increase 7 to 8 fold from our present state in the next 10 or 12 years. But we are committed to that policy and obviously we have to find the uranium resources by then. We are going full steam ahead to develop our uranium resources and we are expanding our uranium exploration programmes. However, I also would like to comment on the question that uranium should not be put in a certain box. Perhaps that may come in the future but for the present it has to remain in a special box for the simple reason that the utilization of uranium has to be controlled to some extent and if it is allowed to pass into all hands you will have no control on the end use of the material. So for the present I do think it should be left in a special box, though perhaps it should not be called strategic.

URANIUM EXPLORATION PLANNING AND STRATEGY

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Abstract

A country may decided to begin uranium exploration for any of three reasons: 1. to meet the needs of a domestic nuclear power programme; 2. to supply uranium as a commodity to the world market in order to earn foreign exchange; 3. to acquire national information on the country's mineral resource potential with a view to long term mineral resource planning. In any of these cases a country must make some basic decisions regarding the means and modes whereby the uranium exploration will be carried out - by national organizations exclusively; by state organizations in joint venture with outside interests; by foreign interests under the control of national regulations.

Most uranium exploration is carried out following an exploration strategy in which the programme is divided into a series of steps or stages. Each of the phases is designed to eliminate areas of low potential to contain uranium deposits while focusing attention on areas of higher potential that will be explored in greater detail at higher cost in the subsequent phase. The methods used in each phase are selected to provide the maximum information at the minimum cost so that at the end of each phase a decision can be made whether to continue to the next phase of stop.

Because uranium exploration is a high cost high risk activity, governments must make decisions at the outset whether they wish to carry out the work alone, and whether they can support the costs involved, or whether they wish to attract foreign investors to help absorb the costs and therefore the risks. In either case major policy decisions are required to be made to establish the legal and fiscal environment in which the programme will be carried out.

I. INTRODUCTION

Why should a country want to explore for uranium? In view of the current oversupply and the known abundance of resources to meet needs well into the 21st century such an activity would seem to be a waste of time and money. This view is frequently heard in the IAEA as well as outside. It comes mainly from the nuclear community who are accustomed to think of uranium as a strategic material rather than as a mineral resource commodity like copper or gold. One could as well ask why a country should want to explore for gold. The answer is, of course, that a country that can mine and sell uranium at a competitive price will find a market for their product, regardless of the resources other countries may possess.

A clear policy needs to be defined, however, before a country embarks on this risky and expensive activity. This policy might be based on one or more of the following objectives:

1. To find uranium to meet eventual domestic needs within the framework of the country's nuclear power programme and to be independent of outside sources.

2. To search for and eventually produce uranium for the world market. In this case the country should have good geological potential for finding attractive (ie. low cost) uranium deposits.

3. To explore for uranium as a part of the country's natural resource evaluation programme. In this case the country's involvement is limited to the provision of basic or preliminary information (geological, radiometric, geochemical and geophysical maps at the regional scale) from which the country's uranium favourability can be estimated.

Over the past 10 or 15 years many countries have begun uranium exploration without a clear policy or long-term objective, only to abandon it after two or three years. In most cases this has been due to a lack of understanding and appreciation on the part of senior management of what uranium, or any other mineral exploration for that matter, is all about. At the level of national organizations the role of the state in the mineral exploration process must be clearly defined and understood. This applies particularly to uranium, which in the past has been considered a special "strategic" commodity assigned to Atomic Energy Commissions or Nuclear Research Organizations. Such organizations are seldom equipped or financed at a level sufficient to carry out meaningful uranium exploration. In addition they are frequently isolated from the national geological community and may make little use of the expertise in mineral exploration methods available in other organizations in the country.

The most effective uranium exploration is carried out within an exploration plan or strategy. The high costs of exploration and high risk of failure require the most careful planning. The exploration methodology must provide a number of decision making points to permit a project to be terminated in a timely manner when results are not compelling.

II. EXPLORATION STRATEGY

The process of exploration for uranium deposits follows a number of steps or phases with the overall objective of greatly increasing the chances of discovering an economic deposit at the least possible cost. Each phase has its clearly defined and understood objective; each has particular requirements as to methods to be used and their cost benefit; each phase terminates with a decision to continue to the next phase at increasing cost or to terminate the project.

The phases of a modern exploration programme are;

(1) planning and area selection,
(2) reconnaissance,
(3) follow-up and,
(4) detailed.

During each phase a process of selection and elimination is carried out with the aim of discarding from further consideration those areas with little or no potential while focusing attention on those areas with greatly increased potential. The areas remaining at the end of each phase become the areas of study during the succeeding phase. At the completion of the detailed phase the prospects found become the subject of a completely different process, that of deposit development. The various exploration phases are illustrated in figure 1 and discussed briefly below.

2.1 Planning Phase

The phase of planning and area selection is the beginning of any phased exploration programme. Starting with a region of perhaps 100 000 km^2, mainly office studies are made in an attempt to define those parts of the region with the greatest uranium favourability. These studies are carried out by a senior, experienced uranium geologist. They entail the compilation of all available geological favourability information, photogeological and remote sensing studies, and rapid field visits to examine geology, radioactivity and general regional uranium distribution by means of uranium geochemical analyses of samples collected. During these visits the geologist will have examined the terrain and surficial environment in order to select the exploration methods most suitable for the programme. Regional data are normally compiled on maps of 1:250 000 or 1:500 000 scale.

Depending on the size of the region studied, area selection may take one or two years, at a cost of perhaps $ 1 - 2/km^2. In the course of such studies perhaps 70 - 80% of the region will be eliminated from further consideration, leaving one or more areas totalling perhaps 20 000 to 30 000 km^2 to be examined in the next or reconnaissance phase. National organizations carrying out the early phases of exploration may decide that the geological environment of the region is favourable for commodities other than uranium and select a larger proportion of the region for multicommodity resource evaluation studies.

2.2 Reconnaissance Phase

The objective of the reconnaissance phase is to locate areas of interest in the region selected for the exploration programme. Several exploration methods may be used during the reconnaissance phase either singly or in combination. Airborne radiometric surveys are frequently used in this phase with line spacing up to 5 km. In suitable environments geochemical surveys may offer advantages in terms of simplicity and increased amounts of data returned. In these cases sample

URANIUM EXPLORATION SEQUENCE

I. **PLANNING AND AREA SELECTION**
Regions of unknown potential >50,000 Km^2

II. **RECONNAISSANCE PHASE (LOW DENSITY)**
Areas of unknown but speculative potential > 5,000 Km^2

- Scale of maps: 1:250,000 - 1:100,000
- Methods: Remote sensing:
  - Geological mapping:
  - Radiometric surveys:
    total count, spectrometer,
    Airborne, carborne, sample site.
  - Geochemical surveys: (0.1 - 1 sample/km^2)
    Stream, lake sediment, heavy mineral,
    water, gases, wide spaced soil.

→ Areas of no interest

III. **FOLLOW-UP PHASE (INTERMEDIATE DENSITY)**
Areas of interest (200 - 2000 km^2)

- Scale of maps: 1:50,000 - 1:25,000
- Methods: Remote sensing:
  - Geological mapping:
  - Radiometric surveys:
    total count, spectrometer,
    Airborne (close spaced), carborne, ground
  - Geochemical surveys: (2 - 10 samples/km^2)
    Stream sediment, soil, water, soil gas.
  - Wide spaced drilling: 1 hole/2 - 5 km^2 *

→ Areas of no interest

* For sandstone type deposits.

IV. **DETAILED PHASE (HIGH DENSITY)**
Significant anomolies (.2 - 10 km^2)

- Scale of maps: 1:5,000 - 1:500
- Methods: Geological mapping,
  - Prospecting, trenching, sampling.
  - Radiometric grid surveys,
  - Magnetic, electromagnetic surveys,
  - Geochemical surveys, soil, bed-rock, soil gas radon, helium etc.
  - Grid drilling (1 hole /0.5 - 1 km^2) *

→ Anomalies of no interest

* For sandstone type deposits.

V. **DEVELOPMENT PHASE**
Prospects

- Methods: Detailed geological mapping,
  - Trenching and sampling,
  - Detailed drilling, ore reserve estimation,
  - Underground testing, mineralogical and petrological studies,
  - Milling tests, pilot plant tests.

→ Failed prospect

Figure 1: The uranium exploration and development sequence.

densities of 1 sample per 1 to 10 km^2 are common. Determination of radon in surface or subsurface waters or radon in soil-air has been used effectively on occasion. In reconnaissance surveys, however, radon methods would not be used alone but in combination with other geochemical and radiometric methods. Data from reconnaissance surveys are usually plotted at scales of 1:100 000 to 1:250 000.

It is normally the case that the reconnaissance programme will eliminate more than 80% of the area surveyed. Costs for reconnaissance level surveys are usually in the order of $ 15 to 50 per km^2, depending on the difficulty of the terrain and the methods employed. The areas of interest or reconnaissance anomalies outlined during the reconnaissance programme are the targets for study in the succeeding, follow-up phase.

2.3 Follow-up Phase

The objective of the follow-up phase is to locate exactly on the ground the extent of anomalies in the areas of interest. This objective is achieved by reexamining the areas of interest at greatly increased density. Where geochemical methods are used densities of 10 to 20 samples per km^2 are normally used. It is customary to sample the same material as that used in the reconnaissance phase. However, where stream sediment or water was used, bank soils may be sampled in addition. Radioactivity measurements made at the same time add valuable information at little extra cost. Radon measurements of waters or soil air are frequently valuable, and if a sufficient number of springs can be found radon content of ground waters should be measured. The occasion may be taken to improve the geological mapping, but this should be done as much as possible without delaying the progress of the sampling. The very high cost of good geological mapping in most cases precludes its extensive use at this stage. The results of the follow-up programme are reported at scales of 1:25 000 or 1:10 000.

The follow-up programme may eliminate as much as 90% of an area of interest, outlining anomalies of a few to perhaps 10 km^2 in extent. These may frequently show strong directional trends, pointing to possible lithological or structural controls. Costs for follow-up surveys may be in the order of $75 to 200 per km^2. The follow-up anomalies outlined in this phase are the subjects of study during the succeeding, detailed phase.

2.4 Detailed Phase

The objective of the detailed phase is to distinguish between anomalies due to potentially economic mineralization and those due to uneconomic mineralization or other causes. It is in this phase that direct indications of a mineral deposit are located and tested. In this phase a wide selection of exploration methods will be used: radiometric grid surveying; detailed geochemical surveys; detailed geological mapping; trenching; core and/or rotary drilling with radiometric and electric logging, etc. Radon measurement of soil air, along with soil sampling for uranium and/or radium determination are frequently used. Bed-rock sampling, including sampling and analysis of core or cuttings for uranium and associated elements should be considered as well.

It is clear that a high density of sampling and measurement will be required in the detailed phase, perhaps as much as 2500 per km^2. For this reason it is difficult to put a cost figure on this phase. Several methods will be employed in order to better define and characterize the prospect. Each method has its own cost and benefit. The data developed during the detailed phase are normally compiled on maps at scales of 1:500 or 1:1000.

The detailed phase, and the exploration programme in general, may be said to terminate with the achievement of ore grade intersections in surface trenches and/or in the sub-surface drilling programme. At this point the project enters the development phase, calling for different techniques and specialists, and presenting different risks.

III. EXPLORATION TECHNIQUES

Uranium deposits are not distributed at random in the earth's crust. They are geologically controlled. The uranium exploration geologist should therefore:

1. Have a good knowledge of the characteristics of uranium deposits (recognition criteria), and the geological environments where they are found, and;

2. Be familiar with the exploration techniques commonly used in uranium exploration.

As illustrated in Figures 2A and 2B, some deposits have a surface expression while others are completely hidden, blind deposits. Conventional vein deposits, calcrete and intrusive associated deposits frequently have a surface expression. In such cases direct evidence is sought. However, many other types of deposits such as sandstone hosted, Proterozoic quartz-pebble conglomerate, unconformity related and other flat or nearly flat lying deposits may have no, or only a very weak, surface expression. In both cases the geological environment will dictate to a large extent the exploration methods to be employed. These will, of course, be closely related to the phase of exploration being carried out. At the same time account must be taken of the nature of the surface environment. Figure 1 illustrates the phases of the exploration sequence and the possible methods commonly used in each.

3.1 Geological Mapping

Although geological mapping is commonly considered an important part of any uranium exploration programme it may frequently be neglected in favour of more "sophisticated" instrumental techniques. Good geological maps are essential for the selection of favourable areas for investigation. They are equally important for the proper interpretation of other exploration surveys, radiometric, geochemical etc.

It is often not realized, however, the cost of good geological mapping and the difficulty in obtaining this information. On a regional scale it is generally considered the role of the national geological survey to make available to

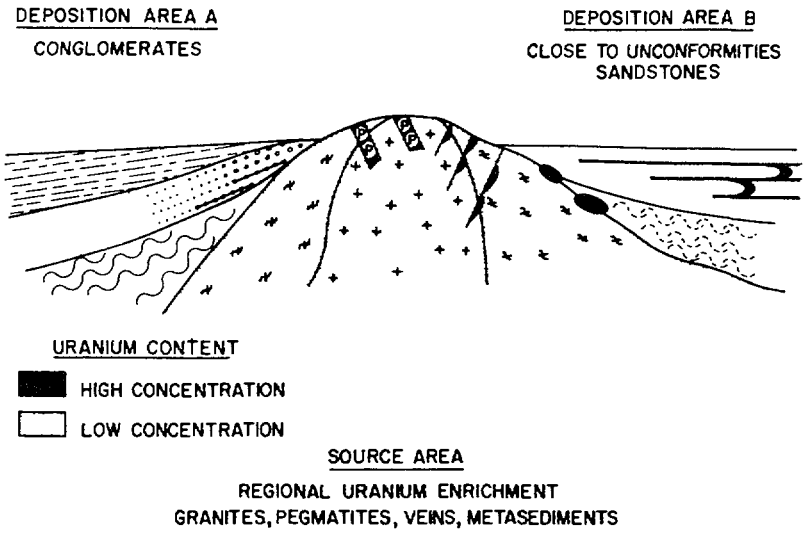

Figure 2A: Schematic diagram to illustrate relationships between a source area and associated depositional areas. The source area consists of uraniferous granites, pegmatites, veins and metasediments; deposition areas exhibit uranium concentrated in conglomerates, sandstones, and in the vicinity of unconformities. (after [1]).

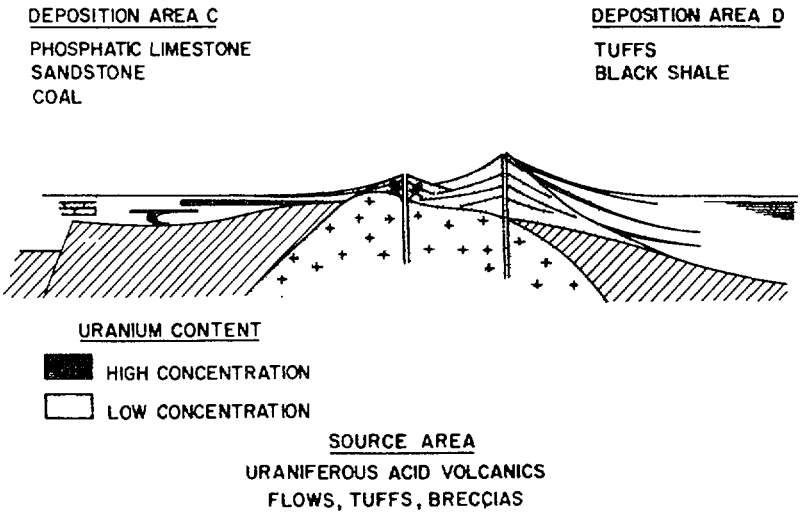

Figure 2B: Schematic diagram to illustrate relationships between a source area and associated depositional areas. This source area consists of uraniferous siliceous lava flows, tuffs and breccias; in deposition areas uranium is concentrated in sandstone, phosphatic limestone, coal and black shale. (after [1]).

interested parties geological maps of good quality. In many countries experienced geological mappers are simply unavailable, with the result that good maps are not being produced. Those that exist may have resulted from earlier work based on outdated concepts and practices, or they may contain no mineral occurrence information. While most exploration projects cannot afford to begin high standard geological mapping, in every case some checking and revision of geological knowledge will be required. Only as the final target (the uranium deposit) is approached will high quality geological mapping be possible.

3.2 Remote Sensing

Remote sensing refers to the use of images remotely recorded or measured. These include aerial photographs, Landsat images, SLAR (side looking airborne radar) images, and other multi-spectral scanning images. These techniques are used extensively to provide additional geological and uranium favourability information on a regional scale. Frequently features of importance are visible on satellite images that cannot be seen on normal aerial photographs. The newer multi-spectral images are providing subtle information on the presence of mineralization undetectable by surface methods. A competent photogeological interpretation can often provide essential basic geological information where other geological maps are lacking or inadequate. It must be stressed, however, that remote sensing techniques must be used in conjunction with other exploration techniques in order to derive the greatest benefit from them.

3.3 Radiometric Methods

Radiometric methods are amongst the most widely used and useful techniques used in uranium exploration programmes. Their main attraction is that they are convenient to operate. Both airborne and carborne total count and gamma ray spectrometer surveys have played a large part in uranium exploration, permitting the coverage of large areas rapidly and conveniently at the reconnaissance and follow-up phases. At the detailed phase grid surveys using total count instruments as well as gamma ray spectrometers are widely used. Radiometric bore hole logging methods come into play during the drilling stage and often permit the calculation of ore reserve estimates.

The user of radiometric techniques must be aware of aspects of the method often forgotten. Firstly, the gamma rays being measured have a short depth penetration, in the order of 50 cm in rock. This means that buried mineralization will not be detected unless special conditions prevail that have permitted the migration of gamma ray emitting elements to the surface. Secondly, users need to be aware that they are not measuring uranium or thorium but ^{214}Bi and ^{208}Tl, daughter gamma ray emitting elements in the decay schemes of ^{238}U and ^{232}Th respectively. Since these two daughters are a number of steps away from their parents in the decay schemes, considerable geochemical separation can occur between them. In every case considerable care must be exercised in the interpretation of radiometric surveys.

3.4 Geochemical Methods

Geochemical methods are fairly recent developments amongst uranium exploration methods. These methods entail the collection of samples of materials from the surface environment, water, lake or stream sediment, soil, rock or gas, and the analysis of these for one or a number of elements. In uranium exploration they have proved particularly valuable at the reconnaissance phase, often providing geological as well as uranium favourability data. In most cases the possibility of multi-element analyses makes collection of geochemical samples cost effective although such surveys are slower and more time consuming than airborne surveys. In addition, geochemical surveys often give indication of processes that have no obvious surface expression and thus help to define the primary halo surrounding buried deposits.

3.5 Other Geophysical Methods

Only recently have non-radiometric geophysical techniques received much use in uranium exploration and then for mainly the unconformity type of deposit. In these cases the association of sulphide minerals, graphite or conducting structures associated with the uranium mineralization provide the basis for their use. Magnetic surveys are frequently used for mapping potential ore bearing structures, particularly in granitic environments.

IV. EXPLORATION COSTS

4.1 Costs

Exploration costs are very difficult to calculate since, it must be remembered, they can only be estimated when exploration is successful. And most exploration efforts are not successful. In Canada the cost to find 1 kg of uranium was [3]:

1968 to 1976	US $ 0.80
1977 to 1978	$ 1.30
1979 to 1981	$ 2.50

Recent figures covering the period 1971 to 1983 are as follows [4]:

Total Canada	US $ 2.08 per kg U
Saskatchewan	$ 1.22 "
Canada, excl. Sask.	$10.86 "

In the U.S.A. between 1973 and 1982 the average cost was US$ 12.41 per kg of uranium while in Australia between 1967 and 1983 the average cost was $ 0.41 per kg uranium [4]. Perhaps a more useful indication of costs is the fact that to find a medium sized deposit of between 5000 to 10000 tonnes U would require a budget of US $ 25 000 000 to $ 50 000 000. A good example is the Swanson deposit in Virginia where, after 5 years and an expenditure of $ 20 000 000, a deposit was discovered with reserves of about 11000 tonnes U. Figure 3 summarizes the probability of failure and cash flows of the mining cycle.

4.2 Lead Time

The lead time, which is the time required from the start of an exploration programme to the commencement of production from a discovered deposit, is conservatively estimated at 15 years (see figure 4). In many cases the lead time is greater

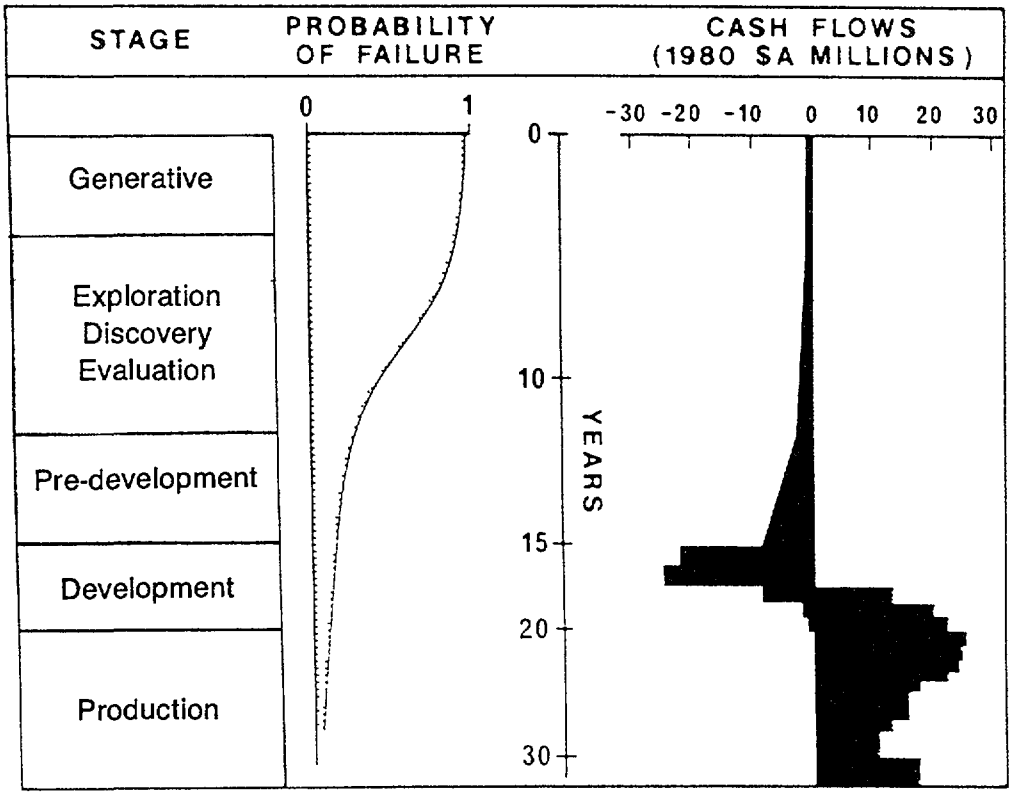

Figure 3: The mining cycle. (after [2]).

EXPLORATION TIME SCALE

PHASE	AREA	TIME	ODDS (*)
REGIONAL	25 - 100000 km^2	1 - 2 YEARS	INFINITE
RECONNAISSANCE	10 - 30000 km^2	2 - 3 YEARS	1 MIL.: 1
FOLLOW-UP	500 - 1000 km^2	1 - 5 YEARS	10000 : 1
DETAILED	0.2 - 10 km^2	2 - 5 YEARS	1000 : 1
DEVELOPMENT	DEPOSIT SIZE	2 - 5 YEARS	2 : 3

(*) The odds against finding a deposit of viable size and grade at the beginning of each phase.

Figure 4: The uranium exploration time scale.

because consideration is seldom given to the acquisition of the basic geological knowledge upon which the discovery was based. Thus many of the important sandstone hosted uranium deposits of the United States were found in regions where previous oil exploration had provided a wealth of subsurface geological information on stratigraphy. In this perspective, to discover uranium resources from new areas (or countries) and make them available by 2010 would require exploration to begin now.

V. CONCLUSIONS

It is be clear that uranium exploration and development are high cost, high risk activities. As with all types of mineral exploration, the players must be willing and able to remain in the game to its conclusion. There is no use carrying out reconnaissance exploration when one has neither the means nor intention of following up the results. If Government organizations enter into the process of mineral exploration they must decide how far they are able or justified to take the process. Frequently government organizations undertake preliminary phases in order to develop background information to attract private investment in the continuation of exploration. If this is the case they will develop means and procedures for getting the information to interested parties. They will also develop terms and conditions under which those parties can operate to mutual advantage. It is not the purpose of this paper to discuss these matters. However, senior levels of government must give careful consideration to them if they wish to have their mineral resources, including their uranium resources, developed in the national interest and to the national benefit. They should not saddle their employees with the impossible task of discovering the country's mineral deposits with inadequate resources and support to carry it out.

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DISCUSSION

Vlasov: What does the speaker think of the high cost of uranium exploration? Is the reason the new modern equipment or is the reason the nature of uranium deposits?

Tauchid: Actually, the cost of uranium exploration is not so high. It also depends on the type of deposit you are looking for. If you look at the history of costs of finding deposits prior to the rich deposits and again at the costs in Saskatchewan or Australia you will notice the difference. In these two cases where rich deposits were found the costs/pound of uranium are quite low. The figures we showed are quite clear on the difference in cost/pound to find lower grade vs. higher grade deposits. People think that they will meet the same costs/pound of uranium but this is not necessarily so for other deposit types.

Money: In Zambia we have been looking for uranium since 1976, initially the Government and followed later by companies. The total cost that has been expended in uranium in Zambia over this period is approximately $70 million. This includes the expenditures of five companies spending on an average of $ 5 million a year. We have discovered a number of small but interesting deposits, but there is no mine yet. This means that the $ 70 million has been spent without end result yet. Three companies have suspended operations now. So the cost is phenomenally high, certainly for a third world country, never mind about Canada or Europe.

Secretary (Smith): I think that this is at the root of the discussion - the fact that the costs are so high. Countries such as yours have got to face the fact that if they want to "get into this commodity", if they have a need for it themselves or wish to enter the world supply market, these are the costs that have to be faced. I don't believe that this commodity is different from others like gold or copper. Exploration is a very high risk business. Uranium is not exceptional - if fact in some respects it may well be cheaper because some of the techniques are easily operated and the signals are sharp and clear, which is not necessarily the case with gold or copper.

Chairman (Fuchs): This is really the topic of discussion: should we do uranium exploration, how should we do it and who should do it. I do not agree that uranium is cheaper to look for. While uranium may be easy to find in traces, it is hard to find an economic deposit because it has to be a big one. The investment costs are tremendously high because we will have to build a chemical factory (to extract the uranium) close to it. For a normal uranium deposit we have to calculate an investment cost of at least $200 million as a minimum, at least in the western world. The exploration has to be done quite thoroughly because before you invest so much money you have to know your deposit. So I believe that uranium belongs to the more expensive commodities rather than to the cheaper ones.

Hemmer: The paper mentions costs of exploration in terms of square kilometres but for developing countries you have to calculate differently because you have to split the costs in a particular way. In these countries the investor has to set up a local office, to provide for the expatiate staff, cars, workshop etc. which are fixed costs regardless of the number of kilometres explored. Then you have overseas fixed costs related to the infrastructure of the company that has to cater for the project and these are fixed costs regardless of square kilometres. Local costs, running costs can be expressed in terms of square kilometres, but you have special things such as airborne surveys and drilling programmes which cost extra so that it is very difficult in the case of developing countries to calculate in cost per square kilometres. It is not the square kilometres that matters but the infrastructure that you have to create regardless of square kilometres.

Chairman: You have to calculate these infrastructure costs in Canada and Australia as well. We have an office in Canada, a car fleet etc. But in some respects you are right because some of the other costs, such as imports and so on are more expensive. Countries interested in attracting investors need to get these costs down and improve these conditions.

Tauchid: I agree, the necessary infrastructure to begin exploration needs to exist, both inside and outside the country. But we use these figures as comparative figures of magnitude for the techniques as a basis for planning.

Verma: We look upon costs a little differently. Since our uranium exploration is linked to the overall nuclear energy programme, we find that if the costs of nuclear fuel is doubled, that is the cost of exploration, mining, fuel fabrication and so on, if these are doubled the effect on the cost of nuclear energy is just 2%. So it does not really matter if we spend a little more on exploration.

Chairman: This brings up the question of the reasons a country wants to do uranium exploration. On the one hand we see India which has an integrated nuclear power programme and so is much more concerned with the supply of uranium as the main factor rather than with the costs of exploration. I assume that the Soviet Union is similar. It is very difficult to compare this situation with countries that want to earn money from uranium. As the paper said, "a country has first to decide what it wants". If we talk about developing countries we really have to stress the point that a country that wants to supply its nuclear power programme is completely different in its strategy from a country that wants to earn money from uranium. These two must be separated in our discussions. For countries that want to look for their own uranium supply, that is a national policy and is not influenced from outside and probably not by the IAEA, either. Talking about policy we have to make this distinction:

Policy -----> strategy -----> infrastructure

Tauchid: We need to provide some reference, however, so that a country that wishes to follow the Indian or the Soviet example will know and understand the consequences of their policy decisions. The Indian experience on costs in relation to the cost of the power programme is useful information for any country that may wish to do the same.

Money: I doubt if any country on the African continent south of Sahara is planning a programme of nuclear power for its own use, other than South Africa, although we are talking of a huge continent. So the primary intention would be the export of a commodity as is the case in Gabon, Niger, and Namibia. That is one group of developing countries. On the other hand you have the heavily populated regions that are still developing and have their own nuclear programmes. To them exploration cost is a very minor component compared to the overall costs that will have to be borne and the overall benefit they are going to derive.

Chairman: As the paper mentioned, policy making is the first thing to define what the country wants - the policy then outlines the strategy and the strategy defines the infrastructure required. That means that for countries that want to explore for uranium to sell, the targets, the geological targets, and the money available to look for the uranium will be quite different than for a country that wants to meet its own needs. So the geological targets are very important to define. To look for uranium that is to be sold on the competitive world market means to look for deposit types which may have a good chance to be competitive in the end. And we have to think from the beginning what targets should we look for, what is our aim and how much money do we have available to reach this goal. So I want to stress again that countries that want to sell uranium on the free market have to be competitive and therefore they have to follow economic rules.

Tauchid: Just to add to that, you may be right for the countries south of the Sahara which are not likely to develop their own nuclear power programmes. But the picture changes drastically when you consider the Middle East and Asia, Syria, Iran, India and so on. All are including in their long term plans the utilization of nuclear power. Since they are members of the IAEA and many do ask for advice on uranium exploration I think it would be misleading if we do not produce something that is useful to them. But I think we have also to show them the consequences of their decisions.

Chairman: Again I think this word "consequences" is very important. What are the consequences we can propose to countries like Syria, Iran, or the Republic of Korea which have big nuclear programmes but hardly any raw material resources; or to any of the other countries that may plan to use nuclear energy within the next twenty years? I still want to stress the point that their decisions must take into account economic considerations. It is better for Syria to buy uranium from Canada if it is more economic. But it still costs money to do exploration and so we must concentrate on what we would consider targets under the present and future

conditions. At the moment I would say it is not useful to look for uranium in phosphates, or calcrete deposits or Rossing type disseminated mineralizations because they will not be economic in the future. It would be better to look for vein type deposits or unconformity related deposits. The targets in such countries should be only those that can produce economic deposits.

Tauchid: The question of economics is very important whether for domestic use or for export. However, if a country already has phosphate deposits, we would be incorrect not to advise the country to look into the possibility of extracting uranium from these deposits particularly if they have a phosphoric acid industry. There is a difference between looking at and exploiting the resources you have. In Pakistan, Mr. Moghul when he was here pointed out the they are exploiting very low grade deposits in Pakistan because that is what they have. So while economics is important, and you cannot extract uranium from granite, but many countries are stuck with the situation of using what they have even if they have to mine 300 ppm uranium.

Müller-Kahle: In this economic assessment there is no black and white, only grey shades. Eventually the same economic laws will apply in USSR, in Pakistan, in China, in the Federal Republic of Germany and in Canada. We are on the way to this point.

Money: Some countries are mining low grade ores at high cost for different reasons. They are forced to do it because they need the foreign exchange earnings that will provide them with other items they need. So even if the local cost of mining may be very high, when the product is sold it is sold for foreign exchange.

Secretary: I agree completely. You cannot look at economics strictly as a cut and dried hard book issue. Each country makes decisions on the economics of this against the economics of that. If you have to work in this way in order to meet the country's requirements then your way is economic isn't it? You have no choice.

CONTRACTUAL ARRANGEMENTS

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Abstract

Conceptually there are a number of different contract models from which a country can select the most suitable for its social, political and economic requirements. These include:

1) the traditional concession,
2) production sharing contracts,
3) service contracts, and
4) equity sharing contracts, i.e. joint ventures

The joint enture arrangement, as it is most commonly used in uranium exploration and mining, is discussed in light of national objectives; geological and technical aspects; infrastructural aspects; and economic aspects. Topics covered include: the exploration phases; the exploration licence; exploration area; minimum exploration commitment; host country investor relationship; financing of exploration expenditures; minerals other than uranium; feasibility studies; taxation and levies; and termination of the agreement.

During the production phase consideration must be given to such aspects as: the operating company; participation ratio; financing of the participation share; export of production; fiscal regime; imports of goods and services; training of local personnel; provision of support by the host country; assignment of rights; duration of contract; disputes and arbitration procedures; decisions making; transfer of technology; safety; environmental protection and compensation; and restoration of sites. These considerations are all discussed, particularly in regard to the joint venture agreement.

The paper emphasises the need, in a successful agreement, for openness and understanding between the parties. No agreement can cover every possible subject that can become a source of disagreement. Only by a sympathetic understanding of each others position and needs can a joint project be successful.

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1. INTRODUCTION

As is the case with many natural resources, uranium activities, including exploration, production and marketing are carried out in an international frame.

In the search for an assured uranium supply, exploration was initiated by a number of organisations in foreign countries as early as the 1950's. Significant uranium consumers in Belgium, the Federal Republic of Germany, France,

the Republic of Korea, Japan, Sweden, Switzerland, UK and USA are importing variable portions of their reactor related requirements.

The development and importance of uranium exploration and production, and their international interrelationship is shown by the following facts. Uranium exploration activities in WOCA (World Outside Centrally Planned Economy Areas) reached their peak in 1979/1980 with expenditures of about US$ 750 million. By 1987 they had declined to about US$ 140 million, or less than 19% of the peak value. The countries where most of the exploration dollars were spent in 1987 included France, Canada, the USA and Australia, but exploration was also carried out in Gabon, Malawi, Niger, Nigeria, Zambia and Zimbabwe. About 50% of the 1987 expenditures were provided by uranium companies based in the consumer countries mentioned above, especially in Japan, FRG and France.

Uranium mining, with a total production of about 36 800 tonnes U in 1987 and an estimated 36 100 tonnes in 1988, takes place in about 18 countries. However, 96% of the total production comes from just eight countries; Australia, Canada, France, Gabon, Namibia, Niger, South Africa, and the USA, while the remaining 4% is produced in 10 countries; Argentina, Belgium, Brazil, India, Japan, FRG, Pakistan, Portugal, Spain, Yugoslavia.

A large part of the uranium mining operations, which supply the WOCA production valued at about US$ 2 500 million, take place at production centres partly or wholly owned by foreign capital.

This international involvement from exploration through mining and marketing creates a need for a sound contractual base, especially in those cases where the ownership rights in the uranium are exclusively vested with the state or, as has recently become the case, with aboriginal groups as in Australia or the USA.

The reader is referred to the relevant contributions by Bourrel, Bulling, Fuchs, Money and Müller-Kahle in IAEA-TECDOC-468 "Contractual Arrangements for Uranium Exploration and Mining" ([2] in the Bibliography).

2. CONTRACTUAL FORMS

Over the years outside capital has had interests in the exploration for all kinds of natural resources located in sovereign countries. This relationship between a foreign investor, who wished to produce natural resources, and states as the sovereign owners of these resources, had to be formalized in legal instruments or contracts. The underlying philosophy of the contract has seen a development reflecting social, political and economic changes in the world. A important achievement of this development has been the declaration of the permanent sovereignty of each country over its natural resources, especially over its non-renewable resources.

There are a number of different contract models from which countries can select the most suitable for its social, political and economic requirements. For the convenience of analysis, the types of contracts are classified under the following headings:

1) the traditional concession,
2) production sharing contracts,
3) service contracts, and
4) equity sharing contracts, i.e. joint ventures

2.1 The Traditional Concession

This form is called "traditional" because it was the customary type of agreement at the beginning of this century. The term "concession" means "grant", which usually covers a large area for a long time, perhaps 50 - 100 years or more. The concessionaire was granted extensive rights in exploiting one or more natural resources, such as timber, minerals or oil.

The agreements concluded along these lines were usually simple. In many cases there were no special laws which needed to be considered and there were almost no other obligations to the host country except to make payments called "royalties" based on the product extracted and exported, and on the land held under concession. This traditional concession had the advantage for the host government that both royalty and surface payments were very easy to levy and that no major administrative organisation was necessary.

The disadvantages included the lack of control by the host government over the land held under concession and the limitation of income other than the royalty and rather nominal surface payments, especially as attempts to establish an income tax system by most of the host countries failed.

These circumstances led to the renegotiation or modification of this type of contract during the period 1940 - 1960. Today, such a model would be considered outdated and unacceptable to any host country, as this type of agreement does not allow the host country to exercise it's full sovereignty over the natural resources of its territory. Whether or not this type of arrangement was ever applied to the uranium industry is not clear. The uranium mined in the Congo under Colonial rule, may have been produced under a concession agreement.

2.2. Production Sharing Contracts

This term describes arrangements whereby the product of the mining operation is divided between the host government and the investor. Production sharing contracts have been employed mainly in the oil industry. However, in uranium exploration, they were the predominant type of contract in the 1960's and 1970's, for example in Bolivia in the mid-1970's.

Parties to the agreement were the now disbanded Bolivian Atomic Energy Commission (COBOEN), a government agency, and AGIP of Italy.

The basic elements of this model are as follows:

- for the Exploration Phase;

  . definition of areas for exploration
  . duration of exploration (8 years)
  . reduction of area
  . budget provision
  . financing of exploration by the contractor.

- for the Development and Production Phases;

  . financing of mine and mill construction by the contractor
  . duration (20 years)
  . production carried out by the contractor
  . production owned by Government
  . production sharing:
    one share to contractor to refund exploration and operational costs,
    remaining share of production is divided between government and contractor according to the following ratios, depending on the uranium deposit mined:

	low grade	medium grade	high grade
Government	32%	52%	68%
Contractor	68%	48%	32%

  . financial obligation: a tax of 3% on the share of production received by the contractor.

Here we see an arrangement, in which the role of the government is already more active than in the traditional concession agreement discussed above. The advantages for the government are:

- it owns the product of the mining operation, without making any investment, or taking any risks,

- it carries out the marketing of its share of production, either within the country, if there is a need for uranium, or on foreign markets, which means that the country retains the sovereignty over its natural resources.

The disadvantages, however, include:

- the necessity to monitor and control the contractor's operational costs. If they are higher than normal, the contractor receives a higher return. The contractor, therefore, has no incentive for a cost efficient operation.

As can be imagined, the main advantage of this agreement, from the Government point of view, is that it receives a raw material supply without any investment or risk taking. The contractor is obliged make all the investment and take all the risk. It is doubtful if this model is applicable to the present day uranium situation, as uranium companies do not feel the need for such a high risk exposure, especially as the lack of any title or ownership on the deposit or production is a hindrance in securing outside financing.

2.3 Service Contracts

This is really a contract type closely related to the production sharing model. If we take the term "service" literally, the contractor should be paid only for his services, either in cash or in kind. In the uranium sector, no example of such a service contract being concluded is available. However, governments have in the past proposed this model to companies, and they are well known in the oil industry.

The features of a service contract are that the contractor finances all the investments and/or operating expenditures. His return, either in cash or in product, will cover the operating costs, including depreciation on the investments made. Apart from this reimbursement of expenses including a profit margin, no further payments are made, otherwise we would have to call this kind of agreement a production sharing type as discussed above.

As stated above, no contract of this type has been known in the uranium industry. There are, however, examples of the operation of open pit iron deposits by contractors, where marketable ore was mined. Their investments were rather small, comprising mainly drilling machines, loaders and trucks.

2.4 Equity Sharing Contracts - Joint Ventures

Finally, we come to the most important contract model, the joint venture, which is widely used in uranium projects in many different countries and situations. It has been proposed to Government organizations in many countries by foreign parties interested in developing their uranium potential.

The meaning of "joint" in "joint venture" is that an activity is carried out by two or more people or parties having equal rights and obligations. The word "venture" has the connotation of "a risky or speculative undertaking". Even though many uranium projects are not entirely speculative, they do have an essential element of risk inherent in all geological exploration activities.

These definitions indicate the essence of the uranium joint venture: shared rights and obligations aimed at minimizing risks and, consequently, increasing the possibility to participate in a larger number of projects and increasing the chance of success.

Since about 1970 a large number of uranium joint venture agreements have been concluded between government agencies and uranium companies, particularly in South America and Africa. An even larger number of joint venture agreements have been signed between private companies that formed such partnerships in order to split risks and expenditures. Here we will be concerned only with agreements made between governments, or their agencies, and private companies headquartered abroad.

Many different legal areas are touched upon in a joint venture contract. As the provisions of such an arrangement must be in agreement with the laws of the host country, it is important that legal specialists in mining, investment and tax laws take part in negotiations. In addition, legal expertise is required in accounting and financing, export and import laws, and in laws and regulations covering the workers' safety and environmental protection.

Legally, the joint venture is not a corporate entity, but rather a group consisting of several independents who have decided to pool their resources in a certain proportion to undertake a project. For the production phase, however, it may be advantageous to incorporate a "joint production company", which will then constitute one legal entity with different shareholders. The reader is referred to IAEA TECDOC No. 468, " Contractual Arrangements for Uranium Exploration and Mining" [2], which includes a listing of essential items of a joint venture agreement for a uranium project.

3. COOPERATION OBJECTIVES

Of the cooperation models reviewed (traditional concession, production sharing, service contract and the equity sharing or joint venture model) the most advanced is the joint venture. It provides an equal basis for all partners, maintains the national sovereignty over mineral resources, and gives the government a chance to participate in the production and profit of the joint venture through its equity position as a shareholder and through taxes and royalties payable by the foreign partner.

It is the obligation of the government through its participating organisation to maximize its profits. Here "profits" are referred to in a wider sense. They include not only financial gains, but also technological, developmental and infrastructural gains. To reach this objective, a political decision has to be made on the national priorities among which may be the following areas:

1) Geological-technical aspects;

- development of certain deposit types,
- introduction of new exploration methodologies,
- acquisition of certain mining and milling techniques,
- development of supporting industries.

2) Infrastructural aspects;

. regional development,
. employment.

3) Economic aspects;

. income,
. additional capital from the foreign partner,
. participation in the uranium trade,
. availability of raw materials for local market.

In general the objectives of the investor are much simpler, and include a return on his investment and/or a long term assurance of raw material supply. It can be observed increasingly that natural resource companies need both ingredients to be interested in a foreign project. The raw material supply alone, without consideration of economics will not, in the long run, suffice for a stable investor - host country relationship.

4. ESSENTIAL SUBJECTS OF A JOINT VENTURE AGREEMENT ON URANIUM EXPLORATION AND MINING

The following is a listing of essential subjects to be included in a uranium joint venture agreement. The list also provides an outline of concepts and recommendations. Additional provisions may be needed to satisfy particular legal and technical situations of the project and special requirements of the parties involved. The list of relevant items is subdivided into the two main activities of a uranium project, exploration and production.

4.1 Exploration Phase

Exploration Phase may include a reconnaissance survey of a relatively short duration, followed by a longer prospecting phase which, in the event of a discovery of a viable ore deposit, may be followed by the construction of a mine and mill.

4.1.1 Exploration licence

Where applicable, licences are issued according to the mining laws of the host country. Exclusivity of operation may not be applicable to the reconnaissance phase, but is needed for the prospecting phase. The duration of the licence depends on type of project (large areas for grass-roots exploration, smaller ones for more advanced projects), climate, planned exploration techniques, etc.

The successful completion of the exploration phase (i.e. the discovery of ore deposit) must lead to the issuance of a mining license upon application. Surface rentals may be required by the host country. Their level should not be too high in the beginning (funds should rather be spent on exploration), but may increase as the project progresses.

4.1.2 Exploration area

The size of the area outlined for the exploration phase depends on the nature of the project, grass-roots or advanced stage, regional or local. The size must be in accordance with the mining law of the host country. These, in general, do not provide for the large areas needed for regional exploration programmes and the application of modern techniques (airborne methods, regional geochemistry).

4.1.3 Minimum exploration commitment

The minimum annual exploration commitment usually amounts to only a fraction of the proposed annual expenditure for an exploration programme and is related to either annual or multi-annual programmes. An increase in such expenditure is to be reflected in accordance with the progress of the project.

Flexibility should be allowed so that excess expenditures can be carried forward to the following year(s), and used to compensate for any shortage in previous years, provided that a minimum annual exploration expenditure level is reached in the year concerned.

4.1.4 Host country-investor relationship

This matter should be decided in the exploration stage. In most cases, a joint venture is agreed upon between the two partners. The host country could either participate financially in the exploration or may request the payment of its share by the investor (see below). Even in this event, the host country must be represented in the technical committee of the joint venture to ensure an early participation in the decision making and supervision of the joint venture's technical activities.

4.1.5 Financing of exploration expenditures

Both joint venture partners could finance the exploration project in accordance with their participating interests. Another alternative, mentioned above, is that the foreign investor provides for the total funding. He will be reimbursed only in the case of success, from the proceeds of the mining operation.

4.1.6 Other minerals

Other metals associated with the discovered uranium mineralization such as gold, vanadium and molybdenum minerals etc. which cannot be mined separately, must be covered by the same agreement. However, other minerals not associated with the uranium mineralization, discovered by the joint venture, and which can be mined separately should be treated in accordance with host country's mining law.

4.1.7 Feasibility study

It is recommended that a detailed list of aspects to be considered in the feasibility study be attached to the agreement.

The following rules apply in respect to decisions to be made following the feasibility study. The concept of "positive" or "negative" is relative and should be weighed carefully as it is dependant on a variety of criteria as time, investment level required, involvement, market conditions, etc.

- Negative or positive for both parties: This should pose no problem. "Positive" in this context means that the investor is willing to proceed towards the construction phase on the basis of feasibility study(ies).

- Positive for host country, but negative for investor: The host country has right to attract a third party after a mutually agreed period. If a third party is found, the investor has the option to participate or assign, provided the assignee is acceptable to the host government and such assignment is accomplished within a specified period.

- Positive for investor, but negative for host country: The investor should have the option to develop the project alone or with third party, for which the assignment clause is applicable.

4.1.8 Taxation and levies

It is necessary for the exploration plan, that all forms of taxation and levies for personnel, services and imported goods be waived, provided such services and goods are brought into the host country for the sole purpose of the activity under this agreement, and are locally unavailable.

4.1.9 Termination of agreement

The investor has the right to terminate his activities year by year after satisfactory fulfilment of all obligations, and has also the right to terminate the agreement giving due notice as provided for under a termination clause.

4.2 **Production Phase**

4.2.1 Operating Company

The production phase includes the actual mining of the ore and the production of a marketable concentrate. To effect this phase an operating company will have to be locally incorporated.

Such an operating company, as the successor of the joint venture, may be a mixed enterprise or the wholly owned subsidiary of a foreign mining company, as the case may be. The criteria for this choice include, the availability of the host government as partner, as well as legal provisions related to the ownership of natural resource companies, liabilities and other implications, such as taxation and marketing.

4.2.2 Participation ratio

The ratio of participation between the host government and the foreign investor is, in most cases, defined according to the local legislation, available resources etc. However, the foreign investor expects to have an interest in accordance with the risk taken by him and his objective in the project (participation in profit and/or supply of raw material).

4.2.3 Financing of participation share

Financing of the mining project may take any of the following forms or a combination of them:

Case 1: Active participation would be in accordance with the participating interest of each partner; financing of such participation consists of equity capital, loans, prepayment for sales, etc. The equity part for the host government may include a free portion, which would be dependent upon the particular fiscal regime and a number of economic and financing factors, e.g. equity capital - debt capital ratio.

Case 2: Automatic participation involves the transfer of shares to the host government up to a level agreed upon by the parties upon recovery of accepted returns of investments by the investor. This concept is considered as the "minimum-take" as for example applied in the Zambian uranium agreements. This is in virtue of the host country's sovereignty over its natural resources.

Case 3: Programmed participation is defined as shareholding in the operating company by the host government through payments for such participation by instalments from the profits of future sale proceeds.

The choice of the options for the host government as regards its participation in the operating company may be influenced by the project's profitability, in addition to socio-economic factors. All implications of the various options should be carefully considered and accepted as appropriate for the particular agreement at a given time.

4.2.4 Export of production

The partners have the right to receive their share of production corresponding to their participating interest. However, the partners may be obliged to make a decision on how to market their respective shares of production after the feasibility stage in order to secure the necessary income for the operating company from long term sales . A mutual right of first refusal to the other partners's production share may be agreed upon.

In general, the host government should agree to unrestricted export of the investor's share of production. However, the host government may introduce a control mechanism to ensure proper sales conditions, acceptable buyers and peaceful uses.

4.2.5 Fiscal regime

This item includes all taxes, royalties, surface rentals, fees, etc. The totality of fiscal obligations must be known at the conclusion of the agreement, as it is of importance for the viability of the mining project.

Both parties, before entering in an agreement, will carry out model calculations on projected costs and returns, under different sets of conditions such as uranium grades and tonnage, uranium prices and the fiscal regime. The objective of this is optimization for both parties, an important ingredient for a successful long term operation. The ideal situation is certainly that of a stable fiscal regime, although many agreements provide for periodic reassessment of fiscal conditions, in the light of changing economics.

The fiscal regime comprises:

- Production related obligations.

  These include royalties, import/export taxes, etc., and have a strong impact on the economics of the project. Where possible facilities to waive or reduce these should be considered especially for the successful implementation of even marginal projects.

- Profit related obligations.

  These include income taxes, corporation taxes etc. Where profits are substantial a higher regime of taxation (excess profit tax) should be considered. This concept balances the possibility of waiving or reducing taxes for marginal projects.

- Tax holidays for a certain period of time should be provided as investment incentive for promotion of projects.

- Reinvestment of profits.

  To promote the development of certain mutually agreed upon sectors of the host country economy, the operating company should be given the option to reinvest all or a portion of the profits which otherwise would be repatriated against granting of tax benefits.

- Surface rentals.

4.2.6 Imports

While accepting local legislation concerning imports, to ensure the successful implementation of the project, it is recommended that no import restrictions be placed on relevant materials and supplies required for the project, provided such goods and services are not available in the host country at comparable price, quality and terms of delivery.

4.2.7 Local personnel and training

Local personnel shall be employed by the operating company at all levels and during all phases of the project, provided, however, that suitable personnel are available.

The operating company should provide both on-the-job training and overseas training facilities for its local employees as appropriate.

4.2.8 Support provision by the host country

In order to facilitate the efficient execution of the project, the host country should provide administrative support for the granting of necessary land rights, work permits, access, power, water, telecommunications, etc. and for the (re-) export of materials and equipment, as appropriate.

4.2.9 Assignment of rights

Provisions should be included in the agreement to allow assignments of rights to an affiliate of the investor. Assignments of rights to third parties, however, should be secured only after approval by the host country, but such approval should not be unreasonably withheld.

4.2.10 Duration of contract

Within the framework of existing legislation, provisions should be made for the granting of a mining licence to the operating company for the duration of the economic life of the deposit(s).

4.2.11 Disputes and arbitration

In order to resolve disputes it is recommended that neutral specialists be used to settle technical disputes in an amicable manner. This concept saves money and time for all parties. However, when disputes cannot be resolved amicably, provisions should be made for arbitration through the International Chamber of Commerce or other mutually acceptable body. The selected international arbitrator should be specified in the agreement.

4.2.12 Decision making

Decision making in important matters, both during the exploration and production phases, may be achieved through simple majority, larger majority or even unanimity depending on the importance of the issue. However, in all cases, suitable safeguards would be required to be made to protect the minority share holder(s). It may be prudent to itemize the issues for which simple majority, larger majority or unanimity is required. Examples of such issues include operating decision, termination of the project etc.

4.2.13 Transfer of technology

Expertise and technology of the parties comprising all fields needed for the production of yellow cake should be transferred without cost to the joint venture or the operating company, as the case may be.

4.2.14 Safety

Suitable provisions for mine and radiological safety must be incorporated into the agreement to protect the personnel and environment. Such safety precautions ought to be in accordance with prevailing international standards.

4.2.15 Environmental protection and compensation

Measures should be included in the agreement to protect the environment along accepted international standards and mining practice. Provisions should be included to provide for compensation to a third party for the loss of use of any convenience or for damage to property.

4.2.15 Restoration of sites

Provisions have to be included so that surface and subsurface disturbances, including contamination of waters caused by the activities under the agreement, be restored or ameliorated in accordance with international mining practice. The cost of this exercise should be provided for by financial provisions made during the lifetime of the operation.

5. CONCLUSIONS

A uranium exploration and mining project needs a number of important ingredients to be successful. These include not only the discovery of uranium mineralization of a size and grade to be minable, but also include a set of legal and social conditions which provide a productive working environment. Nevertheless, the best legal agreement cannot contain provisions for all eventualities. This gap must be filled by the partners' sympathetic understanding of each other's position and needs. Consequently, it can be said that an important by-product of any joint activity is the respect and tolerance of the other partner's requirements and the recognition that co-operation has elements of giving and taking. Only if these are in balance will a joint project be successful.

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DISCUSSION

Chairman: Considering that this paper is a summary of the TECDOC you published two years ago (IAEA TECDOC No. 468, Contractual Arrangements for Uranium Exploration and Mining) have you had any response from any developing country? Did they find the policies suggested too liberal or too strict? (Answer - no replies). Its a pity because we would need to know if this approach would be acceptable to developing countries.

Money: The Zambian PMMC (Prescribed Minerals and Materials Commission) has been discussing contractual formats with countries such as Zimbabwe, Malawi, Tanzania, and certainly they are forming agreements not too different from the structure we have proposed for Zambia. They have taken note of what has been contained in the TECDOC. However, even before this point is reached there is a need for an act or a law in the country outlining the aspects connected with uranium or nuclear materials. Agreements coming after should be based on such a law. This requirement should be reflected in the paper.

Müller-Kahle: Perhaps this is a nice idea from your point of view but from the outside point of view, I think many people are quite happy if there is not such a law which tells exactly what to do because there is then no more flexibility. If the legislation you mention gives enough flexibility, for example in the size of area an exploration permit can cover, then I am definitely in favour. But in many cases it does not and just gets in the way of effective negotiations.

Money: I was not referring to the mining law but rather a law concerning nuclear materials and uranium.

Chairman: Why do many countries still have Atomic Energy Commissions that are responsible for the uranium exploration and mining? This makes it much more difficult to treat uranium as a normal commodity. In the same vein, why do we speak about special agreements and regulations for uranium? When we go to Canada for example we don't need this. We deal with the normal fiscal and administrative environment and work on the basis of existing laws. Most countries have such laws which gives the investor even more flexibility to come and to work under these basic rules, so long as the fiscal and legal regime is well enough developed to allow this (in some countries it is not).

Müller-Kahle: There is one basic legal difference. In many developing countries uranium is vested in the state, while in the USA, for example, uranium belongs to either the federal or state government or even to the farmer who owns the land. But in each case the ownership of the uranium is related to land ownership or, in effect, ownership of subsurface rights. I take a state lease or a federal claim or I make a deal with the farmer. If I proceed with mining then, of course, I have to obey the laws regarding environmental quality, health and safety regulations, and so on. Later on, in the case of export

I have to deal with some control mechanism, such as the Canadian Uranium Export Board. But as soon as uranium is placed under the control of Government then you have to deal with the entity that holds control of this commodity, and that is the state.

Darnley: I don't think there is any country where uranium is treated exactly like any other commodity. Canada may be relatively liberal in its policy but there are certainly restrictions applying to uranium that do not apply to copper or lead/zinc; foreign ownership, for example, and environmental questions and of course, marketing.

Chairman: That is why I raised this question, why do people go to Canada or to Australia to do exploration - because there is relatively little regulation in comparison with Brazil or Argentina, for example. And therefore I brought up this question of the Atomic Energy Commissions; why do these have jurisdiction over uranium mining? If countries want to invite foreign companies to do exploration for the international market, not in the case of India or the USSR where they don't have to compete, but for countries that want to participate in the uranium market, starting from the exploration the Atomic Energy Commission mechanism is definitely a mistake.

Müller-Kahle: We discussed this question at a meeting recently. The view was that the Atomic Energy Commissions are a relict of the past, from the days where uranium was mined for defence purposes. Today they prove to be a problem and a hinderance to effective uranium exploration. And many countries would definitely be better to dissolve their Atomic Energy Commissions, or make them into strictly regulatory organizations, but keeping them away from the practical exploration and mining side.

Tauchid: There is some trend in this direction. In Bolivia, for example, and in Greece, where the Atomic Energy Commissions used to have Raw Materials Groups, these have been entirely removed to other conventional mineral development groups. I want to be clear, however, that I believe that Atomic Energy Commissions have a distinct role to play, particularly on the nuclear research area and in the regulatory aspects. When I speak of separation I speak only of raw materials.

Chairman: This is good to hear. There are other countries where this trend is not so clear. In general it is not necessary or desirable that these things come under the Atomic Energy Commission. It is more important that it be clearly understood that uranium is a raw material which has to be marketed on the world market and therefore there should be as few obstacles as possible.

Darnley: I would just like to make one observation on this subject of Atomic Energy Commissions and their relation to geological work. We don't have anyone here from the United States. But it is interesting to note that in the U.S. all geological programmes related to uranium were carried out by the Atomic Energy Commission and its successor organizations,

until just a few years ago. And whereas there was a reasonable cooperation between the Atomic Energy Commission and the Geological Survey there were certainly areas of friction and disputes over jurisdiction. As an outside observer I think that this division did not benefit the study of uranium in a geological context. And comparing the U.S. NURE programme and the Canadian one, they each had their good and bad points. But I think overall, there has been much more difficulty integrating the U.S. work, on which a great amount of money was spent, into the geological baseline information than has been the case in Canada. So I think that the raw materials aspects of uranium should be dealt with in organizations responsible for all natural resources.

Secretary: I think that this is true. It is perhaps unfortunate that the American example was followed so often by countries around the world, particularly developing countries. It is true that the U.S. is a wealthy country and could afford to support two completely separate organizations doing the same type of work. However most countries are not as wealthy and having two isolated institutions in this way is extremely wasteful of scarce resources.

Vlasov: Of course it is rather difficult to discuss these questions since our country has not had contracts with foreign companies since 1924. I presume that the paper includes the experience of other resources as well as uranium. I would think the ideas presented could be valid for other minerals as well. For us this is new information for the future.

Chairman: May I ask you in this context that, if we have another similar meeting here in two or three years, we would like to have your input, on which points you agree with the approach, or points where you would like to change because this approach did not fit exactly to your situation. Your feed-back would be very important.

Money: Do we have a list of agreements concluded for uranium and what kind of agreements they are - that is so many are joint venture agreements, so many have been concession agreements, and so on. Do we have any such catalogue?

Chairman: We don't. It would be possible to develop an idea of the number of agreements in developing countries, but it would not be possible to give the content of the agreements because this is confidential. My guess is that it would not be more than 30 contracts of all kinds with developing countries.

Money: To follow up on this, in Zambia there is no such thing as an exploration contract nor a mining contract. The agreement concluded spans form the beginning of exploration to the mining stage. The law of the country is such that if you are given a prospecting licence it is mandatory the government has to give you and exploration licence and a mining licence.

Chairman: That is good to hear. In the past this issue has been a very big problem. Often the governments would say - first you find something and then we will decide what the regulations will be, because if it is a marginal deposit the regulations will be quite different that if it is a bonanza. Many negotiations were broken off over this difficulty. Zambia seems to have overcome the problem.

II. THE ROLE OF NATIONAL GEOLOGICAL SURVEYS

THE GEOLOGICAL SURVEY'S CONTRIBUTION TO URANIUM EXPLORATION IN CANADA - A COMMENTARY

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Abstract

This paper reviews the past role of the Geological Survey of Canada (GSC) in assisting and stimulating uranium exploration activities in Canada, and to draw from this some lessons for the future. This is particularly relevant in the expectation that nuclear energy will, of necessity, become of increasing importance in the future.

In Canada mineral resource activities are divided between three jurisdictions: the Federal and Provincial governments and the dominantly privately owned mineral and petroleum industry. Management of mineral resources is a provincial government responsibility. Uranium is an exception, as a consequence of special legislation enacted by the Federal Government in 1942 because of the element's unique properties and strategic importance. This enabled the GSC, as a Federal agency, to make studies of uranium resources, including assessment and the study of deposits, that were not possible with respect to other mineral commodities.

During th 40's GSC participated in early exploration for uranium. In 1951 search for the commodity was opened to private prospectors and this led rapidly to the development of the Beaverlodge, Bancroft and Elliot Lake uranium camps. During this period GSC maintained a watching brief, and undertook research on uranium deposit geology and exploration method development. Exploration method research became particularly active after 1967 with the development of gamma ray spectrometry instruments and methods, and geochemical exploration methods including radon methods. The Uranium Reconnaissance Programme was launched following the 1973/74 oil crisis, and resulted in geochemical surveys mapping the distribution of 8 to 12 elements over 860 000 km^2 and gamma ray spectrometer surveys over 1 590 000 km^2. Information released in the form of hundreds of maps had stimulated many millions of dollars of exploration activity by industry. The data subsequently proved valuable for other commodities in addition to uranium.

GSC provided basic uranium resource information. In addition it encouraged the development of high quality uranium exploration techniques which were subsequently made available to explorationists all over the world through Canada's support of the uranium activities of the IAEA.

1. INTRODUCTION

Throughout this century mineral resources have been of great importance to the Canadian economy. Mineral production (1986, including fuels) accounts for 10% of Canadian GNP, 15% of total capital investment and 20% of all exports. Canada is

the world's leading producer of U and Zn; second in Ni, S, K, gypsum and asbestos; third in Au, Pt group metals, Ti and Cd. Canada, with 9.9 million km^2, is second only to the USSR in land area.

The purpose of this paper is to review the past role of the Geological Survey of Canada (GSC) in assisting and stimulating uranium exploration activities in Canada, and to draw from this some lessons for the future. This is particularly relevant in the expectation that nuclear energy will, of necessity, become of increasing importance in the future. It should be noted that the author is expressing some personal opinions following from 30 years experience of uranium-related work in two of the world's longest-established geological surveys, the British and the Canadian.

TABLE I

Some Canadian Statistics

Geography	
Landmass	9.97×10^6 km^2
Population	25.2×10^6
Population Density	$2.5/km^2$
Value of Mineral Production (1986)*	
Metals	$\$ 8.94 \times 10^9$
Non-Metals	$\$ 4.38 \times 10^6$
Structural Materials	$\$ 2.20 \times 10^6$
Other Minerals	$\$ 0.04 \times 10^9$
TOTAL	$\$15.66 \times 10^6$

* excluding petroleum and natural gas
(from Price, Duke, Findlay 1989 [13])

2. THE DIVISION OF RESPONSIBILITIES

In Canada mineral resource science activities are divided between three realms: the Federal and Provincial governments and the dominantly privately owned mineral and petroleum industry. The universities participate in basic research.

2.1 The Federal Geological Survey--GSC

The work that the Geological Survey of Canada is able to do is defined by its legal mandate. This has not changed significantly since it was formed. The Geological Survey of Canada was founded in 1842 as a colonial government service.

An Act of Parliament of 1845 stated, " ..a Geological Survey of this Province of Canada has been instituted for ascertaining the Mineral Resources thereof". The function of the staff as defined at that time, "..to make an accurate and complete Geological Survey of this Province and furnish a full and scientific description of its Rocks, Soils, and Minerals, which shall be accompanied with proper Maps, Diagrams, Drawings together with a collection of Specimens to illustrate the same", differs, at first sight, only in detail and relative simplicity from what might be written 143 years later. In fact GSC has responsibilities ranging from earthquake prediction and the provision of advice on underground waste disposal to off-shore permafrost mapping. Mineral resources are only one of its many concerns.
In the context of mineral resources it is of interest that, although the two above quotations are taken from the same paragraph, the wording indicates that from the foundation of the Geological Survey there was an element of inconsistency between its objective and the prescribed methods. "Mineral Resources" implies an economic connotation, a need to consider economic viability. In contrast a geological survey, as defined, emphasizes scientific description. As with many other Geological Surveys stemming from the British root, there has thus been some difficulty in reconciling the government expectation that the organization exists to quantify the mineral resources of the country whilst at the organizational level it functions by providing scientific data and remaining at arms-length from economic investigations.

It might seem, in theory at least, that the most efficient way to undertake mineral resource assessment would be to undertake systematic exploration but this has never been adopted by the Geological Survey of Canada. This stems both from national political philosophy and the very practical consideration that the cost to public funds would be unsustainable. Although there have been both Federal and Provincial government owned mining companies, mineral exploration in Canada has traditionally been undertaken by private individuals or companies. and they have been responsible for providing primary information concerning ore reserves, except for uranium as discussed below.

In practice the prime function of the Geological Survey of Canada has been to provide geoscientific information (Price, Duke and Findlay 1989)[13] . Government requires impartial information in order to decide upon resource management policies and matters of public safety, whilst different groups within the population at large use geoscientific information for a wide variety of economic, environmental safety and recreational planning purposes. It should be emphasized that from the beginning it has been a "given" that the results of GSC's scientific work should be public information. This has facilitated the recruitment of high calibre scientists who want to be able to publish work under their own names. Conversely this principle has contributed to the organization's reluctance to become involved in narrowly defined economic investigations which necessarily often involve confidentiality because of the private ownership of mineral resources.

Another major consideration constraining the scope of the survey's work on mineral deposits and involvement with mineral exploration in general has been the fact that in Canada, arising from the 1867 constitution, management of mineral resources is a provincial government responsibility. The one exception pertains to uranium, as a consequence of special legislation enacted by the Federal Government in 1942 because of the element's unique properties and strategic importance. This special legislation enabled GSC to take initiatives with respect to uranium resources, including assessment and the study of deposits, that were not possible with respect to other mineral commodities. This activity continues to the present day.

The Geological Survey of Canada spent approximately $10 per km^2 in 1987 on all aspects of its work (including off-shore), which is about $4 per capita of the Canadian population, or 0.3 cents per dollar of the mineral industry's total production value. In 1987 the scientific, technical and administrative support staff of GSC totalled about 1000 people.

2.2 Provincial Geological Surveys and Industry

In a large country it is desirable to have regional geological survey offices in order to make geological information readily available to the public and local government. GSC has regional research centres on the east and west coasts with prime responsibilities for the off-shore. Its main centre for hydrocarbon related geology is in Calgary, Alberta. Given the size of the country these are insufficient to serve the public, and the existence of eleven independent geological survey organizations, one in every province (except Prince Edward Island) plus two in the Territories fills the gap. The autonomy of the provincial and territorial organizations might seem a source of problems with respect to the division of labours and duplication of efforts. These have occurred in the past but co-operation has greatly improved in recent years through the establishment of the National Geological Surveys Committee in 1979 and related sub-committees which coordinate programmes. As a generalisation, provinces take responsibility for geological mapping at 1:50 000 scale, concentrating in areas of economic importance, whilst the GSC provides a national geoscience overview at 1:250 000 (including geophysics and geochemistry).

In practice the division of resource related activities in Canada, with two levels of government agencies (Federal and Provincial) providing essential scientific information and industry performing actual exploration work, has served the country well. Despite growing understanding of the phenomena controlling ore formation there are still many uncertainties, demonstrated within the past two decades by the discovery of new types of mineralization in unexpected locations e.g.Olympic Dam, Australia; and the Athabasca basin and the Hemlo gold deposits in Canada (Darnley 1987)[3]. There is still a strong element of unpredictability in mineral exploration. By encouraging a large number of independent

organizations to be engaged in mineral exploration, many different hypotheses can be pursued simultaneously in many locations. There is no "short-list" of officially approved target areas. A large monolithic organization would be unlikely to permit several conflicting and possibly heretical theories of ore formation to be the basis for its exploration expenditures. The historical record demonstrates that important exploration successes have occurred in situations which have surprised many contemporary experts.

3. GSC'S GENERAL SCIENTIFIC ACTIVITIES

GSC's 1987 organization structure is shown in Figure 1. Since the first geological surveys were founded early in the 19th Century, geological mapping has been accepted as their main activity. In 1950, after 100 years work, less than 25% of Canada had been mapped because of the country's size and the difficulties of surface travel in much of the interior, . The situation changed dramatically during the 1950's with the introduction of helicopters for the transportation of field geologists. This resulted in the virtual completion of reconnaissance geological mapping (at 1:250 000 scale) by 1975. The geologically recent glaciation of the country creates special problems from the point of view both of geological mapping and mineral exploration. In some parts of the Canadian Shield and Cordillera fresh rock exposures are numerous. Unfortunately there are other large areas where unconsolidated post-glacial materials totally obscure bedrock. For the past 30 years mapping of these surficial materials has been carried out by separate teams of specialised Quaternary geologists.

The wartime development of airborne magnetometers for submarine detection led to experiments with the equipment for mapping purposes in the late 1940's. These quickly demonstrated that aeromagnetic surveys were very useful as a means of locating concealed magnetic ores and as an aid to conventional geological mapping, especially where outcrops were scattered or non-existent. During the 1950's the Geological Survey operated its own aeromagnetic survey aircraft and commenced systematic coverage of the country.

The mineral potential of a region can only be reliably determined by exploration work; industry's willingness to undertake exploration is greatly encouraged by the provision of exploration related reconnaissance data compiled into maps and reports which delineate areas favourable for mineral discoveries. This information focuses industry attention and expenditures, and discourages efforts in areas where current knowledge and technology produces negative results. It assists industry to function more efficiently.

The mineral industry was sufficiently impressed by the usefulness of the aeromagnetic maps produced to persuade both the Federal and Provincial governments to provide more funding. This resulted in the rate of coverage being greatly accelerated from 1961 onwards. Since this was seen as a production and not a research operation the task was

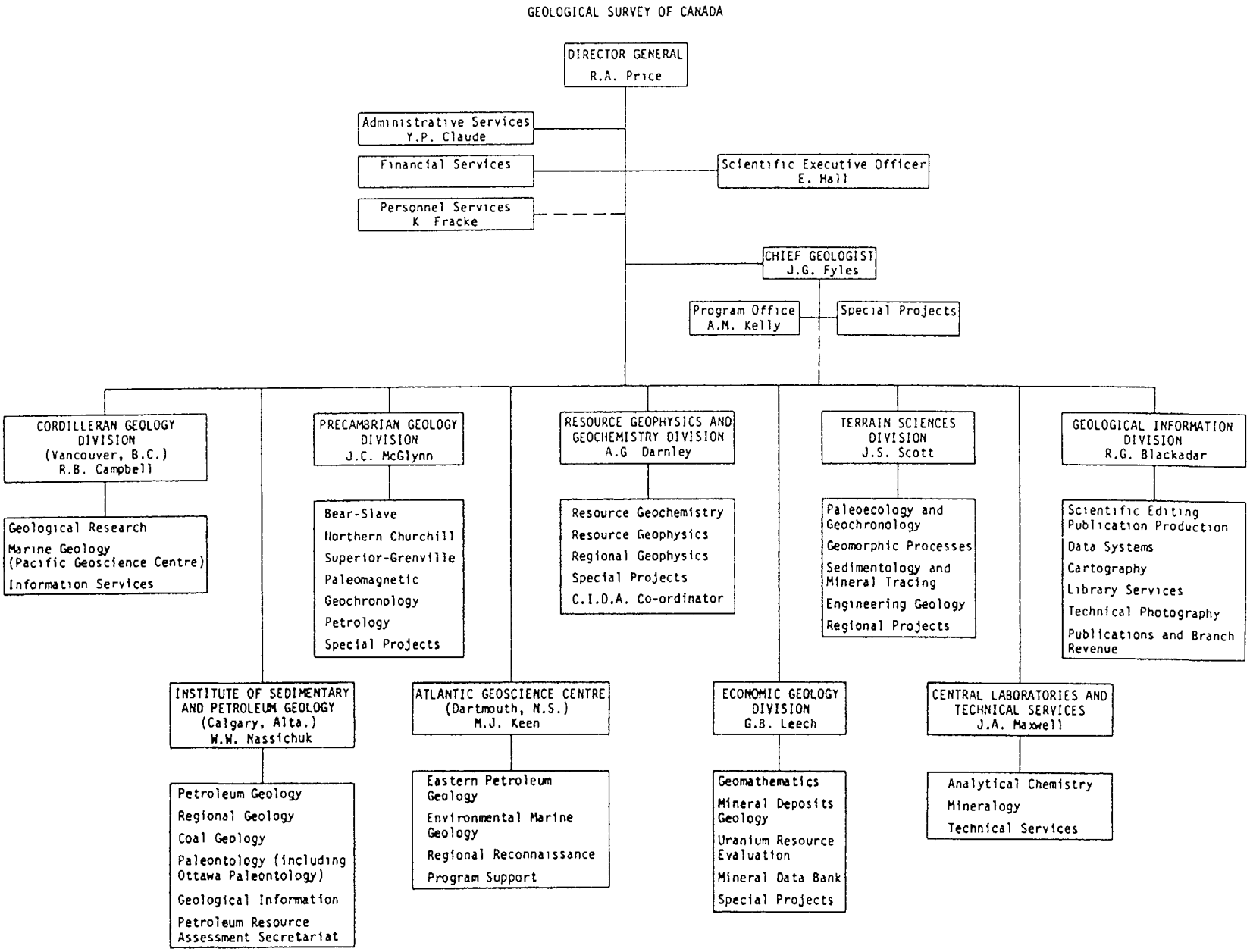

Figure 1: Organizational Structure of the Geological Survey of Canada During the Period 1972 - 1986.

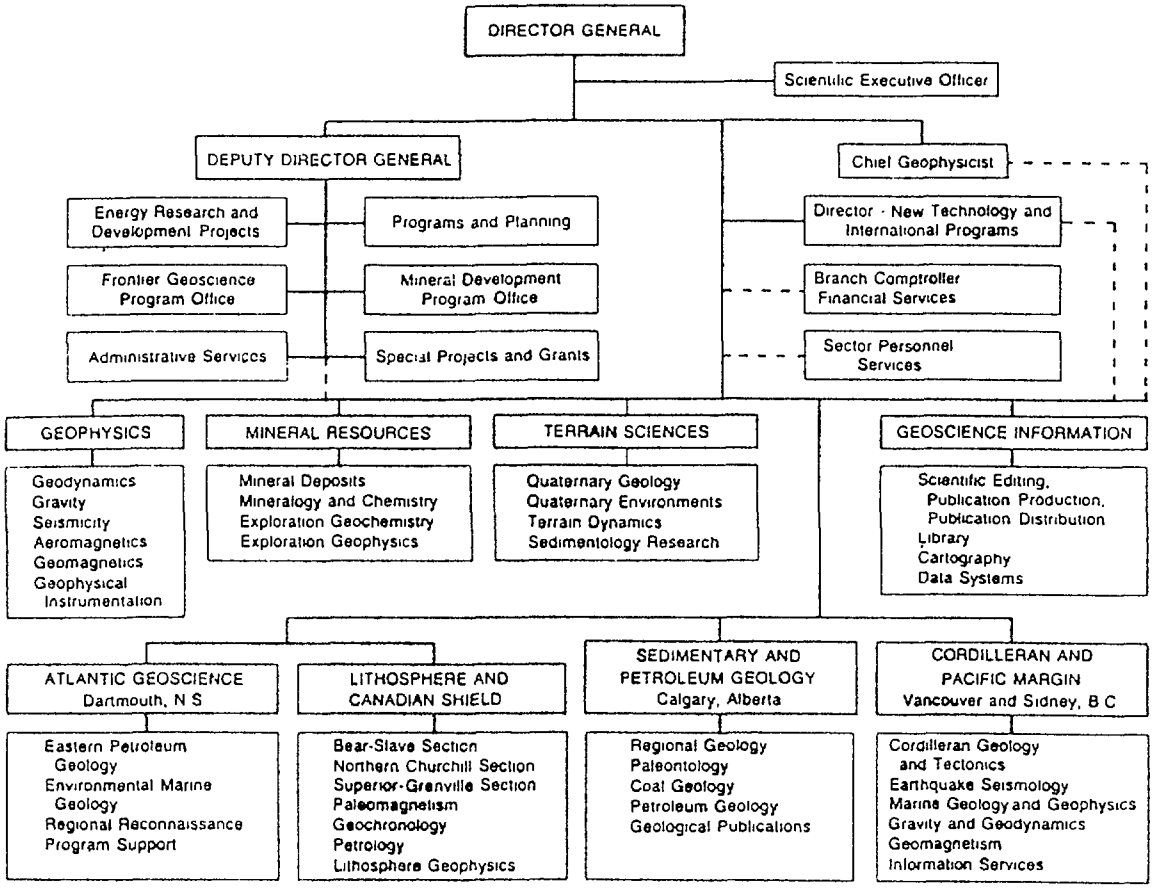

Figure 2: Present organization of the Geological Survey of Canada.

transferred to industry. As a consequence of its experience in operating its own aircraft and equipment, the Geological Survey, was able to write comprehensive but realistic specifications to allow for execution of the work by private contractors. Geological Survey staff became responsible for inspecting the quality of the contractors' work to ensure that consistent national standards could be maintained.

From the mid-1950's and through the 1960's there was a steady expansion of the more fundamental research-related aspects of geological survey work. In retrospect these were "golden years" for government science establishments in Canada. New scientists in new specialisations were recruited, novel equipment was bought, new activities were launched. Optimism was in the air. A large investment was made in applied science, which paid its dividends in the following decade. In the Geological Survey this was the period when isotopic age determination methods were established, electron microscopy revolutionised mineralogy, and work began on the development of new exploration methods and technologies. The activities commenced during this period led to the development of the aeromagnetic gradiometer, quantitative airborne gamma-ray spectrometry and regional geochemical survey techniques. A key aspect of these developments was the attention paid to the development of measurement standards and procedures, which subsequently made it possible to achieve quantitative reproducibility from area to area and from year to year--essential for the conduct of systematic surveys.

The need to develop these techniques arose independently in the minds of several researchers, encouraged by the management of the time. The underlying motivation was recognition of the fact that new technologies would open the door to new types of geoscientific survey, which would be objective and capable of seeing many features invisible to the eye of geologists traversing difficult terrain. Geological maps would provide a reference for the new data, but the new methods would be more directly relevant to the problems of finding non-obvious mineralisation in little known terrain.

By 1971 it was clear that the R&D work on two of the new methods of geoscientific survey, sediment geochemistry and high sensitivity gamma ray spectrometry had shown that they were viable for Canadian conditions, and ready for extensive application. Unfortunately the government science budget had ceased to expand and the prospects for introducing new techniques into routine government practice were not good.

4. GSC'S URANIUM-RELATED ACTIVITIES

Like many other geological surveys, GSC first became involved with questions of uranium supply in the mid-1940's. For the next 20 years this involved the examination of many occurrences, detailed mapping in the principal uranium districts such as Elliot Lake and Beaverlodge, and related laboratory investigations. Questions of ore genesis were addressed and produced some well known studies. The Uranium Resources Evaluation Section has been and continues to contribute to Canada's submission to the OECD-NEA "Red Book" on world uranium resources (Darnley, 1987)[3].

At the beginning of the 1960's interest in uranium had waned, but it began to recover slowly with the introduction of civilian nuclear power plants in several countries. GSC's development of airborne gamma ray spectrometry during this period was done partly in anticipation that it would become a powerful tool for uranium exploration, and partly because it was recognised that it would complement aeromagnetics as an aid to geological mapping. Research was also done on uranium in water and sediment, and radon analysis methods specifically in anticipation of renewed interest in uranium exploration.

4.1 The Uranium Reconnaissance Programme

The oil supply crisis of 1973/74 provided the opportunity to launch, on a systematic basis, some of the new types of geoscientific survey which had evolved over the preceding decade. There was a high level of media and public concern about the energy situation, particularly as the Club of Rome's forecast about impending global resource shortages had been published in the previous year (Meadows et al, 1972)[10]. The government was ready to consider requests for proposals that would guarantee alternative energy sources. Since a rapid expansion in the use of nuclear energy was anticipated it was logical to seek more information about potential uranium resources and to encourage industry to do more exploration.

The GSC proposed a small increase in the staff carrying out uranium resource appraisal, involving examination of existing mines and radioactive mineral occurrences reported by private exploration companies, and a substantial budget increase to launch systematic uranium surveys. The latter were to be carried out by airborne gamma ray spectrometry and by more conventional laboratory analyses of stream and lake sediment, and water samples. Initially there was provision for the airborne survey to undertake electromagnetic measurements simultaneously with gamma ray spectrometric and magnetic measurements. Regrettably this did not happen for a combination of technical, administrative and financial reasons.

The model for this new mapping programme was the Federal-Provincial Aeromagnetic Survey Programme, referred to above, which had been launched in 1961. It had developed into a nation wide mapping activity performed by private companies under contract to GSC. Accordingly, specifications based on the experience acquired over several years of actual operations by GSC staff were prepared so that the various components of the new programme could be performed by contractors. One of the conditions of provincial government participation was that the geochemical analyses should not be restricted to uranium. There was considerable internal discussion as to what its name should be to avert possible adverse reactions from some sections of private industry and some provincial organizations. It was eventually named the Uranium Reconnaissance Programme and was administered by the Resource Geophysics and Geochemistry Division (see Figure 1 which shows GSC's organization structure during the period 1972-1986). It received Federal funding in 1975 and joint Federal-Provincial funding beginning in 1976, two and a half years after the high point of the energy crisis. Its formally stated purpose was "to provide industry with high quality reconnaissance exploration data, to indicate those areas of the country where there is the greatest probability of finding new uranium deposits, and to provide governments with nationally consistent systematic data to serve as a basis for uranium resource appraisal". For a statement of its component parts see Appendix 1. There was also provision for small follow-up parties to be established to undertake ground investigations of a few selected anomalous features found in the course of the surveys, in order to substantiate and describe them and provide better interpretation criteria. In the case of the conventional geochemistry surveys these parties would carry out limited orientation studies in order to better define the specifications for the routine work to be carried out by contractors in a later year.

The programme was to be completed in 10 years at cost of $25 million (1975 value). Although as already indicated it was intended to include other geophysical techniques to provide structural information (and in its concluding stages did so), it was essentially a national geochemical reconnaissance programme, because it provided data with much broader applications than to uranium alone.

Although inspired by the success and utility of the longer established aeromagnetic survey programme, the URP differed from it in one important respect; the density of coverage (i.e. flight line and geochemical sample spacing). The standard aeromagnetic specification required flight lines at 0.8 km (0.5 mile) spacing and 305 m (1000 ft) terrain clearance. This was to allow good definition of any near surface magnetic body with a strike length of the order of 305m.

Some time after the aeromagnetic programme had been launched it was recognised that there are magnetic features in the crust with much longer strike length than most mappable geological units. Because of their continuity these features are traceable with line spacings much wider than the 0.8 km adopted. With this in mind GSC conducted airborne gamma ray spectrometer surveys in 1974 and 1975 at 50 and 25 km spacings respectively, and demonstrated that there are some radiometric features with continuity in excess of these distances. However since their significance from an exploration point of view was uncertain at that time it was decided to compromise and fly the URP radiometric reconnaissance with 5 km line spacing This spacing searches approximately 5% of the land surface.

One sample per 12.5 km^2 was adopted as the standard for the geochemical surveys, based on studies of the hydromorphic dispersion of uranium.

The justification for these measurement intervals was based on the premise that most uranium deposits occur within or marginal to areas of the crust containing higher than average amounts of uranium. It recognised that uranium tends to be found weakly concentrated in granitic rocks, especially those late in the orogenic cycle (or in anorogenic cycles). In these areas uranium tends to be concentrated in high temperature pegmatites or in lower temperature veins. Together these are components of a primary source which through reactivation and/or erosion and redistribution can provide source material for enriched secondary deposits in a variety of possible adjacent geochemical traps.

The reconnaissance programme was designed primarily to identify all zones of primary enrichment within the country, and secondly to indicate, if possible, the limits of areas where secondary processes have operated.

> "It is important not to dismiss anomalous areas as simply being low-grade igneous rocks of no economic importance. Such areas may have considerable potential as source areas, and geological knowledge must be brought into play to determine where the eroded material from these sources has been deposited. It is the first objective of the Uranium Reconnaissance Programme to delineate as rapidly as possible the major areas of uranium enrichment in Canada. There is reason to believe that there are more of these than are generally known at the present time. " (Darnley, Cameron and Richardson 1975)[6].

4.2 Results of the Uranium Reconnaissance Programme

By 1978 the energy crisis of 1973 had faded into memory and there was growing public unease about the long term environmental consequences of using nuclear energy, particularly the problems of waste disposal. It was becoming a less desirable energy option. Private industry had greatly expanded its exploration activities compared with 1973/74 and government wished to cut expenditures. A programme labelled Uranium Reconnaissance was no longer needed, and a decision was taken, at a level higher than the Geological Survey, to terminate it at the end of the 1978/79 financial year. Perhaps if had been labelled National Geochemical Reconnaissance it might have survived unscathed.

It had resulted in geochemical surveys mapping the distribution of 8 to 12 elements over 860 000 km^2 and gamma ray spectrometer surveys over 1 590 000 km^2. The information released in the form of hundreds of maps had stimulated many millions of dollars of exploration activity by industry. Many new occurrences were located and examined. Ironically, because the main discovery area for new uranium deposits proved to be the Athabasca and Thelon basins (which are outlined by the geochemical surveys as large "lows" abutted by "highs" in Darnley, 1988 [4]), the main economic benefits arose from the incidental discovery of other elements, which continue to the present time. Uranium has proved to be an important pathfinder for other commodities, such as rare earth elements, tin, and some types of copper and gold mineralisation. The analyses for other elements besides U, which were part of the conventional geochemical surveys, subsequently led to the discovery of base metal deposits. Changes in U:Th ratios have proved to be important indicators of late-stage and hydrothermal alteration (Darnley and Ford 1989)[5].

4.3 The Athabasca Project

The Athabasca Project commenced as the Uranium Reconnaissance Programme finished. It had been conceived in 1978 because of the great concentration of exploration interest in the Athabasca basin and worldwide curiosity both about the nature of the deposits and about optimum exploration techniques. Fortunately funding for this project was not tied to the URP.

As a general observation, ore deposits seldom occur in isolation and there are usually many sub-economic occurrences in the vicinity of each ore deposit. The Athabasca basin provides a good demonstration of this truism. In such circumstances it is particularly useful to undertake research to try to establish the geological, geophysical and geochemical characteristics, and if possible the origin, of such a family of ore deposits, and use the information to facilitate the search for more ore bodies of similar type.

In 1976, at the IAEA/NEA Symposium on Exploration for Uranium Ore Deposits, a working group recommended that test sites be established "of known geology and mineralization, where the efficacy of individual techniques or exploration

systems could be subjected to field trial". This was the trigger for the establishment of the Athabasca Test Area, a 1200 km^2 rectangular block on the eastern margin of the Athabasca Basin.

The results of this work, which took place over three years and involved the use of many different methods, have been published in Uranium Exploration in Athabasca Basin (Cameron 1983, editor)[1], and in Uranium Exploration Methods (OECD/NEA,1982)[11]. The latter volume also contains papers on related parallel studies in other countries.

Although the Uranium Reconnaissance Programme was terminated prematurely in 1979, the systematic surveys that it launched continued, at a reduced pace, until 1984, supported by GSC's research budget. A new source of Federal-Provincial funding was then introduced for the purpose of encouraging economic growth in the less wealthy parts of the country. This contained provision for both airborne gamma ray spectrometry and conventional geochemistry surveys. Gold became the main object of the search. Uranium continues to be measured and mapped as a matter of course, together with a much wider suite of elements than in 1975-79. The methods developed for Canadian use have been adopted for use outside Canada in support of international technical aid projects. Figures 3 and 4 show the present (1988) extent of systematic geochemical surveys of Canada.

5. LESSONS FOR THE FUTURE

The following points may be helpful to those concerned with the design of mineral exploration programmes in developing countries.

1) Programmes designed to find individual commodities, such as uranium, will not be effective without a comprehensive geoscientific data base. Therefore, a national geological survey should provide comprehensive information appropriate to the geology and geography of the country. It should be designed to facilitate exploration for all commodities that might conceivably exist, not just those that are in current demand. The data base should be periodically upgraded because new and/or more sensitive techniques become available and concepts change. Continuity of work is essential in order to maintain and benefit from the cumulative investment in knowledge which, with good management, steadily increases in value. A comprehensive high quality data base greatly encourages exploration by industry. It should include all aspects of the earth sciences, geology, geophysics, geochemistry, mineralogy etc., since all are needed to discover and exploit mineral deposits. The best way of ensuring high quality data is to ensure that it is systematic, is fully documented and is compatible with recognised international standards. Government organizations are normally the best equipped to maintain the standards and continuity required.

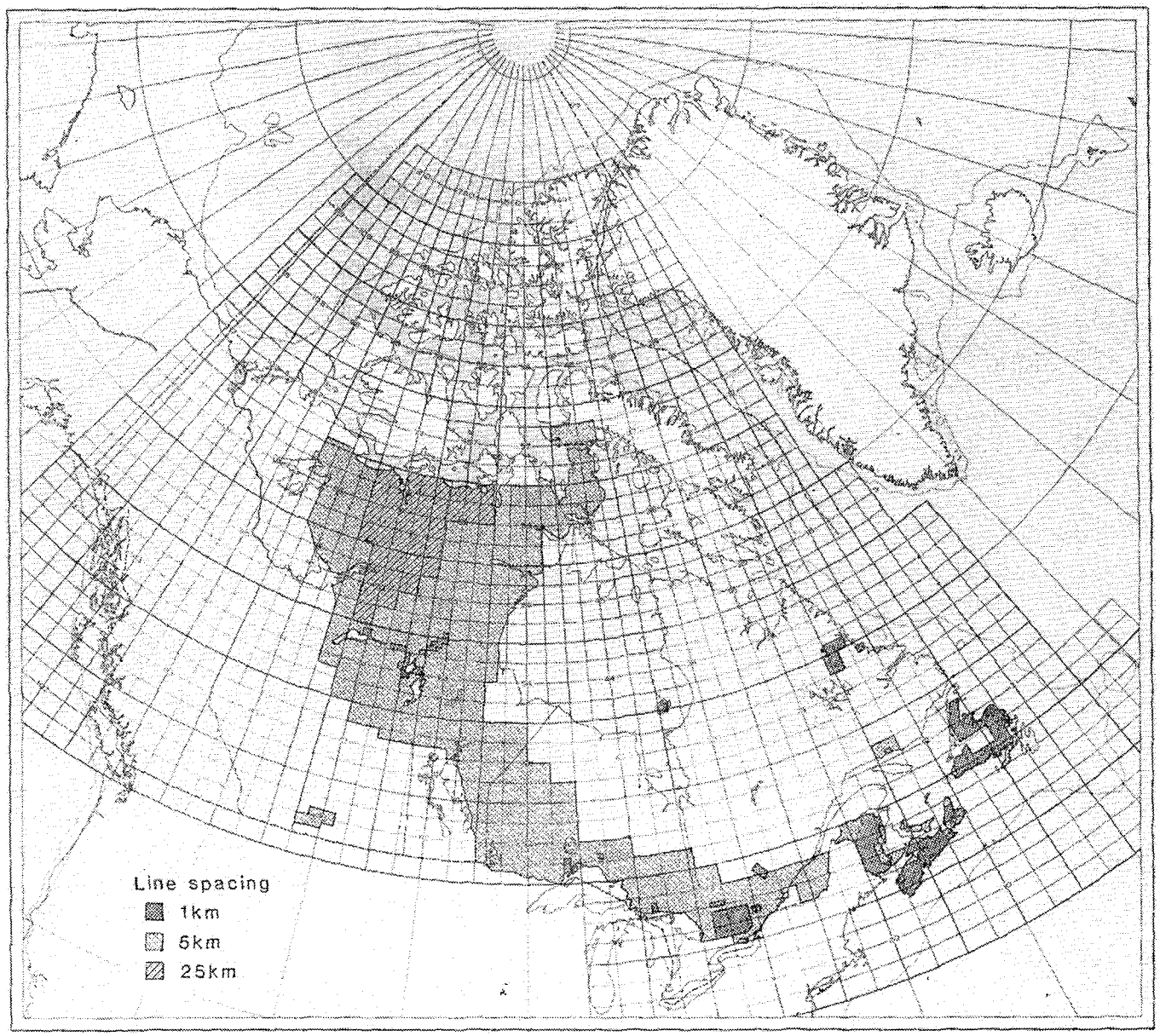

Figure 3: Airborne gamma ray spectrometer coverage of Canada up to 1988.

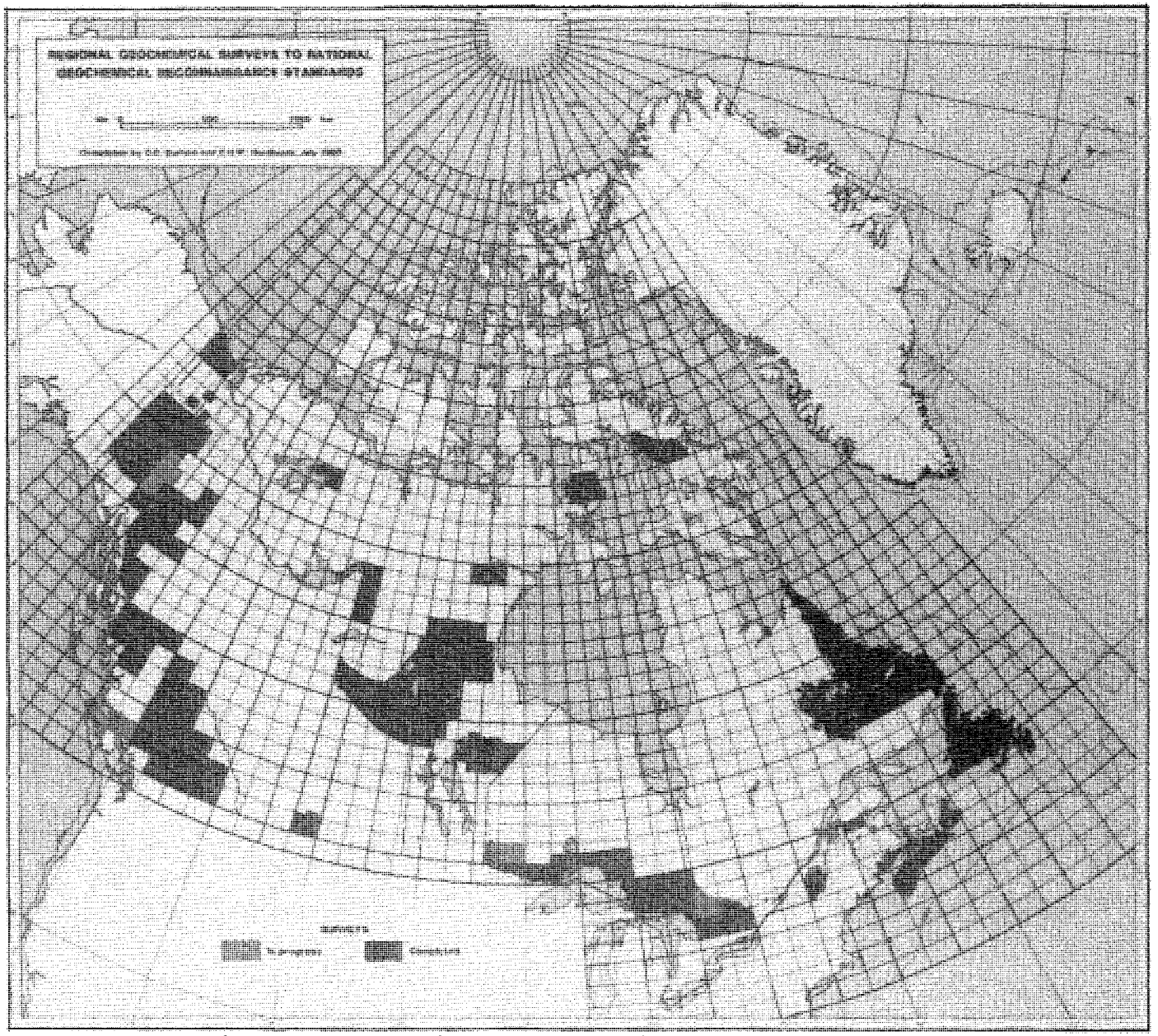

Figure 4. Reconnaissance geochemical survey coverage of Canada up to 1988.

2) Resource exploration requires the use of more techniques than traditional geological mapping - it is necessary to use methods which are capable of recognising features which are not apparent to the naked eye or may not seem significant to the nonspecialist. Many older geological maps were often prepared for general purposes and do not record mineralisation indicators, such as the presence of fine grained disseminated sulphides, clay mineral alteration zones, redox features in sediments etc. Thus exploration must delineate and identify, wherever possible, rocks and structures not exposed at the surface, and point to unusual chemical or mineralogical properties or variations in properties.

Appendix 2 outlines some of the techniques that may be used in systematic resource exploration.

3) Mineral deposits have always been difficult to find in terms of the knowledge and techniques available at any given time in history, and they always will be. For this reason there must be continuing field and laboratory research into improved methods of exploration and the causes of ore formation. Unconventional thinking should be encouraged. Rigid preconceptions about where ore deposits may be found can be unproductive. Current knowledge and theory may point to certain areas having either large or small potential, but scientific understanding of mineral formation processes is incomplete. New exploration environments are still being recognised.

4) Most ore deposits are associated with either rare rock types, structural breaks, fracture intersections, or changes in lithology. These cause physical or chemical discontinuities or anomalies, and so are amenable to discovery by some combination of area search, geophysical-geochemical-geological survey techniques. Every ore deposit is an unusual concentration of one or more valuable elements, and therefore every orebody constitutes a geochemical anomaly, usually with some degree of dispersion. In new or unfamiliar exploration environments it is wise to experiment with a wide range of possible techniques under well controlled conditions in the vicinity of known mineralisation before deciding which methods are most effective for further discoveries. Such experimentation can be costly and is therefore best done on a cooperative basis using the combined resources of government, industry and universities.

5) It is possible to economise in the conduct of exploration work by undertaking surveys in two or more stages, commencing with low density reconnaissance over the whole area, followed by more detailed surveys over parts of the original area. At the conclusion of each stage the results are evaluated and those areas considered to have the lowest mineral potential in the light of current knowledge are eliminated from further work. Since more detailed and expensive methods are applied at each successive stage the selection process must be done with care.

6. CONCLUDING REMARKS

The provision of reconnaissance data by government has been the basis of Canada's outstandingly successful record in mineral exploration and mineral production. Governments have provided high quality exploration oriented geoscientific data to attract industry investment. Industry has responded by using published, readily available, government data as a starting point for detailed exploration work. The demand for different commodities in the international market-place is cyclical and changes over the years. It is a matter of observation that, in general, government organizations have more continuity and are therefore better able than industry to make and preserve long term investments in knowledge and information, whilst industry has more incentive and flexibility to use the information efficiently and quickly.

A comprehensive earth science data base, designed with the special needs of mineral resource exploration and assessment in mind, with careful quality control to ensure that the data conform to international standards, is the basis for rational long term development of mineral resource wealth. The growth of the Canadian mineral industry over the past 40 years provides a good example of the benefits which can accrue to a national economy as a result of the provision of systematic, increasingly comprehensive, public information.

The latest methods of data acquisition, compilation and integration make it much easier to work now towards comprehensive resource evaluation than was the case when geophysical and geophysical techniques first began to be applied to large regions. High quality data have an indefinite life and can be used and reused as theories of ore formation and resource evaluation evolve and new methods of interpretation are developed.

A final comment with respect to the future importance of uranium exploration. The world is suffering from an expanding population, with rising but unsatisfied expectations in terms of possessions and living standards, This is placing increasingly destructive stress upon the natural environment.

A major contribution towards arresting this potentially disastrous trend, will be for the world's population to have access to ample affordable energy, without causing unmanageable pollution. Hydrocarbon combustion gives rise to the greenhouse effect and acid rain, and therefore must be progressively reduced; solar, wind, gravitational and geothermal energy are geographically restricted and therefore limited in availability. Nuclear energy, the waste from which can be contained, appears to provide the only viable solution for energy base load requirements. Hence there is a high probability that it will be necessary to ensure an increased supply of nuclear energy raw materials. Geological Surveys need to ensure there is a systematic, comprehensive data base for resource exploration.

APPENDIX 1

THE CANADIAN URANIUM RECONNAISSANCE PROGRAMME

The programme approval document for the Uranium Reconnaissance Programme listed the following activities (Darnley, Cameron, Richardson 1975)[6]:

1) "Airborne gamma ray spectrometry will be undertaken over all areas of relatively flat topography where there is some outcrop and generally thin overburden. High sensitivity equipment will be employed with a specification similar to that developed by the Geological Survey and proved in use over the last six years. Line spacing for reconnaissance purposes will normally be 5 km. In areas which are rather remote and may not be reached by the main programme for a number of years, some advance reconnaissance work will be done at very wide spacing, for example 25 km, in order to assign priorities for later work. Airborne gamma ray spectrometry will be used principally over the Shield although coverage may be extended over some adjoining areas, and over other parts of the country where the topography is not so rugged as to prevent effective coverage by fixed wing survey aircraft."

2) "Regional geochemistry will be used primarily in mountainous areas, in areas with extensive overburden, in selected areas which are considered particularly favourable for uranium occurrence, and in some areas where the potential for other metals is equal to or greater than the potential for uranium. Regional geochemistry will be based upon stream sediment, lake sediment, or bedrock analysis. Sample spacing will normally be in the range of one per 12.5 km^2 to one per 25 km^2."

3) "Hydrogeochemistry will be carried out wherever possible as part of the regional sampling programme. In addition, this technique has a unique application for the analysis of subsurface waters from aquifers to detect possible uraniferous horizons in flat lying sediments, or below thick overburden."

"Results from this programme will be published as rapidly as they can be compiled. They will be made available simultaneously by the Federal and Provincial authorities, following the established practice of pre-announced timed release."

APPENDIX 2

SYSTEMATIC RESOURCE EXPLORATION - AN OUTLINE

The basic requirements for systematic resource exploration, both regional and detailed, are: up-to-date topographic, geological, geophysical and geochemical maps. Much other supplementary information, for example about ancient mineral workings, is of course important if it is available. Nearly all countries have some existing topographic and geological maps which can serve as a starting point for revision. Current topographic maps are an essential prerequisite for any exploration programme.

Geological maps provide the matrix upon which other quantitative geoscientific information is assembled. In developed countries these have usually been available prior to the start of geophysical and geochemical work. If they are not available, satellite imagery combined with low level airborne multi-sensor reconnaissance data can be used to enable a preliminary geological map set to be prepared in parallel with other compilations.

For geophysical and geochemical data collection, airborne methods are preferred wherever possible because they are rapid, cost effective in terms of cost per unit area, and provide quantitative as well as qualitative data for interpretation. Unlike ground operations involving many field parties, the use of aircraft reduces the number of participants and makes it easier to obtain a uniform product with consistent data.

Geochemical surveys, other than those based on radioactivity measurements, require ground contact. Helicopters may be used for transportation between sample sites if the terrain is suitable, both to accelerate and facilitate consistent work. As with geophysical surveys, because geochemical surveys produce quantitative data, procedures can be applied at every step to maintain quality control.

Geophysical Methods

Geophysical methods provide structural and some lithological information about both concealed and exposed bedrock; they have the ability to penetrate the surface; they can be a direct pointer to ores that are magnetic and/or conductive. The methods which are most widely used in regional exploration are:

Aeromagnetic: the longest used and most general purpose geophysical mapping technique; this has deep penetration and can be used over land or water to delineate major faults and rocks on the basis of their magnetic properties. It pinpoints magnetic iron ores. Not all rocks are magnetic, so it is most useful for mapping metamorphic and basic igneous rocks which form shield areas and underly sedimentary basins. For a general review see Hood et al.(1979)[8].

Airborne Electromagnetic (AEM): this method, which measures the electromagnetic response of the ground to an electromagnetic transmission from an aircraft, picks out conductive bodies or zones. These may be caused by massive sulphides or graphite. It can map the surface conductivity of the ground, which usually reflects changes in clay mineral content relating to lithology and alteration processes. This technique has been used successfully in all parts of the world. For a general review see Palacky,(1986)[12].

VLF-EM: the Very Low Frequency electromagnetic technique makes use of radio waves transmitted for long range communication with submarines. About 15 transmitting stations are located at different points around the world, operating on frequencies in the 15 to 30 kHz band. The VLF radio waves travel through the upper layer of the ground, and they respond to changes in the ground's electrical properties such as are caused by fractures, faults, and lithological contacts. Locating these can be important in exploration. Unfortunately the effectiveness of this technique is dependent upon the distance and orientation of geological features in the survey area in relation to the transmitter (or transmitters) from which a signal can be received. Routine surveys can be delayed by the fact that transmissions are subject to interruption. For a review see Sinha (1988)[14].

Aeromagnetic Vertical Gradiometer: this technique, which was developed by the Geological Survey of Canada, became commercially available in 1984. It is more effective in support of near surface exploration (down to about 350 m) than the conventional aeromagnetic technique; it has proved very successful for mapping purposes under Canadian conditions, having been applied in support of uranium, gold, and base metal exploration. The method has not been tried in equatorial latitudes where the earth's magnetic field is nearly horizontal. For a description of the method see Hood et al.(1979)[8].

Gravity: the oldest geophysical technique is not usually considered to have much direct relevance to mineral resource exploration at the regional level. However it complements magnetics, has relevance to petroleum exploration, and identifies deep rooted structures with which some types of uranium and lithophile mineralisation appear to be associated (Darnley,1982)[2]. It is not yet a routine airborne survey technique, although the reintroduction of airships as mode of transportation, combined with 3-dimensional precise positioning systems will probably permit this within a decade. Gravimeters are often transported by air between ground measurement stations.

For a discussion of ground and borehole geophysical techniques such as must be used for detailed ground exploration see Hood (1979)[7] and Killeen (1986)[9].

Geochemical Methods

Geochemical (including radiometric) methods provide information about the composition of surface materials and in addition to discriminating between lithologies, can point directly to mineralization; however they do not have the capability to penetrate blanketing cover rocks:

Conventional geochemistry; stream sediment surveys have been the most widely used geochemical technique over the world as a whole; the method normally requires ground access, which makes it slow and relatively expensive in many undeveloped areas; however surficial geochemistry can often provide more information of direct exploration interest than any other method, because it is standard practice to analyze samples for at least 15 elements, and it is becoming common practice to add more. Significant information can often be derived from consideration of multi-element assemblages. For a recent review see Thornton and Howarth (1986)[15].

Radiometric methods; airborne gamma ray spectrometry in particular has proved to be of much more general application to both geological mapping and exploration than was recognised 15 years ago; widespread use has demonstrated that the technique is relevant to exploration for many commodities in addition to uranium (Darnley and Ford,1988)[5].

A new international initiative has recently been taken to commence the compilation of a "World Geochemical Atlas" which will facilitate the standardisation and comparison of data and lead to new insights concerning metalliferous regions.

Products and their utilization

Modern surveys produce digital data which can be used to provide an almost infinite variety of products, from traditional maps, to maps involving complex processing of several parameters, to quantitative interpretations.

The major advance of the last decade has been the ability to present complex geophysical data in formats which are readily digestible by non-specialist earth scientists; this has been made possible through the introduction of computer controlled colour plotters. The benefit has been both psychological and technical. It has provided exploration geologists with multi-parameter geophysical and geochemical data in geological style formats which can be directly related to the available conventional geological information. This new information usually points to previously unrecognised features, some of which may merit exploration.

The most striking recent results pertaining to mineral exploration have been obtained by preparing ternary colour maps from airborne gamma ray spectrometry data. A ternary map shows in a single picture the relationship between potassium, uranium, and thorium over the map area. A different colour is assigned to each element so that small changes in the ratios (proportions) of the elements are immediately apparent. For

reasons connected to the chemistry of these elements the most marked changes in the ratios are associated with uncommon rock forming or hydrothermal processes which, when they occur, often give rise to mineralization. Many types of mineralization may be indicated in this way. For examples and further references see Darnley and Ford (1988)[5].

Systematic resource exploration is designed to lead to the discovery of economic mineralization; airborne surveys at close line spacing (250 m) can provide very detailed data over priority areas, but ground work is essential in order to investigate the cause of anomalies; ground work can be very expensive in remote districts with difficult access.

A key cost control factor in exploration is the ability to select for investigation only those anomalous features that have a high probability of being related to mineralization. This is best assured when several independent parameters give favourable indications. When a decision has been made to conduct a ground investigation it is important to use the most effective ground methods to prove or disprove a target. These will vary according to the environment and type of mineralization.

One of the most useful approaches to determining the diagnostic characteristics of mineral targets in any particular geological/climatic region (remembering that climate and topography are major factors in determining the exploration signature of a given type of deposit) is to carry out well controlled trials over known mineral occurrences; those geophysical/geochemical methods which from first principles might be expected to prove useful in the search for additional targets of the same general type should be assessed in this way; those that are shown to be effective can then be used with confidence for an on-going exploration programme. For an example of a comprehensive investigation of the type recommended see Cameron (1983)[1].

Controlled investigations of this type are perhaps best performed by public agencies because the results can be published and used to upgrade the effectiveness of all exploration work in the region; thereby the whole community benefits; the establishment of a number of test areas can also be useful for training purposes. This approach has been followed in a number of countries. If these test areas are set aside for long term use, they are then available for the comparative evaluation of new methods and equipment in the future.

ACKNOWLEDGEMENTS

Canada's success in building up an effective resource exploration data base would not have been possible without the vision and commitment of past senior members of GSC management, in particular J. M. Harrison, L. W. Morley, Y. O. Fortier and C. H. Smith.

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DISCUSSION

Sikatali: I noticed that work in Canada has been carried out only in certain areas. What were the criteria for the selection of those particular areas?

Darnley: You may have noticed that whereas the airborne radiometric surveys was a large block essentially around the edge of the Canadian preCambrian shield, the geochemical surveys (stream sediment-lake sediment surveys) were done in a lot of smaller areas, scattered all over Canada. This reflects the fact that conventional geochemistry is a slower and more time consuming method and is also somewhat more expensive to do. There was a stronger input from the provincial geological survey organizations in the geochemical surveys. They wanted to start in areas where they considered there was a greater potential for mineral discoveries. We also wanted to have control information in the vicinity of known uranium mineralization. With every technique you have to have control data, you have to know how the technique responds in relation to the type of mineralization you are likely to find in a region. This was the reason for the original blocks of geochemical data, and they have sort of grown outwards from these. The radiometric technique, being faster, was started in three different centres with three different contractors.

Money: Is there any statutory requirement to oblige a contractor to submit his data to a national body, in this case the Geological Survey?

Darnley: In the case of uranium there was for many years the requirement to report any radioactive occurrence to the Atomic Energy Control Board and they would automatically notify the Geological Survey. This continues for the Resource Appraisal and companies are required to open their books each year.

Perhaps the legal requirements are not so stringent as they were in the past. However, the mines recorders, the people who give you the land rights, require that you report every year. Actually, mineral rights in Canada are vested with the provincial governments. They administer the mining laws and all have reporting requirements. These assessment reports are part of the requirement for retaining land (claims or concessions). The information is retained in the files, and if the land becomes open, the information is available to subsequent prospectors. This information is also available to the provincial geologist to compile maps of the favourability of certain areas (for all commodities, including uranium). This system has a lot to commend it to developing countries when they are considering reporting requirements.

Money: In Zambia it is a statutory requirement, regardless of the mineral commodity, that anyone who has been issued with a licence is required to submit a report quarterly on what has taken place in that quarter of the year.

Chairman: This question of reporting is very important and needs to be emphasised, particularly for developing countries much more than it was in the past. This is one of the very important ways for government organizations to accumulate information.

Bourell: I agree with the requirement for companies to have to give their data to the country. However, we should also recommend that the country must assure that they have the manpower to read and make use of this data, and not simply put it in a dirty room and lose it. Sometimes that is what happens.

Chairman: In your paper you noted that in Canada the Geological Survey does the scientific work and the private companies are doing the economic work. That is an important factor, that should be more and more tried in developing countries. Naturally it depends on the country, but if private industry is already developed, then they do the exploration while the Geological Survey provides the informational infrastructure.

Money: Do the private companies in Canada enjoy any incentives, tax holidays or such special privledges?

Darnley: As far as uranium is concerned I think not. Government assistance was in the form of information. Recently there have been special tax concessions to encourage exploration, but not specifically for uranium. The provincial governments may also assist by infrastructure building, roads, power lines and so on. We also have mineral development agreements between the federal and provincial governments that have supported the building of roads, mainly, of course to make ground access easier.

Chairman: To summarize then:

- first, geological programmes should not only be for uranium but should be comprehensive geological work and multi-commodity oriented.

- There is need in the Geological survey organization for R & D and unconventional thinking and look for new types of deposits.

- Geological mapping should include recording all elements of economic interest, alteration zones, mineral showings and so on.

- Also from the economic point of view, it is important to have a comprehensive data base and the private companies working in the country should report to this base, probably in the keeping of the Geological Survey.

THE ROLE OF THE GEOLOGICAL SURVEY DEPARTMENT IN NATIONAL MINERAL DEVELOPMENT - THE ZAMBIAN EXAMPLE

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Abstract

The major functions and duties of the Geological Survey Department include; - to map the country geologically in a systematic manner at appropriate scales, and to publish such maps and geological reports for use by public; -to search for minerals in a systematic way and make available such information through reports, maps and assay results; - to provide up-to-date information on the mineral potential of Zambia to the Government; - to provide the facilities and to act as the national repository for all information on geology, minerals and mining.

Growing interest in atomic energy and in uranium led in 1976 to the enactment of the Prescribed Minerals and Materials Commission Act, and to the establishment of a Commission to formulate policies and draw guidelines for work connected with uranium and other naturally occurring radioactive minerals and compounds. The Act defines prescribed minerals as uranium, thorium or other naturally occurring radioactive metal ores and includes plutonium and other artificial elements with their respective compounds. The functions of the Commission are wide and are concerned with the search for, exploitation of and usage of radioactive minerals and materials for the production of energy.

The PMMC and the Geological Survey Department cooperate closely in their activities. The Geological Survey provides facilities for the technical activities of the PMMC, which currently has a staff of about 30, of whom seven are professionals. One joint activity currently under way is the development of a Uranium Resource Atlas of Zambia. This programme is making use of geochemical stream sediment samples collected by the Geological Survey since the early 1960's. These are being analyzed for uranium and the data are being entered into a data base system leading to the eventual production of regional uranium distribution maps of the country.

The recognition of major radiometric anomalies arising from the countrywide geophysical surveys conducted in the 1970's led to a major upsurge of activity in uranium exploration by international companies such as AGIP Nuclear of Italy, Saarberg Interplan Uran of the Federal Republic of Germany, Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan and more recently COGEMA of France and Central Electricity Generating Board of Great Britain.
The activities of these companies are monitored and regulated by the PMMC which stores and reviews the data provided by the companies in regular reports of their activities.

The paper describes the legal and fiscal environment established in Zambia to attract and regulate the foreign mining companies working in uranium exploration. The conditions established have proved to be highly successful in attracting foreign interests and investments and can be recommended to other developing countries interested in attracting such investment.

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1. INTRODUCTION

The natural resources of a nation provide the basis for internal industrial growth, development of a manufacturing sector, earning of foreign exchange through trade, national self sufficiency and indeed a better quality of life for all its inhabitants. Thus a nation's mineral wealth and the attainment of adequate economic independence is not only a function of the geological mineral endowment, but also depends upon the effectiveness with which such minerals as it might possess are sought for and developed. The mechanics of search, identification, evaluation, exploitation and marketing, though related to the historical development that preceded national independence, began to be systematically followed so as to achieve rapid growth in the shortest possible time.

2. THE GEOLOGICAL SURVEY DEPARTMENT

In Zambia, as in many other parts of Africa, the search for minerals during the colonial period was left to the companies and the private sector. However, in order to embark on some geological mapping and provide inputs especially on the low value, high volume commodities so fundamental to construction and industrial development of the growing urban economy, a government geologist was appointed in 1950 and attached to the Department of Labour and Mines. The formal establishment of a Geological Survey Department under a separate Director did not come about until 1952, and at the time of independence some twelve years later the total number of professional officers was eighteen.

The need for geological data and the drive to attain industrialisation led to the progressive expansion of the Department in the number of professional officers, support staff, the type of work carried out and indeed the budget. The interest of the Government to search for, evaluate and develop the mineral resources of the country encouraged the growth and development of a major national earth science institution similar in concept and structure to those of the industrialised nations but smaller in size. The current strength of the Department is approximately one hundred and fifty with fifty professional officers, thirty technical personnel, ten administration staff, twenty five drivers and over forty others as support staff.

Regional programmes initiated in cooperation with the United Nations Development Programme (UNDP) in 1968 led to the adoption of a multidisciplinary approach in exploration programmes for regional evaluation. This, coupled with countrywide airborne geophysical surveys and systematic

geochemical prospecting, provided a boost that launched the Department and the nation on an aggressive exploration initiative. The systematic release of data of surveys through publications led to a growing interest and involvement of mining companies such as Noranda of Canada, Amax of U.S.A., DeBeers of South Africa, Anglo American. Climax, Chartered Exploration etc. in prospecting and exploration in Zambia.

The recognition of major radiometric anomalies arising from the countrywide geophysical surveys conducted in the 1970's led to a major upsurge of activity in uranium exploration by international companies such as AGIP Nuclear of Italy, Saarberg Interplan Uran of the Federal Republic of Germany, Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan and more recently COGEMA of France and Central Electricity Generating Board of Great Britain.

The major functions and duties of the Geological Survey Department include;-

- to map the country in a systematic manner at scales considered appropriate, and to publish such maps and geological reports for use by public. This is the fundamental function of a Geological Survey Department in any country,

- to search for minerals in a systematic way and make available such information through reports, maps and assay results,

- to provide up-to-date information on the mineral potential of Zambia to the Government,

- to provide answers to parliamentary questions on geology and minerals and to prepare draft legislation on matters affecting minerals,

- to process and give opinion on the applications for mining rights (Prospecting, Exploration and Mining Licences) submitted by companies, individuals, co-operatives etc. through the Chief Mining Engineer,

- to monitor the geological work carried out by licence holders,

- to provide the facilities and to act as the national repository for all information on geology, minerals and mining,

- to collect, collate and compile relevant geological information on Zambia for use by the public,

- to represent Zambia in all international organisations related to geology and minerals,

- to analyze the reports of mining companies, to assist and if necessary and appropriate, sit on the boards of state companies according to the directives of the Minister and Permanent Secretary,

- to prepare and compile geological and mineral data on the Southern Africa Development Cooperation Council (SADCC) countries (Zambia is the SADCC Coordinator for Geology, Minerals and Mining),

- to provide mineral identification, analysis and authentication facilities to sister departments of the government and to the public,

- to provide scientific literature on geology and minerals for use by interested parties,

- to provide assistance by way of guidance to public in their search for minerals,

- to assist in the drafting of agreements affecting geology and minerals, and

- to perform other special duties of a relevant nature assigned by the Minister and the Permanent Secretary.

3. MINES AND MINERALS ACT

Despite the fact that the Zambian economy has been dominated by the minerals industry since the turn of the century, it was not until late 1960's that a separate Act was passed and a Ministry of Mines set up. In order to define, determine and regulate the role of various bodies connected with mineral exploration and exploitation, a comprehensive Act known as the Mines and Minerals Act was passed in 1969. According to the Act all rights of ownership in, searching for, mining and disposing of minerals are vested in the President of the Republic on behalf of the State. The Geological Survey Department is a statutory body under the Act. This law was subsequently amended in 1976 and provides that the State has the option to acquire an interest in any mining venture that may be developed. This amendment also provides for the control of sales of all reserved minerals and requires that prospecting, exploration and mining be carried out in an efficient and competent manner, avoiding wasteful mining and metallurgical practices.

The level of interest and the scale of operation uranium in the light of the growing awareness of nuclear energy led to the enactment of a separate Act in 1976 known as the Prescribed Minerals and Materials Commission Act, and the establishment of a Commission to formulate policies and draw guidelines for work connected with uranium and other naturally occurring radioactive minerals and compounds.

4. PRESCRIBED MINERALS AND MATERIALS COMMISSION ACT

The Act defines prescribed minerals as uranium, thorium or other naturally occurring radioactive metal ores and includes plutonium and other artificial elements with their respective compounds and any other substance that may be a prescribed mineral under the Act. Generally, the provisions of

the Prescribed Minerals and Materials Commission (PMMC) Act and the Regulations made there under follow those of the Mines and Minerals Act and the Regulations. The major difference lies in the establishment of a Commission which is a corporate body with perpetual succession and which is capable of suing and being sued and, subject to the provisions of the Act, of doing all such acts as a body corporate may by law perform.

The Commission consists of the Rt. Honourable the Prime Minister as Chairman; the Honourable Minister of Mines as Vice-Chairman; the Honourable Minister of Power, Transport and Communication; the Honourable Minister of Finance; the Permanent Secretary of the Ministry of Mines; the Permanent Secretary of the Ministry of Defence; the Secretary-General of the National Council for Scientific Research and not more than three members appointed by His Excellency the President. An officer is appointed by His Excellency to serve as Director of the Commission and the Commission may appoint a Deputy Director and such other staff as it deems expedient.

The functions of the Commission are wide and are concerned with the search for, exploitation of and usage of radioactive minerals and materials for the production of energy. These functions are:-

a) to search for, mine, extract, process and dispose of prescribed minerals and carry out research into any matters connected therewith;

b) to import and export prescribed minerals;

c) to produce, use and dispose of atomic energy;

d) to acquire, process, store transport and dispose of any radioactive substances;

e) to regulate all matters relating to prescribed minerals, atomic energy and radioactive substances, including the acquisition of patents in all cases associated therewith;

f) to advise Government on matters relating to prescribed minerals, atomic energy and radioactive substances and on such other matters as amy be referred to it and;

g) to regulate and control pollution levels and other health hazards resulting from natural radiation or other causes.

The Commission may enter into or execute such agreements or contracts with parties considered appropriate and suitable for the purpose of carrying out prescribed minerals operations. To this end, the Commission has powers to grant for such consideration as it may determine, a prospecting licence, an exploration licence or a mining licence to any suitable person upon such terms and conditions as it may think fit, and such conditions may include the right of the Commission to participate in prospecting, exploration or development of any area held under such licence.

Application for mining rights under Part IV of the Act shall be made to the Commission through the Engineer in the Commission in the prescribed form as specified in the Mines and Minerals Act. Equally, all mining rights granted under the provisions of this Act shall be registered by the Engineer under Part XIV of the Mines and Minerals Act.

The PMMC and the Geological Survey Department cooperate closely in their activities. The Geological Survey provides facilities for the technical activities of the PMMC, which currently has a staff of about 30, of whom seven are professionals. One joint activity currently under way is the development of a Uranium Resource Atlas of Zambia. This programme is making use of geochemical stream sediment samples collected by the Geological Survey since the early 1960's. These are being analyzed for uranium and the data are being entered into a data base system leading to the eventual production of regional uranium distribution maps of the country. The techniques being used for the production of the uranium maps are also being used in the development of geochemical atlas maps of other metals determined on the same samples in the past. This atlas programme is expected to provide a very good overview of the mineral potential of Zambia for an important range of mineral commodities.

5. DEVELOPMENT PROJECTS AND INVESTMENTS

Development projects are a function of investment. Such projects very greatly both in type and in origin. Some are conceived and implemented by the national government, others by international institutions, some by foreign governments, a few by multinational corporations and fewer by individuals. Investment may be in any form: man power, technology, equipment, services, expertise, funds, indeed a combination of some or all.

The quality and quantity of investment that a country attracts is largely a function of a number of parameters, both inherent or natural and induced or man-made.

5.1 Inherent and Induced Parameters

The inherent parameters are those with which the country has been endowed. Among the inherent parameters the most important is the geological environment for the occurrence of the mineral. Thus unless the ore or the desired mineral is present or perceived to be present, no investment would come about. Often a set of geological criteria will attract attention. Evidence of a favourable geological environment therefore is an attraction for investment.

Another inherent parameter is a hospitable climate. Harsh climatic conditions are generally not conducive to investment unless, of course, the return on investment is sufficiently substantial to compensate the hardships endured. This explains why much of equatorial forest areas and the cold tundra belts remain scantily explored.

Apart from these two inherent parameters, of which the first is an essential or apriori condition, all other parameters are largely man-made. They are, however, significant and play a major part in influencing decisions on development projects and investment. The induced or man-made parameters may be classified as follows:-

- Organizational climate,
- Information climate,
- Financial climate,
- Political climate and,
- Communication climate.

The success of development projects, and therefore of investment is largely a function of above factors, all man-made. The development of the Zambian mineral economy had been possible because of a favourable framework of the above factors for investment.

5.1.1 Organizational Climate:

Organizational factors include the presence of suitable institutions such as government departments dealing with geology and mining; financial institutions such as banking facilities etc. In Zambia, the Ministry of Mines and Prescribed Minerals and Materials Commission together with the state companies such as Zambia Consolidated Copper Mines (Z.C.C.M), Reserved Minerals Corporation (R.M.C.), Minex, Mindeco Small Mines, Maamba Cocheries etc. provide not only the scientific institutional framework but also the back-up support as partners whenever this is required. Foreign investors are able to identify readily with whom to deal. The banking facilities and the well developed financial and legal framework provided security and ease of operation. Legal framework includes appropriate legislation in relevant areas to regulate the mode of conduct. The various Acts outlined earlier, passed by the Parliament give sanctity to the operations and protection to the investor. The physical climate also includes infrastructure facilities, such as communication facilities and social amenities. A network of good roads, ready air access, social and medical facilities provide confidence to the foreign investors and their personnel.

5.1.2 Information Climate:

There is the need for basic information on geology, mineral occurrences, maps and other relevant publications to encourage investment. The availability of geological reports, maps, geochemical and geophysical surveys provides the scientific pull for foreign investment. The information dissemination should be such that even the common man should feel that there is potential for development and therefore the possibility of a better quality of life. Such public awareness renders the population not only receptive to work but to

genuinely cooperate in programmes and not to consider the foreign investor as an alien exploiter and unwanted intruder. Genuine openness in dealing with the outside investor and avoidance of suspicion makes dialogue and interchange of ideas and opinions easy. A good information climate is important to develop and maintain a favourable reception from the international investment community.

5.1.3 Financial Climate:

Development demands investment and as indicated, this can come from within or outside. Where the host government treasury is rich, it could undertake not only the national country wide programmes to create the basic information but also undertake mineral exploration and mining programmes, either as "go-it-alone" projects or in partnership with foreign collaborators. The country wide geophysical surveys which led to a number of foreign uranium companies entering Zambia is an example. Initially this project was possible because a cash rich national chest was available. More recently the Government, with the assistance of a World Bank loan, undertook an airborne and geochemical survey to provide additional information.

Where the project requires a partnership the need for investor protection arises. Here, the conclusion of acceptable agreements with the relevant agencies of the host government is important. Such agreements should provide for an equitable return for all parties along with some level of investor protection on capital and remittance of dividends. The return on capital, the rich-reward ratio are crucial to the foreign investor. The three uranium agreements concluded in Zambia provided the basis for exploitation of the mineral and the levels for government revenue. Clauses were included to protect both parties. The concept of "minimum return" and government holding in the equity of the company on the basis of return on investment were cordial and novel features. During a period when investments in uranium were declining Zambia succeeded in attracting investment expenditures from foreign companies of over five million dollars annually for the past twelve years.

Flexibility in agreements is also important. They should provide for changing financial circumstances. There should be provisions to deal with excess profit circumstances, compensation and arbitration clauses and independent dispute settlement facilities. This built in flexibility leads to investor confidence.

Investment from within can come about as a result of a national crisis. The need to keep industry moving may force a government, if need be, to borrow and invest. The closure of the international border upon the unilateral declaration of independence by Rhodesia in 1965 forced the Zambian Government to invest and develop her coal resources. Today, on account of those circumstances, there is a viable coal industry in the country. Equally, investment may have to be maintained in order to continue earning the requisite foreign exchange and to maintain people in employment.

Investment strategies and policies are dictated by the socio-economic conditions of the venture. Thus the financial climate for the internal investor may be somewhat different from that for the international investor. In either case, however, a suitable financial climate must exist to attract the investor. The national government will obviously need to analyze the mineral development projects in terms of the direct and the indirect, the tangible and the intangible, benefits, and the overall advantages and disadvantages accruing to the nation from the project.

5.1.4 Political Climate:

A stable political climate along with law and order are major prerequisites for attracting the foreign investor. Whereas most of the investors and multinational corporations are generally apolitical and do not often concern themselves with social concepts, they do demand a stable political environment. Law and order are crucial to their continued presence. Where this has broken down the immediate withdrawal of personnel and investment can be expected. If Zambia has been successful in attracting foreign investment despite its recent financial difficulties, it is largely because of her political stability, law and order.

5.1.5 Communication Climate:

Effective communication, publication of reports, presentation of geological data and dialogue with potential investors are all issues that should addressed seriously if investment is to be attracted. The initiation and the success of an investment programme in a development project demands aggressive marketing. Promotion programmes are therefore vital. Zambian experience has shown that an active campaign outlining all aspects for the project and presenting them to potential investors yields positive results. Equally important is communication between earth scientists and policy makers. Such dialogue should be in a language that is readily understood.

6. CONCLUSION

The Zambian experience in attracting investment in the mineral sector has been a success. The mechanics of this has been through an evolutionary sequence where the Geological Survey has played and continues to play an important role. The Zambian example may not be typical but certainly offers a useful model to follow.

DISCUSSION

Chairman: The Zambian methodology is, in my opinion, exactly on the right track, and quite different from countries I have dealt with ten or twelve years ago. Perhaps you should offer consulting services to countries based on your experience - for your neighbouring countries and even South America.

Money: SADCC (Southern Africa Development Consultative Council) is a grouping of nine countries in Southern Africa. Each country is responsible for one sector. Zambia is responsible for mining and minerals. The GSD (Geological Survey Department) sits on the minerals committee in all these countries. That's how we have been involved in many of the programmes and contracts and agreements which are now being concluded. I think we are providing the advice you suggest and are slightly changing that attitude in some of the countries in regard to attracting foreign investment.

Chairman: It surely is a big task to undertake the development of a uranium data base for such a big country as you are doing. I hope that, when the market picks up investors will be interested to come in to follow up on your work. Now you have the time to improve your infrastructure and to prepare for better times.

Tauchid: We have seen that responsibility for uranium has been transferred from the Geological Survey to the PMMC. Will this not lead, in the future, to a non-unified data bank for the mineral inventory, if PMMC has its own data base on uranium and the GSD has its own on other commodities. How will the two be unified? We have noticed that such specialized agencies, when they grow larger, tend to lead to separation.

Money: As things stand, all information, all inventory data is stored with the Geological Survey, and under law the Geological Survey will continue to be the repository for all information. All work must be submitted to the GSD.

Müller-Kahle: Doesn't this scheme lead to a little overlapping, and does it not call for a bit of streamlining of objectives and activities between the GSD and the PMMC. My understanding was that the PMMC was more of a regulatory body, more of a monitoring body. But the actual technical work should be housed in the GSD, in my view.

Money: As this moment, PMMC is housed in the GSD. In its regulatory capacity the PMMC obviously needs personnel. They are funded and paid for by the Commission. But they need the exposure to be able to regulate; they need the training. This means doing the work themselves. There is obviously dialogue between the two. But I don't think we are duplicating. I think we are making an effort so that the PMMC has staff capable of monitoring the fiscal aspects, the geological aspects, the pollution aspects, the agreements, etc.

Chairman: We are always a bit worried to have too many institution duplicating the same work and having difficulties keeping separate. If you have too many bodies then they hinder

the actual work. In Zambia, who is actually doing the physical work that you call the reconnaissance or prospection for uranium?

Money: The country wide programmes, that is the airborne geophysical surveys, the geochemical surveys etc. until about 1985 have been the responsibility of the Geological Survey. The PMMC was a small group of people carrying on dialogues with the companies. Their geological work was delegated to the Geological Survey. Now the Commission has staff, and they have taken over these responsibilities. That is uranium reconnaissance work.

Tauchid: This points up the need for a better definition of responsibilities and tasks of each government organization dealing with raw materials.

Chairman: In our understanding and experience the fewer the bodies, the more that jurisdiction is concentrated in one body, and the less the regulatory requirements in the country, the cheaper and easier it is for foreigners and therefore the more acceptable.

Money: I would like to know how other countries operate? I don't mean the USA but the smaller countries.

Chairman: In Germany, for example, we have uranium exploration. The Geological Survey does its job in making all the regional data available. Companies come, pick it up, and do their work. They have to report to the normal mining authorities to fill their commitments concerning expenditures, safety, environmental protection etc. The Geological Survey gets all the geological data, and they have the right to visit the work sites.

Bourrel: In France anybody can ask for a licence and he has only to report to the Geological Survey. The Government itself does not undertake any work.

Chairman: It seems that in future it will be advisable to have the fewest bodies, to have everything concentrated in the Geological Survey and to try to give to them the authority to do the regional geological work and to prepare everything for the private investors or government company as the case may be. Can I ask about the costs. Does a private company have to reimburse the Survey for its reconnaissance information or can they just start from zero?

Money: In the past when an applicant asked for a licence the Government asked for some reimbursement. If the Government was going to get involved in a joint venture, these Government costs were considered as part of the Government contribution. Now there is a tendency for the Government not to ask for this. This information is considered as part of the inducement we offer to attract the investor. If you have a licence and it expires, no one else can apply for it for a period of one year. After one year all the information the previous applicant may have collected is at the disposal of the new investor.

Tauchid: I noted in your agreements you require that part of the funds invested be provided to assure the good operating capability of your national organization. This applies not only to training of national staff but access to the foreign exchange to purchase necessary supplies and equipment. This is a very interesting solution to a very serious problem. However, I would like to comment that, certainly for many countries that derive a good part of their GNP from the mineral industry, not a big enough proportion of the money received by the government is invested for this purpose. Governments should take the responsibility to plough back some of the money for this purpose.

Money: The annual income Zambia derives from the mineral industry is in the order of $1.5 billion. For effective operation of the mining industry you need at least $500 million to operate the industry and produce the metal for export. Quite often the Government is unable to provide that amount of input in foreign exchange to the industry. They provide $300-350 million in dollars. Obviously that is not enough. For ourselves, there is no money coming except the annual budget and this is in local currency terms. If you want something from abroad, you queue up along with everybody else at the National Bank for allocation under the foreign exchange regulations. You cannot function without some mechanism to find necessary foreign exchange. We have come up with this mechanism.

III. THE ROLE OF OUTSIDE INTERESTS

THE ROLE OF OUTSIDE INTERESTS

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Abstract

Exploration for uranium has become more and more a high cost high risk activity. Production of uranium has more and more become concentrated in the hands of fewer and fewer producers. Within the next ten years it is expected that two countries, Australia and Canada, will supply almost all of the western world's uranium needs from large high grade deposits, with decreasing amounts from other producers such as the United States. This situation will encourage consumers to seek other sources in order to have more diversity of supply.

The high cost of uranium exploration and the need to discover deposits that can compete with the Canadian and Australian supplies means that exploration will have to be concentrated on geological environments favourable to similar deposit types. At the same time exploration in such environments will be beyond the capability of the developing countries with the most promising geological environments. If they wish to participate in the uranium market such countries should make every effort to encourage the participation of foreign mining groups with the financial resources and expertise to carry out the necessary exploration. The paper discusses the conditions under which such venture capital can best be encouraged to the best advantage of both parties.

The potentially monopolistic supply situation may encourage consumers as well as uranium mining companies to search for new resources outside of Australia and Canada. New interest may be attracted to those countries with favourable geological environments that offer competitive operating conditions. The discovery of new resources will be of benefit not only to consumers but to host countries as well.

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1. INTRODUCTION

Uranium has lost its importance as a strategic mineral and should, therefore, be treated like any other commercial raw material. For countries that want to have a completely independent national uranium supply, specific legislation for uranium exploration mining and export may be justified. However, for countries that only want to commercialize their raw materials, no specific legislation is necessary except for legislation dealing with the trading of uranium, where strict safeguard regulations have to be applied.

Past experience has shown how expensive uranium exploration is compared with the exploration for most other minerals and metals. The investment costs to develop a uranium mine are also comparatively high. Uranium exploration and mining is in itself a high risk business and, therefore, can be done only where stable legal and fiscal conditions exist.

From an economic point of view it is, for any country, much more realistic, but also by far more profitable, to invite foreign companies to carry out uranium exploration and mining as they have the expertise and the money to do this. The foreign companies should have the possibility, either to work on their own or to work together with the local government or preferably with some local private company. The equity share of the local participant or participants should be in the range which can be financed by them. As the yellow cake has to be sold on the world market, the production costs have to be competitive. Therefore, the legal and financial conditions under which the foreign company has to find uranium and to develop a uranium mine have to be competitive as well.

2. THE PRESENT SITUATION

By the end of this century a greater part of uranium will come from three countries: a limited amount from small mines in the United States, and the main share from large low cost producers in Australia and Canada. The present production from the United States, but even more, so from Africa and Europe, will decrease further, either because the mines are exhausted or the production cost are too high to be competitive with uranium mines in Australia and Canada. Because of political reasons the relatively low cost uranium from the Republic of South Africa will become increasingly more difficult to sell and will not count any more in the future.

After the amalgamation of SMDC (Saskatchewan Mining Development Corporation) and Eldorado Nuclear Corporation to the new company CAMECO, there has been an even further concentration of uranium producers to only a few large companies. This tendency will continue as it is very unlikely that new uranium mines will be developed outside of Australia, Canada, and to a lesser extent, the United States, within the next ten years. As a result of this not only will there be a strengthening of the price, but also there amy be renewed tendency, on the part of consumers, to look for new, low cost resources outside of Australia and Canada because many consumers prefer to have a more diversified supply.

This situation leads to the question, why does such a concentration of high grade, high tonnage uranium deposits occur only in two countries? Is it only because there are very special and favourable geological conditions or may it also be the result of the fact that only in these two countries have such low cost deposits been found because a great amount of money has been spent to find them? Would there have been a similar rate of success in other countries, where similar favourable geological conditions exist if similar amounts of money had been spent to locate such high grade deposits?

This may be the case but such an extensive search for uranium has not happened in the developing countries because the political, financial, legal, administrative and infrastructural conditions were and are not as inviting as in Canada or to a lesser extent in Australia. This means that the investment conditions in these countries were not competitive with those in Australia and Canada.

3. HOW TO IMPROVE THE SITUATION

The concentration of uranium producers in a few companies and countries may soon lead to some rethinking by the consumers, as this situation is not in their long term interest. They will be forced to look for possible new sources in order to be less dependent on the expected monopoly situation the present producers may create.

If this turns out to be the case, all those countries which have potentially favourable geological environments for the existence of low cost uranium deposits may be interested in attracting uranium exploration companies to become active in their countries. To do this they have to offer foreign companies competitive conditions for uranium exploration, mining and export as they have neither the expertise nor the money to do it on their own. In a paper by BOURREL et al. [1] the essential requirements have been listed. If these are used as a basis for agreements, a first step will be made in the right direction. But even more important is a favourable legislative and fiscal framework, which will be the best incentive for foreign investors to spend money.

The basic rule for any cooperation has to be mutual benefit for all parties involved. It was previously quite often the case that discriminating conditions were established, where the foreign company had to agree to pay for all the geological, technical and financial risks and, in the event of success, received only a marginal profit. This has provided no basis for cooperation, as we have seen in the past. Except for Niger and Gabon, there are no producing uranium mines in developing countries that do not produce for local consumption. I do not believe that this is due only to unfavourable geology.

Cooperation on equal terms, however, is not easy to achieve since the administrative, legal and fiscal frameworks in developing countries are much different from those in developed countries. In addition, there is a strong distrust of larger foreign companies becoming active without a tight controlling involvement of the government in the project.

This attitude has to change, otherwise foreign companies will remain hesitant to become active in such countries and will choose to invest in countries with more favourable conditions.

To overcome this problem, developing countries have to establish a well developed legal and fiscal regime which defines the rules, regulations, and laws for foreign investments in great detail. This will enable the local government to control the activities of foreign companies and to benefit later through the appropriate fiscal laws, even without being a partner in the project. For the foreign companies this has the great advantage of allowing them to know the rules from the beginning. They will have a basis to decide quite early, before spending much money, if the terms and conditions are acceptable. If they are reasonable and better than in other countries, then they will not hesitate to come as long as the geological conditions are right.

If such a regime is established and if a country is prepared to provide competitive terms for foreign companies without giving up its own identity and sovereignty then there will be a good basis to attract far more foreign companies in the future and for them to spend much more money on all types of exploration, but also for uranium exploration.

4. PROPOSED GENERAL TERMS FOR COOPERATION

The only workable contract system for metal/mineral exploration and mining projects is either a cooperation in a "Joint Venture" or in a "Joint Company". The so-called "Production Sharing Contracts" or "Service Contracts" are not applicable for such projects because, unlike oil projects, the financing of mining projects based on such contracts is not possible. This is the reason why there is no operating mining project - to the writer"s knowledge - based on such a contract.

The basic idea of a "Joint Venture" (or "Joint Company") is the equal rights as well as the equal obligations of the cooperating parties. Agreements of this type are the most common ones in developed countries and this should also be the case for the developing countries. Unfortunately this is not the case. Due mainly to the lack of financially strong partners, local governments demand to participate in future mining projects, but without any financial obligation in the high risk exploration phase. This is hardly acceptable as there are many other countries where this demand does not exist.

This problem has to be understood and overcome. In the writer's opinion the best way to do this is to allow the foreign investor or group of investors to choose either to go ahead alone or, if possible, to seek a local private or state company to participate in the joint venture, but with the clear understanding that it has to pay its own share. One possibility for the local partner to achieve this is through a grant from international development funds. Another is for the local enterprise to negotiate with the foreign partner or partners, an option agreement for the later acquisition of shares in the project in case it is feasible. In this case, however, a market-related price will have to be paid for the acquired share which may be higher than the actual costs the company has spent for finding the deposit.

This approach, however, is only possible if in the host country provides a sufficiently detailed and well established legislative and fiscal regime to control the activities of the foreign companies or Joint Venture. The sovereign rights of the host country must not be jeopardised by any means. Thus, in developing countries less emphasis should be put on the question of how individual agreements for cooperation with international companies should framed, and much more on finalizing the legal and fiscal regime and to include the necessary instruments for attracting and later controlling foreign companies working in the country.

Another basic rule should be that any new laws and regulations which are more favourable than the existing ones become applicable to companies already working in the country. In the case that new laws and regulations are less favourable than existing ones, the existing agreements should not be affected by the new laws and regulations (the is called a Grandfather Clause), because the company already operating has based its investment plans on the previous regulations and laws and a change for the worse may jeopardize the whole project. This would be a disadvantage for the company, but it may turn out eventually to be a financial loss for the host country as well.

The mining law should, in essence, follow the mining laws of countries which have a long mining tradition like Australia and Canada. Without going into details, the main requirements are:

Three types of land rights (permits, claims, mining leases) are commonly used depending on the advance of an exploration programme. In all cases there should be limitations on size of area, time, and the amount of money to be spent on the ground for holding the rights. The land holding for more regional exploration should be a permit with a relatively large extension, should require relatively low expenditures and have a relatively short duration period, let us say a maximum of one to three years. If a certain geological target is outlined the area should then be covered by claims. The size of the area retained should be smaller and the work requirement relatively higher. The claims, if the commitments have been fulfilled, may have a maximum duration of about ten years. If a deposit is identified, the orebody can be covered by mining leases which should have a reasonably long lifetime which should include also the mining period. This means a period of at least ten years and a maximum of twenty years with the possibility to extend the lease in the case that the mining operation continues. Usually a rental fee for the leases has to be paid to the authorities.

In all three cases it is very important that the mining law provide a guaranty that the next higher order of landholding will be automatically issued if the legal obligations have been met. If a company has provided a positive economic feasibility study and plans to go ahead with the investment and production, the permission to go ahead with the project must to be granted automatically. The investors also have to have the right to export the products at market price so long as they follow the legal, fiscal and safeguard regulations of the host country.

In general, the fiscal regime should not have special terms, conditions and laws for a mining operations. They must be the same as for all mining companies operating within the country. There should be the possibility, however, to allow for certain fiscal and administrative advantages in the case that the project turns out to be marginal. On the other hand, certain additional royalties could be levied if excessive profits can be realized, as long as the royalties do not jeopardise the competitiveness of the product on the world market.

The foreign exchange situation, in general, and foreign exchange control, in particular, is one of the most critical obstacles for foreign investors working in developing countries. While the above proposals permit a government to improve the conditions and therefore also the attractiveness for foreign investors, the foreign exchange problem can only be partly influenced by the host government and thus cannot be easily resolved. In the writer's opinion this problem can only be overcome by allowing the investors to have a foreign account for which strict regulations have to be clearly defined to avoid any misuse.

Through this foreign account the payments outside the country have to be made in the following order of importance:

- operating costs (spare parts, consumables, salaries of expatriates, etc.),
- payment of interest on foreign loans, repayment of foreign loans and finally, profits. These payments have to be guaranteed as long as the company operates profitably. If this cannot be guaranteed, a private investor may look for other, better opportunities.

Beside the main legislative and fiscal topics already mentioned, which will have to be improved, there are still other areas which are of concern to foreign investors. Due to the less developed administrative and technical infrastructure, but often also due to the lack of professional staff, the operational costs in developing countries are higher than in developed countries. These unavoidably higher costs have to be compensated, at least to some extent, in several ways:

- by granting duty free import and export licenses for equipment, cars, etc.,
- by allowing free recruitment of expatriates and local staff and,
- by allowing the company to use outside sub-contractors and consultants, etc.

Usually the local geological data base is less complete and often has not been up-dated to modern requirements. The problem can be overcome in part by technical assistance programmes which can improve the geological infrastructure in the developing country. It must be emphasised, however, that such assistance should not be purely scientific, but that the programmes should be designed in such a way that the results can be readily used by exploration companies.

5. SUMMARY

There are clear indications, not only of a concentration of uranium production in only two or three countries, mainly Australia and Canada, but also of a concentration to only a few uranium mining companies. This will clearly lead to a more monopolistic supply situation for uranium in the future and will probably be connected with a gradual price rise for uranium. This situation may increase the incentive for uranium

consumers and also for uranium mining companies to search for new resources outside of Australia and Canada. If countries with favourable geological environments offer more favourable or more competitive conditions to foreign investors to search for new uranium deposits, they may attract new interest. This will increase the chances of finding new deposits which will be of great benefit both for the host countries and for the uranium consumers.

ACKNOWLEDGEMENTS

I would like to thank Dr. R. Gatzweiler of Uranerzbergbau GmbH, Bonn, and Dr. J. Madel of Interplan Uran GmbH, Saarbrücken, for their constructive contributions to this presentation.

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DISCUSSION

Money: Your paper reflects what we have been aiming at in Zambia. At a time when there has been less and less uranium exploration we have certainly been able to attract companies to invest in Zambia, and the reason for this is, I believe, the fiscal, legal and administrative infrastructural framework which we present.

Tauchid: I believe that the climate for investment has changed for the better over the last 15 years. Opportunities were lost for some developing countries in the past. The climate for investments was full of suspicion, jealousy towards ones property and this was a hinderance to the possibilities that existed in the mid 70's.

Hammer: I agree with your point that a licence should have a relatively large extension, relatively low expenditure requirement and relatively short duration period. In Zambia we had a licence of 30,000 sq.km. and in Zimbabwe we are still holding part of a licence of originally 34,000 sq.km. Originally a licence in Zimbabwe was limited to 300 sq.km. but we managed to explain to the authorities that it is necessary to have larger areas for the application of modern methods like airborne surveys and for quick assessment of the original area. However the possibility for longer periods in special cases should be available, by means of extensions, for example, and also for special tax incentives from the beginning in the case of marginal exploration projects.

Chairman: The paper was intended to be very general in nature. Each country will deal with the problem differently. We want to encourage the developing countries to follow the strict conditions observed in the developed countries. To be fair, we

have to include the normal disadvantages in these contracts. What is the reason to provide for big areas to do airborne surveys and to cut the time relatively short? This forces the foreign investor not to take more land than he can survey in two or three years. This gives enough time to select potential areas but then the company has to decide which areas it should keep and to open the rest of the area to other people. Its in the interest of the country to have as many investors working as possible. No single company should hold for too long a certain area. Land should be held only long enough for one or two surveys, not for a survey which may be done four or five years later. The countries must have the chance to invite as many investors as possible. Therefore no single company should hold big areas for too long.

Money: What about the possibility of forced relinquishment of land after each year. For example, 50 % of the remaining area at the end of each year. In Zambia we have charged relatively high surface rentals (in foreign currency) per sq.km. retained. We have not yet had contracts with forced relinquishments in minerals but have used this method in recent hydrocarbon agreements.

Chairman: Again I think we have to have a system to release areas in a reasonable period of time to open them to other companies. I don't agree with the high rental system because it is not in the real interest of the country, except to gain immediate money. I would be much more interested to attract other companies to come in. For example in Zambia, in the Katanga belt, there is no point to have one or two companies hold the whole belt under concessions. It would be much better to have twenty companies working. Then you have the benefit as a nation, but also the companies benefit because more ideas are brought to bear on the resource potential of the area. The second point on these special conditions for mining enterprises, again every investor should follow the rules of the country. That means the basic legal and fiscal regime. What I wanted to stress in this paper is that we should not ask for special laws; we should ask for a stable basic legal and fiscal regime. And on the basis of this, foreign investors can invest in the country without too many specific regulations which lead only to arguments. So special conditions should not be the rule.

Tauchid: I support the idea of a limitation on the time of exploration concessions. Your comment is very important to allow other operators to have the chance to look into the ground. From past experience, certainly in Canada, that maybe after the third operator going over the same ground, the deposit has been found. The Chibougamu area in Quebec is an example of this situation. The old Read Lot land grants in Newfoundland did little to develop mineral deposits but, on the contrary clearly blocked development. One company monopolizing the ground does not guarantee success, even given the time and money.

Bourell: I completely support your point on relating production costs to market price. Sometimes it is a good thing to let the country itself to sell some part of the production

on the market. In this way they will learn what is the spot market, and what is the long term market.

Chairman: It is very difficult to fix the market price, and very difficult to come to an agreement with the country for a fair solution. For the exporting countries the main thing is that they not sell the material below market price. On the other hand the exporting countries cannot expect to have more taxes and royalties and other payments which are above what can be earned on the market.

Müller-Kahle: Maybe we should say contract price rather than market price. The contract is something you can show to the export board of the country, while the market price is much more difficult to arrive at.

Vlasov: This subject of contractual arrangements is a relatively unknown field to us. I have a question. Who is responsible to control the results of the different stages of the geological research. Maybe you have some experience in this. When the host country invites a foreign company to carry out a programme phase by phase, who controls whether the project is positive to go ahead and who is finally agreeing to the reserves and to the economics of the deposit.

Money: In our experience, both in the metal mining as well as if uranium mining takes place, at all stages we will have to monitor. In some developing countries they have the facilities to do this, others do not have. In our case we had to appoint a consultant along with Zambians to do the monitoring. In the case of uranium, even at the stage where we concluded the agreements, we sought the assistance of the Commonwealth Secretariat who appointed a tax expert from Australia, a geologist expert from Canada - in all, four experts sat with us and helped to put together the package that was discussed with the companies concerned. If in the case of mining we find that the miner is adopting a wasteful practice we tell them they cannot do that. If he is mining an ore and leaving behind reasonable grade (eg. taking off the 3% level and leaving behind the 2.5% material) it is our job to stop them.

Bourell: When an investor does some work he works as well as possible in his opinion. It is his money that is being spent, and he is responsible for this money. It is necessary for him to be entirely free to chose the methods he will employ. However I am referring only to the exploration stage.

Chairman: So if a company is spending money it is responsible for the decision making. If they think phase two was not successful and they do not chose to go into phase three because the grade found was too low, they should be free to decide so. But this has to be within the legal frame of the country. In regard to your statement that there should not be wasteful mining, there should be regulations preventing this because no country is interested that someone high-grades their deposits. But I want to make a strict line - these are two different things. Decision making should normally be done by the investor because he has the risks and he is doing the best possible. But there should not be absolutely free choice

for certain things like wasting a mineral deposit, and therefore there must be some regulatory means which have to be discussed. However, we have to be a bit careful. If the economic cutoff is 0.25% and this is in connection with the market at the time, it is very difficult to accept that a government body can say "No, your cutoff has to be 0.2%", because it may not then be saleable - then there is the problem. But this has to be negotiated and there has to be some means of solving such problems.

Darnley: This is a matter of genuine concern. A country's mineral resources are a wasting asset and, clearly, nobody in a country wants to be left with the feeling that they are being exploited. There is a sort of competition going on in peoples minds. On the one hand they want to get some income now from the development of their mineral resources, but on the other hand there is always the suspicion that if they wait until later they will become more valuable and a better deal can be obtained. The only real way for a government to have control is through the joint ownership route. They need to put some money into the investment so that, by definition, they are part of the management of the operation; they are familiar with all the decisions that are being taken and why, and they have a vote in those management decisions. The problem most frequently occurs in companies where the financial people have management control rather that the technical people. There will often be strong pressure to maximize profits to the extent of wasting resources, leaving resources in the ground that will probably never be subsequently exploited, because you have high-graded the deposit and left material in the ground that will be totally uneconomic under any foreseeable conditions. This is a difficult question and it cannot be played down. In Canada during the 70's the number one consideration in energy policy was that there should be no suspicion that the sale of Canadian energy resources should be permitted that would ever cause a shortage for Canadian domestic energy producers in the future. The present view is somewhat different, more short term and dictated by market forces.

Money: While we appreciate that market forces are a factor in determining investment policy, we cannot get away from the fact that countries have to optimize the mineral resources they possess. And the only way to do this is to effect the exploitation even if the return is going to be marginal to the investor and to the country. I believe that we must come strongly on the side of maximum exploitation rather than on the side of returns on investment. Optimum use has to be made of the mineral resources. And if this means not mining a deposit for a few years I would rather do this than exploit a deposit for immediate gain, leaving behind substantial reserves in the ground that can never be mined in the future. I speak for the government side and the government must take a long term view - 50 or 80 years - not the view of immediate profits over 3 or 4 budget years.

Chairman: It is clear that a middle way must be found. I do not want to be too lenient with the companies either. But you have to accept some how, in some way, to attract foreign

investors, and therefore we have to find this narrow path where both sides can accomplish their aim - the one side has to make a certain profit, and I agree it should not be a "rip-off", while the other side wishes to maximize the amount of material of the resource mined. This means that a normal profit should be accepted but in the case of higher profit levels it is probably better not to ask for royalties because of super profits but we should be going in a different direction - that is to lower the cut-off grade to get more resources out. This should be the basis for cooperation between the both interests.

Verma: When we talk of a mining project we are not talking of three, four or five years but for the life of the mine of 15 to 20 years or more. So the investor cannot take too short term a view, and cannot only consider the current market conditions because these will change over 15 - 20 years.

Chairman: This is true, but when you have to sell your uranium year by year you have to be flexible in your mining operation and you may change the cut-off because when the price goes down your cut-off goes up. This mechanism should be introduced but I think everybody would agree if you open a mine you should run it to the end if this is economically possible.

Müller-Kahle: There is a basic difference in the world as regards economics. We have definitely, on the one side, free market economies and we have others that are planned economies. Even the market economies are often "social market economies" meaning that even market economies have to consider certain social aspects. We are going to see that the planned are going to accept more and more market criteria. So we definitely see two viewpoints. Many of the developing countries have certain aspects of planned economies, but that may change in the future and it will change the whole environment for investors from market economies. This is why we see in many developing countries the very strong desire for control and direction which investors from a market economy do not like to see and do not like to accept.

ATTRACTING FOREIGN COMPANIES
(Summary)

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The question of attracting foreign companies to undertake uranium exploration and development is typically a national problem and has to take into account, among other things, political policy, national needs, investment capability and choice, technological level of the country reached and/or planned. These considerations are not specific to uranium exploration; the same questions can be put for growing corn (or rice), producing television sets, or manufacturing space rockets. The answers are necessarily different for each country.

However, mineral exploration (including uranium) presents important differences that are related to the special investment risks associated with these activities. The investor in mining development can never be sure of earning his money back. This will not be the case in other industries as long as the business is operated in an adequate way. Under these conditions it is very difficult to provide precise guide lines. The host country must pay close attention to the risk involved when making incentive regulations. The best way is for the government to understand very well the foreign investor's motivations and to accommodate, as well as possible within national policies, respect for the interests of both parties.

If it is decided to attempt to attract foreign mining investment, what conditions and controls should the government apply to these operations?

- During the exploration period, as little control as possible, particularly in regard to decisions involving the risks to be taken (especially technical decisions).

- During the exploitation period, the feasibility study should establish a mutually agreed basis for necessary controls while leaving the possibility of adjustments as may be needed as a result of changed market conditions, new discoveries or new technology, etc.

- During both periods, national and/or intentional rules and standards should apply for matters concerning aspects of work organization (personnel, employment, security, environmental considerations, etc.).

In any event, the regulations and controls must be clearly established; they must be clearly understood; and, they must be stable and consistent over a period of time in keeping with the normal life of a mining operation (15 - 20 years).

What information and services can the government be expected to provide?

Services and support for exploration and mining investment will normally be provided by the national geological survey. The role of the national geological survey will usually be:

. to create-
. to collect-
. to store-
. to release-

all basic technical and legal information about the country in regard to the mining business (including uranium).

- to create

  It is well understood how useful can be the basic geological data and programmes to improve the general geological knowledge of a country as an inducement to mining exploration.

  It is, perhaps, less well understood that the geological survey has the important task to make the government authorities (particularly the treasury department) aware of the specific aspects of the mining industry in order to promote adequate regulations, and to help in the welcome of potential foreign investors.

- to collect

  Any company or organization (national or foreign) carrying out mineral exploration in the country produces reports on their work. The geological survey must control the punctual submission and the technical quality of such documents. However, some of the information collected will be secret and confidential, and must remain so for an agreed period of time.

- To store

  This task has to be managed carefully in order to attain long term easy access to the data. To understand the importance of data storage one need only look at how much money and staff large international mining companies devote to this job.

- To release

  This last office is probably the most difficult to do efficiently. A useful release should be the result of an exhaustive and careful synthesis and analysis of all available information. This is a job for a senior geological information specialist.

In conclusion, the point should be made that careful attention needs to be paid to the disposal of information, particularly that obtained from private investors. The protection of the confidentiality of their information for an agreed length of time before putting these documents on "open file" can go a long way towards improving the cooperation between the geological survey and investors, absolutely necessary for mutual success.

The question of the various types of contractual arrangements has been adequately dealt with elsewhere. However, it is worthwhile emphasizing that this task can be done best by a specially trained and empowered "foreign investment committee". This committee should keep in mind these important ideas:

- it is necessary to accommodate the foreign investment regulations to the special risks taken by investors in the mineral exploration.

- it is necessary to provide long term stability of the contractual arrangements in keeping with the time scale and delays of mining industry.

- it is important and necessary to maintain flexibility in the contractual agreement concerning the marketing of the product. Nobody can precisely estimate the future production capacity of a prospect. Furthermore, according to the situation of the market (over or under supply), the interests of the parties can be reversed, even several times, during the life of a mining complex.

One can say this regarding the export of the uranium: the situation of the market now, and probably for long years to come, makes it improbable that a foreign company plans to invest in uranium exploration, especially in developing countries, for the sole purpose of earning a profit. The ore bodies able to provide a normal (or better) return are becoming more and more rare, and more difficult and expensive to find. So, if the foreign company does not expect to discover a "Bonanza" deposit, their motivation is to diversify their sources of raw materials.

These and other questions require decisions before a uranium exploration and development policy is established and exploration begun.

DISCUSSION

Chairman: I would like to point out a factor we have not yet looked at and that is the increasing cost of exploration. While this is definitely the case for Canada or Australia. There we have to look for deeper deposits or blind deposits and introduce new techniques. But I am not sure this is the case in Africa. Costs may increase more for administrative and infrastructural reasons than due to the fact that all the surface deposits have been found and we have to look deeper. There are regions in various countries where with systematic work surface deposits can still be found. For developing countries we cannot yet state that they have to go into later stages of exploration. Outcropping deposits may still be found. However costs will increase for these other reasons, and this needs to be reflected in the arrangements made between host countries and investors.

But in your opinion there will be no investors who will be interested in going into new geological areas in developing countries. You seem to be very pessimistic about this.

Bourrel: I am not sure. But in the past it was very difficult to find an ore body. Today when you have to find a bonanza it is even more difficult. How many bonanzas have been found in the past? Your chance of success today is very low. Maybe some companies can take the risk, but I don't know of any.

Money: Surely this is a question of demand and supply. If uranium becomes in short supply or the cost is such, obviously they will be willing to take risks and go into areas and look for things.

Müller-Kahle: Right now it looks as though there is not pressing need to find new resources. There may be a need in 10 years of so for new mines, but in Saskatchewan there are quite a number of developments going on that may be ready to produce in 10 years or when ever the market needs this additional supply. On the question,"Is there any need for exploration", what companies do we know that are doing any "armchair geology" for new areas? This is the first indication of activity for new areas.

Secretary: I don't think there is any need for countries like Zambia to sit back and wait for companies to rush to them. They have an obligation to look for the favourable mineral resource situations in their own countries. This means that they have got to develop the skills of their own professionals, their experience to be able to recognize and understand the favourable environments, and the techniques that will provide the most useful information at the smallest possible cost, and then apply them. Then they have the job to go out and interest the investors. I believe that if you find a bonanza, a good deposit, it will be mined regardless of who else has uranium. And if it is produced at an economic price it will be sold.

Bourrel: My pessimism stems from the question who is providing money for exploration. In a normal company this is risk money, and comes from benefits (profits), or perhaps from state subsidies. Today the subsidies are no more to my knowledge. As for profits, who is making profits from uranium? Some Canadian mines and these do not want more uranium - they have enough for a long time. So if there is no profit, where is the money to make exploration? That is the reason for my pessimism.

Chairman: This point has to be taken seriously.

Darnley: I would just like to emphasise again, by and large the methods that were used during the 1970's to find uranium were the result of research and development work done during the 1960's. For example the G.S.C. spent a relatively large amount of money on method development during the 60's at a time when the economic interest in uranium was extremely low. That situation again prevails and we are all talking of the possibility of a renewed demand ten years hence, but the necessary research to provide new ideas, new methods 10 years from now is not taking place. The investment for the future is no longer taking place neither in government nor, from what you are saying, in industry either. This is a matter of serious concern. (Off the record - this stems from the obsession with the market economy which responds to short term requirements and is very efficient at satisfying short term consumer requirements. But it is not efficient at supplying long term future requirements. There is nothing in the system to provide anybody with a reward, the uncertainties are too great, it doesn't function in this way. We should try and register this in a way that will be noticed.)

Bourrel: I agree completely. But we have to make recommendations not only to developing countries but also to financial people because these financial people have the power over the money.

Money: This ought to be highlighted because it is extremely important. Private investors are not interested because they have found enough uranium for the next umpteen years, while government sectors are not geared to undertake programmes to discover deposits. But those countries that can do a modest level of work will carry on. Countries such as India or China may be different because they have nuclear power programmes, whereas in Africa a modest level of activity will carry on in their own resource assessment programmes.

Chairman: We must stress the need for geological surveys and for international groups such as the Agency to bridge this time with work, not only on the geological side but also on the legal side to be prepare for the time when this information will be needed so that countries that are best prepared from the geological and legal side will benefit first.

Secretary: While new research is not going on now, developing countries like Zambia or India still have gaps in their use of the research that was done in past years. They are still needing to learn the effective application of the techniques

that probably the developed countries know how to use very well. This is one of the Agency's jobs, to make these techniques available to them. It is their job to apply them, at whatever level they are able to, financially and economically, in building up this background information.

Darnley: It is extremely important that the Agency should continue to provide international coordination in this field. It is even more important, at a time when the general international effort is low, to try and take an overview and act as a forum of what is going on, and act as a forum for informed opinion.

Bourrel: For this preparative research you are talking about, be careful what you prepare. The geology of uranium has changed, and those countries that prepared material on too low a grade of deposit have less chance to attract investment. It is better to focus attention on high grade chances if possible.

Chairman: We have emphasised this before and need to do so again.

Money: We see that many mining companies with experience and expertise in prospection and mining have dropped these activities because of the availability of uranium in the market. We are losing the personnel with experience. Under these circumstances it is more important than ever for national governments to pay specific attention for continued exploration work and continued expertise to be retained.

Chairman: This is certainly the case with private companies but I think with geological surveys and international organizations this does not have to be the case. They are more continuous.

Secretary: This is exactly our position and the reason for what we are doing, which is to attempt, in the developing countries, to raise the level of expertise and keep the awareness there.

IV. THE ROLE OF STATE EXPLORATION ORGANIZATIONS

ROLE OF GOVERNMENT AND GOVERNMENT ORGANIZATIONS IN URANIUM EXPLORATION PLANNING AND PRACTICE IN THE UNION OF SOVIET SOCIALIST REPUBLICS

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Abstract

Uranium exploration is carried out it the USSR according to the "Principles of Legislation of the USSR and Union Republics on Mineral Resources Utilization". The following organizations are concerned:

Ministry of Geology of the USSR plans, arranges and carries out prospecting and exploration activities within the whole territory of the USSR.

Soviets of Working Peoples' Deputies and their executive and administrative agencies carry out the state control in the field of mineral resources utilization and protection and solve the problems of environmental control.

The State Committee on Mineral Reserves is a body of the Council of Ministers of the USSR and serves to solve the following problems;

- conducting of unified technical policy in the field of practical estimation of explored mineral resources, developing of raw materials cut-off criteria and determining the period of commercial mining of the deposit;

- establishment of consistent mineral raw material cut-off criteria necessary to calculate mineral reserves, and provision for complex and effective utilization of country's mineral raw materials;

- revision of data on mineral resources supplies compiled by ministries and departments. On the basis of these data the decisions are made to construct new mines and reconstruct operating mining properties, to allocate capital investments, and to work out prospective plans for mineral industry development.

Under the authority of the State Committee on Mineral Reserves is a Council of Experts, which includes leading scientists, distinguished geologists, geophysicists, hydrogeologists, miners and economists. The Council considers proposals, issues recommendations in the field of mastering of exploration methods, makes estimates of mineral raw reserves and solves the problems of classification of ore reserves in deposits as the base for development of feasibility studies.

Ministries and departments operating the deposits (Ministry of Non-ferrous Metals, etc.) carry out exploitation surveys through the geological services of mining properties.

State Committee of the USSR for Safety Inspection in Industry (Gosgortechnadzor) carries out the industrial safety measures required while conducting geological prospecting survey.

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1. GENERAL

Uranium deposits, like any other mineral deposits, are part of a country's natural resources and represent national wealth to be used to solve socio-economical problems.

The basis of mining relations in the USSR, i.e. social relations in the field of mineral resources utilization and protection, comprises the state property for mineral resources that creates the conditions for planned, rational and complex utilization of mineral resources.

In the USSR exploration for uranium as for other mineral commodities is carried out in accordance with the "Principles of Legislation of the USSR and Union Republics on Mineral Resources Utilization" according to which all mineral resources constitute a unified fund including the deposits being operated or not.

According to item 5 of the "Principles..." under the authority of the USSR is the regulation of the following mining relations:

- disposal of the universal state fund of mineral resources in the limits necessary for carrying out the powers of the USSR in accordance with the constitution of the USSR;
- establishment of base regulations and determination of universal technical policy in the field of mineral resources utilization and protection;
- development of all-union plans for rational utilization and protection of mineral resources;
- state control and supervision over mineral resources utilization and protection, and over geological investigation of mineral resources;
- regulation of other problems in the field of mineral resources utilization and protection in accordance with the Constitution of the USSR and present "Principles.."

In accordance with item 7 of the "Principles..." state control of mineral resources utilization and protection is carried out by the Council of Ministers of the USSR, Councils of Ministers of Union and Autonomous Republics, Executive Committees of Local Soviets of Working People's Deputies and special state organizations by the procedure determined by the Legislation of the USSR and Union Republics.

Geological investigation (exploration activity) is one of the ways of mineral resources utilization (item 9 of the "Principles...") and is aimed at discovering and evaluating mineral deposits, studying the mechanisms of their formation and distribution, clearing up the conditions of mining.

Mineral resources are made available (including geological survey) on the basis of permits given by state organizations in accordance with the Legislation of the USSR. Mineral resources consumers may represent state, cooperatives, social organizations, enterprises and individuals as well.

In accordance with item 17 of the "Principles..." all activities related to geological investigation for mineral resources are subject to state registration aimed at general and comprehensive utilization of received results and at prevention of duplication of works. Execution of works of geological investigation without registration is forbidden.

To determine the commercial value of the deposits and to estimate the reserves, cutoff criteria on raw materials are developed for every deposit. Cutoff criteria represent the whole complex of economical requirements for quality and quantity of mineral resources, for geological and other technical conditions of mining. Cutoff criteria for mineral raw materials (including uranium) are worked out with consideration of base and by-product mineral commodities utilization in accordance with the Legislation of the USSR.

In accordance with item 51 of the "Principles...", in the case when an International Treaty of the USSR states rules other than contained in the Soviet Legislation on mineral resources, the rules of International treaty are applied. The same concerns the Legislation of Union Republics on mineral resources utilization.

2. CLASSIFICATION, RESERVE CATEGORIES

One of the main tasks of state organizations is a comprehensive calculation of mineral reserves. Based on its socio-economical value, uranium reserves, as are the reserves of any other mineral raw material, are divided into two groups, each of them is subject to individual evaluation, estimation, and registration;

- profitable reserves - reserves, the utilization of which is economically advantageous at present. Profitable reserves must satisfy all cutoff criteria approved for reserves estimation;

- unprofitable reserves - reserves, the utilization of which is economically disadvantageous at present because of low ore contents, small zone thickness, low ore grade, complex mining conditions or because of the lack of modern technology for mineral extraction (uranium in particular). The obligatory condition of relating reserves to that group is the availability of real opportunity to mine them in commercial scale in the foreseeable future.

By the grade of investigation ore reserves are divided into four categories: A, B, C_1, C_2. First three categories refer to explored reserves; the latter to preliminarily evaluated ones. Depending on complexity of geological structure, the deposits are classified into four groups with definite relationship of reserves for every group. Uranium deposits are usually characterized by complex geological structure, sharply changing bedding elements, variable ore grade and uneven uranium distribution (coefficient of ore contents 0,3-0,8), hence they refer to groups 2 and 3. Considering all mentioned above, those groups are explored to meet categories C_1 and C_2 requirements. Their relationship is 80% and 20% for C_1 and C_2 respectively.

3. URANIUM DEPOSIT EXPLORATION STAGES

Geological exploration for uranium follows the principle of step-by-step investigation. According to this principle the exploration process consists of a series of successive stages and operations within each of which the deposit is being investigated with increasing grade of activity.

3.1 Prospecting and Exploration Survey Stage

At this stage comprehensive investigation of ore manifestations on the surface is carried out to determine potential deposit type, its geological limits (in plan and to depth) within which category C_2 reserves will be estimated.

3.2 Preliminary Survey Stage

If, as a result of large scale feasibility study analysis, it is found that the discovered deposit meets the cutoff criteria, then a preliminary survey is carried out.

At the stage of preliminary survey the total grade of mineralization is cleared out, mean grade of mineral raw material is evaluated and the succession of commercial utilization of deposits is determined. The tasks of that stage include:

- determination of basic geological laws defining the location of mineralization and mean parameters of ore bodies. Preliminary survey is completed with the estimation of categories C_1 and C_2 reserves, compilation of an expert report summarizing the main observations, conclusions and recommendations and with the development of temporary commercial cutoff criteria for an ore deposit. According to temporary cutoff criteria the reserves of uranium ore, uranium and associated mineral commodities are estimated on C_1 and C_2 categories.

Beyond the area of reserve estimation and on deposits discovered within an ore field under prospection-exploration activities probable reserves are evaluated on P_1 category.

If the deposit is positively approved in the expert report and is planned for commercial mining in the next 10 - 15 years, it is subject to detailed survey. Deposits that are not planned for commercial mining during that period are referred to prospective ones, their reserves are estimated on the basis of preliminary survey data.

3.3 Detailed Survey Stage

At the stage of detailed survey a comprehensive estimate of the deposit is carried out followed by commercial mining. The tasks of the detailed survey include a comprehensive and thorough investigation of the geological structure of the deposit, its morphology, chemical and mineral composition, distribution mechanisms of uranium in separate areas and blocks. At the stage of the detailed survey collection of data necessary for the development of a construction project for mining and treatment complex is carried out. The detailed survey is completed with reserve estimation of categories A, B and C_1 and compilation of the report on the detailed survey results. Data on the reserve estimation and the report must be approved by State Committee on Reserves of the USSR followed by financing of the construction project.

3.4 Exploitation Survey Stage

Beginning with the development of the deposit and to the end of its mining, exploitation surveys are carried out on it. The aim of the exploitation survey is the provision of detailed data on mineral reserves in blocks to be extracted. The task of that stage is to obtain more detailed information on uranium ore distribution within blocks being mined and precise estimation of every block's reserves.

Under the conditions of the operating mining property prospect, surveys in peripheral parts and on deep horizons, and on areas neighbouring the deposit are carried out.

4. FUNCTIONS OF GOVERNMENT AND STATE ORGANIZATIONS PARTICIPATING IN PLANNING AND EXECUTION OF GEOLOGICAL EXPLORATION ACTIVITIES

In planning, arranging, executing and controlling geological exploration activities, including geological prospecting for uranium, the following government and state organizations take part:

1) Ministry of Geology of the USSR plans, arranges and carries out prospecting and exploration activities within the whole territory of the USSR. Data on completed geological exploration activities are kept in the geological files of the Ministry.

Taking into account specific properties of uranium ores and their specific requirements for geological exploration methods, and to provide for safety of the activities, prospecting and exploration works for uranium are carried out

by specialized territorial geological organizations, the infrastructure of which includes expeditions and field crews. Those expeditions and field crews carry out works on definite territories. Prospecting and exploration works for uranium are carried out on prospect areas identified in the process of total geological prospecting of the territory of the USSR.

The Ministry of Geology of the USSR through its agencies of geological control establishes state control over the geological investigation of mineral resources.

In accordance with the Principles of Legislation of the USSR and Union Republics on mineral resources utilization the main task of state control over geological prospecting for mineral resources is carrying out of the established rules of geological surveying, prospect exploration, hydrogeological, geochemical, geophysical and other activities in geological prospecting of mineral resources, rules for the utilization of mineral resources, and the requirements in the field of mineral resources protection, to the thorough and complex investigation of them, and provision for effective fulfilment of mentioned works.

2) Soviets of Working Peoples' Deputies and their executive and administrative agencies, in accordance with their competence, carry out the state control in the field of mineral resources utilization and protection and solve the problems of environmental control.

3) The State Committee on Mineral Reserves is a body of the Council of Ministers of the USSR and serves to solve the following problems;

- conducting of unified technical policy in the field of practical estimation of explored mineral resources, developing of raw materials cutoff criteria and determining the period of commercial mining of the deposit;

- establishment of consistent mineral raw material cutoff criteria necessary to calculate mineral reserves, and provision for complex and effective utilization of country's mineral raw materials;

- revision of data on mineral resources supplies compiled by ministries and departments. On the basis of these data the decisions are made to construct new mines and reconstruct operating mining properties, to allocate capital investments, and to work out prospective plans for mineral industry development.

In its activity the State Committee on Mineral Reserves is guided by the Legislation of the USSR, by government resolutions and instruction, and bears the responsibility for the validity of mineral raw materials cutoff criteria, trustworthiness of approved reserves in accordance with technical policy and latest scientific and technical methods.

Under the authority of the State Committee on Reserves the Council of Experts functions. The council includes leading scientists, distinguished geologists, geophysicists, hydrogeologists, miners and economists. The Council considers proposals, issues recommendations in the field of mastering of exploration methods, makes estimates of mineral raw reserves and solves the problems of classification of ore reserves in deposits as the base for development of feasibility studies.

4) Ministries and departments operating the deposits (Ministry of Non-ferrous Metals, etc.) carry out exploitation surveys through the geological services of mining properties.

The result of the exploitation survey may be a significant increase of mineral raw material base at the expense of peripheral areas and deep horizons of deposits and neighbouring districts.

5) State Committee of the USSR for Safety Inspection in Industry (Gosgortechnadzor) carries out the industrial safety measures required while conducting geological prospecting survey.

6) State Committee on Planning of the Council of Ministers of the USSR (Gosplan), on the basis of 5-year and 1-year plans of development of geological activity, finances and gives technical allocations for their realization.

5. PRINCIPLES OF PLANNING OF GEOLOGICAL EXPLORATION FOR URANIUM

Planning of the amount and trends of geological exploration for uranium, aimed at the provision of the necessary increase of explored reserves, is dictated by the needs of national economy, first of all by the need in energy resources and is regulated by perspective and five-year national economic plans.

Based on the needs of consumers, the level of mining volume and raw materials base of operating mining properties, plans for development of exploration work for uranium are developed. Those plans are kept at the Ministry of Geology of the USSR and distributed by it within territorial industrial geological associations. Within the limits of those associations, 5-year and 1-year plans are developed, and projects for prospecting and exploration activities are made. On the basis of these plans and projects, necessary financing funds and material and labour resources are determined. Plans and projects are considered and approved by the Ministry of Geology of the USSR and a special department of "Gosplan". On the basis of them, financial and material resource allocations are made.

Costs of geological prospecting and exploration activities constitute 60% and 40% respectively of the total costs of geological prospecting.

DISCUSSION

Verma: I would like to know how you control the environmental questions, what are the checks and controls on large mining projects in the USSR. What precautions do you take?

Vlasov: The environmental control is a main task of the local councils. And it is also the task of higher level councils (committees). We have a department in our Academy of Science which controls the environment. We monitor all environmental aspect, radon, water etc.

Verma: Are there any deposit types in the USSR that are not known elsewhere in the world?

Chairman: For example the metasomatic type that are little known elsewhere, albitite deposits.

Tauchid: Where does your Institute of Geological Exploration of the State Committee on the Utilization of Atomic Energy fit into the scheme you outlined in your paper?

Vlasov: Our institute prepares geologists for uranium exploration. We have a Geological Faculty and a special group where students are trained. But our Institute is under the authority of the higher ministry of education since it is basically a teaching institute.

Hammer: You mention that mineral resources are available for disposal also by individuals. Does this mean that a private person could apply for a mining licence? And would this apply only to Soviet citizens or also to foreign investors?

Vlasov: Although we do not make any distinction between uranium and other minerals this applies only to gold. (Laughter!!!)

Müller-Kahle: In you paper you outline your resource categories, A, B, C_1 and C_2, and I think we are roughly familiar with these. But later on you mention a P_1 category. Where does that come in relation to the others?

Vlasov: Category P_1 and we also have category P_2 are uncommercial reserves (M.K. - prognosticated) yes prognosticated. But these are nearby to deposits and near ore fields - so P_1 is near and P_2 is farther away, completely undiscovered resources.

Chairman: Concerning your cut-off criteria determination, I think that this is one of the most important institutions you have in your system. This decision making body, containing economists, miners, and geologists, and they will outline certain guidelines. But how often do they change. Your needs will also change so that these cut-off criteria will probably change continuously, not year by year, but continuously through out the year.

Vlasov: Indeed we have some cut-off criteria, for example cut-off grade, cut-off thickness, and unfortunately we change these only in the preliminary survey (reconnaissance) stage. When we reach the detailed survey stage these cut-off criteria are controlled by an organization and they are constant, unfortunately. During the whole period of mining they remain constant. But now for us it is a very important problem to change cut-off criteria, not only for the whole life of the deposit but for separate parts of a deposit as well. This change has not yet been made.

Chairman: I have a question concerning the separate institutions and who is doing what type of work. You mentioned that in some cases you do mining but outside of the mining areas you do exploration which is the normal thing. Is this additional exploration done by the mining group or is the Geological Survey or other institutions involved outside of the mining areas? There might be a possibility of conflict in such a case.

Vlasov: We do not have conflict between institutions because the work of each is laid down in the central planning - each has their assigned place to carry out the work.

Money: Yours is a teaching institute. When you do exploration do you have to obtain a permit like other groups?

Vlasov: In our institute we have a small research department that carries out research on deposits including uranium. Our students do their practice in connection with this, not in specific areas, and not only uranium.

URANIUM EXPLORATION IN INDIA - PERSPECTIVE AND STRATEGY
(Abstract)

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Exploration for uranium, together with other strategic elements like Th, Zr, Nb, Ta, REE, and Y, is the sole responsibility of the Atomic Minerals Division (AMD) of the Department of Atomic Energy (DAE), which is the Government of India organization established to conduct all functions related to research and development of atomic energy. To meet the growing industrial and agricultural demands for energy, DAE is having a nuclear power programme to generate 10,000 MWe by 2000 AD. This programme is based almost exclusively on natural uranium fuelled thermal reactors, followed by plutonium fuelled fast breeder and thorium based reactors, the last two planned to be operative by early next century, and in such a programme, uranium is to play a critical rile for the next three to four decades.

The Atomic Minerals Division has so far identified indigenous resources needed for the planned 10 000 MWe nuclear generating capacity, at an exploration cost of less than 1% of the value of proved uranium reserves and a low metreage of drilling (5 - 60 m) per ton of U_3O_8, by pursuing a policy evolved since 1948 and modified from time to time, in conformity with changing concepts and methodology of uranium exploration the world over. Thus in the early years, the emphasis was directed to the known uranium occurrences in favourable rocks and environments by on-foot radiometric surveys using bulky portable GM counters followed by isorad and geological mapping, trenching, pitting and drilling on a low key that proved a few deposits in the Singhbhum region of Bihar. With the advent of new insights in the geochemistry of uranium and the time-bound character of major uranium deposits the world over and rapid development in the instrumentation, the exploration strategy is accordingly modified to the present status, which encompasses a multi-disciplinary and multi-phased approach that includes remote sensing, airborne radiometric and magnetometric surveys, carborne and on-foot surveys, isorading, trenching and pitting, exploratory and evaluation drilling, detailed geological and structural mapping, core checking, radioactive and non-radioactive geophysical surveys, petromineralogical and mineral beneficiation aspects of ores. Such an integrated approach has results in discovering significant low-grade uranium occurrences of all known types of the world U deposits, with the exception of the unconformity related type, in diverse geological environments in terrains, even outside the earlier known U provinces, like the one of the Southern Peninsular India.

The planned strategy for the near future envisages large inputs of indirect methods of exploration in areas selected on sound geological reasoning and concepts, together with substantial increase in drilling activities, so as to discover new concealed deposits, possibly of higher grade and large tonnage, besides finding extensions of the presently known deposits and exploiting the small tonnage numerous low grade deposits be developing suitable mining and low cost heap leaching techniques, as also economic extraction of uranium from refractory ores, clays and iron oxides.

DISCUSSION

Chairman: You mentioned the fast breeder programme. Do you feel there is a chance to get this programme on an economic basis before thirty or forty years?

Verma: We are still in the stage of developing the technology and at this stage it is not yet possible to arrive at the economics of the process.

Tauchid: At what stage does AMD relinquish a project to the mining companies?

Verma: The Uranium Corp. of India eventually does the mining and milling of the ore. AMD is closely associated with it even in the final stages when we evaluate ore reserves. We pass on our report; they examine the report, then we have a joint evaluation. We may have to modify it, because the mining engineers have to be satisfied that our reserve estimates are reliable and dependable. They then prepare a feasibility report and eventually a detailed project report is prepared and submitted to the Government. Another corporation, the Indian Rare Earths Ltd. is directly under the Department of Atomic Energy. They take up the other minerals in the beach sands that are not covered by the Uranium Corporation. So there are two corporations that eventually make use of our exploration data.

Tauchid: It seems to me that you have very close relations, because you have technical people who are borrowed or even exchanged between the corporations.

Verma: That is correct. The corporations were started by people from AMD who were finally absorbed.

Chairman: We have discussed the exchange of information between, let us call them Atomic Energy Commissions and their exercising group, and the Geological Survey. You collect a lot of geological data in the AMD. How is this exchanged between your organization and the Geological Survey, do you automatically send it to them?

Verma: We do. When we come across any other associated economic minerals in the course of our exploration we pass on this information to the concerned agency, whether the Stancorp Ltd. or the G.S.I. They may even come and sample our drill

cores so they can do their own studies. We pass on all the relevant information. We do not pass on all the detailed maps of our prospect areas unless they have a bearing on their work. We have a Central Geological Programming Board under the Ministry of Mines. The AMD Director is also a member so that all the annual programmes of the AMD, the G.S.I. and the various other state organizations are discussed before the G.S.I. programme is finalised. In this way we know what each of the organizations concerned with geological work is doing, their programmes can be coordinated and there is no duplication as such.

Tauchid: This problem of exchange of data is one we meet every place we go. The question is how to stimulate this exchange. The Board is one mechanism; another thing I noticed in India - you have frequent national meetings and this is an avenue where people are able to present their work. So these two mechanisms should be stressed.

Verma: In addition to the Central Geological Board we have also 22 state governments with mining and geology departments. They have their programming boards on which the AMD is represented along with the GSI. So there are frequent meetings and interactions between the various organizations working in the different areas.

Money: There are a large number of universities in India presumably doing some work connected with uranium for example in sedimentological studies and so on. Is this university work coordinated with the other programmes.

Verma: Yes. Some universities, like Benares University have carried out a programme of sedimentological studies and we had interaction on this. We also finance research projects in the universities and institutes of technology. The Department of Atomic Energy gives scholarships and contracts. We employ fresh graduates on fixed term contracts to carry out scheduled projects which helps them to learn about the work and frees our staff for more specialized work. So there is a lot of interaction with the universities.

Money: Are there any possibility for private sector companies or foreign companies to take up exploration programmes in India?

Verma: The policy does not preclude such ventures. In fact this year we had some interaction with COGEMA (France). They were there for quite some time looking at some of our promising areas where we thought there was a possibility for the unconformity related types. They gave us some recommendations, and some of our people have visited COGEMA's operationa in France and in Canada. I don't see why in the future there could not be more contacts.

Chairman: But there is not yet any legislation which would theoretically allow a foreign company to take up an area and to do work either alone or jointly with you.

Verma: We would think about that when we feel there are certain areas where our own expertise is not sufficient. But where we feel we have the capacity to do the job ourselves naturally we go on our own.

Money: What is the size of the uranium programme, the staff, the budget annually.

Verma: That has been changing. We started with a very modest figure in the early 60's in the order of $1 million per year. It has been steadily increasing and by now is about $20 million. We hope this will increase as we increase our drilling programme. As to staff, we have around 250-260 geoscientists. In addition we have a lot of auxiliary and technical staff.

Tauchid: This is substantial and should be of interest to others. If you are serious in doing uranium exploration following this model you have to spend the money and you have to have the staff.

Chairman: You mentioned that you plan by the year 2 000 to have about 10 000 Megawatts generation capacity. That would require roughly 1 500 to 2 000 tonnes of uranium per year. If you want to have ten years reserves ahead that means you have to have about 17000 tonnes reserves available. That is a substantial amount of uranium.

Verma: We have given our estimate of established reserves to IAEA - around 76000 tonnes.

Chairman: How do the Indian people react to nuclear power. Is there any resistance to the programme.

Verma: In some areas where nuclear power stations are running there is no resistance. In other areas, for example in the state of Karnataka there has been some opposition. Here a public debate has been organized to explain to the public and dispel their apprehensions. So creating public acceptance is very much a part of the programme.

Müller-Kahle: Could you give us some idea of your average discovery costs for your programme?

Verma: Our conditions vary widely, our terrains are different, some are easy, some are very difficult, so costs vary widely. So a general figure would not mean much.

Chairman: One final question. What body is supervising the environmental protection of uranium mines. Logically it should not be done by the Atomic Energy Commission which is itself involved. Is there a different body?

Verma: Yes. There is a Department of Forests and Environment. Unless they give clearance to a project we cannot go ahead. This Department is absolutely separate and independent. One of our projects took a full five years to get clearance from the Department.

V. CONCLUSIONS

The Advisory Group reviewed the main points raised during the meeting under the following headings:

1. exploration planning and strategy
2. role of national geological surveys
3. role of state exploration organizations
4. contractual arrangements and role of outside interests

It was not the Group's intention to make firm recommendations to readers as to which path should be followed. Rather their intention was to emphasise the points that must be considered under each heading, so that a clear basis for a sound decision is available.

I. Exploration Planning and Strategy

Every country has to define what role uranium will play in its economy. This is in the realm of national policy. Two main purposes should be considered:

- uranium is required purely to meet national needs,
- uranium is desired as a means to earn foreign exchange.

In both cases funding of the programmes, targets, institutions, phases of the work, definition of economic criteria, must all be considered. However, it should be recognized that there are political considerations in the policy making, over and beyond the strictly economic considerations. It must be remembered that strategic minerals are minerals where there are more than just economic concerns to be considered - questions of availability, shortages, cartel control or influence on supply, nature of the use, etc. All of these are more than just market concerns. Uranium has unique properties that make it special. The reader should refer to the discussion at the beginning of the document concerning the special "strategic" mature of uranium and the associated problems.

Strategy should also be concerned with single or multi-commodity approach. Someone trying to determine future plans and policy should consider both sides of the argument. The pros and cons of searching for uranium as a unique element and one to be searched for by itself, can be listed. There are arguments in favour as well as arguments against. Consideration should also be given to which national institution(s) should be involved, and at what stage: geological surveys, atomic energy commissions raw materials divisions, state mining companies, etc.

II. The Role of National Geological Surveys

The national geological survey normally provides the infrastructural and information base for mineral development. Unless national policy dictates otherwise, the geological survey will confine itself to the type of scientific

investigation described below and refrain from work of an economic nature to avoid any conflict of interest. This type of economic risk taking is not normally the task of geological surveys and they are not equipped to do this well. It may be necessary in some cases, however, for the survey to carry its work farther into the "economic sphere" than would normally be the case in order to improve the information on certain neglected areas to attract foreign investment. In general, however, its scientific work should be done for the purpose of releasing to the public information for the general good in order to raise the level of knowledge and performance in the country.

The level of work carried out may also depend on the type of entrepreneurial development desired. Large companies do not need nor want the level of assistance and encouragement by the geological survey that the small companies do. This comes back to national policy. In most developing countries, the small private prospectors that found most of the deposits in Australia, Canada or the USA, do not exist..If the Government is interested in encouraging such small entrepreneurs or small partnerships, these will have a real need for the additional technical support and direction. Large companies tend to take the view that this type of support simply encourages undesirable competition from the small entrepreneur.

A number of tasks are customarily carried out by the Geological Survey. These include:

- systematic evaluation of the resources of the country in order to provide Government with basic information on the potential of the country for mineral resources. This basic information is obtained through the reconnaissance programme of geological, geophysical and geochemical mapping. Routine geological mapping must, in future, include much more information on mineralization factors and environments. This should normally multi-commodity rather than single commodity information. It is normally more efficient and more economical to conduct multi-commodity surveys than single commodity crash programmes, which are inherently inefficient. A multi-commodity resource oriented mapping approach should, therefore, be adopted.

- release of the information gathered in order to attract industrial interests to potential areas for development. The geological survey should be encouraged to publish and publicise the results of its work as quickly and completely as possible. This is particularly important if it is the wish of the government to attract foreign participation in the development of the mineral potential of the country.

Where private companies, either local or foreign are active in mineral exploration and development, the geological survey may have an additional role - to monitor, collect and store the data developed by the companies during their exploration and development programmes. The geological survey must, therefore, be provided with proper data storage

facilities. These data should be assessed as to quality and an adequate standard of quality of data should be encouraged. Confidentiality of data must be maintained for some agreed period of time. But in the long term, all data must be made available to the public. It should always be borne in mind that the collection of exploration data has cost money and so these data should be maintained in as complete and readily accessible a form as possible.

The geological survey must maintain a certain minimum level of activity in order to provide continuity of information and knowledge without the cyclic boom and bust of commercial activity that waxes and wanes according to economic conditions. This implies a certain minimum level of staffing and support. It would be of great help to the health and good functioning of the geological survey if the government allotted a portion of the revenues derived from mineral products to the financing of the geological survey. Contracts with outside interests could include provision for an amount of foreign exchange to be made available to the survey to allow for the purchase of essential equipment and supplies from outside.

The geological survey should carry out adequate R.& D. work on exploration methods, encouraging unconventional thinking by its staff. The workers of the survey should have the possibility, from time to time, to carry out more detailed work for the purpose of developing and testing exploration methods, and to encourage their scientific and technological development. The results of this work should be made freely available to all those interested.

III. The Role of State Exploration Organizations

The term state exploration organizations refers to state owned and operated institutions, other than geological surveys, that are concerned with exploration and mining for minerals. These are most often the operators of exploration and mining ventures, in place of private mining companies. In the case of uranium, they are often a division of the Atomic Energy Authority and have exclusive jurisdiction over the commodity. This mechanism is most appropriate where the country is seeking to meet its own internal needs for uranium. It is used for uranium in the USSR, India (as described in papers in this meeting), as well as in China, Argentina, Pakistan, and Turkey, to name a few. The French state company COGEMA might be considered to be of this nature, although it does not have exclusive jurisdiction over uranium in France, and in its operations overseas it acts as a private company.

The meeting noted several points to be considered if this mechanism for uranium exploration is to be followed by a country.

-The country starting such an organization must have a good grasp of the size of budgets and staff, along with the infrastructure required to properly develop and support such an organization. In India, for example, a budget of $20,000,000 per year and a staff of 2500 people is available to the Atomic Minerals Division.

-Some mechanism must be found to monitor the efficiency of the organization in the absence of market forces and of competing companies with which comparisons can be made. It would be necessary to go outside and compare the costs of various operations against some independent yardstick. The arrival at a satisfactory mechanism will be difficult. In India, a 9 member board reviews the work and makes a technical audit of the organization every year. In any case the problem must be considered because it is wasteful of the country's resources to do the work inefficiently.

-Efficiency also may be judged by the final cost of the product compared with the cost of the uranium on the world market. A number of considerations may come into play in this case. It may be of interest to pay somewhat more for the uranium and, at the same time, to encourage the development of technical personnel, to preserve foreign exchange, to develop an independence and assurance of long term supply, etc. In other words, a country may elect to pay more internally - but, it must establish clearly how much more. In the final result, decisions have to be made as to the size and grade of deposits that are to be worked and the cut-off grade, and exploration decisions must be based on these. In no case should exploration proceed without these decisions.

-The organization must have very good communication with other state organizations in the field, particularly with the geological survey organization. Findings made by the geological survey should be communicated quickly to the state exploration group.

-There must be a clear separation of operation from regulation. The organization should not be left to regulate its own safety and environmental aspects, for example. There is a need for an independent regulatory body to do this.

IV. The Role of Outside Interests

The meeting discussed the question of what circumstances would make it desirable to involve outside interests in the country's uranium exploration activities. Some of these are:

-the country may have areas of interesting uranium deposit potential, but not have sufficient indigenous resources, staff, funds or infrastructure to carry out the exploration independently. The country may not have a need for uranium itself but may wish to test the possibility of earning foreign exchange from the sale of uranium. The foreign company mechanism may offer the best means of achieving that end. The outside company offers the possibility of transfer of knowledge and expertise, as well as of financial investment. Without their involvement, such knowledge and expertise might have to be acquired through the hiring of consultants or through technical assistance programmes.

The question of safeguards must be considered. At the stage of exploration this presents no problem. However when the uranium produced is to be sold, the country will want to assure itself that the sales are to valid buyers and are for peaceful purposes only. At this moment it will be necessary to have machinery and regulations in place to monitor and regulate sales. These regulations should be developed and made known as early as possible in order that they will not have to be introduced or changed once selling has begun. It is desirable to develop, from the beginning of the operation, the reputation as a reliable supplier.

To attract foreign companies it will be necessary to develop serious and satisfactory technical, legal, fiscal and administrative conditions under which the companies will operate. If conditions are not realistic this may lead to a loss of opportunities and of investment. Consideration should be given to the size of concessions allowed. On the one hand these should be large enough to make reconnaissance surveys feasible but large concessions should be available for strictly limited periods of time. In general it is of interest to attract more rather than fewer investors and this means more, somewhat smaller, rather than fewer, larger, concessions.

The more companies that are attracted to invest, the greater the chance of finding something because of the increasing amounts of information that become available. Sharing of information increases the chances of success.

Mining laws that recognize old entrenched land grants or old small concessions with no time limit serve to block development and are not in the best interest of the country seeking increased development. It may or may not be of interest to require local participation in foreign mineral development through joint ventures, etc. If this method is followed the each side of the venture should be required to finance its own share. Facilities and mechanisms must be provided for independent arbitration in the case of legal disputes.

If foreign participation is to be encouraged mechanisms must be found to advertise the potential of the country and to attract the interest of the foreign investor. In addition, information of high quality must be available to convince the investor of the potential of the country.

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