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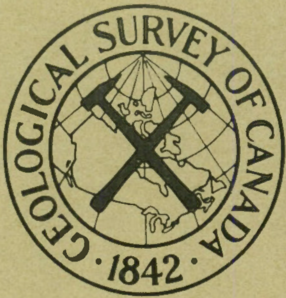

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UNEXPLORED URANIUM AND THORIUM RESOURCES OF CANADA

(Report and 1 figure)

S. M. Roscoe

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February 1, 1966

UNEXPLORED RESOURCES OF URANIUM AND THORIUM IN CANADA

Uranium ore reserves in Canada have been reported to contain about 210,000 tons of U_3O_8 mineable at prices less than $10 per pound (Griffith and Roscoe, 1964). Production in 1965 was about 3,600 tons of U_3O_8. Production could be raised rapidly to about 9,000 tons per year without major expenditures for new milling facilities or mine development. By the mid-nineteen seventies rapidly growing markets are expected to be able to absorb this much Canadian uranium; thereafter, new plants and ore deposits, not yet discovered, will be needed in increasing numbers.

ELLIOT LAKE AREA

The most obvious place to look for new ore deposits is the Elliot Lake area where ninety-two per cent of Canadian reserves occur in quartz-pebble conglomerate beds within a Huronian formation. In addition, it has been estimated that there are about 130,000 tons of U_3O_8 mineable at U_3O_8 prices of $10 to $15 per pound and 100,000 tons mineable at prices of $15 to $20. The $10 - $15 potential ore is mainly in conglomerates above those now being mined and in fringe areas of the latter. The $15 - $20 potential ore is mainly in extensive sheets east of the two great orebodies. Grades of these potential ore sources are not well known so the tendency has been to make conservative estimates. It now seems probable that substantial amounts of potential ore in the two higher categories should be placed in the next lower cost categories.

All of the conglomeratic ores and potential ores contain at least 0.02 per cent ThO_2 and some contain as much as 0.4 per cent. Most of this thorium could be extracted cheaply as a by-product of uranium production. Some is now being recovered but most of that contained in ores mined to date has gone into the tailings storage areas from where it could be extracted at a later date. Large markets for thorium would result in a reduction in grades of ore mineable and an increase in reserves. The same is true of other possible by-products. Some yttrium is now being recovered at one treatment plant. In addition to resources of thorium recoverable as a by-product of uranium mining, there are extensive conglomeratic deposits that contain high thorium but little uranium.

It has been estimated that ore and potential ore found to date in the Elliot Lake area is probably only about one half of the total that is present to mineable depths within the Huronian belt. To appreciate the basis of this prognostication, it is necessary to understand certain features of the main ore occurrences. Valleys in the ancient pre-Huronian surface are important controls of ore distribution; these are most likely to be found where there are contacts between dissimilar basement rocks. Radioactive conglomerates may be cut off at disconformities where they were removed prior to deposition of overlying rocks. They are eliminated in places where pre-Huronian hills poke up through the strata. Individual layers thin and become smaller pebbled, less uraniferous and relatively more thorium-rich toward the south and east. Conversely, a low grade bed followed towards the northwest may strengthen and thicken until it becomes ore grade. It will also gradually converge with the basement in this direction. The most abundant, thickest and richest conglomerate beds have been found to the north, just south of a position where their host formation wedges out and the overlying formation rests directly on basement. Regional stratigraphic relationships indicate that this line of wedge-out once extended 75 miles east and west of Quirke Lake. Towards the east most of it has been eroded, but where it is present north of Espanola, beds containing 0.09% U_3O_8 and 0.3% ThO_2 have been found immediately south of it. Towards the west, the wedge-out is everywhere buried - in places to depths of as much as 7,000 feet - and there has been no exploration whatever along it. Weakly to moderately radioactive conglomerates outcrop or have been intersected in drill-holes in many places several miles south of the projected line of wedge-out. These attest to the existence of richer conglomerates to the north near the wedge-out line. Contacts between dissimilar basement rocks cross the buried favourable zone in places; along them there will be pre-Huronian valleys and ridges like those that have controlled the distribution of deposits in the Elliot Lake area.

Large deposits will be found cheaply and rapidly and could be brought into production within five years of the start of intensive deep drill-hole exploration. We have good reason to suppose that production from Huronian conglomerates could be raised to about 20,000 tons per year during the 1970's.

BEAVERLODGE AREA

Estimated reserves of about 12,000 tons of U_3O_8 in the producing area at Beaverlodge are very small compared to those at Elliot Lake but they do not give as significant a measure of the total potential of the camp. The character of the deposits does not permit the sort of reserve and resource estimates that have been attempted for the stratified deposits of the Elliot Lake area. These deposits can be compared to some of the gold deposits or even native silver deposits in northern Ontario. Some of the former have been operating for four or five decades with no more than a few years' reserves in sight at any time. Silver has been produced from Cobalt mines through an even longer period but reserves have been all but non-existent from the outset. It can be assumed that new pitchblende deposits will be found within the extensive favourable area around Beaverlodge at a rate adequate to ensure continuing, if not substantially increased, production for several decades.


Metamorphic and igneous host environments for pegmatitic, disseminated, and some vein types of uranium-thorium deposits
Post-orogenic sedimentary-tectonic host environments for pitchblende veins, 'sandstone'('Red bed' or 'plateau') type uranium deposits, quartz pebble conglomerate type uranium-thorium deposits:
(a)
(b)
(a) principally of interest for pitchblende
(b) principally of interest for conglomerate deposits
Miles
0
400
GSC

EXPLORATION POSSIBILITIES OUTSIDE OF PRODUCING AREAS

Igneous and metamorphic host environments

Areas of crystalline rocks containing pegmatites comprise more than ten per cent of the surface of Canada. These rocks are within former orogenic belts where great thicknesses of predominantly shaly sediments were once deeply buried, heated, recrystallized and partially melted. In this process, uranium and other trace elements, somewhat concentrated in shales to begin with, became appreciably concentrated in pegmatitic and other rocks that were in effect 'sweated out' of the sediments. These pegmatite-bearing gneissic terrains occur in the cores of many mountain systems and are abundant in crystalline basement rocks beneath covering sediments on all continents but nowhere are they so extensively exposed as in Canada.

By far the greatest number of radioactive occurrences containing more than 0.05% U_3O_8 reported in Canada are in pegmatitic or related types of deposits. Most of these are in the Grenville region of southern Ontario and Quebec. Similar occurrences are also abundant throughout less accessible extensive areas in the Prairie Provinces, Northwest Territories, northern Quebec, and the Cordilleran region.

Pegmatitic ore containing about 0.09 per cent U_3O_8 has been mined at several properties in the Bancroft area at uranium prices averaging slightly more than $10 per lb and considerable amounts of potential ore remain in the area. Some fairly extensive exploration work has been done in other areas of radioactive pegmatites, notably the Charlebois Lake area in northern Saskatchewan and the Kenora area in western Ontario. Potential ore in such deposits begins to approach important tonnages at the 0.08% level. At the 0.04% or 0.02% levels there may well be hundreds of thousands or millions of tons of potential resources of U_3O_8 and ThO_2 in the extensive pegmatitic terrains.

Production from large igneous and metamorphic deposits may eventually become important, even without rises in the price of uranium, through reductions in costs and through multi-product operations. Uranium is accompanied by thorium and rare earths in these deposits, and many slightly radioactive and highly radioactive deposits contain concentrations of commodities such as niobium, beryllium, lithium, rubidium, molybdenum, copper, iron, titanium, apatite and fluorite. Uranium and thorium could be recovered fairly cheaply from many such deposits either as by-products or as major products with part of the cost of operation defrayed through sale of other products.

Uraniferous shales and phosphorites

Uraniferous shales and phosphorites form a large part of reserves of high cost, moderate cost and by-product uranium in countries other than Canada. Canada also has potential resources of these types but no attempt has been made to assess them. Phosphatic strata are found in the southern Rocky Mountain area and prospects may develop for fertilizer operations which could lead to by-product uranium production. Uraniferous shale formations, extensive beneath the Prairies, also outcrop in the Rocky Mountain area. Such formations occur elsewhere, in Precambrian as well as in younger strata.

Post-orogenic sedimentary-tectonic host environments

Most of the world's past production and almost all reserves of low cost uranium have been derived from conglomeratic deposits and disseminated deposits in non-marine sedimentary rocks. Much of the remainder has come from pitchblende deposits near or within areas that contain similar non-marine sedimentary rocks and, commonly, abundant volcanic rocks. The accompanying map shows the distribution of such stratified rocks considered to be favourable on the basis of a number of criteria that need not be discussed here. The selection was made in consultation with a number of Geological Survey geologists who were personally familiar with the rocks under consideration. An attempt has been made to separate areas of interest primarily because of possibilities of pitchblende occurrences, or of conglomeratic deposits, from those of interest mainly because their lithology and tectonic setting resembles that of Colorado Plateau and related subtypes of deposits but favourability for one of these types of deposits does not eliminate the possibility of finding either of the other two types.

Close duplicates of the lithologically unusual Huronian rocks are not known anywhere else in Canada. Quartz-pebble conglomerate beds, however, have been noted in some fairly similar sequences and concentrations of radioactive minerals, gold, other minerals common in placers, or pyrite have been reported in several of these. There is a possibility that conditions were most favourable for formation of conglomeratic deposits in earliest Proterozoic time when the Huronian and Witwatersrand sequences were deposited. If this were so, we would have to downgrade chances of finding new Elliot Lake camps in younger quartz-pebble-bearing sequences such as basal Carboniferous rocks in the Maritimes and perhaps the 1,400-mile-long belt of younger Proterozoic rocks along the eastern Cordillera.

Known occurrences of uranium and its common associates, vanadium, or copper, in sandstones are rare in Canada. There are a number in Carboniferous rocks in the Maritimes. A single occurrence of uraniferous lignite is known in Tertiary rocks in southeastern Saskatchewan;

many deposits have been found in equivalent coaly beds directly south in North Dakota. Small amounts of vanadium and uranium are present in Mesozoic Athabasca tar sands. Several reported occurrences of secondary uranium minerals in the Interior Plateau of British Columbia may be in Tertiary sediments but descriptions are not clear. Many small patches of sedimentary rocks are found intercalated with more abundant Tertiary and Mesozoic volcanic rocks throughout the plateau region but the most interesting areas in the western Cordillera are larger Mesozoic basins in southern Yukon, northern B.C., east of the Coast Range in southern B.C., and west of the Coast Range on Vancouver Island. Small amounts of vanadium have been found in sandstones in the latter area (Rose, personal communication). Copper occurs in red beds in the Redstone area in the District of Mackenzie near the Yukon boundary. Extensive areas of Palaeozoic red beds occur in the Arctic Islands and in northern Yukon. Concentrations of secondary uranium minerals have been found in the Proterozoic Athabasca sandstone in northern Saskatchewan. Other large areas of flat-lying Precambrian sandstones occur west of Hudson Bay and on northern Baffin Island. Organic material was an important precipitation agent for uranium in many United States deposits ranging from Devonian to Tertiary in age. It might be supposed, therefore, that Precambrian continental sediments, lacking plant debris may be less favourable than younger sediments.

Pitchblende deposits occur in areas that have had similar tectonic histories to those that may contain sandstone or conglomeratic deposits but favour locales where post-orogenic tectonic activity was relatively intense. Deposits occur in deformed post-orogenic sedimentary and volcanic rocks but the most important ones are commonly found in adjacent, older crystalline basement rocks. These relationships apply in the pitchblende-bearing Beaverlodge, Lake Superior and Seal Lake areas. Native copper and other copper minerals occur in basalts and sediments in these areas. Similar areas in Newfoundland, Nova Scotia, the Coppermine area, and Victoria Island in the Arctic warrant careful investigation.

The abundance of favourable geological environments for low-cost uranium deposits in Canada attests to the existence of abundant resources outside of presently productive areas, but of course it is not possible to make quantitative estimates. We could surely hope that these possibilities will eventually reward us with a discovery rate and consequently a production rate of many thousands of tons of low cost U_3O_8 per year in addition to production from Huronian conglomerates.

THE SPECTRE OF RESOURCE DEPLETION

Perhaps many would consider that I am being unduly optimistic about our prospects for discovering new sources of low cost uranium. This may be so, but it is certain that those who base their predictions on present ore reserves alone will be proven unduly pessimistic. If we considered future supplies and probable prices of other mine products and oil in the same way that some of us are looking at uranium, the predictions would imply dire consequences indeed for our industrial economy. Such predictions have, in fact, been made many times in the past. The final report of the Royal Commission on Canada's Economic Prospects, 1957, considers such predictions, terming them "the spectre of resource depletion". Its conclusions, based on an examination of production, reserves and prices during the period 1925 to 1955, are as follows:

> "Over the last 30 years, despite increasing resort to lower-grade or less accessible mineral deposits and despite rather prolonged periods of short supply and marked short-term fluctuations, the long-run tendency of the prices of most minerals has actually been to remain stable or to decline in relation to those other goods and services. We would expect that short-term movements either up or down will continue to occur from time to time. Over the longer term, however, we would expect that the relative prices of minerals as a group will decline from their levels in 1955, continuing the downward drift evident in the last three decades."

The record of the past ten years strongly supports this conclusion. Average prices of most mineral commodities during the 1955-1965 period were comparable to prices during the previous ten year period. Prices of some metals, notably copper and silver, were higher but these increases are not great if the general decrease in purchasing power of the dollar is taken into account. Since 1955, Canadian production of oil has doubled, we have produced the equivalent of 80 per cent of 1955 reserves, yet 1965 reserves are nearly three times those of 1955. Metal production has increased by 50 per cent, the equivalent of about 25 per cent of 1955 reserves were produced, yet reserves of all metals (except uranium and gold) have increased by more than 10 per cent. Among individual metals, zinc production has doubled and will increase another 50 per cent within a few years; reserves have increased by more than 30 per cent. Molybdenum production has increased tenfold and will double again within a few years.

GEOCHEMICAL CONSIDERATIONS

It is worthwhile considering whether there are any fundamental geochemical factors that could lead to a relative scarcity of uranium concentrations compared to concentrations of other metals. First let us compare prices and production of uranium to other metals in terms of their relative abundances in common rocks. For example molybdenum is half as abundant as uranium, yet a price of $2 per pound is adequate to generate a world's production of 50,000 tons per year from deposits containing a concentration 2,500 times that in ordinary rocks. The 'abundance equivalent' production for uranium would be 100,000 tons per year from deposits containing 0.8 per cent U_3O_8, requiring a uranium price of only about $1 per pound. In the accompanying table, these calculations are made for eleven metals, Au, Ag, Mo, W, Sn, Ni, Pb, Cu, Zn, V, and Mn, in increasing order of abundance. Gold is only one thousandth as abundant as uranium. Manganese is 200 times more abundant than uranium. Metals like Fe, Al, and Mg that are major rock components cannot be treated this way; neither can metals whose demands and production are very low, or ones that are produced almost entirely as by-products.

				U abundance equivalent	
	U:metal (crust)	conc. ore:rock	world prod.[x] 1963	annual prod.[x]	grade ore %
Au	1,000	2,500	2	2,000	0.8
Ag	50	3,000	8	400	1.0
Mo	2	2,700	50	100	0.8
W	2	5,000	60	120	1.5
Sn	1 1/2	5,000	200	300	1.5
Pb	0.2	1,700	2,800	560	0.5
Ni	0.1	200	350	35	0.06
Cu	0.07	200	5,000	350	0.06
Zn	0.05	700	3,800	190	0.2
V	0.03	100	6,000	200	0.03
Mn	0.005	300	15,000	75	0.1

x = 1,000 tons

The table illustrates that low cost uranium deposits should be sufficiently abundant to sustain prolonged high production levels provided that geochemical factors do not discriminate strongly against concentration of uranium as compared to other metals.

Comparisons of the very complex geochemistry of uranium with that of individual other metals are much too involved to attempt here. Some characteristics are detrimental. Its strongly lithophile character, for example, results in lack of uranium deposits in regions that may contain abundant, rich deposits of metallic sulphides, silver and gold. Its tendency to become adsorbed on various materials can produce low grade deposits but it results in dispersion in shales and reduction of amounts available to form richer deposits. The same tendency, however, restricts its dispersal into the oceans where it would be unavailable for later geological recycling. Other factors, such as its ease of change of valence state, are favourable. Its large ionic radius prevents it from becoming locked (like nickel, lead and zinc) in the lattices of insoluble silicate minerals. Its great atomic weight and even its radioactivity, which results in autodestruction and easier solution of dispersed uranium minerals, are also plus factors. In balance then, geochemical factors are not portentous of rapid rises in the price of uranium relative to other metals.

FACILITY OF EXPLORATION

Let us carry this comparison of low cost uranium deposits with ore deposits of other metals a little further and consider whether the former are likely to be relatively more difficult to find. Unlike other metals, uranium, thorium and potassium advertise their presence through their radioactivity or that of their daughter elements. This makes exposed deposits and mineralized areas likely to contain hidden deposits relatively easy to find. Does this mean that most of the best exploration 'bets' have already been discovered and tested? Most of Canada was all but inaccessible in the nineteen-fifties compared to conditions that will prevail in the future. Even in relatively accessible parts of Canada, it is doubtful that the efforts of individual geiger counter-carrying amateur and professional prospectors have eliminated any of the areas that seem favourable in the light of present knowledge. The more intensive organized programs of the late forties and early fifties were concentrated in relatively limited sections of the country.

Future exploration will benefit from past experience, from geological mapping of large regions that were unmapped ten years ago, from new knowledge concerning uranium deposits, and from new techniques that have expedited discoveries of deposits of other metals in recent years.

CONCLUSIONS

Renewed exploration will result in discoveries of many low cost uranium deposits. In a six year period preceding the nearly total cessation of exploration in 1956 an average of 50,000 tons per year of U_3O_8 mineable at prices less than $10 per pound were discovered in Canada. A future discovery rate in the 1970 to 1990 period in excess of 20,000 tons of U_3O_8 per year in comparable ores is not difficult to envisage. Such a discovery rate, together with present reserves could sustain an average production of about 30,000 tons per year in the period between 1980 and the turn of the Century. More than 5,000 tons per year by-product thorium could also be produced and additional thorium could be reclaimed from tailings dumps if required. When required, large resources of lower grade uranium and thorium ore will be available. As demand increases, it will become possible to exploit progressively lower grade deposits, but greater sizes of such deposits, continual improvements in operations, and by-product revenue will tend to minimize price rises.

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