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URANIUM NEWSLETTER

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA

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THE NEW URANIUM NEWSLETTER

The International Atomic Energy Agency (IAEA) decided in 1986 to begin publication of an annual Uranium Newsletter. Publication of the first issue was planned for early 1987. The present Newsletter is the result.

Readers will remember the more or less annual publication by the OECD Nuclear Energy Agency (NEA) of the Newsletter "R&D in Uranium Exploration Techniques" which began in 1979. That publication drew upon reports and notes presented by national representatives at the annual meetings of the NEA/IAEA Joint Group of Experts on R&D in Uranium Exploration Techniques. From its first ussue the R&D Newsletter had a considerable readership. Over 1300 copies in English and French were distributed by NEA of each issue. With the demise of the Joint Group of Experts in 1984, the source of material for the newsletter disappeared and its publication ceased.

Since 1984, at Technical Committee meetings, Advisory Group meetings, Consultant's meetings as well as in personal contacts, the IAEA has received suggestions and requests to continue publication of a Uranium Newsletter. Lacking the regular mechanism of an annual Joint Group meeting, other means had to be found to provide material for the publication. It was decided to solicit contributions from individuals willing to act as national reporters. Starting with a relatively small group known to staff members of the IAEA Division of Nuclear Fuel Cycle, a group of reporters was approached and most agreed to contribute. In addition, members of the Division of Nuclear Fuel Cycle concerned with uranium were enlisted to report on the activities of the IAEA in aspects of uranium resources, geology and exploration. These activities are rather wide ranging and include the "Red Book" on Uranium Resources Supply and Demand, recent and planned technical meetings on uranium topics, recent and planned publications, IAEA Technical Co-operation projects, and Agency supported research contracts in uranium topics.

The above list of topics to be covered will indicate the difference between the old and the new newsletters. Rather than focusing on R&D in exploration methods, an area at rather low ebb at the present time, it will aim to inform a wider audience of the continuing role of the Agency in uranium exploration and development. At the same time, through the country reports, it will aim to provide information and contacts to those with a continuing interest in uranium development. That this continues to be a significant community is evidenced by the tremendous response to our efforts to up-date the original NEA mailing list. Clearly there are interested people still around. Many of these are in organizations other than uranium exploration groups. These people are aware of the wider value of the data and expertise developed during the boom days of uranium exploration. It is hoped that these people will find the material of the Newsletter of interest and value.

Many readers will find that uranium activities in their country are not covered. They should take this as a challenge and submit a contribution to the next issue. Through the contributions of our readers the quality and value of the newsletter will increase. The repoters of the national contributions should be contacted for further information on activities reported. The members of the IAEA Secretariat are always ready to provide further information on any aspect of the Agency's activities. We hope the Uranium Newsletter will become a forum for the exchange of information and ideas on all aspects of this important commodity. Your contribution will help to make is so.

WHO WE ARE

In this first issue of the new Uranium Newsletter it may be of interest to our readers to learn something of who we are and what we do here in the IAEA. Figure 1 shows the organization of the IAEA. The Uranium Unit is a group within the Nuclear Materials and Fuel Cycle Technology Section, which is one of two sections of the Division of Nuclear Fuel Cycle.

ORGANIZATIONAL CHART

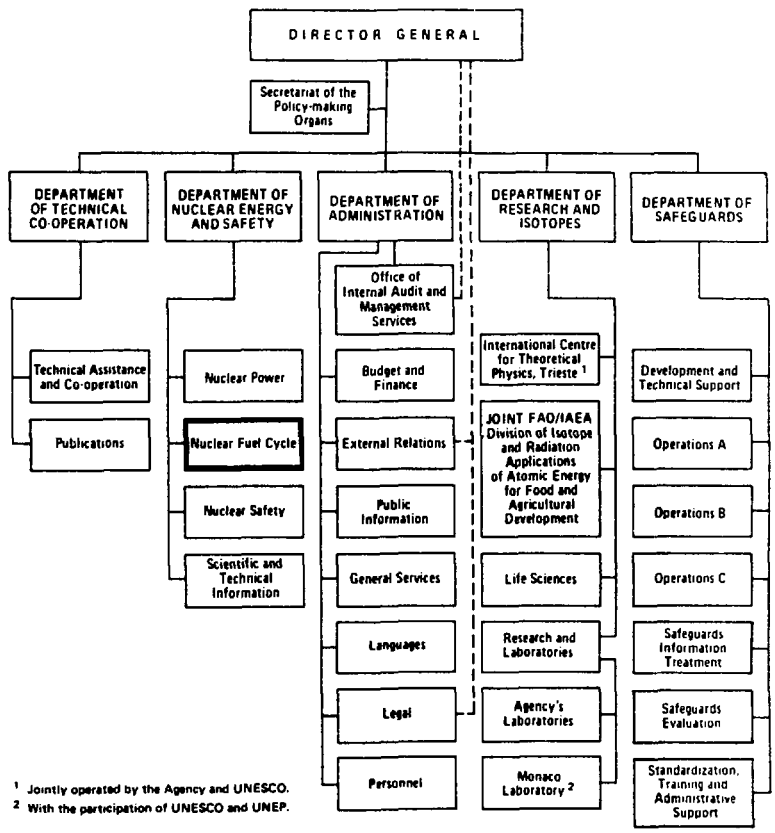


Figure 1

Organization of the International Atomic Energy Agency

The IAEA has been involved with uranium since its founding in 1957. The first Agency expert in uranium prospecting was sent to Burma in 1959. Staff members cover the fields of uranium geology, exploration, development, and mining. All members cover aspects of technical assistance projects, to which one member devotes most of his time. Most members are involved in servicing the Research Contract programme.

As has been noted, the activities of the Agency in uranium cover the field of uranium geology, exploration, uranium analysis, and mining. Various

mechanisms have been developed over the years to fulfill the Agency's role of gathering and disseminating information on these subjects. Amongst these are technical meetings, publications, training, technical assistance projects and research contracts.

Several types of meetings have been organized to bring together experts and others interested in various aspects of the uranium industry. Examples have been the Panel Meeting on Uranium Exploration Geology held in 1970 and the Panel Meeting on Uranium Exploration Methods held in 1972, the Athens (Greece) Symposium on the Formation of Uranium Ore Deposits, held in 1974, and the Symposium on Exploration for Uranium Ore Deposits, held in Vienna in 1976. These meetings each led to a major Agency publication. A third symposium was organized in 1982 jointly with the NEA (OECD) on Uranium Exploration Methods.

At the first panel meetings working groups were formed to make recommendations to the Agency. The working group members, under a chairman selected from the group, frequently maintained contact and exchanged information over the years. In the case of the Geology Working Group, this resulted in the compilation and publication of volumes on the important types of uranium deposits.

After 1976 panels and symposia were replaced by several types of meetings; Advisory Group Meetings, Technical Committee Meetings and Consultants Meetings. Advisory Group Meetings are comprised of a rather small group of specialists convened at the expense of the Agency to advise on particular topics. Technical Committee Meetings are somewhat larger gatherings of interested participants nominated and financed by their Governments to consider topics of mutual interest. Consultants Meetings are comprised of three or four specialists called and financed by the Agency to make recommendations on a particular topic and/or to prepare a document for publication. A recent example of an Advisory Group Meeting was that held in November 1986 on the Use of Airborne Radiometric Data to Define the Natural Background Radiation Environment (see report below). An example of a Technical Committee Meeting was that held in Spain in 1986 on Uranium Deposits in Magmatic and Metamorphic Rocks (see report below). In 1983 a group of three consultants considered the requirements for and the preparation of a set of standard reference materials for the determination of potassium, uranium and thorium in geological materials by gamma-ray spectrometry. Another group met in 1984 to begin the preparation of a manual on the Use of Radon in Uranium Exploration.

The various meetings mentioned above have led to the publication of a number of volumes of several types. These include Proceedings, Technical Reports and Technical Documents (TECDOCs). In Agency usage the first two of these are "sales publications" while the third, the TECDOC is distributed free of charge on request. The Proceedings volumes normally contain the full texts of papers presented at the meeting in the original language with abstracts in English, and Working Groups reports. An example is the Proceedings of the Symposium on the Formation of Uranium Ore Deposits. Technical Reports are usually the texts prepared by the specialists as a result of a Consultants Meeting. An example of these is the Technical Report on Radiometric Methods in Uranium Exploration. TECDOCs have been used mainly to publish the work of the working group on Uranium Geology. An example is the TECDOC (no. 328), "Geological Environments of Sandstone Uranium Deposits". A complete list of Agency publications on uranium is available from the Newsletter Secretary.

Technical Assistance has always formed a large part of the work of the Uranium Unit. Two types of technical assistance projects are carried out by

the Agency. Projects are conducted under the Agency's Regular Programme of Technical Co-operation. In these, the funds are provided by the Member States of the Agency on an annual basis as part of the regular budget process and are entirely administered by the Agency Secretariat. Regular Programme activities include general advisory missions, prospection, exploration and ore reserve estimation, instrument electronics, mineralogy, uranium analysis, drilling, university teaching and consultant missions (on, for example, legal aspects of uranium exploration and mining). These projects are requested each year for the following years' execution. They are usually of a relatively specific nature and of relatively short duration, although requesting organizations are encouraged to regard Agency assistance within a longer term plan of development. Projects typically entail the provision of an expert for up to six months or even one year in a few cases; the provision of field or laboratory equipment, and; the provision of one or more scientific visits or fellowships for training abroad. One of our staff is named technical officer for each project. Typical project budgets may range from a few tens of thousands to several hundred thousand dollars, spread over several years. Requests are received from thirty to forty countries annually. Agency Technical Assistance projects in uranium since 1959 are shown on the attached map.

The second type of technical assistance project is the large-scale project funded by the United Nations Development Programme (UNDP), or through other special funds. Projects in the fields of uranium exploration and development, are executed by the Agency on behalf of UNDP. They typically extend over several years, include more experts, equipment and fellowships. Such projects are developed within the countries' five year Country Programme for Technical Development. The Agency has executed ten large-scale projects in uranium exploration and development since the first in 1971. These were in Greece (2), Pakistan, Chile, Turkey, Peru, Ecuador, Madagascar, Colombia and Costa Rica.

Training courses are the third mechanism of Technical Assistance and these have been held on a variety of topics since the first, in Uranium Prospecting and Evaluation, was held in Argentina in 1969. These may be regional or inter-regional in scope, and normally are confined to about twenty students. While they have generally been held every second year, this interval is not fixed, recent courses having been held in 1981, 1982, 1983, 1985 and 1986. They are usually held in a host country able to provide adequate facilities and some of the teaching staff. Additional course lecturers and facilities are provided by the Agency. Courses are ussually of six to eight weeks duration, providing time for in-depth coverage of the topic and extensive interchange between students and staff. Participation of the selected students is financed by the Agency or by the UNDP.

Other activities of the Uranium Unit include the Research Contract programme and INTURGEO. The Agency carries out no research itself in the field of uranium exploration and development. Instead research is encouraged through mechanisms collectively called Research Contracts.

Three types of arrangements are possible; the Research Agreement, the Research Contract and, the Coordinated Research Project. The Research Agreement is a contractural agreement between a research organization in a Member State and the Agency on a topic of mutual interest. No funding is provided by the Agency but such agreements are found worthwhile by research organizations because the association with the Agency often makes local funding and support easier to obtain.

The Research Contract is a formal agreement between the Agency and a research organization in one of the Agency's Member States to carry out a specific piece of research. The proposal may come from the organization or

from the Agency. Modest funds are available, usually up to $5,000/year. Contracts are renewable for up to three years. Particular efforts are made to place research contracts with developing country research organizations as a means of assisting their growth. However, a number have been placed with developed country organizations as well. Publication of the results of the work is encouraged, either by the researcher or by the Agency. One such contract was carried out by the Risó National Laboratory, Denmark, on an intercomparison of gamma-ray spectrometer calibration facilities. Continuing over a period of three years as an activity of the former Joint NEA/IAEA Group of Experts on R&D in Uranium Exploration Techniques, the contract was completed in 1985. Through the mechanism of the Consultants Meeting described above, the final report is being redrafted as a manual on the Preparation and Use of Calibration Facilities for Field Gamma-Ray Spectrometers.

The Coordinated Research Project is the most substantial mechanism available to the Agency for the support of research and development. This mechanism provides for the participation of research organizations in up to about ten Member States, developing anf developed, in a coordinated research activity on a topic of common interest. The researchers undertake aspects of the project within their capabilities, coordinated by the group. Developed country organizations are usually associated through Research Agreements, while developing country organizations may enter into Research Contracts, providing them with funds for necessary equipment or services. Funds are available to permit participants to meet once each year-and-a-half in Research Coordination Meetings to review past work and plan for further stages of the programme. A Coordinated Research Project normally has a life of three years, but extensions of further three years periods are possible.

Since 1978 the Agency has been developing a data base called the International Uranium Geology Information System (INTURGEO) on world uranium deposits, their settings and characteristics. Currently, more than 5000 entries have been described in the system. Data from developing countries has shown a trend towards more complete and accurate descriptions. Data from developed countries, while more voluminous is far less detailed. Data are being analized to develop more representative and diagnostic recognition criteria as well as an improved deposit classification scheme.

As a result of efforts in system design and programming, the Agency now has available software to establish data centers in Member States so that information may be exchanged in a more effective way. Brazil, for example, is actively engaged in a project to establish a national uranium geology information system.

The data of INTURGEO will be presented in a world atlas being prepared as an IAEA technical document. The atlas will have detailed maps and brief descriptions of uranium deposits and occurrences, and will also include microfiche records of the full database.

The collection and dissemination of past experience and knowledge on uranium geology and exploration techniques is of particular benefit to the Agency's developing Member States, many of whom had not participated in the advances made in the boom years. Many of these countries have geological environments favourable for the discovery of world class uranium deposits that will be needed in the future. In addition the techniques of uranium exploration have applications in many other fields, in understanding and defining the natural radiation environment for the identification of natural and other radiation hazards, and in exploration for other commodities, to name only two. We consider that the Agency must take a long-term view of its brief to gather and disseminate information on nuclear technology. It is our hope that the Uranium Newsletter will make a contribution to this task.

THE 1986 RED BOOK

In August, the 1986 edition of "Uranium Resources, Production and Demand", known also as the "Red Book", was issued jointly by the IAEA and the NEA. Based on questionnaire replies from 57 countries, the Red Book assesses World Outside Centrally Planned Economy Areas (WOCA) uranium resources, exploration, current and projected production, demand, and supply-demand relationships. Country reports describe the uranium situation in the 57 countries. A section reports on thorium resources.

Reasonably Assured Resources (RAR), recoverable at costs of up to $130/kg U, amount to 2.2 million metric tonnes t U, an increase of about 12% from late 1983 estimates. In addition during 1983 and 1984 some 75 000 t U were produced. Uranium exploration declined in 1984 to about 145 million US$, only 15% of the 1979 level. Nearly half of the exploration money was spent overseas. Uranium production was 39 000 t in 1984, and was highly concentrated: 98% of WOCA's current production comes from eight countries (Australia, Canada, France, Gabon, Namibia, Niger, South Africa, USA).

Overproduction and consequent large inventories continue. But in 1985, for the first time, uranium production was less than reactor requirements. For the short term (up to the year 2000) uranium production capabilities in existing and committed mines and mills are sufficient to meet reactor requirements until the early 1990s. For the long term (up to the year 2025) high demand case projections, future production capabilities from RAR and EAR-I below $130/kg U should be sufficient until about the turn of the century. For the low demand case projections, however, production capabilities from known resources are sufficient to meet demand for some ten to fifteen years longer. To meet future needs exploration efforts will need to increase and efforts to develop additional resources must continue. The dependance on a few producer countries raises concern about security of supply. However, given the proper market environment, it should be possible to find and produce sufficient uranium to meet future demands until well into the next century.

The Red Book, in English or French, is available from OECD Sales Agents or from the OECD, Publications Service, 2, rue André-Pascal, 75775 Paris, Cedex 16, France. Price: 210 FF or $42.

In October 1986 OECD/NEA issued a ten page "Uranium Resources, Production and Demand; Statistical Update 1986", which contains data as of early 1986. Available free from the address above.

TECHNICAL COMMITTEE MEETING ON URANIUM DEPOSITS IN MAGMATIC AND METAMORPHIC ROCKS

The IAEA held a Technical Committee Meeting on Uranium Deposits in Magmatic and Metamorphic Rocks in Salamanca, Spain, from September 29 to October 2, 1986. The meeting had 48 participants from 22 countries. Six technical papers were presented. Panels were held on the genesis and characterization of these deposits and on exploration. A publication of the papers and panel reports is expected. The group visited uranium mines at Ciudad Rodrigo and Don Benito after the technical sessions. Professor Antonio Arribas of the University of Salamanca, Geology Department, was host and general chairman of the meeting.

ADVISORY GROUP MEETING ON THE USE OF AIRBORNE RADIOMETRIC DATA TO DEFINE THE NATURAL BACKGROUND RADIATION ENVIRONMENT

An Advisory Group Meeting was held in Vienna from November 4 to 7, 1986, on the Use of Airborne Radiometric Data to Define the Natural Background Radiation Environment. Representatives and observers attended from ten countries.

The Advisory Group Meeting considered three main topics:

1. The use of preexisting radiometric data to prepare radioelement maps and maps of natural background radiation;

2. The acquisition of new radiometric data and the standards and specifications required, and;

3. The use of the airborne radiometric methods to provide emergency response data in the event of a nuclear accident of any kind.

On topic 1 the meeting concluded that the first task was to compile information, on a worldwide basis, on existing data and its quality from all Member States and to prepare an index map showing this information. It was recommended that a Consultants' Meeting be called to prepare a Technical Report on the requirements and standards to be maintained in making use of such data, the requirements for back-calibration of earlier data of lesser quality, and to recommend procedures and specifications for the preparation of appropriate maps.

The acquisition of new data should aim at the highest standards of equipment and calibration. Most countries have been following the Agency's recommendations published in Technical Report 174 in 1978. It was recommended that the Agency prepare a new, up-to-date edition of this report incorporating the considerable advances made since 1978. It was noted that the Technical Report on the Construction and Use of Calibration Facilities for Field Radiometric Instruments, currently in preparation, will cover some, but not all aspects of the subject.

With regard to item 3, emergency response requirments, the meeting made clear the great importance the uranium exploration community can have in making available its unique expertise in the event of a nuclear accident. The information provided by the Swedish Geological Company on their actions in response to the Chernobyl disaster amply demonstrated this. It further demonstrated the importance of the Radiation Protection authorities being aware of the existence of this expertise.

The Advisory Group Meeting suggested that a series of flight lines be carried out in Europe for inter-calibration of national radioactivity level measurements. It further recommended that a Technical Report be prepared by the Agency outlining the requirement for airborne radiometric survey equipment and its calibration to meet emergency response requirements. Finally, the meeting recommended that the Agency compile detailed information on equipment and facilities available in its Member States with the names of contact persons, to be updated on a regular basis.

TECHNICAL ASSISTANCE PROGRAMME

Since its formation in 1957, the Agency has assisted 51 developing Member States (see map) in the field of uranium exploration and development. This assistance was in the form of expert services, the provision of equipment and supplies, and the granting of fellowships and scientific visits. Additionally, the Agency has conducted 15 Interregional and Regional Training Courses on various aspects of uranium exploration techniques and ore processing.

In 1986, the Agency has had 30 technical co-operation projects involving 25 countries in Africa, Asia, Latin America, the Middle East and Europe (see map). Two projects were funded through UNDP and UNFSSTD. The overall budget of these 1986 projects was around 2 million Dollars.

The level of Agency technical co-operation projects in nuclear raw material fields is expected to remain at the same level despite the general slow down or complete stopage of these activities in the industrialized countries. One can note a tendency of increasing activities in Asia and the Middle East. This tendency seems to reflect the countries' commitment to or serious consideration of the use of nuclear power.

CURRENT RESEARCH CONTRACTS IN URANIUM EXPLORATION

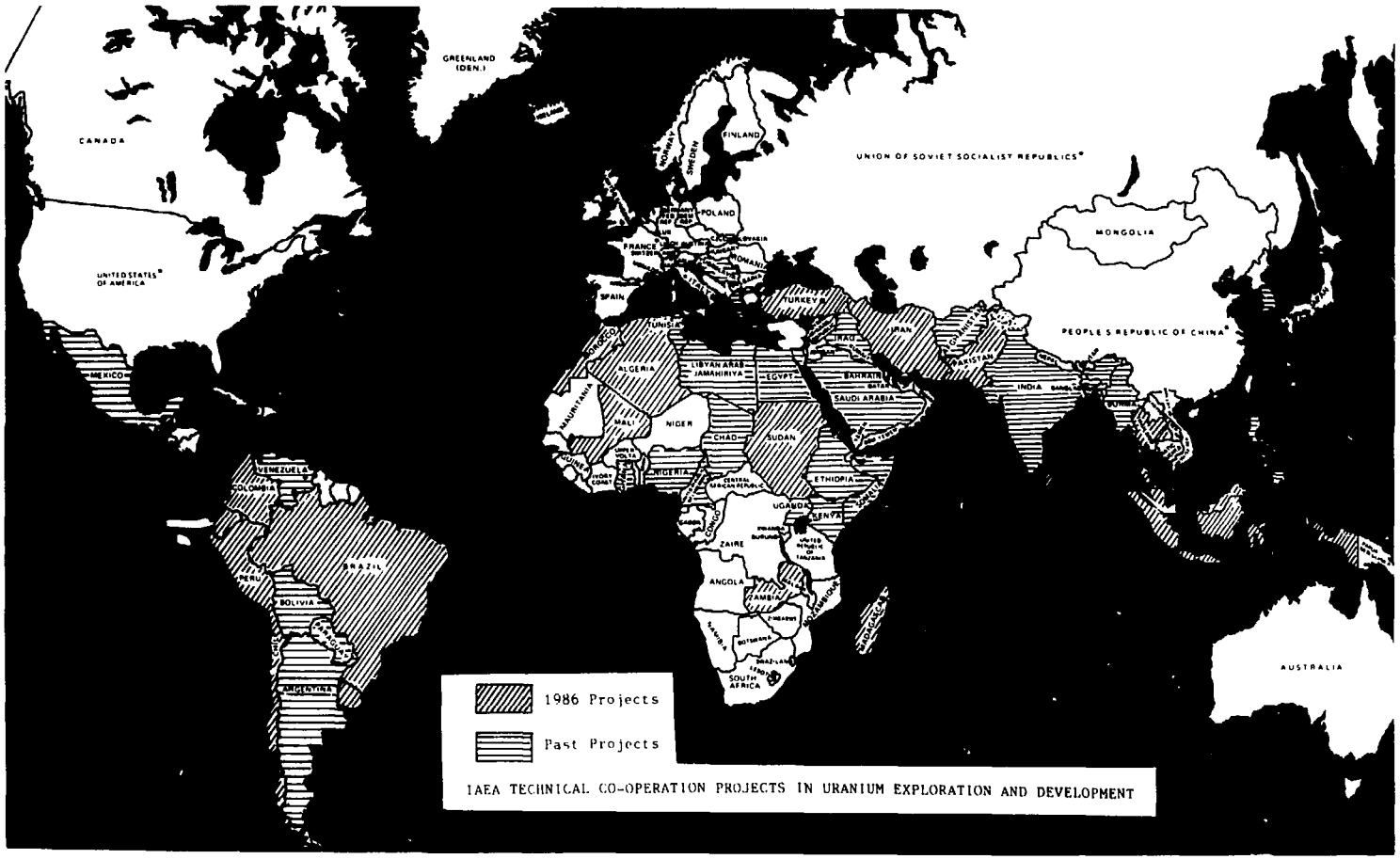
Several research contracts are being carried out under the Agency's 1986 Research Contract programme. These are briefly noted:

- No. 4253/B Secondary Dispersion Characteristics of Uranium in the Wet Tropical Environment - BATAN, Jakarta, Indonesia

  This project will study the secondary dispersion of uranium in Kalimantan and Sumatra, Indonesia. Samples will be taken of waters, soils, stream sediments, heavy mineral concentrates and rocks in order to define the dispersion mechanisms of greatest importance. The project is expected to contribute to a better use of geochemical prospecting for uranium in wet tropical conditions.

- No. 4220/RB Concentration and Dispersion of Uranium in Iron Oxy-hydroxides - Geological Survey, Lubljana, Yugoslavia

  This project is studying the fixation of uranium in secondary iron oxy-hydroxides, both at the weathering surface and in the modern stream environment, and the mechanical dispersion of these secondary iron oxides. Previous work has indicated that substantial quantities of uranium are fixed in secondary iron phases and mechanically transported in the surface environment. Samples from Yugoslavia, Syria and Greece are being examined by electron microprobe analysis as well as partial and total extraction techniques for uranium.


GREENLAND (DEN.)
CANADA
UNITED STATES OF AMERICA
MEXICO
VENEZUELA
COLOMBIA
PERU
BRAZIL
BOLIVIA
PARAGUAY
ARGENTINA
ICELAND
NORWAY
SWEDEN
FINLAND
UNION OF SOVIET SOCIALIST REPUBLICS
POLAND
FRANCE
SPAIN
MONGOLIA
PEOPLE'S REPUBLIC OF CHINA
TURKEY
IRAN
IRAQ
PAKISTAN
INDIA
MYANMAR
MOROCCO
ALGERIA
LIBYAN ARAB JAMAHIRIYA
EGYPT
SAUDI ARABIA
MAURITANIA
MALI
NIGER
CHAD
SUDAN
ETHIOPIA
NIGERIA
UGANDA
KENYA
ZAIRE
ANGOLA
ZAMBIA
ZIMBABWE
NAMIBIA
BOTSWANA
SOUTH AFRICA
MADAGASCAR
AUSTRALIA
1986 Projects
Past Projects
IAEA TECHNICAL CO-OPERATION PROJECTS IN URANIUM EXPLORATION AND DEVELOPMENT

- No. 4226/RB Definition of Uranium Deposition Models in the Argentinean Puna - Comisión Nacional de Energía Atómica, Buenos Aires, Argentina

  This project is studying the nature and distribution of uranium mineralizations in ignimbritic rocks of the eastern Andes Mountains. Examples of this type of mineralization are found in Bolivia and Peru as well. The study is examining the distribution of uranium and associated elements in rocks and alteration features and their paragenesis related to this type of mineralizaion. It expected that the study will provide insights into the source of uranium, its mode of transport and the means of accumulation, with which to guide further exploration efforts in the eastern Andean belt.

- No. 4480/RB Geochemical Behaviour of Uranium in Lateritic Soils and Weathering Mantle - Universidade de Sao Paulo, Brazil

  The objective of this project is to characterize the distribution and geochemical behaviour of uranium in soil and weathering products over several uranium deposits in Brazil. Efforts will be made to define the influence of supergene alteration processes on uranium distribution, and the conditions for fixation of uranium in soil material.

Readers interested in establishing contact with the Principal Investigator of any of these research projects should write to the Newsletter Secretary.

CERTIFIED REFERENCE MATERIALS FOR RADIOMETRIC ANALYSIS OF GEOLOGICAL MATERIALS

Following recommendations made by a Consultants' Meeting held in December 1983, and in co-operation with the Canada Center for Mineral and Energy Technology (CANMET) and the Geological Survey of Canada (GSC), a set of standard reference materials for the determination of K, U and Th in geological materials by gamma-ray spectrometry has been prepared. These materials are designed to fill a long felt need for uranium and thorium materials in radioactive equilibrium and with concentrations suitable for the calibration of laboratory spectrometers. Materials RGU-1 and RGTh-1 have been prepared by dilution. RGU-1 was prepared from Canadian Certified Reference Material BL-5, and contains 400 ppm U, ± 8 ppm U. RGTh-1 is based on a thorium material collected by the G.S.C. from Oka, Quebec, Canada, and contains 800 ppm Th, ± 16 ppm. Both materials are in radioactive equilibrium. RGK-1 is certified reference grade Potassium sulphate powder and contains 45.0 wt % K. These certified reference materials will be distributed as a set of three bottles of 500 grams each, at a cost of US$ 150 for the set. They will be available in mid-1987 from:

International Atomic Energy Agency
Analytical Quality Control Services
Laboratory Seibersdorf
P.O. Box 100
A-1400 Vienna, AUSTRIA

IAEA TECHNICAL COMMITTEE MEETINGS 1987 OF INTEREST TO THE URANIUM COMMUNITY

Metallogenesis of Uranium Deposits	Mar 9 - 12	Vienna
Uranium Resources and Geology of North America	Aug 31 - Sep 4	Saskatoon Canada
Technological Aspects of Uranium Mining	Sep 21 - 24	Montpellier France
Uranium Exploration Planning and Practice	Oct 27 - 30	Vienna

For further information on these, contact the Newsletter Secretary.

TECHNICAL COMMITTE MEETING ON METALLOGENESIS - 1987

The IAEA will convene a Technical Committee Meeting on the topic of Metallogenesis of Uranium Deposits in Vienna on March 9 through 12, 1987. The meeting seeks to bring together work on a number of deposits types following up studies sponsored by the Agency and covered in a series of publications. Focus will be on the basic underlying processes involved in the formation of uranium deposits including uranium sources, transport, host rocks, physics and chemistry of deposit formation, geological time and setting considerations, comparison to other metal deposits types and exploration considerations.

RECENT PUBLICATIONS

Vein Type Uranium Deposits (IAEA-TECDOC-361)

This is the fourth of five volumes prepared by the Working Group on Uranium Geology organized by IAEA. Previously published reports are:

- Proterozoic Unconformity and Stratabound Uranium Deposits
  IAEA-TECDOC-322, 1984

- Surficial Uranium Deposits
  IAEA-TECDOC-328, 1985

This 423-page volume contains descriptions of the regional and local geological characteristics of 25 vein-type uranium deposits and prospects of 16 countries, as well as discussions on their genesis.

Practical Borehole Logging Procedures for Mineral Exploration, with Emphasis on Uranium (STI/DOC/10/259)

This report complements an earlier one entitled "Borehole Logging for Uranium Exploration: A Manual" (STI/DOC/10/212, 1982). The 44-page report concentrates on the practical aspects of the operation of a logging system and the interpretation of the obtained data of interest to those actually engaged in day-to-day field work. The report is priced at A.S. 130.

Correlation of Uranium Geology between South America and Africa (STI/DOC/10/270)

The IAEA recently announced the release of a 500-page report with four large colored maps on the "Correlation of Uranium Geology between South America and Africa". The result of several years effort with contributions from over 40 experts, the report covers the basic geology of the two continents and the related occurrence of uranium. The report covers six basic geological topics:

1. Precambrian Cratonic Areas
2. Late Precambrian Mobile Belts
3. Precambrian Sedimentary Cover
5. Early Paleozoic and Gondwana Sequences, and
6. Alkaline Rocks and Carbonotites.

These are analyzed in light of known uranium occurrences to identify areas favourable for uranium occurrence. In view of the new basic information the report is expected to be of value to geologists and explorationists interested in many commodities. The report is priced at A.S. 1,000 and the 4 maps at A.S. 600.

Long-Term Uranium Supply-Demand Analyses (IAEA-TECDOC-395)

In 1986, a long-term (through 2035) supply-demand study was been made by the staff of the Division of Nuclear Fuel Cycle, using the computer model RAPP 3 ("Resource and Production Projections") developed originally by the US Department of Energy and modified by the IAEA.

Supply and demand data were taken from the 1986 OECD (NEA)/IAEA "Red Book". Additional data on speculative uranium rsources for this study were those from an estimate made by the former NEA/IAEA Steering Group on Uranium Resources, revised and compiled by the IAEA in 1983.

Three demand cases were selected on the reactor strategies of plutonium recycling (high case), an improved Light Water Reactors (low case) and a mixed strategy (mid/base case).

To test these demand cases, supplies were modelled to be produced from presently known uranium resources (Reasonably Assured and Estimated Addditional Resources, Categories I and II) produceable at costs of up to $130/kg U, and three ranges of Speculative Resources. These combinations constitute the low, high and mid/base supply cases.

For the modelling of the long-term supply-demand relationship 23 cases were simulated. These included supply-demand cases, "could do" cases and sensitivity studies.

The most important conclusions to be drawn from these studies are:

- The uranium supply for the most likely demand case could be adequate through the year 2035 assuming a timely development of the $130/kg U known resources, the construction of the necessary mines and mills to make the supplies available and the timely discovery of presently unknown resources. However, it must be stressed that known resources of this cost category are in part uneconomic under present market conditions.

- A larger uranium supply could be made available given a favourable economic climate. This indicates that uranium supplies do not appear to be a limiting factor for a larger than anticipated growth of nuclear power.

- The most sensitive parameter for the supply situation is the cost category. Under the assumption of a cost category of $80/kg U, more in line with the present market price for uranium, additional supplies of newly discovered low cost resources will be needed sometime between the years 2000 and 2015 to fill the projected base case demand. This means, for the explorationists, that complacency with the present uranium resource situation is not justified in view of the long lead times and the capital and manpower needed to discover, develop and produce low cost uranium.

The report (92 pages), issued as IAEA-TECDOC-395, is available free of charge from the Agency.

IAEA PUBLICATIONS ON URANIUM IN PRESS

Recognition of Uranium Provinces, Proceedings of a Technical Committee Meeting held in London in 1985

Development of Projects for the Production of Uranium Concentrates, Technical Committee Meeting Proceedings

Manual on Geochemical Exploration for Uranium, a Technical Report Series guidebook prepared by consultants and IAEA staff

Uranium Deposits in Asia and Pacific: Geology and Exploration, Proceedings of a Technical Committee Meeting held in Jakarta, Indonesia, in 1985

Uranium Deposits in Proterozoic Quartz Pebble Conglomerates, Technical Document with paper by a group of experts

Nuclear Fuel Cycle Facilities, Technical Document based on the IAEA Nuclear Fuel Cycle Information System

Uranium Deposits in Magmatic and Metamorphic Rocks, Proceedings of a Technical Committee Meeting held in Salamanca, Spain, in 1986.

COUNTRY REPORTS

AUSTRALIA

We have received two reports from Australia, one from the Bureau of Mineral Resources, and one from CSIRO. Both reports are of interest, and so we are publishing both.

BMR REPORT

The decline in uranium exploration in Australia and a redirection of BMR's research priorities have resulted in the termination of specific uranium research projects in BMR for the present, though some BMR activities remain relevant to R & D in uranium exploration techniques.

The results of a biogeochemical and soil geochemical study over the Ranger One, No. 3 orebody were recently published in Uranium. No gross deformities or differences in vegetation were noted over the orebody. Although all species of shrubs and trees show some U enrichment over the orebody, only the larger species gave sufficient anomaly contrast. In all species, leaves showed greater and more consistent anomaly contrasts than twigs, fruit, or wood. Though variations in U content occur between leaf samples from different parts of the same tree, these proved to be insignificant in relation to the overall anomaly.

Ore genesis studies at Turee Creek in the Pilbara region of WA have been concluded and reported in the same issue of Uranium (Vol 3). The Angelo River prospect at Turee Creek has broad similarities in geological setting to deposits in the Alligator Rivers region; however, the mineralised zones are associated with a faulted contact between Middle Proterozoic sandstone and early Proterozoic greywacke, shale and dolomite rather than an unconformity . Brecciation at the contact has facilitated the movement of near-surface acid oxidising groundwaters, which have leached U from syngenetically enriched early Proterozoic lithologies in particular. Uranium has been concentrated predominantly as secondary minerals at the contact in response to increased solution pH resulting from solution-wall rock reactions.

Regional geological and geochemical work in the Pine Creek Geosyncline is at the writing-up stage with many publications either released, in press, or in preparation. Regional geochemical studies of the early Proterozoic metasedimentary sequence which hosts all of the major U deposits in the Pine Creek Geosyncline indicate that these rocks, unlike the granitoids, are not syngenetically enriched in U.

Regional stream sediment geochemical surveys conducted by BMR in areas of northern Australia have indicated that U anomalies, particularly where they are associated with streams draining granitic terrains, are mainly related to resistant detrital minerals such as monazite. These anomalies need to be assessed with consideration for the associated Ce and Th values, before their potential for uranium mineralisation are evaluated.

In the Mt Isa region, the dispersion of U out of a U-enriched granite (10-30 ppm U in the Sybella Granite) during regional metamorphism, which post-dates the age of intrusion, is being assessed. Small U deposits are spatially related to the granite in surrounding sediments.

In geophysics, BMR is now flying with an improved gamma spectrometry system with downward (1000 cubic inch) and upward (250 cubic inch) looking crystals. This will benefit U exploration in the remaining areas of Australia to be covered by airborne spectrometer surveys.

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CSIRO REPORT

Following the Australian Government decision to confine the export of U to the two existing producers (Ranger and Narbalek), and the forthcoming Olympic Dam project, the past few years has seen a severe decline in U exploration in Australia. However, the subject of U is frequently before the public with major disagreements over the resumption of embargoed exports to France in mid 1986 and the resumption of exploration in areas of the Kakadu National Park (Pine Creek Geosyncline).

Research on U related matters is at a low level, reflecting the state of the industry. At CSIRO, research using hydrogeochemistry and radionuclide analysis has confirmed that the source of excess radium in sediments near many sandstone escarpoments throughout the north of Australia is U and Th distributed within the sandstone formations. Radium is only weakly adsorbed in the low-salinity, acidic waters draining from the sandstones and can be transported out of the sandstone units to be adsorbed by organic matter in swampy area.

In parts of southern Australia acidic groundwaters of high salinity have been found to contain high concentrations of radium and U, as well as many other trace elements. If these groundwaters reach the surface, then precipitation of various minerals, such as gypsum and jarosite, can preferentially trap radium and generate quite extensive radiometric anomalies. Studies of the hydrogeochemistry and radium isotopes within such waters demonstrate that the source rocks of all the various traces metals are the aquifer rocks and not undiscovered mineral deposits.

Other studies in CSIRO comparing geochemistry of groundwaters in contact with economic U mineralization hosted by carbonaceous, pyritic sands in arid areas of inland Australia, with those from geologically similar but sub-economic or non-mineralized prospects show the characteristics which distinguish groundwaters from an ore environment. These include neutral pH and equilibrium with carbonate minerals and a high degreee of decomposition and wide distribution of associated carbonaceous matter. This research has shown that economically significant U mineralization occurs in palaeodrainage sediments where the presence of carbonate minerals maintains the alkaline conditions in the groundwaters, greatly increasing the rate and degree of organic matter decomposition and consequently the extent of U enrichment.

Airborne radioemetrics are proving to be of major use for geological mapping and studies aimed at improving the quality of the data have been made at CSIRO. For example, U channel data alone often show banding parallel to the flight-line direction. This can be substantially removed by making assumptions regarding the relative correlations between K, U and Th within the survey area. Noise in the U channel due to atmospheric radon, for instance, can then be removed from individual flight lines by adjusting the correlations within a line to those for the survey area.

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NOTE: We have received the following note from the Department of Mines and Energy of South Australia:

"We have built, in conjuction with the Australian Mineral Development Laboratories (AMDEL), a series of calibration models for gamma-ray probes. The latest addition is one with a concentration of roughly 1825 ppm eU308 and hole sizes of 60 mm, 76 mm, 96 mm, 108 mm, and 122.6 mm with zone thicknesses of 1680 mm and 50 mm. When core assay results have been finalized we will send you fuller details for inclusion in the newsletter".

BRAZIL

Exploration

Exploration for uranium, which is a responsibility of the state owned NUCLEBRAS, has been at a complete halt since 1985. For this reason many qualified staff left the company. The only field operation is at Poços de Caldas uranium mine/mill which remained on standby with a minimal production. Foreign groups continue contacts with NUCLEBRAS for possible joint-ventures in exploration/production. So far the results have been negative.

Late August 1986, the Geological Survey (DNPM) contracted 195.000 linear km of high sensitive airborne magnetic and gamma-ray surveys in

the states of Pará and Amazonas. These contracts were given to three Brazilian geophysics companies, LASA, ENCAL and PROSPEC. Upon completion, these surveys will provide geological and radiometric data over large areas of the Amazonia region. Total radiometric coverage in Brazil now approachs 2 million linear km.

Research and Development

A calibration facility for surface radiometric instruments was constructed by CNEN (Dr. Paulo Barretto) at the Radiation Protection Institute-IRD in Rio. It consist of eight concrete pads disposed in a circle with a water pond in the center. It is a result of a close collaboration with RISØ National Laboratory (Dr. Leif Løvborg).

Also completed was the manufacture of the first sets of national rock standards for chemical and radiometric determination of U, Th and K. They consist of five powdered rocks with different matrix: F-1 (feldspar), FT-1 (phosphorite), C-1 (Caldasite), M-1 (Monazite) and (Zirconite). Internal demand for such standards has been very large but some are available for exchange.

Uranium behaviour in the tropical environment continues to be a chalanage for explorationists. The University of S. Paulo (IAG-USP) started in October 1986 a large international project to study dynamic behaviour of uranium in lateritic covers. This is a five years' project supported by USP (Brazil), ORSTOM (France), IAEA and CNEN. The area of the Lagoa Real Deposit, in Bahia State, was selected for the first phase of the project. Exchange of information and/or collaboration is welcome. Write to Prof. Adolfo Melfi, IAG-USP, P.O. Box 30627, S. Paulo (01051), S.P., Brazil.

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CANADA

In 1986 Canada was the western world's leading producer of uranium with the output of about 11,700 tonnes U in concentrates according to preliminary estimates. The 1986 production represents 7.5 per cent increase from the previous year. The largest production from a single operation was from the Key Lake mine, operated by the Key Lake Mining Corporation and owned 50 per cent by the Saskatchewan Mining Development Corporation, 33.33 per cent by Uranerz Exploration and Mining Limited and 16.67 per cent by Eldor Resources Limited. The remaining producers were Denison Mines Limited and Rio Algom Limited, Elliot Lake, Ontario and Eldor Resources Limited and Cluff Mining, Athabasca Basin area, Saskatchewan. The total Canadian production is in the contect of Canada's recoverable Reasonably Assured (Measured and Indicated) and Estimated Additional Resources I (Inferred) amounting to 545,000 tonnes U as of January 1, 1986.

Uranium exploration activity in Canada was in 1986 focussed mainly on search for unconformity-associated deposits in the

Athabasca Basin region, Saskatchewan, and in the Baker Lake - Thelon Basin region in the Northwest Territories.

The exploration targets in the Athabasca Basin region were located in areas with potential mineralization under a thick cover of sedimentary rocks. New advanced geophysical methods allow identification of drill targets even at depths exceeding 600 metres. In addition a recently developed method using near surface bedrock geochemical sampling was successfully tested on the Cigar Lake deposit in Saskatchewan, the world's largest known high grade deposit containing in excess of 110,000 tonnes U at grades about 12 per cent U. The Cigar Lake deposit occurs at a depth exceeding 410 metres below the surface.

According to a recent announcement by the Ministry of Energy, Mines and Petroleum Resources of the Province of British Columbia the provincial government decided to let the seven-year moratorium on uranium mining and exploration to expire as scheduled February 28, 1987. During the period of the imposed moratorium the Ministry of Health's Radiation Protection Service has been active in monitoring ambient levels of radiation in 28 areas of the province and the Ministry of Energy, Mines and Petroleum Resources has continued with multi-element geochemical surveys, including uranium, in stream sediments.

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PEOPLE'S REPUBLIC OF CHINA

The uranium prospecting and exploration works in China was started in the mid-fifties. Many industrial U-deposits of more than ten types were discovered in the vast territory of China over the past 30 years. According to the host lithologies they can be mainly classified into the following types:

Granite Type

This is the U-deposit type discovered earliest and accounts for the majority of the U-resources in China. U-deposits of this type are typical hydrothermal U-bearing veins and occur generally in Mesozoic granite massifs, partly in sedimentary rocks within exocontact zone or superimposed basins. Uranium mineralizations are controlled by silicified faults and fracture zones. U-minerals are pitchblend with small amounts of coffinite. Gangue minerals are microquartz, fluorite, calcite and clay minerals. Three mineralization stages are recognized, namely 87 Ma, 67 Ma and 47 Ma respectively.

Volcanic Type

This is another important U-deposit type distinguished from granite type by its higher ore grade and more complicated ore composition.

U-deposits of this type occur in Mesozoic acid volcanic rocks and may be subdivided at least into three sub-types according to their geological settings, namely collapse-caldera, volcanic-downpunching basins and

volcaninc-downfaulted basins. The uranium host rocks may be volcanic lavas, sub-volcanics or volcanic clastic rocks. Spatially, U-mineralizations were controlled by both volcanic systems and fault structures. Ore compositions are always more complicated. Among the major elements associated Mo and Ag may be extracted as by-products. The ages of U-mineralization are similar to those of the host rocks.

Carbonaceous-siliceous-pelitic Rock Type

Uranium deposits of this type usually occur in cabonaceous slate, carbonaceous-siliceous slate and siliceous limestone of the Sinian-Cambrian Periods. Uranium mineralization took place by lixivation and hydrothermal events caused by the remobilization process during the Mesozoic-Cenozoic era and were controlled by both strata and fracture zones.

Sandstone Type

Sandstone-type U-deposits occur in the Mesozoic inter montane basins of geosynclines or in large basins of platforms, in the source area of which there are always outcrops of granite and acid volcanics. U-mineralizations occur in red clastic formations, dark clastic formations or volcano-sedimentary clastic formations and bear syngenetic-epigenetic origin.

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DENMARK - GREENLAND

Evaluation of uranium occurrences in South Greenland.

From 1979 to 1986 the Geological Survey of Greenland (GGU) undertook uranium exploration in South Greenland as part of an energy research programme financed by the Danish ministry of energy and supported by the European Economic Community. The uranium exploration part of the programme was terminated in 1986, and GGU issued a report (in two volumes) in January 1987 on the results of the investigations.

The main result was the establishment of the South Greenland uranium province containing three different types of uranium mineralisation: 1) sediment-hosted, metamorphosed, of Mid-Proterozoic age, 2) disseminated magmatic associated with highly differentiated late Proterozoic alkaline rocks, and 3) late Proterozoic veins associated with fault zones in Mid-Proterozoic granite.

The disseminated magmatic type includes the large, previously assayed, low-grade Kvanefjeld deposit. The other two types were found during the exploration and were studied in detail. Volume 1 of the above mentioned report deals with the vein-type uranium occurrences and discusses the regional structural pattern, and the prospecting methods, mineralogy, age and genesis of these occurrences. Volume 2 contains a detailed description of one of the sediment-hosted uraninite occurrences with respect to geological setting, mineralogy, age, genesis and size.

Judged by the surface indications the occurrences studied so far do not have an economic potential. However, the report concludes that the region as a whole has a high uranium potential and more deposits are likely to be found by further prospecting.

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FINLAND

Responsibility for uranium prospecting in Finland has been assigned to the Geological Survey of Finland alone. However, in the 1980s the specific exploration efforts for U have been considerably slowed down. To-day, the Geological Survey is keeping minimum level of activity and expertise in uranium exploration, mainly for interpretation and follow-up studies of the airborne radiometric survey. Automated classification of the multi-channel airborne radiometric data has been started to intensify the selection of promising targets. The Geological Survey will also continue on-going target studies in northern Finland (Kuusamo schist belt) and the reconnaissance surveys of late-kinematic granites in southern Finland. The most common methods used in detailed exploration will be geochemical surveying, geophysics, geological mapping, trenching and diamond drilling.

In southern Finland an uranium province has been recognized in the migmatized Svecofennian schist belt (Geologist E. Räisänen). The province is located at the marginal zone of a late-kinematic microcline granite in chemically variable gneisses: quartz-feldspar gneisses, garnet ± cordierite gneisses, all partly pyroxene bearing charnochites. The Palmottu deposit in Nummi-Pusula is estimated to contain about 1000 tons of uranium with an average grade 0.10% U. Uranium occurs as uraninite crystals in pegmatitic and granitic veins in folded micaceous gneisses. The late-kinematic granites in southern Finland can be potential for further uranium resources.

In the Kuusamo schist belt, northern Finland, several uranium (and Co-Au-Mo) mineralizations have been discovered in the 1980s (Geologist E. Vanhanen). The Kouvervaara mineralization is stratiform, three kilometer long and hosted by albitized sericite quartzites, however the mineralization is narrow and low-graded. The Co-Au-Mo mineralizations in Sivakkaharju and Konttiaho were found by ground radiometric surveys carried out in 1985 and 1986. These deposits occur in the brecciated quartz-albite-carbonate rocks and are manifesting the positive correlation between uranium and gold, according to the preliminary assays up to 30 ppm Au, 0.3% U and 0.2% Mo. Genetically the sulfide deposits in Kuusamo are associated with deep-seated fracture and fault zones, controlled by ancient hot-spot acitivity and continental rifting.

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GERMANY, FEDERAL REPUBLIC OF

1. Uranium exploration was maintained at a constant level over the past three years being only about 50 % of the annual expenditures spent around 1979 and 1980. Significant discoveries were not made. During 1984 exploration activities were resumed at the Grosschloppen occurrence in Bavaria by a joint venture of ESSO, Saarberg Interplan Uran and CEGB.

   Exploration of the sedimentary deposit at Müllenbach, Black Forest, was terminated due to environmental restrictions.
   The underground exploration at the deposit of Menzenschwand was carried on despite the fact that the mining lease for this deposit was not granted.

   Current exploration activities are concentrated in areas with known uranium occurrences. Underground exploration takes place at the Menzenschwand deposit, Black Forest, and Grosschloppen, Fichtelgebirge, NE Bavaria. In the vicinity of Grosschloppen additional surface exploration is carried out on prospective targets. Currently three mining companies are involved in ongoing exploration projects, with a total land area of 7 000 km^2.

2. At present a R + D project on the use of remote sensing techniques is carried out in NE Bavaria by INTERURAN and DFVLR. In the present phase more precise recognition and localisation of geological structure zones, which are important for the exploration, are

to be achieved through the use of new spectral bands and increased ground resolution in satellite imagery. Further on the detection of alteration phenomena and vegetation stress on such structural zones will be investigated. A refinement of software will be developed for a better interpretation of data. Staged compression and data reduction will be used to accelerate the processing time. The aim of the project is to prepare a reproducible remote sensing technique which can be transfered to geologically comparable areas and thus be applied in mineral exploration as a cost-effective and efficient complementary method.

3. Immediately after the reactor accident in Chernobyl a survey of radioactivity was carried out in Lower Saxony by the Geological Survey using common scintillometers. The nuclear fall-out which reflects the amount of precipitation during the first days of May 1986 was mapped, showing a strong areal variation. Soil samples were taken in target areas and analysed by means of gamma-spectrometry. The content of the different nucleides was measured.

   A correlation between the radioactivity of the main fall-out nucleides and the increase of the overall radioactivity could be proved. The results of the investigation are presented in maps (μR/h; Bq/kg).

   (Contributers: Dr. F. BARTHEL, Dr. P. GEHNES; Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, D-3000 Hannover 51, Federal Republic of Germany).

MALAYSIA

Systematic exploration for uranium in Peninsular Malaysia commenced in mid-1977 when the Central Belt Project, a regional geochemical sampling programme, was launched with technical assistance from the Canadian International Development Agency (CIDA). This programme, which for the first time incorporated uranium analyses of geochemical samples, has continued to assume an important role in assessing the mineral potential of the Project area covering some 31,000 sq km in north-central Peninsular Malaysia. To complement this geochemical survey, a helicopter-flown spectrometric and magnetometric survey was conducted over the Project area between April and November 1980.

Anomalous areas with uranium potential have been identified. A multi-phase follow-up survey involving detailed stream sediment sampling, soil sampling, radiometric mapping, radon gas emanometry and exploratory drilling was successfully undertaken between 1979 and 1982 by the department over one such particular area, the Sok prospect, in Kelatan. Besides base and precious metal mineralization, uranium mineralization has been discovered within this prospect. The uranium mineralization is

granite-hosted, and exists in the form of uraninite as well as the uranium-bearing phosphates, rhabdophane and florencite.

More recently, the department has recorded radioactive showings at Muar Granite Quarry, Johore, and Papan Quarry, Perak.

In Sarawak, exploration for radioactive minerals was initiated in 1978. A reconnaissance survey involving stream sediment sampling, stream water sampling and radiometric measurements was conducted by the department over 11,000 sq km in the area between Batang Sadong and Batang Lupar, West Sarawak. Several geochemical anomalies were subsequently outlined, and between 1981-83, the anomalies at Sungei Rayong and Ulu Umdup were followed-up. This Radioactive Minerals Survey Programme has received support from IAEA. Under the auspices of this IAEA programme, experts from the Federal Republic of Germany and the United States of America have made short-term visits to Sarawak. Results, however, were discouraging.

Presently, the results of the Central Belt Project, are being appraised by an IAEA expert who has been with the department since August 1986. Several areas have been identified for detailed work.

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PHILIPPINES

Although areas containing radioactive minerals are open to private companies for mining location and disposition, only the Philippine Atomic Energy Commission in engaged in uranium exploration and research in uranium extraction technology.

An uranium reconnaissance geochemical survey is continuing in the northeastern part of Luzon. This involves the collection of stream sediments and panned heavy mineral concentrates as well as water samples. Radioactivity at the sampling site is also measured. The sampling density is about one sample per ten square kilometers. The solid samples are analyzed for uranium and at least eight other trace metals.

Modest laboratory testworks are currently being done on the extraction of uranium from wet phophoric acid produced by a major fertilizer plant. The use of adsorbents for extraction indicate encouraging laboratory results.

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PORTUGAL

In the last years the exploration activities in Portugal were performed by Direcçáo Geral de Geologia e Minas (DGGM) - a governmental agency - mainly in sedimentary formations of West Border and in Trás-os-Montes areas of the Hesperic Massif (NE of the country) and by Empresa Nacional de Urânio (ENU) in a reserved land area of 9 000 km^2.

The total expenditures in 1985 were US$ 692, 693 (US$ 352,121 by ENU and US$ 340,572 by DGGM) including the costs of 26 958 metres of surface drilling. The estimations for 1986 and planned for 1987 are US$ 100,000 and 40 000 metres per year.

Negotiations with foreign companies to participate in exploration projects are in course.

The total uranium production of the country was 119 tonnes U in 1985 and 110 in 1986.

The feasibility study of Nisa project with a production capability of 200 tonnes/year was concluded last year.

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SUMMARY OF IN-HOUSE AND SPONSORED RESEARCH

1. In-house Research

Significant progress is being made in understanding the geochemical cycle of uranium and thorium in the Proterozoic mobile belts of Namaqualand and Natal, and the Vredefort Structure. An inventory has been compiled for radiometric anomalies in Natal and a similar survey is being undertaken for Namaqualand. A geological map of the Vaalputs Radioactive Waste Disposal Facility was completed and is available with explanatory notes.

2. Sponsored Research at Universities

University of the Witwatersrand: A project on isotopic investigations related to uranium mineralization in the Karoo Sequence by Drs. M.J. Duane and H.J. Welke which has terminated, has shown that the Karoo uranium deposits may have originated, as a result of low temperature remobilization of uranium from detrital minerals. The whole rock and diagenetic mineral data reflect "mixed" Pb-Pb ages, with an older age inherited from uraniferous detrital minerals and a less

radiogenic Pb age derived from uranium minerals accumulated since 245 Ma. The "best estimate" age of mineralization is 200-245 Ma, except Rystkuil, where resetting of ages occurred at circa 170-200 Ma ago, possibly correlated with emplacement of the Stormberg Lava Group. A source area age of 550 Ma has been identified for uranium in the most southern Karoo deposits.

The geology of the Witwatersrand Basin and its concomitant exploitation has developed in quantum leaps since the discovery of gold, following developments in extraction processes, geophysics and sedimentology. The provenance of gold and uranium has remained somewhat of an enigma. Fission-track studies of uranium bearing granites undertaken by Dr. L.J. Robb, have shown that the hinterland to the Witwatersrand Basin is characterized by the extensive development of fertile, high-level hydrothermally altered granites (HAGS), which, together with the concept of palaeoregoliths and the Vredefort profile, point towards a hinterland that was anomalously endowed with uranium and gold. The future outlining of the sub-surface distribution of these HAGS may well disclose preserved extensions to the Basin elsewhere.

The AEC sponsors the uranium component of a project on tectono-sedimentary and geochemical studies of the northern part of the Witwatersrand Basin by Prof. T.S. McCarthy. The structural model proposed has implications for the existence of possible outliers of mineralized Upper Witwatersrand stratigraphy. This project is supplemented by the interpretation by Dr. B. Corner of the structural framework of the Witwatersrand depository using gravity and aeromagnetic data.

At the University of Pretoria a project on uranium mineralization in the Bushveld Complex and related rocks is co-ordinated by Prof. G. von Gruenewaldt. The research undertaken in 1986 entailed the re-assessment of radiometric data of the Bushveld Complex and anomalies are currently being followed up.

A comparative study of the uranium and thorium contents of selected granites in the south-western and north-western Cape was completed by Prof. A.E. Schoch of the University of the Orange Free State. This project included a reconnaissance investigation of the Khubus pluton in the Richtersveld. The bulk of spectrometric uranium and thorium determinations cluster near 10 ppm U_3O_8 and 100 ppm ThO_2, with zircon being the most important uraniferous phase, showing wide fluctuations in radio-element contents. This is an important aspect to be considered in isotopic dating of Cape granite zircons. Generally the uranium and thorium in Cape granites reside chiefly in primary accessory minerals, which differ in importance from one pluton to another.

R. Scheepers of the University of Stellenbosch is studying the radio-element behaviour during <u>in-situ</u> kaolinization and weathering of selected Cape granites. This project which was initiated during 1986 aims to study the behaviour of radio-elements during crystallization of granites formed by fractional crystallization and through mixing of melt and restite. Kaolinization and weathering of these different granite types is also studied, which obviously has important implications for element mobility in the storage or disposal of high-level radioactive waste.

The AEC sponsors two projects relating to experimental sedimentology. Investigations by Dr. J.P. le Roux of the University of Stellenbosch are aimed at understanding the factors controlling permeability in sediments which, together with the distribution of organic material, seem to be the main controlling factors of uranium mineralization in the Karoo Sequence.

Flume studies of heavy mineral segregation during sediment movement were initiated in 1986 by Prof. W.E.L. Minter, and are aimed at determining the effect of different bed forms and flow conditions on the transport and concentration of heavy minerals.

Radiometric studies in the south-western Cape Province are carried out by Prof. A.O. Fuller of the University of Cape Town. This low-key project, which aims at the field follow-up of radiometric anomalies, progessed apace with investigations centred around the Malmesbury area.

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SPAIN

URANIUM EXPLORATION ACTIVITIES IN SPAIN, 1985-1986

The uranium exploration in Spain has been carried out by the Spanish Empresa Nacional del Uranio (ENUSA), a public company, until December 1984, date in which it was cancelled.

In June 1986 a very reduced Exploration Department has been created which staff is the remain of the already disappeared Exploration Division.

Exploration activities are to be concentrated in the Salamanca province and mainly in the Precambrian - Cambrian-schists of its western part. Evaluation drilling is being carried out in the Retortillo ore body in Ordovician-schists. As exploration techniques; detailed geological mapping, resistivity profiles, VLF, diamond and persussion drilling are being used.

The only other company that operates in Spain on uranium exploration is CISA, a private company; CISA (Compañìa Ibèrica de Materias Primas y Energèticas, S.A.) is currently exploring for uranium in the Càceres province (Extremadura).

CISA is working on exploration leases belonging to the hercynian domain (granite and schists) where the following type of activities have been developed in 1986:

- Geological mapping
- Systematic radiometric measurement on anomalous zones
- Geochemical survey (soil, alluvium, water)
- Geophysical survey (VLF)
- Drilling (percussion and diamond)

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SYRIAN ARAB REPUBLIC

This contribution is concerned with the application of orientation and reconnaissance multielement geochemistry coupled with ground scintillation gamma-ray measurements to investigate the dispersion patterns of uranium and other major and trace elements in the arid Palmyrides region of central Syria. Rocks, wadi and playa sediments, overburden and groundwaters have been studied.

The region occupies an interplatform depression in the northern part of the Arabia Plate, upon which sedimets up to 10 km thick have accumulated. Outcrops of strongly fractured Mesozoic and Cenozoic rocks form two major mountain belts, the northern and southern Palmyrides, between which is located the closed Ad-Daww basin, with a thick Neogene and Quaternary clastic cover. Among the various lithologies, phosphorites, enriched in U, are well represented. In and around these phosphorites numerous traces of secondary U mineralization occur.

Lexan-fission track registration was performed on selected samples to investigate the distribution of uranium. Results of this technique show that U is closely related to phosphate particles, collophane mud and organic matter in the carbonate rocks. Secondary U enrichment along fractures and micro-fissures was also found. Integrated mineralogical and geochemical procedures utilizing optical and scanning electron microscopy, electron microprobe and various x-ray diffractometric methods indicated the presence of carnotite, tyuyamunite, meta-tyuyamunite and un-named urano-vanadate mineral similar to ferghanite.

Univariate and multivariate statistical methods are used to interpret the geochemical data. These methods involve generating histograms, boxplots, scattergrams, QQ plots, interelement correlations, multiple linear regrassion using ridge constants, hierarchical cluster analysis and principal component analysis. The aerial distribution of U, its associated elements and multivariate geochemical functions and factor scores are mapped using computer graphics.

Low order anomalies of U, accompanied by various combinations of anomalous concentrations of Mo, Se, Sr, As, Ba, Cd, P and V are recognized in all the sampling media used in this work. Lithogeochemistry provides geochemical dispersion patterns with good contrast, and the hydrogeochemical anomalies are of particular interest: multielement signatures similar to those related to known sedimentary uranium deposits elsewhere in the world occur in an aquifer of coarse clastic Neogene sediments.

It is concluded that U and associated elements have been incorporated into the Upper-Cretaceous and Lower Palaeogene sediments, especially the phosphate rocks, from three possible sources, namely, sea water, Lower Cretaceous volcanism and metalliferous fluids leaking along taphrogenic lineaments. Results of the factor analysis indicated that the dispersion patterns of U and associated elements are controlled by a combination of structural, lithological and environmental factors. Uranium and associated elements have subsequently been leached out of the phosphorite and other U enriched clayey limestone and carbonate rocks into the hydrogeological regime. Redistribution of these elements is taking place along fracture zones and major faults. A degree of U accumulation in the Neogene-Quaternary aquifer of the Ad-Daww basin is evident. There is also some evidence of U concentration in recently formed thin duricrusts of calcrete and gypcrete. Indications of bifacies

of oxidized and reduced lacustrine formations of the lower Neogene suggest a further means of U precipitation; this phenomenon merits further investigation. Recommendations for further uranium exploration in Syria are reported.

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UNITED KINGDOM

GENERAL

In the United Kingdom, public interest in aspects of the nuclear fuel cycle has remained at a high level throughout the year for four main reasons, 1) the Chernobyl accident which resulted in radioactive contamination of the UK, especially in some hill-farming areas of England, Wales and Scotland with consequential damage, in particular to the sheep farming industry; 2) New nuclear powerstation developments; 3) Site selection for disposal of low and intermediate level wastes; and 4) Nuclear powerstation decommissioning procedures and disposal arrangements.

The Chernobyl accident has had the effect of stimulating interest in the geological community for a new round of environmentally related research topics, at a time when investment in exploration and R&D is at a low ebb.

Initiation of site investigations by NIREX engineers and contractors for low and intermediate level nuclear waste disposal sites were however notable for the well-organised and articulate opposition they encountered from local residents which was widely reported in the media at the time. The results of the test drilling are awaited with interest by both the local inhabitants and the wider scientific and geological communities.

REGIONAL GEOCHEMISTRY

The systematic geochemical surveying of the UK landmass, which includes U determination by DNM of high density sampling of drainage samples (sediment and water), is carried out by the British Geological Survey and is funded by the Department of Industry. The BGS anticipates that the Great Glen Atlas at 1:250,000 scale, the next in the series, will be published in 1987 together with provisional datasets for the Clyde-Malin Atlas.

REMOTE SENSING

A new facility, the British National Remote Sensing Centre (BNRSC) has recently been established at Farnborough. It utilises the GEMS image analysing system of British design and manufacture. This is particularly useful for the study of integrated databases in the evaluation of U and other metalliferous mineralisation. The British Geological Survey has established a Geological Interactive System Analysis (GISA) facility at this location in collaboration with the BNRSC. BGS digital databases for Geochemistry, Geophysics, Geology and Remotely Sensed data can be studied interactively in REAL time to customer reqirements.

U MINERALOGY

A CASE award student, Mr C. Pointer at Aston University, Birmingham has nearly completed his thesis and is presently writing up his results, mainly on U mineralogy from various locations in the UK and overseas.

ANALYTICAL TECHNIQUES
An Inductively Coupled Plasma Mass Spectrometer, which was developed under EEC Uranium R&D contracts is now installed and operational in the British Geological Survey, Geochemical Division, London.

U METALLOGENY
Although public funds for R&D in the UK are presently very limited there is some continuing interest in this topic which has been noted by British experts who have been working in countries where special conditions persist for seeking further reserves.

Indeed some of the models presently in use for uranium exploration clearly require considerable further re-evaluation if they are to take account of changes and developments in the underlying scientific concepts in the last few years. This expertise amoung UK scientists is also presently being deployed on collaborative R&D studies with other countries.

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UNITED STATES OF AMERICA

Uranium exploration in the United States in 1986 has been largely in the Grand Canyon area in northwest Arizona, where the targets have been the high-grade uraniferous solution-breccia pipes. According to the Uranium Industry Annual 1985, DOE/EIA 47 (86) released recently by the Energy Information Administration (EIA) of the U.S. Department of Energy (Forrestal Bldg., Rm 1F-048, Washington, D.C. 20585), about 432,000 meters of exploration drilling was done in Calendar 1985. The level is expected to be about the same in 1986. The Department of Energy is neither contracting nor carrying out any uranium exploration R.&D. The main activity of EIA is assessing the viability of the domestic uranium industry (Z.D. Nikodem, Forrestal Bldg; EI 532, MS-2G090, Washington, D.C. 20585). In 1985, it ruled that the industry was not viable, and some Congressional action is pending to limit imports and to take other actions to revitalize the industry.

Through recent reorganization of the Geologic Division of the U.S. Geological Survey, the efforts of the Uranium and Thorium Investigations (UTI) program became diffused into several Branches. Many of the scientists in the original Uranium and Thorium program of the 1970's are now in Branches doing other mineral commodity studies. The main effort of UTI is in the newly named and reformed Branch of Sedimentary Processes (formerly Branch of Energy Minerals, 1983-1986; Branch of Uranium and Thorium Resources, 1972-1983; Uranium Section, Rocky Mountain Mineral Resources Branch, 1969-1972; Branch of Radioactive Minerals, 1957-1969; Trace Elements Planning and Coordination Office,

Geologic Division, 1948-1957), Thomas D. Fouch, Chief and UTI program coordinator. The program continues at a greatly reduced scale (FY-87 funding just under $2 million; $.5 million of this for environmental radon studies; thorium studies funded under Strategic and Critical Minerals Program, T. J. Armbrustmacher, Denver) mainly through uranium investigations in the San Juan Basin and other parts of the Colorado Plateau and in the Rocky Mountain basins. Topical products are expected in the fields of radiogenic and stable isotopes, sedimentology, petrology, framework geology, paleohydrology, water-rock reactions, and geochemical redox systems.

The principal topics and geographic areas of study in FY-87 are (1) surficial uranium deposits (SUDS) throughout the U.S. (J.K. Otton, National Center, MS-955, Reston, Virginia 22092), (2) uranium in collapse-breccia pipes in the Grand Canyon region, Arizona (K.J. Wenrich, Denver), (3) uranium in sedimentary rocks of the northern High Plains (K. A. Dickinson, Denver), (4) uranium deposits in metamorphic rocks of the Piedmont physiographic province of the Eastern States (L.C. Gunderson, Denver), (5) naturally occurring radon associated with uraniferous terranes relative to environmental concerns (J.K. Otton; A.B. Tanner, MS-990 Reston), (6) uranium endowment estimation in six 1°x2° quadrangles in northern Arizona containing potential uranium-bearing collapse-breccia pipes (W.I. Finch, Denver; R.D. McCammon, MS-920, Reston), and (7) continuation of defining uranium provinces in the conterminous States (W.I. Finch).

The most significant publication of the past year was the AAPG Studies in Geology No. 22 volume, A basin analysis case study: The Morrison Formation, Grants uranium region, New Mexico edited by C.E. Turner-Peterson, E.S. Santos, and N.S. Fishman, 1986 (American Association of Petroleum Geologists, P.O. Box 979, Tulsa, Oklahoma 74101).

The USGS has a substantial High-Level Nuclear Waste program, Newell Trask, program coordinator (MS-908, Reston). Uranium exploration techniques per se are only a small part of the studies related to site selection. A recent example is the Applications of U-Th-Pb Isotope Systematics to the Problems of Radioactive Waste Disposal by J.S. Stuckless, Chemical Geology, 55, (1986), which utilizes methods and knowledge gained in studies of granitoids in the Wyoming uranium districts. A second example is Rock-water interaction in ash-flow tuffs (Yucca Mountain, Nevada, USA)- The record from uranium studies by R.A. Zielinski and others, Uranium, 2, (1986), which uses evidence for past uranium mobility to predict the behavior of chemically analogous actinides of a waste package.

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ZAMBIA

URANIUM EXPLORATION DEVELOPMENT IN ZAMBIA

Following radiometric survey conducted in the 1940's in the Zambian Copperbelt, a uranium deposit was found in the Mindolo copper ore body (Kitwe) in the lower parts of the Proterozoic Katanga Supergroup. This uranium was mined out between 1957 and 1959.

The discovery of uranium in the Copperbelt prompted further uranium investigations in the 1950's. A carborne radiometric survey in the Gwembe Valley by the Geological Survey Department led to the discovery of uranium anomalies in Karoo sediments (Carboniferous to Jurassic). Airborne radiometric surveys in North Western Province by Mwinilunga Mines led to another uranium discovery in the Domes Area within the Katanga metasediments.

In the period 19670-76, the Governmenet undertook an airborne radiometric survey which was country-wide except for Western Province an area dominantly underlain by Quarternary sands. The objectives were to speed-up mineral exploration operations in both Karoo and pre-Karoo rocks, attract uranium explorationists and diversify mining activities from the Copperbelt to other parts of the country.

Three private companies have been exploring for uranium for several years now. These are: AGIP SpA since 1970; Power Reactor and Nuclear Fuel Corporation (PNC) since 1973; and Saarberg Interplan since 1980. AGIP SpA holds prospecting licences in the Zambezi Valley (north of Lake Kariba) and the North-Western Province in the Domes Area. PNC now holds only a prospecting licence in the Zambezi Valley, having abandoned one licence area in North Luangwa Valley (Lundazi). Saarberg Interplan holds prospecting licences in the Zambezi Valley, Luangwa District and the Copperbelt extending into the North Western Province. Work in the Zambezi Valley and the Domes Areas, which has involved intensive drilling, shows the existence of important uranium anomalies and occurrences. In the Zambezi Valley, these anomalies/occurrences are located in the Upper Karoo sedimentes while in the Domes areas, they are found in lower parts of the Katanga succession. Drilling programmes in these two areas to check their economic significance are still in progress. PNC work in the Lundazi licence have only showed insignificant uranium mineralization in the Upper Karoo sediments and near the Karoo/Basement contacts.

In view of the increased activities in uranium exploration in the 1970's an act of Parliament was passed which led to the formation of Prescribed Minerals and Materials Commission (PMMC). The Commission was charged with regulating and controlling radioactive mineral exploration, mining and marketing radioactive materials and with the disposal of radioactive wastes in a way beneficial to the country yet acceptable to the international community.

The Geological Survey Department and PMMC have been receiving assistance from IAEA in the form of equipment/materials, expert services and the training of personnel. The Department has been analyzing geological, radiometric and geochemical data to define target areas where uranium mineralization might be encountered. This has focused on Basement/granitic areas which have received little or no attention by private companies. The Western Province comprising Quarternary sediments has not been checked radiometrically either on the ground or from the

air. Nevertheless there may be potential for superficial uranium deposits and this possibly could be followed up in the future.

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COMMISSION OF THE EUROPEAN COMMUNITIES

At this moment, the Commission is not directly supporting uranium exploration projects nor does it have an R&D programme specifically directed at uranium exploration techniques. However, the results of some previously undertaken studies are now being published and some on-going activities will be of interest to workers in the field of uranium exploration.

In 1986 the Commission published a report of work unertaken as part of the R&D programme in the sector of raw materials in the area of uranium exploration. This document contains nine papers on the topic "Discovery of uranium provinces, uranium geology and metallogeny", seven papers on "Exploration techniques", three papers on the "Transportation and deposition of uranium" and one paper on "Borehole logging". These papers describe work done by different organisations in Community Member States under contract with the Commission. The 184 page report has the title "Results in the area of uranium exploration (1980-1984)". Further information can be obtained by writing to the attention of M. Jean Boissonnas, DG XII/G/2, Commission of the European Communities, 200 rue de la Loi, B-1049 Brussels, Belgium.

Two other very recent publications relate to the studies on remote sensing in mineral exploration. The first of these, "Remote Sensing in Mineral Exploration" (Report EUR 10334 EN), describes some of the results of the past R&D programme of the European Community on Primary Raw Materials (1978-1981) as well as some more recent work concerning the development and application of remote sensing techniques in mineral exploration. The 186 page report contains six papers on remote sensing, one of which is an analysis of Landsat imagery from East Greenland.

The second publication on remote sensing (EUR 10511 EN-FR) is a report on the "First European Workshop on Remote Sensing in Minerals Exploration". The main aim of this workshop was to outline for the mining industry the increasing importance of remote-sensing techniques in mineral exploration by examples taken from the CEC's (DG XII) R&D raw materials programme and from experiments realized at national level. The papers in the report are mainly based on the results obtained by image processing of the first generation of satellites and on some experiments performed with airborne sensors. The 250 page report contains 13 papers presented at the workshop.

Both these reports can be obtained from the Office for Official Publications of the European Communities, L-2985 Luxembourg. The former, EUR 10334 EN, at a price of ECU 13.28 (US$ 12) and the latter, EUR 10511 EN-FR, at a price of ECU 18.18 (US$ 18). Further information on these

reports and on this area of the Commissions R&D activities can be obtained by writing to Mr. L. Van Wambeke, DG XII/G/2, Commission of the European Communities, 200 rue de la Loi, B-1049 Brussels, Belgium.

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BELGIUM

GREECE

Uranium exploration in Greece continued over the last year on a moderate level. At present 21 exploration projects are active ranging from deposit evaluation to follow-up exploration. The main projects are located in Northern Greece (Macedonia-Thrace), where the two drilling projects are found in Paranesti district.

The activities in exploration are focused mainly on the continuation of exploration over potential areas, the evaluation of promising districts by drilling, and the final evaluation of results from drilling campaigns for ore reserves estimation.

The funds for this exploration programme are entirely provided by the Government and all the exploration work was carried out by the Institute of Geology and Mineral Exploration (I.G.M.E.). The activities of the Greek Atomic Energy Commission (G.A.E.C.) in uranium exploration have recently been transferred to I.G.M.E. as well as a part of the personnel and equipment.

The uranium resources of Greece estimated as of the end of 1986 are 400 tonnes of reasonably assured resources of U (R.A.R.) at a cost up to $ 80/kg U.

These resources are contained in the Archontovouni deposit (Paranesti district) which consist of oxidized minerals as impregnations and fracture-filling in a coarse-grained granite. Although the U grade is not high the recovery of U from this surface deposit is very good according to metallurgical tests.

The rest of the resources belong to the estimated additional resources (EAR) and they amount to about 6000 tonnes of U.

They include resources in various geological environments such as:

1. The Paranesti granitic rocks;
2. The extrusives and intrusives of the Haintou Xanthi area;
3. The lignites and lignite-bearing shales of Serres and Kotili sedimentary basins;
4. The uranium-bearing phosphorites of Western Greece.

In the above areas there are in progress intensive exploration projects mainly in the Paranesti area where a big number of uranium occurrences have been located including one prospect with pitchblende mineralization which is currently under intensive drilling operations.

The most promising areas of Greece for the discovery of additional uranium deposits (with the existing information) are the following:

1. The Rhodope massif for various types of uranium deposits connected with intrusive and extrusive rocks as well as with metamophics;

2. The sedimentary basins located in the vicinity of high U background rocks of the Rhodope massif;

3. The Permo-Carboniferous clastic rocks of Central Greece;

4. The Tertiary clastic rocks of intramontane basins of Central and West Greece;

5. The intrusive and extrusive rocks of Aegean islands.

The ultimate responsibility for all aspects of geology, and mining of uranium rests with the Ministry of Industry, Energy and Technology. Under the Ministry, I.G.M.E. is responsible for all activities of mineral exploration, scientific and geological investigations.

At present there is no mining activity for uranium in Greece.

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