MAKING THE YELLOW CAKE GO ROUND

"Yellow cake" is the name given to uranium oxide (U_3O_8) by the mining profession. Ore containing about a million tons of it and capable of processing at reasonable cost has to be found by 1980 if reserves are to kept in balance. Many areas of the world are favourable for exploration and experts are confident that additional resources exist.

In a review of the subject given at Agency headquarters, James Cameron, IAEA Division of Nuclear Power and Reactors, considered that promising regions for exploration were:

1. The whole eastern side of the North, Central and South American Cordilleran belt from Alaska through USA and Central America to the south of Argentina. Despite exploration success in USA and Argentina there are favourable areas still untouched. These include difficult geographic areas of the Upper Amazon in Bolivia, Peru, Ecuador, Colombia, Brazil and Venezuela.

2. Accessible parts of the flanks of the Alpine-Himalayan belt. This could be in Italy, Yugoslavia, Greece, Bulgaria, Turkey, Iran, Afghanistan, Pakistan, India, Burma and USSR.

3. In Central Europe, Portugal, Spain, France, Austria, all of Germany, Czechoslovakia, Poland, Hungary and USSR.

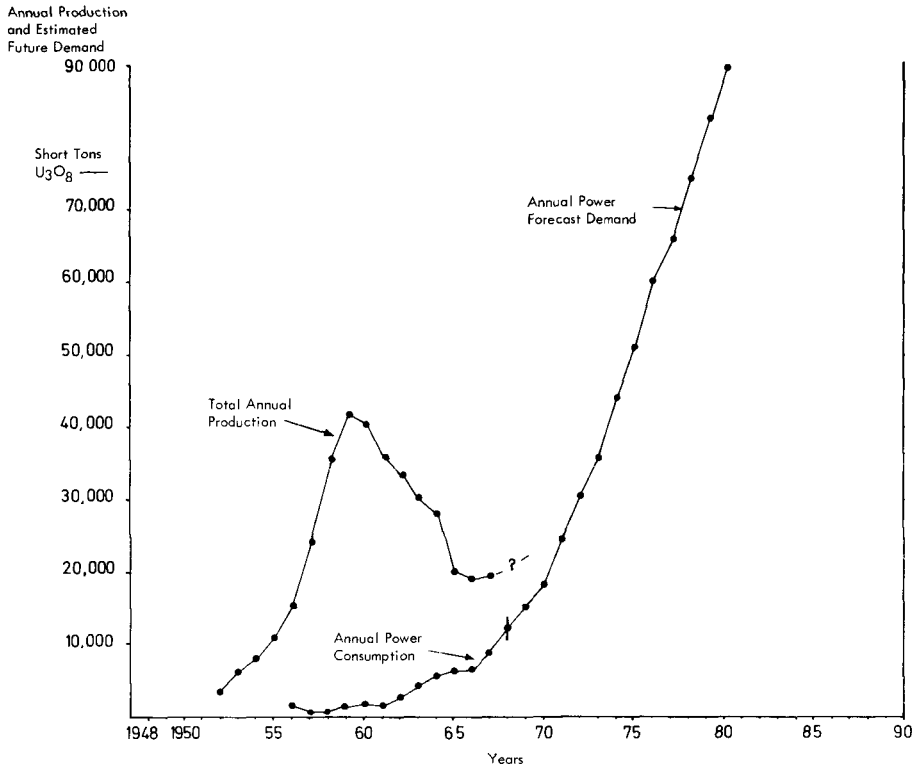
4. Based on a theory associating uranium with the Pre-Cambrian "shield" areas, Canada, Guyana, Brazil, Scandinavia, Greenland, West Africa, Central Africa, Southern Africa, India, Australia, USSR.

Although coral islands and recent volcanic areas might be excluded, it is dangerous to be dogmatic about parts of the world unfavourable for uranium occurrence.

RESERVES AND DEMAND

If no new uranium reserves were to be found from the present time, said Mr. Cameron, the low-cost reserves would be exhausted between 1981 and 1983. He pointed out, however, that the forward reserve position should not be viewed simply against year to year demand.

All minerals used require a "forward reserve" to allow for flexibility and efficiency of operation. The oil industry has always operated on a minimum of reserves calculated for ten to twelve years ahead. For uranium



(Graph) Uranium oxide annual production, consumption to 1968 and estimated future demand.

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the view of most experts is that an eight-year forward reserve is essential, Present estimates of demand mean that by the end of 1980 there should be 1 100 000 tons of the oxide in low-cost reserves. During the years up to then approximately 600 000 tons will have been consumed. A total of 1 700 000 tons should therefore have been definitely established during the period. As there are 700 000 – 826 000 tons now established as reserves, the deposits to be discovered, evaluated and proved by 1980 should contain between 874 000 and a million tons of oxide.

Technically, the annual discovery and proving of reserves should be equal to current annual consumption plus the requirement for the eighth year ahead. Owing to the fact that exploration virtually ceased in the early 1960's it is unlikely that this rate can be restored immediately. On the other hand there is now substantial exploration going on in the major uranium countries, particularly North America; this, with the considerable present reserves, provides leeway for the future exploration programme to be put on a good technical basis. Without new uranium a technical surplus would still exist until 1973. If only replacement ore were found the surplus would still exist up to 1975.

"It would be preferable" said Mr. Cameron "to get up to the eight year forward discovery rate as soon as possible, and to achieve the proper reserve position. 1969 could be a critical year for decision making, to try to avoid either a shortage or higher prices being forced on us from about 1973-75".

He made it clear that he was dealing with low-cost reserves costing less than $10 a pound. Above this cost, up to say $30, substantial reserves and resources do exist and will probably become increasingly important after 1980. Metal mining history gave every support to the belief that improvements in technology would eventually reduce production costs and make it possible to exploit such supplies economically. It would, however, be safer to regard them as post-1980 supplies.

WHERE URANIUM IS FOUND

Uranium is a highly ubiquitous element, found in nature in a great variety of minerals and in widely different types of occurrences. Economic deposits occur in sandstone, shales, quartz-pebble conglomerates, granites, pegmatites, veins, phosphates, lignites, etc.

The quartz-pebble conglomerate type of ore dominates the present reserve table but the reserves are confined to two areas of the world only; the Witwatersrand in South Africa and the Elliot Lake (Blind River) area in Canada with reserves almost equally divided between them. The South African ore occurs in relatively thin but persistent quartz-pebble conglomerate horizons in an ancient rock series. The ore averages only 0.025% of uranium oxide but is economically workable because of the association with gold. In Canada the ore type is similar but the average grade is 0.12 and although there is no gold, the higher grade and width enable uranium to be worked as the main product with thorium and rare earths as by-products.

The disseminated uranium deposits in sandstones form about 25% of present reserves and are typically developed in the Colorado Plateau area of the USA. The ore bodies are irregular but generally tabular in forms. Other deposits of this type exist in Argentina and more recent discoveries have been made in Africa, e.g. Niger. Host rock and mineralizing conditions of this type exist in many parts of the world and further exploration will undoubtedly be directed to favourable sandstone areas.

Vein deposits are normally, relatively narrow, steeply inclined, filled fractures in a wide variety of host rocks, ranging from granites to limestones. Other metals may occur with the uranium. Among present reserves, France has the largest potential of this type and other occurrences are in Canada, Spain, Portugal and Central Europe. The famous Shinkolobwe deposit in the Congo was of this type.

Among the miscellaneous types of deposits, granite pegmatites are worked in Canada and were previously worked in Australia. Other massive replacement type deposits exist in Somalia, Madagascar and Greenland.

After having impurities and valuable materials (such as radium) removed at the mining site, crude uranium oxide is transported to the processing factory in drums. Photo: UKAEA

Entirely different from these is the association of uranium with shales and carbonaceous deposits such as lignite coals. Usually these are low-grade and high-tonnage such as the huge, but presently high-cost deposits in Sweden.

The main potential source of by-product uranium is in uraniferous phosphate rock. Total resources are large (as in Morocco, Tunisia, UAR, Jordan, Senegal and the USA) but because of the low-grade and extraction problems, only a relatively small amount can presently be regarded as potentially economic.

The historical background of uranium production shows that a peak production of just over 42 000 tons of uranium oxide was reached in 1959 and after that there was a steady decline to 1966. Nineteen hundred and sixty-six was the bottom of the trough. There was an increase in 1967 and this was accelerated in 1968.

The total cumulative production up to the end of 1968 was about 400 000 tons of oxide. The ten-fold increase in annual production rate in the eight-year period (1951-1959) was unique in metal mining. In 1951, world uranium reserves were estimated at around 50 000 tons, and in 1958 the figure was over one million tons. However, the exploration effort was over-successful and by 1958 it appeared that all foreseeable uranium requirements had been met for a period of at least 15 years.

The anticipated build-up for nuclear power requirements could not then be accurately estimated and a marked slump in uranium prospecting, mining and production ensued in the early 1960's.

The demand picture began to change in the mid-1960's as estimates of nuclear power growth were continuously revised upwards. The most recent authoritative estimate of uranium demand for power production up to 1980 has been made by a study group of the European Nuclear Energy Agency (ENEA) and IAEA. The figures show a median requirement of about 600 000 tons between 1968 and 1980 (tonnages from the USSR, Eastern Europe or mainland China are not included as figures are not available).

("Uranium Production and Short-term Demand" is available from ENEA at 38 boulevard Suchet, Paris 16e.)

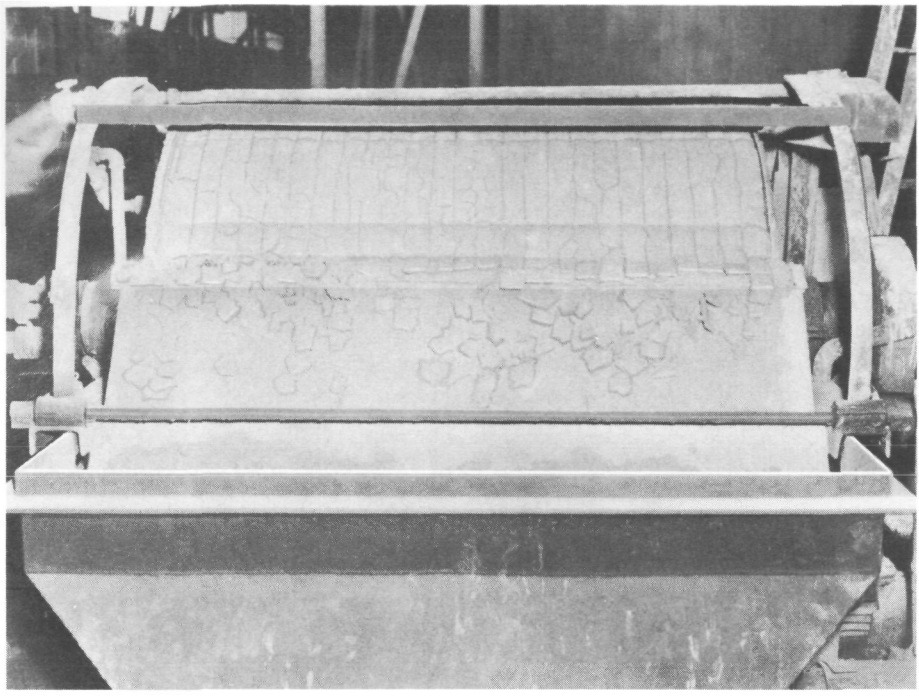
Slightly earlier estimates from UK and US sources indicated a requirement of 550 000 tons to 1980 and extended estimates to the year 2000 up to 3 500 000 tons.

THE TIME FACTOR

Time is an important factor. New ore reserves cannot just be turned on from one year to the next. Exploration time may be influenced by fortuitous circumstances but the average time taken between the start of an exploration programme in a new area and the proving of ore reserves is likely to be three to five years, and the bringing into production of a mine or mining group six to ten years.

As exploration was practically non-existent in the early 1960's and has only re-started in North America and a few other areas in the last few years, production capability from new exploration is some years away – certainly in the mid 1970's.

Production capacity also presents a time lag. At the present time total capacity is rated at 23 500 tons per annum and partly by re-opening old plants it is thought capable of expansion to 40 000 tons per annum within five years. The necessary further expansion up to nearly 60 000 tons in 1976 and 90 000 tons in 1980 involves a construction time lag of three to five years and as some of the relevant deposits may not even be located yet – a total exploration-to-production time lag of six to ten years is readily envisaged.



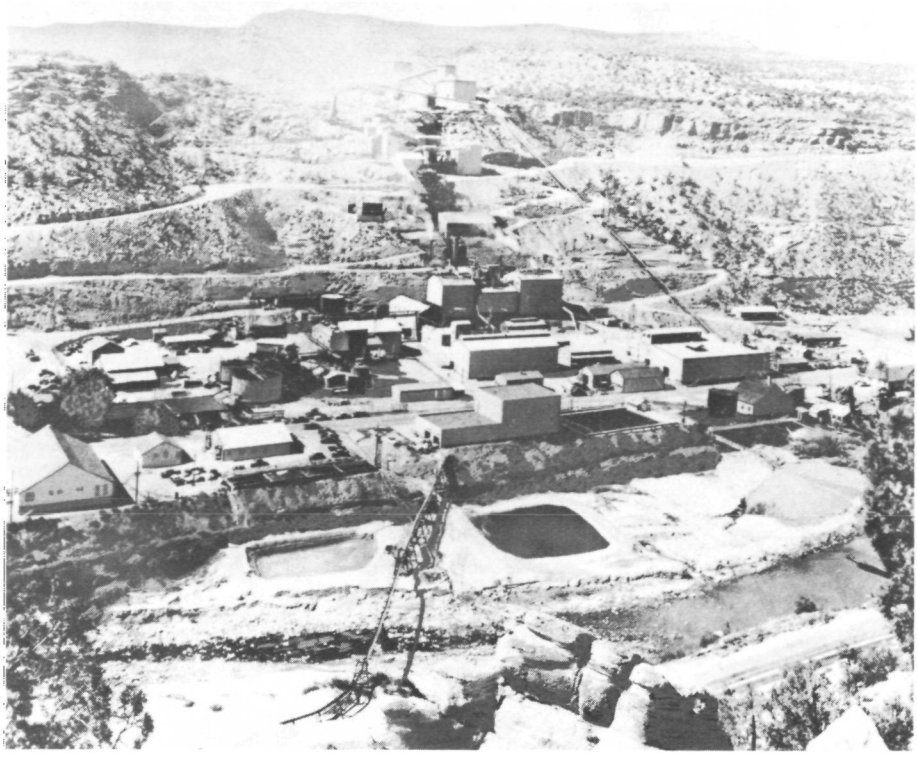
What the yellow cake looks like after final filtering at the mine's uranium treatment plant. Photo: Australian AEC.

$100 MILLION A YEAR FOR EXPLORATION

The present average price range of $6.00-7.00 is unlikely to be maintained and most long-term planning is based on a price of US$8.00 per lb of uranium oxide. The target up to 1980 would have a value of between 14 and 16 billion dollars.

Exploration costs in the USA in the campaign of the 1950's were of the order of 20 to 30 cents per pound, low figures due partly to the near surface location of the deposits. Estimates for the future in the USA are that exploration costs will be higher, possibly of the order of 50 cents per lb.

In general, technical good practice puts a limit of 10% of the total content values as the allowable expenditure on exploration and evaluation, in this case 80 cents per lb. This would mean that from now until the end of 1980, between one and one-and-a-half billion US dollars should be, and almost certainly will be spent on uranium exploration and evaluation — or around an average of 100 million dollars per year.



The uranium mill at Uravan, Colorado. Photo: Union Carbide

The probability is that the greater part of this money will be spent by commercial or national organizations from the more developed countries. Where it will be spent is another matter. No doubt the highest proportion will be spent in the more developed uranium countries, but much favourable ground has already been gone over in these countries and this and other factors will tend to send a great deal of money seeking exploration facilities in developing countries.

THE ROLE OF THE AGENCY

The speaker gave some opinions on what the role of the Agency might usefully be in this anticipated large increase in uranium exploration and production over the next twelve years and beyond.

Two general aims would seem to be foremost – firstly, the evaluation and provision of information on uranium exploration and supplies in relation to nuclear power requirements, and secondly, to assist Member States when so required, to develop, utilize and exploit their natural resources of nuclear raw materials in the most beneficial and efficient manner.

One requirement is a re-study and assessment of theories of uranium mineralization and favourability. It is hoped that a panel meeting of leading uranium geologists can be held in early 1970 to discuss this and help to define geological guidelines for fiture exploration. To supplement this, an uranium exploration register of work done in Member States up to the present has been started and it is hoped that this will give statistical information on favourability and exploration methods.

The Agency is already responsible for authoritative information on uranium and thorium reserves, resources and production capacity jointly with the European Nuclear Energy Agency through a Study Group of geological experts. Three publications have been issued by the Group and have become authoritative statements on this subject. It is highly probable that such Study Group meetings will continue and it is hoped that the Agency's contribution will become increasingly significant.

In regard to operational information and the development of techniques there are quite a number of possibilities, one being the possible promotion of research in prospecting instrument design and another the publication of revised and up-dated guides or handbooks on exploration and evaluation methods.

Advice and assistance to Member States on all aspects of exploration, evaluation and production of nuclear raw materials would, of course, be available. Included in this are training courses such as one on uranium exploration methods which is arranged for the South and Central American region in the autumn of this year.

Because of the considerable amount of money which is likely to go into uranium exploration in the next decade, and the proportion which would be seeking an outlet in developing countries, he felt that, when and where requested, the Agency could play a very important role in advising Governments on these matters. This would involve not only technical, but also economic, commercial, administrative and legal advice.