Formation of Uranium Ore Deposits

Proceedings of a Symposium
Athens
6-10 May 1974

PROCEEDINGS SERIES

FORMATION OF URANIUM ORE DEPOSITS

PROCEEDINGS OF A SYMPOSIUM ON THE
FORMATION OF URANIUM ORE DEPOSITS
ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
AND HELD IN ATHENS, GREECE, 6-10 MAY 1974

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1974

FORMATION OF URANIUM ORE DEPOSITS
IAEA, VIENNA, 1974
STI/PUB/374
ISBN 92-0-040274-7

FOREWORD

The increase in uranium production which will be required during the remainder of this century is unprecedented in the history of mineral development and poses a major challenge to uranium geology and exploration. Basic to any exploration effort is knowledge and understanding of how uranium deposits are formed. Increased knowledge of the chemical, mineralogical and geological controls and of the regional, tectonic and geochemical distribution of uranium is required to support the exploration programmes of the future.

The International Atomic Energy Agency, conscious of the importance of the study of uranium geology and exploration techniques, first sponsored a panel meeting in April 1970 to discuss uranium exploration geology and, as a result of that meeting, a number of Working Groups were set up to study genetic concepts, the various principal types of uranium deposits and their formation. It was later recommended that a further and more broadly based meeting be held to discuss all aspects of the formation of uranium deposits.

As a result, a Symposium on the Formation of Uranium Ore Deposits was convened by the Agency and held from 6 to 10 May 1974 in Athens at the invitation of the Government of Greece. A total of 220 participants from 40 countries and two international organizations attended the Symposium, at which 43 papers were presented. The subject of the Symposium proved to be timely and important because recent changes in the world energy situation compel even greater emphasis to be placed on the future development of nuclear power.

Uranium deposits in sandstones and quartz-pebble conglomerates at present form the bulk of known uranium resources. Yet there is reason for believing that there may, in the future, be geological limitations to the continued discovery of such deposits in numbers sufficient to meet the envisaged needs; work is needed here to determine whether there are in fact such limits, and if not, how the deposits yet undiscovered can be rapidly identified. New types of deposits, low in grade but larger in size, may have to supply the bulk of future resource additions, and investigation is required on the characteristics of such deposits and the means of identifying them.

At the Symposium, these problems were discussed and all subjects related to the genesis and formation of uranium ore deposits were reviewed under the topic headings of the six Working Groups, each of which also prepared a summary report. The papers, discussions and Working Group reports are presented in these Proceedings.

The Agency is grateful to all those who contributed papers and took part in the Working Groups and in the general discussions. Thanks are especially due to the General Chairman, Mr. R.D. Nininger, Assistant Director, Division of Production and Materials Management, USAEC, and the eight

session chairmen. The Agency also wishes to thank the chairmen of the Working Groups: Messrs S.H.U. Bowie (UK), H.H. Adler (USA), D.S. Robertson (Canada), E.E.N. Smith (Canada), J.W. von Backström (South Africa) and V. Ziegler (France). Finally, sincere gratitude is expressed for the excellent conference arrangements and the general hospitality to the participants and to the Agency staff afforded by the Government of Greece and the staff of the Democritos Centre of the Greek Atomic Energy Commission.

EDITORIAL NOTE

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INTRODUCTORY REVIEW PAPER

Review Paper

THE WORLD URANIUM SUPPLY CHALLENGE – AN APPRAISAL

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Abstract

THE WORLD URANIUM SUPPLY CHALLENGE – AN APPRAISAL.

The first Symposium on the Formation of Uranium Ore Deposits is a milestone in the expanding activities of the International Atomic Energy Agency in the field of nuclear raw materials. During this expansion, the Agency has greatly increased and improved international cooperation in uranium geology exploration and resource evaluation. In addition to stimulating an exchange of information, it has also expanded technical assistance in uranium exploration to developing countries in cooperation with the United Nations. These activities are very important at this critical point in the development of nuclear power, highlighted by recent problems in the world energy supply.

The world demand for uranium during the remainder of the century is projected at around 4 million tons. It could be greater if the trend towards the use of electricity is accelerated and if other fuels continue to become more expensive. The increase in uranium production which will be required is unprecedented in the history of mineral development and poses a major challenge to uranium geology and exploration.

World reserves at a cost of up to $ 15/lb U_3O_8 are estimated at little more than 2 million tons and additional resources at an equivalent amount. However, the production levels needed towards the end of the century will require a resource base approaching three times the present resource estimates.

A number of questions and problems are presented by the magnitude of the uranium supply challenge and should be addressed in this Symposium. Uranium deposits in sandstone and quartz-pebble conglomerates presently represent the preponderance of uranium resources. Yet there is a question whether geological limitations on the occurrence of such deposits may preclude their discovery in numbers sufficient to meet the eventual resource needs. New types of deposits, low in grade but larger in size, representing the equivalent of the porphyry copper deposits, may supply the bulk of future resource additions. Further investigation is needed on the characteristics of such deposits and the means of their identification. Similarly, additional investigation is needed to determine whether limits on the more conventional deposits do in fact exist and, if not, what advanced approaches to rapid identification of additional such deposits might be employed.

The world probably cannot rely on the very low-grade deposits such as most uraniferous black shales for both economic and environmental reasons. There is probably a minimum grade between 100 and 500 ppm below which uranium deposits cannot be effectively exploited for nuclear power.

A number of papers at this Symposium address some of these questions, and it is hoped that the ensuing discussions will shed additional light on the means by which the world's nuclear fuel requirements will be met.

The International Atomic Energy Agency is to be congratulated on convening this first Symposium on the Formation of Uranium Ore Deposits. It is the culmination of an intensive effort by the Agency to expand and improve international cooperation in uranium geology, exploration and resource evaluation begun some seven years ago. This has included the joint Working Parties on Uranium Resources and Demand with the OECD and the Panels on Uranium Exploration Geology and

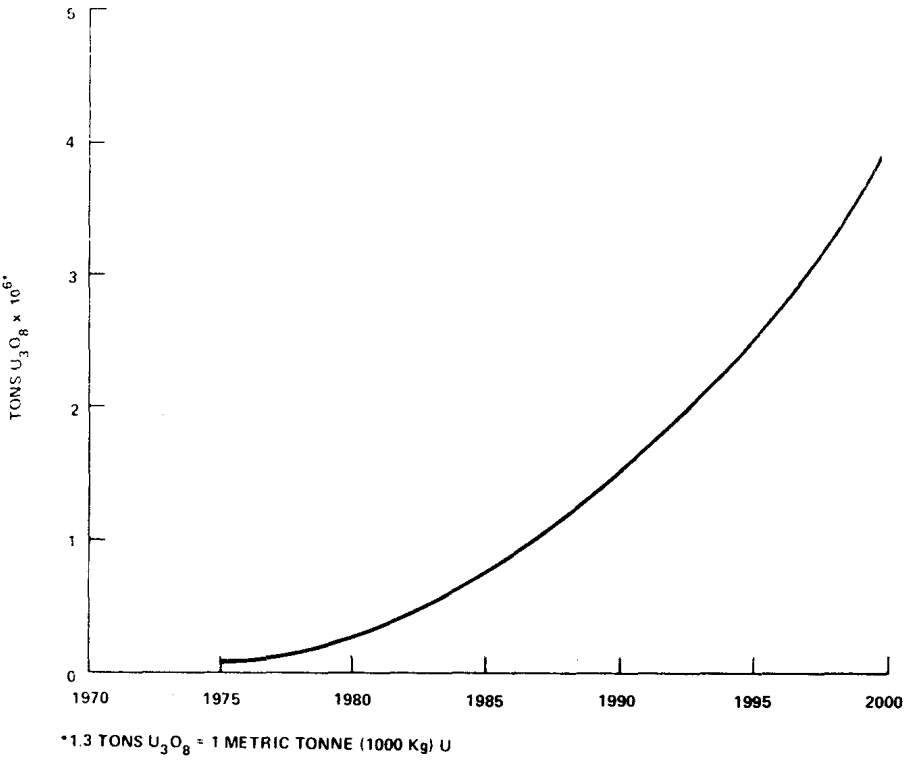

FIG. 1. World uranium requirements - cumulative. (Excludes China, USSR and Eastern Europe[1]). 0.20% enrichment tails.

Uranium Exploration Methods. In addition the Agency has undertaken several long-term technical assistance programs to developing countries in cooperation with the United Nations Development Program.

This Symposium marks the end of this initial period of expanding activity in the field of uranium raw materials as well as the much needed beginning of fuller international cooperation and exchange of information in the critical area of uranium geology and exploration.

The Agency must also be congratulated for its success in attracting to this Symposium such a large and prestigious group of uranium geologists. This augurs well for its success and its impact on future uranium supply.

The convening of this Symposium is timely. This is highlighted by the most recent developments in world energy supply. The confluence of the oil embargo and the realization that the consumption of energy in the industralized countries was rapidly outstripping the traditional supplies

have placed even greater emphasis on the development of nuclear power which was already foreseen to be the major source of the world's electricity by the year 2000. As a consequence, the projected increase in resources and production of uranium needed, unprecedented in the history of mineral development, may now be further increased. Accordingly, the challenge to uranium geology and exploration has become even greater.

What is the magnitude of the challenge; what questions and what problems does it pose; and what are some possible answers? I shall address myself very briefly to these subjects and identify a few which I hope may be explored at this Symposium. One may hope that at least the general direction in which the answers to some of the questions lie may be suggested during the ensuing discussions.

The consensus on the probable world[1] demand for uranium during the remainder of the century is about 4 million short tons of U_3O_8 (1) (Figure 1). Against this requirement, world reserves at a cost of up to $10 lb. of U_3O_8 amount to 1.2 million tons (Figure 2).

The present estimate of additional undiscovered resources in this cost range is 1.1 million tons. Incremental reserves and estimated additional resources in the $10-$15 range amount to another 1.7 million tons (Figure 3). Much larger resources will be needed to support the production level of about 300,000 tons per year which will be reached by 2000 (Figure 4). Demand will continue to climb for some years after 2000 even with the successful commercial introduction of breeder reactors in the 1980s. Figure 5 shows a comparison of the rate of increase in uranium production needed over the next 20 years with the maxima achieved in world production of three other minerals over similar periods in the past. Uranium production must increase at an average annual rate of more than 12 percent.

The reserves plus resources which need to be identified by the year 2000 to support the required production levels through 2000 and beyond may approximate 12 million tons, about three times the present estimate of reserves and resources at $15 per pound (Figure 6).

These then are the dimensions of the uranium supply challenge. Now let us review some of the geologic and exploration ramifications.

Figure 7 shows the geologic distribution of reserves and potential resources at $10/lb U_3O_8. Deposits in sandstones and in quartz pebble conglomerates predominate. Figure 8 shows the geologic distribution of $10-$15 resources. Except for the addition of the significant resources of uranium in the black shales of Sweden, the picture is much the same.

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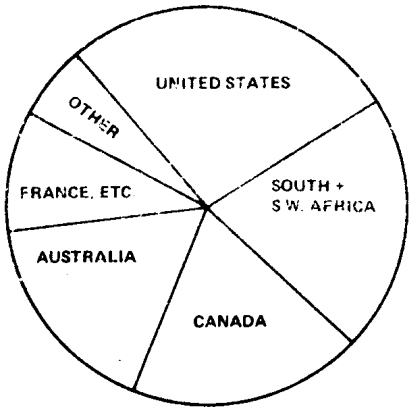
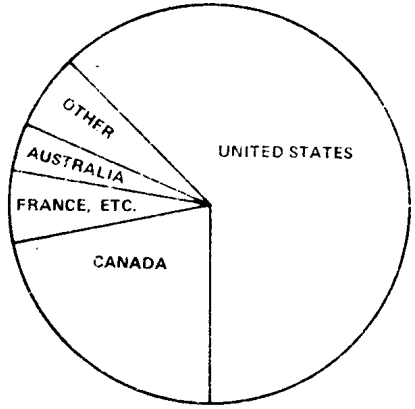
[1] "World" as used in this paper excludes China, USSR, and Eastern European states for which data are not available, with the exception of Yugoslavia.



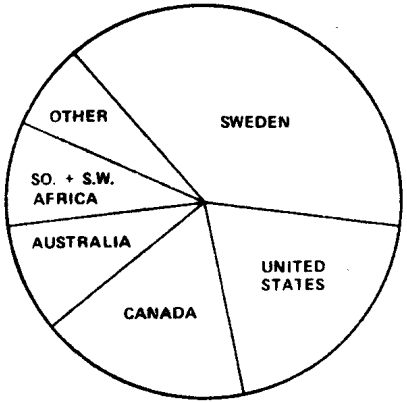
REASONABLY ASSURED – $10/LB U_3O_8 (RESERVES)	TONS $U_3O_8 \times 10^3$*	%
UNITED STATES	340	27
SOUTH + S.W. AFRICA	260	21
CANADA	240	19
AUSTRALIA	210	17
FRANCE, NIGER, GABON	130	10
OTHER	60	6
TOTAL	1240	100



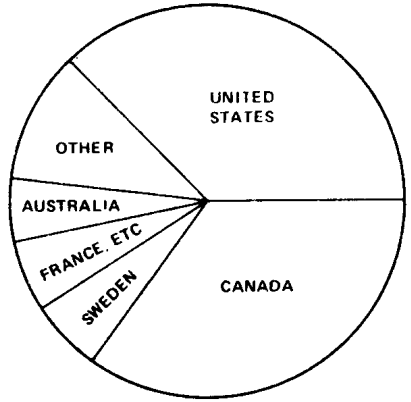
ESTIMATED ADDITIONAL – $10/LB U_3O_8 (POTENTIAL)	TONS $U_3O_8 \times 10^3$*	%
UNITED STATES	700	62
CANADA	250	22
FRANCE, NIGER, GABON	60	6
AUSTRALIA	50	4
OTHER	70	6
TOTAL	1130	100

*1.3 TONS U_3O_8 = 1 METRIC TONNE (1000 Kg) U

FIG. 2. World uranium resources – $10 per lb U_3O_8. (Excludes China, USSR, and Eastern Europe[1]).



REASONABLY ASSURED $10-15 (RESERVES)	TONS U_3O_8 x 10^3*	%
SWEDEN	350	38
UNITED STATES	180	20
CANADA	160	17
AUSTRALIA	80	9
SOUTH & S.W. AFRICA	80	9
OTHER	70	7
TOTAL	920	100



ESTIMATED ADDITIONAL $10-15 (POTENTIAL)	TONS U_3O_8 x 10^3*	%
UNITED STATES	300	37
CANADA	280	35
SWEDEN	50	6
FRANCE, NIGER, GABON	50	6
AUSTRALIA	40	5
OTHER	100	11
TOTAL	820	100

*1.3 TONS U_3O_8 = 1 METRIC TONNE (1000 Kg) U

FIG.3. World uranium resources – $ 10 to $ 15 per lb U_3O_8. (Excludes China, USSR and Eastern Europe[1]).