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CANADIAN DEPOSITS OF URANIUM AND THORIUM

A. H. Lang, J. W. Griffith, and H. R. Steacy

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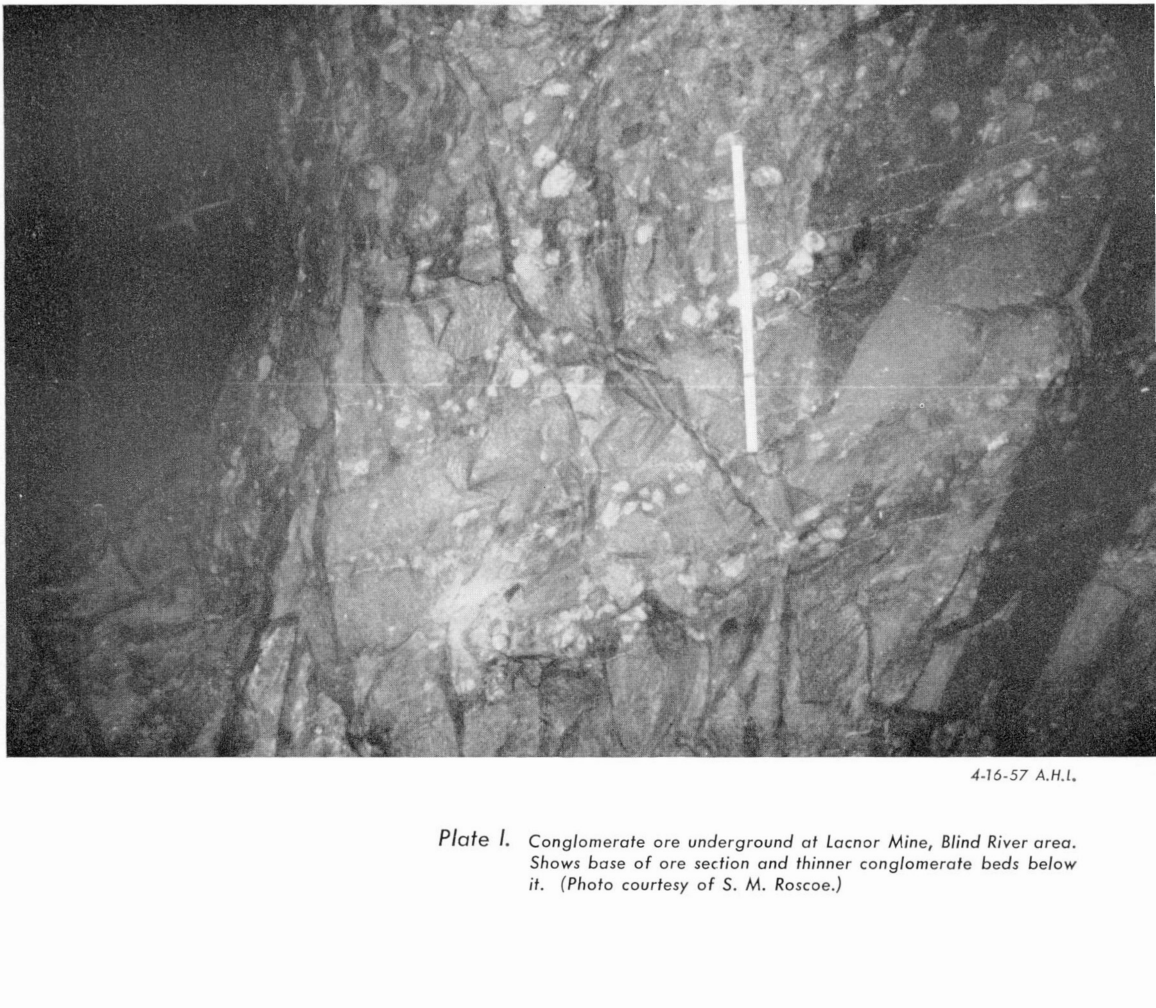

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Plate I. Conglomerate ore underground at Lacnor Mine, Blind River area. Shows base of ore section and thinner conglomerate beds below it. (Photo courtesy of S. M. Roscoe.)

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PREFACE

Uranium has rapidly become the principal metal produced in Canada[1] and, despite greatly increased production in several other countries, Canada has maintained her position as one of the world's leading suppliers. This report is, therefore, timely as a summary of information on the geology of deposits, comprising data scattered in many publications as well as unpublished data, the latter including generalizations based on the writers' field and laboratory work and review of the literature. When additional supplies of uranium are required the report will be found to contain information useful in prospecting and in selecting properties for further exploration of prospects already found. Thorium is included because the two elements are related in many respects.

The first edition, published in 1952, has been out of print for some time. A new edition rather than a reprinting was necessitated by a great increase in geological information and in uranium discoveries and producing mines. The first edition was an interim account, prepared to meet an urgent demand for information. Much remains to be learned about the subject and this volume actually is a second interim account prepared fairly quickly in order to make information available in compact form without undue delay.

This edition has been prepared by three geologists of the Mineral Deposits Division because the author of the first edition, A. H. Lang, could devote only part of his time to the present work. He is mainly responsible for Parts I and II and for supervision of the work in connection with Parts III and IV; J. W. Griffith prepared Part IV, assisted greatly with Part III, and contributed some data for Part II; H. R. Steacy made many of the mineralogical identifications included in descriptions of deposits, and wrote the sections on radioactivity, geochemistry, and mineralogy. The writing of the report was completed in June 1959.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, April 16, 1960

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[1] In 1960 uranium was third in value of production, being exceeded by nickel and copper.

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CANADIAN DEPOSITS OF URANIUM AND THORIUM

Abstract

From a relatively small beginning, stemming from a radium mine operated before World War II, uranium deposits were quickly found in several parts of Canada and production has grown so that uranium became the leading metal produced in Canada in 1958. The value of Canadian uranium production in that year was more than $274,000,000. This report is a summary of information on the geology of more than 1,000 mining properties containing uranium. Thorium is discussed also, because it is related to uranium and occurs with it in several deposits; a few deposits contain only thorium, or thorium with only traces of uranium. The descripitions of areas and deposits are as of December 31, 1957; generalizations include information gained in 1958 and early 1959.

Seventy uranium or thorium minerals and varieties have been found in Canada, but of these the only important ore minerals are brannerite, uraninite (and its variety pitchblende), uranothorite, and uranophane. Uranium occurs in small amounts in a wide variety of deposits, but the ores are of three main types: 1) conglomerate; 2) pitchblende veins and disseminations; and 3) pegmatitic granite and syenite. Occurrences are widespread, but most are in the Canadian Shield, particularly in its margins. Most Canadian production of uranium now comes from conglomerate ore in Blind River area, Ontario, where ore reserves in 1958 were sufficient for about 20 years at current rates of production. Additional ore is partly blocked out; when still more is required the better prospects now known in various districts can be tested further, and additional prospecting can be done in areas suggested, using techniques explained.

Résumé

Après des débuts relativement modestes, qui remontent à l'exploitation d'une mine de radium avant la Seconde Guerre mondiale, la découverte de gîtes d'uranium s'est effectuée rapidement dans plusieurs parties de notre pays, et la production a pris des proportions telles que l'uranium a tenu le premier rang parmi les métaux produits au Canada en 1958. Cette année-là, la valeur de la production au Canada avait dépassé 274 millions de dollars. Le présent rapport constitue un résumé des renseignements qu'on possède au sujet de la géologie de plus d'un millier de propriétés minières qui contiennent de l'uranium. Il y est également question du thorium, car ce métal se rattache à l'uranium et s'y trouve associé dans plusieurs gîtes. Quelques gîtes ne contiennent que du thorium, ou encore du thorium accompagné de traces d'uranium. Les descriptions des régions et des gîtes sont basées sur les données connues au 31 décembre 1957. Quant aux généralisations, elles font entrer en ligne de compte les renseignements obtenus en 1958 et au début de 1959.

On a trouvé au Canada soixante-dix minéraux et variétés minérales d'uranium ou de thorium, mais, parmi ceux-ci, les seuls minéraux considérés comme minerais importants sont la brannérite, l'uraninite (et sa variété appelée

pechblende), l'uranothorite et l'uranophane. L'uranium se trouve en petite quantité dans une foule de gîtes différents, mais les minerais appartiennent aux trois principaux types suivants: 1) conglomérat; 2) filons et disséminations de pechblende, et 3) syénite et granite pegmatitiques. Il existe des gisements en plusieurs endroits, mais la plupart se trouvent dans le bouclier canadien, tout particulièrement dans les zones marginales. Le gros de la production canadienne d'uranium provient maintenant du minerai du type conglomérat de la région ontarienne de Blind River, où, en 1958, les réserves de minerai étaient suffisantes pour soutenir la production au rythme actuel durant environ 20 ans. On a partiellement délimité d'autres réserves de minerai. S'il faut plus d'uranium à l'avenir, les gîtes les plus prometteurs relevés dans diverses régions pourront être étudiés plus à fond, et de nouveaux travaux de prospection pourront être exécutés dans les régions indiquées en utilisant à cette fin les techniques expliquées dans ce rapport.

PART I

INTRODUCTION

Canada has been one of the world's leading producers of uranium since the metal became important as a source of atomic energy in 1942. Because of the discovery and development of large additional supplies she has maintained this position despite important finds in other countries. Reserves of uranium ore in the Blind River region of Ontario are now among the largest in the world, and possibly the largest except for by-product ores. In 1956 Canadian production of uranium was valued at about $40 million, the metal then being eighth in value of production among Canadian minerals; by 1958 several additional large mines had begun operation, and the output that year had a value of more than $274 million, uranium being the leading metal produced. High production is expected to continue at least until 1962 or 1963, when present contracts for production will expire.[1]

Thorium was not produced in Canada until recently, nor is it in great demand at present. It is, however, associated closely with uranium in many deposits, and it occurs alone or with insignificant amounts of uranium in others. A plant for production of thorium as a by-product of certain of the mines at Blind River was completed in 1959.

Because of the place of Canadian uranium in world markets and in the domestic economy, the geology of the deposits is of great importance, both for the understanding of present operations and for the discovery and selection of additional deposits if or when required. Thorium is related to uranium in some of its physical and chemical properties and in many deposits.

Scope and Nature of Report

The main purpose of this report is to provide as much information on the geology of Canadian deposits of uranium and thorium as is possible in a volume of convenient size, and to give references to more detailed literature where available. The report also contains information on other topics related to economic geology, such as history of discoveries, regulations concerning prospecting and mining, methods of prospecting and exploration, and minimum coverage of foreign and domestic demands, production, and potentialities.

The attention devoted to uranium deposits in Canada during the last 10 years has resulted in many reports and papers on individual deposits and areas, scattered in publications of federal and provincial government departments and in scientific journals. Much valuable unpublished information has also resulted from the work of company geologists and has been made available to the Geological Survey of Canada. Therefore, although the authors of this report have devoted much time

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[1] Preliminary figures for 1960 indicated a value of about $263 million for Canadian uranium production, this being exceeded by the values of production of nickel and copper.

to field and laboratory investigations, a large part of the contents is a selection and integration of the work of others, resulting, it is hoped, in a compact and balanced whole.

The report is divided into four parts. Part I contains introductory material, including brief discussions of such subjects as radioactivity and geochemistry, which are equally applicable to deposits in any country.

Part II contains generalizations on Canadian deposits resulting from the writers' field and laboratory observations and from tabulations, plots and other compilations of data on roughly ten thousand occurrences. Although foreign deposits are mentioned occasionally, where comparisons are desirable, the generalizations are essentially Canadian. For this reason the section on geochemistry is in Part I, whereas that on mineralogy is in Part II. In scope, the discussions are limited so far as possible to information desirable for a mining geologist or advanced prospector. Thus mineralogy is not discussed in detail suitable for a specialist in mineralogy; and geophysics, economics, mining, and the treatment of ores are discussed only so far as information on these topics is required in prospecting for, appraising, and exploring deposits, and not to the extent required by economists, accountants, mine operators or metallurgists. The generalizations deal mainly with uranium, information on thorium being included where it closely parallels that on uranium; a separate section on thorium deposits provides generalizations that are not presented adequately in the foregoing way. The authors are keenly aware that all discussions in Part II leave many unsolved problems; they hope merely that the summaries may serve as stock-takings of present knowledge and as stimuli to further research.

Part III contains short accounts of the main uranium areas and of the producing mines. These descriptions are almost entirely geological, but some other pertinent data are included; references to more detailed publications are also included. Where several references are available on a topic, the more recent or more complete have been chosen. The areas containing the larger numbers of producing mines are described first; the descriptions of individual mines are arranged alphabetically. These descriptions are followed by short accounts of a few deposits that exemplify types not well represented by producing examples. Inclusion of these examples and exclusion of others in no way signifies opinions on economic potential.

Part IV comprises tables listing principal data for most known occurrences reported to contain material assaying 0.05 per cent or more of uranium or thorium oxides or from which uranium or thorium minerals have been described. As some of the occurrences have not been examined by the writers, the information is not guaranteed. Some occurrences are omitted because permission to disclose them was not available. The tables are much abbreviated from more extensive ones used in preparing some of the generalizations stated in Part II. They were shortened partly to save space and partly because information that discoverers or owners of properties did not wish to have revealed specifically could be included in the generalizations but not in the tables. The addresses of the last-known owners of properties are included; readers wishing further information should write the owners, not the Geological Survey of Canada.

The report closes with an index and a list of titles and sources of publications mentioned in the text and tables. A complete bibliography is not included because it would be very long and many of the publications would be out of date and superseded by more recent ones. A bibliography of Canadian literature on the subjects involved, virtually complete to the end of 1955, has been published by the Geological Survey (Griffith, 1956)[1]. This and the list at the end of the present report jointly provide a fairly complete bibliography. The index does not duplicate information contained in the tables in Part IV or in the list of references.

The tables in Part IV were prepared as of 31 December, 1957; the few discoveries reported during 1958 did not justify revising the lists. Wherever possible other parts of the report include data for the year 1958, and mention of a few important matters that became known in 1959.

The roles of the authors in the preparation of this report were as follows: Lang studied radioactive deposits for five seasons and supervised work for six additional years. Griffith studied deposits for two seasons. Because of the large number of deposits to be visited these studies were necessarily brief; much helpful information was obtained from local geologists, attention being concentrated on specific factors for which the authors required personal observation. Steacy examined some deposits and for eleven years was in charge of a laboratory established to perform radiometric assays, mineral separations, and mineralogical studies other than by X-ray methods; this work was partly a special service to prospectors undertaken for the Atomic Energy Control Board, and partly in connection with research projects. Steacy prepared the sections on characteristics and uses, geochemistry, and mineralogy, and assisted in several other parts. Griffith was responsible for the tables in Part IV; he also prepared some data for the generalizations in Part II and assisted greatly with Part III. Lang supervised the project and prepared the sections not mentioned above.

Usages

Conventions, abbreviations, and other usages for this report are standardized as much as possible. Many are explained in appropriate places, and the principal ones are outlined here.

Tons refer to short tons of 2,000 pounds.

Uranium contents are usually stated as "per cent U_3O_8", but also as "pounds of U_3O_8 per ton" for certain ores. The compound U_3O_8 is not known to occur in nature but is the customary unit for reporting analyses. Thorium contents are stated as "per cent ThO_2", the customary unit for reporting analyses for thorium.

In some contexts a distinction is made between small mineral 'occurrences' and larger mineral 'deposits', but in other instances, such as the title of the report, no such distinction is implied. For statistical and practical purposes an occurrence

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[1] Names and/or dates in parentheses refer to references listed at the end of this report.

is not considered to be radioactive unless it contains 0.05 per cent or more of U_3O_8 or ThO_2, but in certain contexts leaner occurrences are mentioned. A mining property is usually regarded as a mining claim or group of adjoining claims held in common, but in some instances occurrences that are not known to have been staked, or whose staking may have expired, are included.

Information supplied to the Geological Survey of Canada confidentially is not included except that some such data were reviewed in preparing the generalizations, without in any way disclosing the locations or other information that could affect the interests of the discoverers or property owners.

Acknowledgments

The authors are strongly aware that this report is greatly enhanced by the extensive use made of the published and unpublished work of many geologists, prospectors and others. This has been acknowledged wherever possible, usually by citing a reference, but there are many instances where this was not practical. Grateful acknowledgment is here made to these authors, to many prospectors, to company officials who provided unpublished information and other courtesies, and to many colleagues on the staffs of the Geological Survey, the Mines Branch, provincial mining departments, the Atomic Energy Control Board, Eldorado Mining and Refining Limited, and Atomic Energy of Canada Limited. Because of the large number of mineral identifications cited the names of the mineralogists responsible are mentioned only where the identification has special significance; many of the identifications were completed by X-ray tests performed in the laboratories of the Geological Survey.

Historical Notes

General

The element uranium was discovered as a result of studies of pitchblende, a mineral known since 1727 at Joachimsthal in the ancient mining region of Bohemia. In 1789, Klaproth extracted from pitchblende a yellow oxide which he considered the oxide of a new metal and which he named after the then recently discovered planet Uranus. Curiosity regarding marked differences in the degree of radioactivity (*see* p. 12) of pitchblende and uranium led to discovery of the element radium by the Curies in 1898. Radium was found in minute quantities in all naturally occurring uranium, in the ratio of about 1 part radium to 3,000,000 parts uranium. It is strongly radioactive and accounts for much of the radioactivity of impure uranium.

Important uses were soon found for radium, mainly in the treatment of diseases, and for a time the mines at and near Joachimsthal, then in Czechoslovakia, were the only sources. Shortly afterwards, however, important production began in the Colorado plateau of the United States as a by-product of the mining of vanadium ores.

In 1915, uranium was found in the Katanga region of the Belgian Congo, as a result of prospecting for copper. This deposit was opened in 1921 as the Shinkolobwe mine, which became the world's leading source of radium. The Eldorado mine at Great Bear Lake in Canada, discovered in 1930 and brought into production in 1933, became the second largest source. Smaller deposits were worked for radium at times in other parts of the world, mainly at Urgeirica, Portugal; Cornwall, England; the Front Range of Colorado; Madagascar; Radium Hill, Australia; and Ferghana, Turkestan. The total world production of uranium or its equivalent, up to 1940, is estimated at 7,500 tons; it should be noted that this figure represents tons of uranium, not tons of ore, and that virtually all was for the extraction of radium. This element was valued at about $170,000 a gram from 1912 to 1918; by 1930 the price had declined to about $70,000 a gram. It was lowered further to about $25,000 a gram after production began in Canada in 1933. The high cost of radium was caused chiefly by the need for very elaborate refining techniques, rather than by scarcity of the raw material, and prior to World War II the price of uranium after the radium had been extracted was about $1 a pound.

The phenomenon of radioactivity was discovered in 1896 but it was not until the work of Rutherford and his associates a few years later that the nature of radioactivity and the structure of the atom began to be understood. Physicists realized that enormous amounts of energy are stored in atoms and began to speculate on possibilities for releasing it. Shortly before World War II, they discovered that part of this energy could be released when uranium atoms underwent splitting, or fission as the process came to be called. The military possibilities of this discovery were quickly realized, and by 1940 research teams in several countries were working independently to try to develop an atomic bomb. As is well known the combined efforts of teams working in the United States, England and Canada resulted in successful development of the atomic bomb by 1945. A few years before this date it had appeared that large amounts of uranium would be required for the allied atomic-energy program; steps were taken to obtain these, chiefly from the Shinkolobwe and Eldorado mines.

After the war the demand for uranium for the stockpiling of atomic weapons, and the great strides made in peaceful uses for atomic energy, caused intense and world-wide interest in prospecting and mining for uranium. Uranium occurrences proved to be much more common than was previously supposed. Large deposits were discovered in Canada, the United States and South Africa, and smaller or less-known ones were found in several other countries. In a very short time compared to the slow development of mining for other principal metals, uranium changed from almost a scientific curiosity to one of the major metals.

The value of uranium mined in Canada, United States and South Africa places it among the leading metals produced in these countries. On the other hand, radium has become of relatively minor importance, and the superior qualities of certain isotopes, such as cobalt 60, produced in atomic reactors, have caused a further decline in the demand for radium. The market for radium has decreased to such an extent that many large plants built recently to treat uranium ores are not designed to save the radium.

The element thorium was discovered in 1817. Deposits found in several countries other than Canada have supplied the limited industrial requirements for the metal to such an extent that for some time the supply has exceeded the demand. In recent years it has been shown that thorium could be used as a fuel for certain types of atomic reactors, but thus far this has not greatly increased the demand for thorium.

During and immediately after World War II great secrecy regarding resources and uses of uranium prevailed. This was reduced gradually in most countries, as emphasis changed from military to industrial uses and as more countries became producers of uranium. Canada was one of the first to release extensive information. Many nations contributed varying degrees of data to the First International Conference on the Peaceful Uses of Atomic Energy sponsored by the United Nations in 1955, and to the second such conference in 1958. An International Atomic Energy Agency was established in 1957 with official approval of many countries. Its basic objective is to speed and expand the contribution of atomic energy to the welfare of all peoples.

Prospecting and Mining in Canada

The following account covering the general history of prospecting and mining for uranium in Canada is divided into three sections: the first deals with the period prior to World War II when interest was in radium rather than uranium; the second, during and immediately after the war, when all work was closely controlled by the federal government for security reasons; and the third, from 1948 to the present, when controls were relaxed as much as possible to permit prospecting and mining by private individuals and companies. The histories of some important mines included in the descriptions of areas and mines are not discussed here.

Early activities. The first Canadian uranium discovery occurred about the middle of the last century, on the shore of Lake Superior. The mineral proved to be pitchblende, apparently found by a Captain Stannard who was in charge of a schooner plying the lake in connection with the fur trade. Short papers on the occurrence, dealing mainly with mineralogy, were published in 1847, 1849, and 1857 (LeConte, Whitney, Genth), but the location was not described exactly. Summarized accounts of this occurrence were included in three reports of the Geological Survey of Canada (Logan, 1863; Malcolm, 1914; Ellsworth, 1932), and prospectors and government geologists tried at various times to find it again but for long were unsuccessful because of the vagueness of the original description. In 1948, a prospector equipped with a Geiger counter found pitchblende at Theano Point north of Sault Ste. Marie. At first this was thought to be the actual Stannard occurrence but that is now believed to have been at the site of another occurrence found in 1949 a few miles farther along the shore; in any event there is no doubt that the find in 1948, which became known as the Camray, revealed the general whereabouts of the old discovery. This matter is of considerable historical interest as the stimulation of prospecting in the general region caused by the Camray find resulted in the first discovery of uranium-bearing conglomerate in the Blind River area late in 1948.

In 1904 a uranium mineral was found in Quebec, north of St. Lawrence River. Soon afterwards, uranium minerals were found in several pegmatite deposits in the southern part of the Canadian Shield in Quebec and eastern Ontario, but none of these was in sufficient quantity to be of commercial interest at that time (Ellsworth, 1922, 1932).

Interest in radium caused the governments of Ontario and British Columbia to offer in 1914 cash bonuses for discoveries of radioactive minerals in commercial quantities (Brunton, 1915, p. 91). The rewards were unclaimed and the offers were withdrawn in 1937 and 1938, respectively.

In 1930, G. A. LaBine and E. C. St. Paul flew to Great Bear Lake to investigate an occurrence of cobalt reported by J. Mackintosh Bell, who made a reconnaissance there for the Geological Survey in 1900 (Bell, 1902). Camsell (1950) stated that LaBine was interested in the possible association of silver with the cobalt. They found native silver, pitchblende and cobalt at or near the locality mentioned, and staked the discovery for Eldorado Gold Mines Limited, which LaBine had previously organized to develop a gold property in Manitoba. The discovery at Great Bear Lake became known as the Eldorado mine, and was brought into production in 1933 after a concentrating plant had been built on the property. Much pioneering was necessary, as the mine is in a remote region, only 30 miles south of the Arctic Circle, and because there was no previous experience in treating ore of this kind in Canada. A refinery for extracting radium from the concentrates was built at Port Hope, Ontario. The mine produced large amounts of silver, radium, copper and cobalt, and its discovery soon caused several other finds of silver and pitchblende in the region, one of which produced on a small scale.

1939 to 1947. Early in World War II the Eldorado company found itself with large inventories of radium and its markets dislocated because of the war; the mine was, accordingly, closed in 1940 and allowed to fill with water. Soon, however, advances in research on atomic weapons made it desirable to establish a large source of uranium on this continent, and the company was asked to reopen the mine in the spring of 1942 with a minimum of publicity.

In September 1943, Orders in Council were passed reserving to the Crown all new discoveries of radioactive minerals in Yukon and Northwest Territories. Staking and mining for these minerals by private individuals and companies were banned, as was publication of information on uranium occurrences. Certain provincial governments took similar action. In 1944 the federal government acquired the shares of the Eldorado company, as a security measure, and the undertaking was transferred to a Crown company, now Eldorado Mining and Refining Limited. The Crown company asked the Survey to assist in searching for new ore and in making geological studies at the Eldorado mine and in other parts of Canada. This work was begun in 1944 by sending three parties to Great Bear Lake, as well as parties to other districts. Many radioactive occurrences were found and investigated by Eldorado and Geological Survey parties. Prospecting was facilitated by Geiger counters developed and built jointly by the Survey and the National Research Council.

Interest in the Box gold discovery at Lake Athabasca[1] in northern Saskatchewan had caused the Geological Survey to restudy the region in 1934. The resulting report (Alcock, 1936, pp. 36-37) recorded two occurrences of pitchblende at a gold-copper prospect called the Nicholson, but this information was not then of great interest. The Box mine produced gold from 1939 to 1942, after which the town of Goldfields that had grown nearby was abandoned. In 1944, when all known uranium deposits were being studied, R. Murphy of the Crown company and A. W. Jolliffe of the Survey visited the Nicholson claims, which were in good standing although no work had been done on them since the decline of the Goldfields camp. These geologists advised Eldorado to acquire claims in the neighbourhood, and large blocks of claims were, accordingly, staked. Systematic prospecting was begun by prospectors employed and supervised by Eldorado, more detailed geological mapping was done by the Survey, and prospectors were added to the Survey parties. This combined effort soon resulted in the discovery of about a thousand pitchblende occurrences or radioactive indications in what came to be called the Beaverlodge region. Several of the more promising deposits were tested by surface trenching and diamond drilling.

The passing of the Atomic Energy Control Act in 1946 vested control of matters pertaining to atomic energy in Canada in a board called the Atomic Energy Control Board. It did not establish separate technical staffs, but made use of existing government agencies. Thus, as agents for the Board, the National Research Council continued to investigate the industrial and medical uses of atomic energy, and established extensive research facilities at Chalk River[2], Ontario, for this purpose; the Mines Branch of the Department of Mines and Technical Surveys continued research on the concentration and extraction of uranium ores; and the Geological Survey continued research on the mineralogy and geology of radioactive occurrences, made geological maps of favourable areas, and compiled confidential data on resources of uranium and thorium.

1948 and after. Late in 1947, the government, on advice of the Atomic Energy Control Board, decided to permit and to encourage private prospecting and mining for uranium. The restrictions on staking in federal territories were removed, and a minimum price for uranium oxide was guaranteed for 5 years; this period was later extended to 1962, and development and milling allowances were added (*see* p. 91). The Eldorado company was made the sole buyer of privately produced uranium ores or concentrates. The provincial governments concerned

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[1] The official spelling of this word was changed in 1948 from 'Athabaska' to 'Athabasca'.

[2] A separate Crown company, Atomic Energy of Canada Limited, was formed in 1952 to operate this establishment.

removed the restrictions in their respective provinces. The regulations of the Atomic Energy Control Board concerning prospecting and mining were designed to give all possible encouragement to the undertaking of such activities by the public under a minimum of controls. These controls provided, however, that all radioactive discoveries containing 0.05 per cent or more of uranium or thorium be reported, that an exploration permit be obtained from the Board before undertaking advanced exploration of a discovery, and that a mining permit be obtained before beginning mining. These permits stipulated that periodical reports be made on the work accomplished. The reporting periods have been lengthened from time to time as needs changed; annual reporting is now required. At first there were restrictions on publication of information on treatment methods, production figures and ore reserves, but these were removed in 1956 or earlier. The Survey undertook to issue special publications on uranium; to make free radiometric tests on samples submitted by prospectors; to identify radioactive minerals for prospectors and companies; and to act as official agent of the Board in receiving and compiling reports of discoveries and of work done by permit holders.

The removal of the restrictions on private prospecting and mining was quickly followed by prospecting by qualified prospectors who had previously devoted their attention to other metals, and who easily learned to use Geiger counters properly, as well as the relatively small amount of special knowledge desirable for prospecting for radioactive minerals. It was also followed by much prospecting by novices, most of whom had formed greatly oversimplified ideas of the ease of prospecting for uranium, largely as a result of glamorous publicity given to insignificant discoveries and to Geiger counters, which soon were being manufactured in Canada and in other countries and sold widely. Radioactive occurrences were discovered in many parts of Canada. At first, both the larger numbers of occurrences and the most attractive prospects were found in the region north of Lake Athabasca in northwestern Saskatchewan, and in the part of the Northwest Territories lying between Great Bear and Great Slave Lakes. Many of the more favourable finds were acquired by companies, and soon more Canadian prospectors were seeking uranium than any other metal, and more prospects of uranium were being explored than those of other metals. Most of the companies involved, however, were newly formed; the established mining companies did not at first show substantial interest in uranium, largely because of doubt regarding the economics of uranium mining and the extent to which secrecy and controls might hamper their operations. Despite the large number of discoveries, up to 1953 none yielded results comparable to those being obtained at Eldorado's Ace property in the Beaverlodge region where considerable tonnages of medium-grade material were being outlined. Extensive research was undertaken to develop a treatment process that would make material of this grade and character economic. Of the privately explored properties, the higher-grade ones proved small, and those where substantial tonnages were indicated contained either very low average contents of uranium or averages that were considered too low grade at that time.

The first definite success in the establishment of additional uranium mines in Canada occurred when the Eldorado company announced in March 1951 plans for production at the Ace, necessitating construction of a leaching plant and many other buildings. This was a large undertaking because the Beaverlodge region, although much less remote than Great Bear Lake, is far north of rail facilities and is served by a barge route. Production began in 1953 at 500 tons a day and the plant was enlarged afterwards to 750 and again to 2,000 tons.

The first major private development occurred in 1953 when Gunnar Gold Mines Limited announced that diamond drilling on its property discovered the previous year in the Beaverlodge area had shown a large deposit of medium-grade ore. A treatment plant with a capacity of 1,250 tons a day, later increased to 2,000 tons, was built and the mine began production in 1955. The demonstration of substantial ore at the Gunnar property, the contract made by the company with Eldorado for delivery of uranium precipitates to the value of about $77 million,[1] and the demonstration that government controls did not greatly hamper private enterprises caused increased activity by prospectors and companies and encouraged several of the leading Canadian mining companies to take greater interest in the possibilities of uranium mining.

During the earlier efforts to find additional uranium mines in Canada attention was devoted largely towards the discovery of high-grade pitchblende deposits, because the mine at Great Bear Lake as well as the one in Belgian Congo is of this kind. As it became clear that, although many small high-grade pitchblende occurrences were being found, nothing comparable in size to the Eldorado deposit at Great Bear Lake had been discovered, more attention was paid to the possibilities of deposits of medium and low grades. As a result, costs of operating such deposits and research to develop commercial treatment processes for them were given increased attention. Also, because there had been no private production under the published schedule of prices, other than a few small test shipments, the situation with respect to the purchase of ores under special price agreements was clarified. Here it should be noted that since World War II all uranium produced in Canada was sold by Eldorado to the United States Atomic Energy Commission in the form of high-grade precipitates from the refinery at Port Hope. Metallic uranium required for Canadian research reactors was purchased from the United States authorities because the small amount then required in Canada did not warrant a Canadian plant for its production. In 1953, the president of Eldorado pointed out that the authorities concerned had always been prepared to consider special price contracts to meet special situations. He stated that the company would be prepared to consider such negotiations on a property with a proved tonnage of substantial dimensions, but in such a location or with a grade such that production would not be worth while under the published price schedule, and also on a property which planned to produce a high-grade product after large expenditures for a plant, such as a leaching plant, as such a product would not require extensive refining afterwards. The first such special price agreement was made

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[1] This contract was increased later.

with Gunnar Mines Limited. As a result of these considerations, greater attention was paid to the possibilities of lower-grade deposits, particularly those accessible to transportation.

The next great development after the successful testing of the Gunnar deposit occurred in the Blind River region of Ontario, where, as previously mentioned, a low-grade occurrence of uranium-bearing conglomerate had been discovered in 1948. Chiefly as a result of the efforts of F. R. Joubin, a geologist, the Pronto mine was brought into production in 1955, and several other deposits of the same general kind, but larger in size, were outlined. The Blind River area became Canada's main uranium district in 1957.

Many occurrences of uranium minerals in pegmatitic deposits were found in various parts of Canada, chiefly in the southern part of the Canadian Shield in Ontario. At first most of these were shown to contain only scattered crystals of uranium minerals that did not, in the aggregate, form deposits of favourable size or average uranium content, and the few exceptions that suggested fairly large tonnage showed average grades that were considered too low to be economic. With the gradual emphasis on lower-grade deposits, however, and clarification of the provisions for contracts at special prices, more attention was paid to the possibilities of exceptional pegmatitic occurrences. The first deposit of this kind to be developed successfully was the Bicroft, near Bancroft, Ontario. Production began there in 1956 followed shortly afterwards by production at the Faraday mine, and later by two others, all in the same area.

By the end of 1956 five large private uranium mines were producing with their own plants, one at Beaverlodge, three at Blind River, and one at Bancroft; four smaller mines in Beaverlodge region had shipped ore to the Ace plant under special agreements with Eldorado, and additional contracts for delivery of uranium precipitates at special prices had been negotiated for fourteen mines in various parts of Canada, chiefly in the Blind River area, and plants for them were either under construction or in the planning stage. The total value of contracts for delivery of uranium precipitates up to 1962 and 1963, when all contracts will terminate, was more than $1,500 million. Uranium was no longer in short supply and the government had announced that applications for contracts at special prices would not be received after March 31, 1956. Prospecting for uranium had declined greatly by 1956. The number of exploration permits reached a peak of 432 in that year, but many of the properties concerned had been closed down without requests to have permits cancelled. After this time exploration was much curtailed, although some activities were continued with a view to the long-range demand for uranium.

Plans to build a plant at Port Hope to produce fuel elements for nuclear reactors were announced in 1956 by a private company; this plant began operation in 1958. In 1957 a contract was signed for the sale of uranium concentrates to the United Kingdom. Subsequently, arrangements were made for the supply of concentrates to Germany and fuel elements to Switzerland and small quantities of uranium concentrates and compounds were made available to a number of other countries for test purposes.

In 1958, nineteen mines in five districts were producing uranium from individual treatment plants, and ore from seven additional mines was being shipped to certain of these plants. Uranium became the leading metal, by value, produced in Canada in that year, and was in fifth place among commodities exported, being outranked only by newsprint paper, wheat, lumber, and wood pulp.

Characteristics and Uses of Uranium and Thorium

Radioactivity

In 1896 Becquerel found that salts of uranium emitted an invisible radiation that was capable of penetrating matter and of fogging a photographic plate. Much research on the nature of this radiation followed. Rutherford and others later showed that uranium actually emits three kinds of radiations, each possessing characteristic properties. These radiations were called alpha, beta, and gamma rays. Elements that emit one or more of these rays are called radioactive elements, or radioelements, and the radiative phenomenon associated with them is termed radioactivity. The term is derived from *radius,* the Latin word for ray.

The radiations. Alpha and beta rays are actually particles having both mass and electric charge. The alpha particle has a mass four times that of the hydrogen atom and carries two positive charges of electricity. Upon neutralization of its charge, it becomes an atom of ordinary helium. The beta particle has only about $\frac{1}{1838}$ the mass of the hydrogen atom, and it carries one negative charge. Gamma rays, in contrast to the others, have neither mass nor charge, but are electromagnetic vibrations, or 'packets' of energy, similar in nature to X-rays. A gamma ray frequently accompanies the emission of a beta ray. All three types of rays are emitted spontaneously and at high velocities by the radioelements, and the emission is unaffected by either temperature or pressure.

Because the rays possess greatly different characteristics, they have different penetrating powers. Alpha rays are stopped by a sheet of ordinary paper. Beta rays, being smaller and travelling at higher velocities, are more penetrating, but most of them are stopped by a sheet of aluminum one eighth of an inch thick. Some gamma rays are strongly penetrating, even more so than ordinary X-rays, and according to Johnson (*in* Faul, 1954) their absorption in air is negligible up to about 100 feet. Most gamma rays from uranium and thorium minerals, however, are absorbed by 3 inches of lead, or roughly a foot of granite. Thus radioactive deposits that are buried or hidden by 2 feet or more of rock, or by about 4 feet or more of overburden, will probably not be detected by gamma-ray counters, regardless of the size or richness of the deposits. Experiments made by L. W. Morley, Geological Survey of Canada (personal communication), showed that gamma rays from a specimen of rich pitchblende ore weighing 2.4 pounds could not be detected by a portable scintillation counter when the specimen was covered by 25 inches of water.

Table I

Disintegration Series of Uranium 238

(Principal members only; isotopes constituting less than 0.2 per cent of the decay products are omitted)

Uranium 238 [4.51×10^9y]
$\downarrow \alpha$
Thorium 234 [24.10d]
$\downarrow \beta$
Protactinium 234 [1.14m]
$\downarrow \beta$
Uranium 234 [2.48×10^5y]
$\downarrow \alpha$
Thorium 230 [8.0×10^4y]
$\downarrow \alpha$
Radium 226 [1,622y]
$\downarrow \alpha$
Radon 222 [3.825d]
$\downarrow \alpha$
Polonium 218 [3.05m]
$\downarrow \alpha$
Lead 214 [26.8m]
$\downarrow \beta$
Bismuth 214 [19.7m]
$\downarrow \beta$
Polonium 214 [1.50×10^{-4}s]
$\downarrow \alpha$
Lead 210 [22y]
$\downarrow \beta$
Bismuth 210 [5.02d]
$\downarrow \beta$
Polonium 210 [138d]
$\downarrow \alpha$
Lead 206 [stable]

Table II

Disintegration Series of Uranium 235

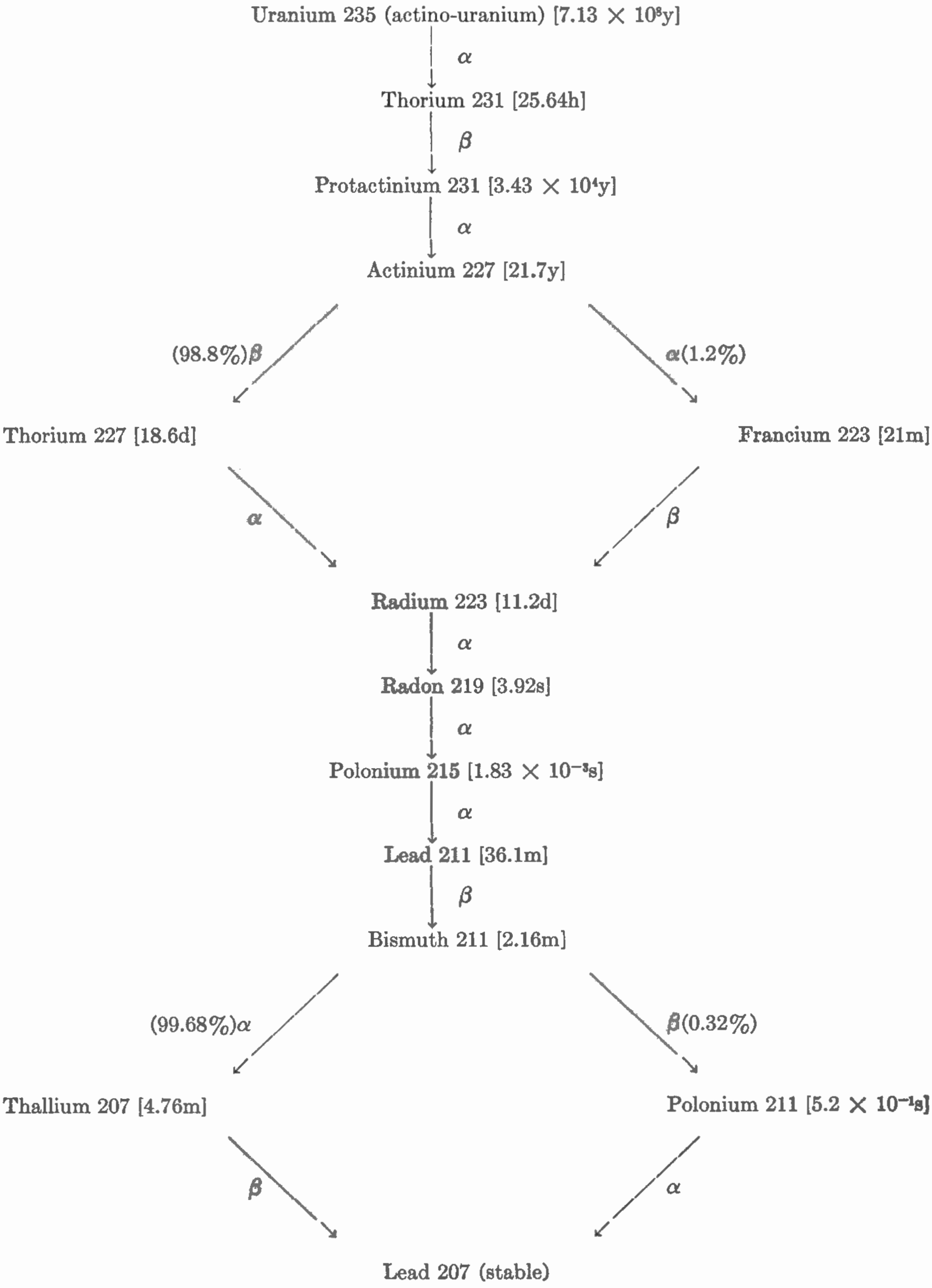

Table III

Disintegration Series of Thorium

$$\begin{tikzcd}
 & \text{Thorium 232 [1.39 $\times$ 10^{10}y]} \arrow[d, "\alpha"] & \\
 & \text{Radium 228 [6.7y]} \arrow[d, "\beta"] & \\
 & \text{Actinium 228 [6.13h]} \arrow[d, "\beta"] & \\
 & \text{Thorium 228 [1.90y]} \arrow[d, "\alpha"] & \\
 & \text{Radium 224 [3.64d]} \arrow[d, "\alpha"] & \\
 & \text{Radon 220 [54.5s] (popularly called thoron)} \arrow[d, "\alpha"] & \\
 & \text{Polonium 216 [0.158s]} \arrow[d, "\alpha"] & \\
 & \text{Lead 212 [10.6h]} \arrow[d, "\beta"] & \\
 & \text{Bismuth 212 [60.5m]} \arrow[dl, "(66.3\%)\beta"'] \arrow[dr, "\alpha(33.7\%)"] & \\
\text{Polonium 212 [3.0 $\times$ 10^{-7}s]} \arrow[dr, "\alpha"'] & & \text{Thallium 208 [3.1m]} \arrow[dl, "\beta"] \\
 & \text{Lead 208 [stable]} &
\end{tikzcd}$$

Structure of the atom. The discovery of radioactivity led to greatly increased knowledge of the structure of the atom. The modern concept of the atom is that it consists of a nucleus accounting for virtually all the mass, and is surrounded by lighter particles called electrons. It may be compared with our planetary system if we think of the sun as the nucleus and the planets as the electrons. The nucleus is complex, the principal constituents being protons and neutrons, each of whose mass is approximately equal to the mass of the ordinary hydrogen atom. The total number of protons and neutrons in the nucleus is called the 'mass number' and this is roughly equal to the atomic weight. Each proton carries one positive unit of electricity, thus causing the nucleus to be positively charged, and the total charge on the nucleus is a characteristic of each element. The neutrons themselves are uncharged. Revolving around the nucleus are electrons whose mass is only about $1/_{1838}$ of the mass of the hydrogen atom, each carrying one negative unit of electricity. The number of electrons is sufficient to balance the positive charge on the nucleus. As most uranium has a mass of 238 and a charge of 92 units, it can easily be realized that atoms of uranium, and other such heavy elements, have very complex structures.

Disintegration processes. Radioelements are unstable; by emitting an alpha or a beta particle they transform into new elements having different chemical and physical properties. The elements produced by the transformation may themselves be radioactive; if so, they too will eventually change into new elements. This process of transformation or disintegration continues until a stable element is produced. Some varieties of elements possess the same nuclear charge but have different atomic weights; such varieties are called 'isotopes', and are discussed more fully later in this section. Gamma rays frequently accompany the disintegrations; they appear to be forms of energy released during the structural rearrangement of an atom.

The disintegration of uranium 238 may be considered as an example. This element has an atomic mass of 238 and a nuclear charge of 92 units; it disintegrates with an emission of an alpha particle. Because the alpha particle has a mass of four and a nuclear charge of two positive units, its expulsion by uranium 238 will result in the formation of a new element with a mass smaller by four, and a nuclear charge smaller by two units. This new element therefore has a mass of 234 and a nuclear charge of 90 units. It possesses the same nuclear charge as ordinary thorium, and is therefore an isotope of thorium: thorium 234, also called uranium X-1. Eventually it disintegrates by the emission of a beta particle. Because the emission of a beta particle does not appreciably affect the mass of the element but increases the nuclear charge by one, the decay-product of uranium X-1 will have a mass 234 and a charge of 91 units, and constitutes an isotope of protactinium: protactinium 234, also called uranium X-2. Most atoms of this isotope eventually disintegrate by the emission of a beta particle to form an isotope of uranium: uranium 234. Uranium 234 therefore has the same mass as its parent protactinium, but it has one more nuclear charge, namely 92. This process of disintegration continues through several elements, by the emission of an alpha or a beta particle, as the case might be, until finally a stable isotope of lead is reached. The lead so produced is called 'radiogenic lead', and has a slightly different atomic weight than ordinary lead.

In the example explained above, the third element formed (uranium 234) has the same nuclear charge as the original element (uranium 238), although its atomic weight is different. Because the nuclear charge determines the chemical properties of an element, uranium 234 has the same chemical properties as uranium 238. Elements such as these two, which have the same nuclear charge and, therefore, the same chemical properties, but which have different atomic weights, are called isotopes. Isotopes are separable from one another only with very great difficulty. Naturally occurring uranium is a mixture of three isotopes, uranium 234, uranium 235, and uranium 238, whose respective percentages as reported by Lounsbury (1955) are approximately 0.006, 0.720, and 99.27.

Because the atoms of radioelements disintegrate spontaneously, it is impossible to predict the instant at which any particular atom will disintegrate. For atoms in large numbers, however, it has been found that on the average the number disintegrating in any one period of time is a constant fraction or percentage of the number present at that time. The ratio of the number disintegrating to the number present is known as the 'disintegration constant' of the element. After one half of any given number of atoms of a particular radioelement have disintegrated, one half of the remaining number will also disintegrate within the same time interval, and so on. The time taken for one half of any number of atoms to disintegrate is called the 'half-life period', or more simply the half-life. This may vary from a fraction of a second to millions of years for different radioelements but each radioelement has a characteristic half-life.

Disintegration series. Forty-seven unstable isotopes are known to occur naturally, most being members of three distinct radioactive families, or series. The parent elements of the three radioactive series are uranium 238, uranium 235 (also called actino-uranium), and thorium 232. The isotopes produced are called 'daughter elements'. The end-product of each series is a stable isotope of radiogenic lead. The three series are illustrated in Tables I, II, and III, the data being according to Chadwick (1953). The type of radiation emitted by each member is indicated, and the half-life period is also shown, the letters s, m, h, d, and y standing respectively for seconds, minutes, hours, days, and years. As will be seen from the series, a few individual elements may disintegrate through the emission of either an alpha or a beta particle. Two common radioelements that are not members of these series are potassium and rubidium. These elements are not of interest as sources of atomic energy, but their radioactive properties permit them to be used in determining the ages of many of the rocks in which they occur. Also, some rocks containing potassium are sufficiently radioactive to cause misleading results when using radiation detectors in prospecting for uranium and thorium.

Radioactive equilibrium. Uranium and thorium are said to be in equilibrium with their daughter elements when the daughter elements are all disintegrating at the same rate at which they are being formed. When this state is disturbed, uranium and thorium are said to be out of radioactive equilibrium. The disturbance may be caused by leaching of one or more of the daughter elements, or by loss of one of the radioactive gases, such as radon. Specimens or samples taken near the surface of a uranium deposit are often out of equilibrium because of the susceptibility of uranium minerals to alteration and leaching. On the other hand, thorium-bearing compounds are rarely out of equilibrium, because the members of the thorium series have relatively short half-lives, and so recover their equilibrium quickly.

Physical and Chemical Properties of Uranium

Uranium is the heaviest of the naturally occurring elements, having an atomic weight of 238.07 and atomic number 92. In its natural form it consists of a mixture of three isotopes, of masses 234, 235, and 238, which are always present in a constant proportion. The most outstanding physical property of uranium is its radioactivity, explained in the previous section of this report. The general chemical character of uranium is that of a strong reducing agent, particularly in aqueous solutions (Katz and Rabinowitch, 1951, from which much of the following data are also taken).

Metallic uranium is obtained by the reduction of uranium oxides or halides. The metal is white on fresh fractures or freshly polished surfaces, but it tarnishes readily—usually within a matter of hours—upon exposure to air. It has a density of 19.05, which is about two and one-half times that of steel; is hard, but not quite so hard as steel, and is capable of taking a high polish; is malleable and ductile. The metal can be forged, drawn or extruded at high temperatures, or it can be worked cold; is pyrophoric, thus will produce sparks when sawed or filed; is a poor conductor of electricity, its conductivity being about half that of iron; and is weakly paramagnetic. The melting point of the metal is 1,133°C, which is approximately 50 degrees higher than that of copper and 400 degrees less than that of iron. The ultimate tensile strength of uranium varies between 50,000 and 200,000 p.s.i., depending upon cold-working and thermal treatment of specimen; cold-working gives the highest tensile strength.

Uranium has many chemical properties in common with chromium, tungsten, and molybdenum. It is very reactive chemically, and combines readily with all the non-metallic elements, especially when in finely divided form. It reacts vigorously with fluorine and bromine, becoming hot and incandescent in the process. It may be alloyed with most other metals to form intermetallic compounds, which vary considerably in physical properties and chemical reactivity. The metal is dissolved by dilute nitric acid and by dilute hydrochloric acid, and, with the addition of an oxidizing agent, by dilute sulphuric acid. Uranium is a quadravalent element with valencies of 3, 4, 5, and 6. It forms several oxides, the commonest of which are uranous oxide (UO_2), uranic oxide (UO_3), and urano-uranic oxide (U_3O_8), which is sometimes called uranoso-uranic oxide. Uranous oxide is a brownish to black powder that often forms an oxidation tarnish on uranium metal; it may also be formed by the reduction of one of the higher oxides. Uranic oxide is orange to red, and is formed by heating uranium compounds in air to a temperature of about 500°C. Urano-uranic oxide is a green to black powder that is produced by heating the other oxides in air to 1,000°C. It is believed to consist of a mixture of uranous and uranic oxides, probably in the proportion $UO_2 \cdot 2UO_3$. Urano-uranic oxide is the accepted form for reporting the results of uranium analyses, one reason being that it is the final product weighed in some methods of analyses. A fourth oxide, uranium monoxide (UO), has been identified as a thin surface layer on uranium metal. Uranium is amphoteric, acting as a base to form salts such as uranous chloride, or as an acid to form compounds such as sodium uranate. Many uranium compounds fluoresce under rays from an ultraviolet lamp. The position of uranium in the electromotive series is not known exactly but it appears to be close to that of beryllium.

Uses of Uranium

Apart from military requirements, most uranium produced is used as a fuel in atomic, or, more accurately, nuclear reactors. So much information is now available on these that the subject need only be outlined here. Reactors fuelled with uranium are heavily shielded vessels in which the uranium atoms split or 'fission' under controlled conditions to release tremendous quantities of heat and large numbers of neutrons. The amount of heat released by the fission of one pound of uranium 235 is equal to that obtained from the burning of 1,500 tons of coal.

Reactors may be classified roughly into three main groups: research, production, and power. Research reactors were the first to be constructed and continue to be of great importance for both research and the production of radioisotopes. Among this class are the NRX and NRU reactors at Chalk River, Ontario. Some reactors are designed primarily for the production of artificial fuels such as plutonium—hence the name production reactors.

In power reactors the heat energy released in the fission process is used to convert water into steam, which in turn is used to drive a turbo-generator. The generation of electricity by nuclear power stations is expected to be the most important use of uranium in terms of the quantities required. Many nations already have nuclear power programs underway and in future an increasing share of the world's electric power production will be derived from uranium fuel. Nuclear power stations are operating in the United States, United Kingdom, the Soviet Union, and France, and several nations have plants under construction. The United Kingdom, which has one of the largest and most advanced nuclear power programs, is a good example. Several large nuclear power stations are in an advanced stage of construction and a station of 1,000 megawatts—the largest in the world—has recently been announced. This one station will require an initial fuel supply of more than 1,000 tons of natural uranium, and more than 100 tons each year thereafter for its operation. The United States has a large advanced program of nuclear power development, with several stations in operation and under construction. Most European countries plan to build nuclear power stations and a large co-ordinated program is being carried out by the "Euratom" countries (France, West Germany, Italy, Belgium, Netherlands and Luxembourg). Other parts of the world, particularly the less-developed countries, are looking to nuclear power as an important aid in their development.

In Canada, the main objective of Atomic Energy of Canada Limited is the development of economic nuclear power. The success of this program will ensure that nuclear power will be available wherever a new source of power is required to supplement existing sources. The first station, called NPD-2, will be in operation in 1961. It is expected that several large stations, probably around 200 megawatts each, will be built in Canada in the late 1960's.

Nuclear reactors have important applications as propulsion units for submarines and ships. The outstanding success of the American nuclear submarine is well known, and it is expected that the navies of the world will rapidly convert to nuclear power. Nuclear-powered ships are under construction and nuclear cargo-submarines are being designed. As in the production of electricity, uranium fuel will supply an increasing amount of the power requirements of the world's ships and submarines.

Though only the uranium 235 present in natural uranium is immediately useful as reactor fuel, any uranium 238 in the reactor is partly converted into plutonium, another fuel. Similarly, any thorium present is partly converted into another reactor fuel, uranium 233. Some research reactors, called breeders, can actually produce more new fuel than they consume. The development of commercial power reactors of this type would permit more efficient use of uranium and would also permit the use of the more abundant thorium. Cockcroft (1958) considered, however, that the "super-abundance of uranium which is forecast for the next two decades has shown that this is not an urgent problem".

Research has been carried out on the possibility of developing nuclear fusion reactors in which isotopes of hydrogen may be combined to form helium, with the release of much energy in the form of heat. If the rapid strides made in nuclear fission during the last few years are considered, the possibility that such a process may be developed to a point where it might supply economical power cannot be ignored. The consensus of the Second International Conference on the Peaceful Uses of Atomic Energy, however, was that about 20 years will be required to develop this process.

In addition to the foregoing, uranium also has limited applications in the chemical, electrical, glass, and ceramic industries, although the consumption in these industries is not more than a few tons a year at present. Because of its reactivity with ordinary gases, uranium may be used to clean argon and other inert gases of gaseous impurities such as hydrogen and nitrogen. Hampel (1954) stated that uranium is eminently suitable as a shield against powerful gamma-ray emitters, like radium and cobalt-60 (pure uranium itself emits alpha rays); he cited an instance where 850 pounds of uranium provided the equivalent shielding of 3,330 pounds of lead for a cobalt-60 therapy unit. Uranium may be alloyed with most other metals and research in this field is being pursued actively, especially to find alloys suitable for nuclear energy purposes, which require strong resistance to corrosion.[1] Because of its physical and chemical properties uranium is unlikely to compete with the common base metals in their customary applications. The chief uses of uranium will, therefore, almost certainly be in the nuclear energy field, although significant quantities may be used for other purposes.

The production of radioactive isotopes in nuclear reactors has already become an important industry, and one that will doubtless increase in future. The present annual value of sales and rentals of isotopes produced by Atomic Energy of Canada Limited is several millions of dollars. Radioactive isotopes are made by inserting materials such as phosphorus, iron, cobalt, etc., into a nuclear reactor where they are bombarded with neutrons. Isotopes produced in this way have so many uses that it would be impractical to try to enumerate them here, but the following examples will serve to illustrate their versatility. One of the commonest industrial uses is for gauges for measuring and automatically controlling the thicknesses of various materials during their manufacture, such as paper, linoleum, sheet metal, etc. In this application the material to be measured passes between an isotope source and a detector unit, the thickness of the material being proportional to the amount of radiation it absorbs. Gauges of somewhat similar types have also been designed for measuring the densities of liquids and slurries in pipes, and the levels of liquids in large tanks. Gamma-emitting isotopes are used for detecting flaws in metal plates, castings, welded joints, etc., by radiography, using the same principle as is used in taking an ordinary X-ray photograph. In medicine, isotopes are used to treat blood disorders, to locate and treat thyroid conditions, and irradiate cancerous growths. Isotopes are used extensively in agricultural, biological and other forms of research, and in the sterilization of foods. They are also much used as 'tracers', whose chief advantage is that they may be detected in extremely small amounts. Tracers are used for locating leaks in water mains and oil lines, for marking the boundaries between different petroleum products flowing in oil lines, for studying complex chemical reactions, for controlling the processing of ores, and for many other purposes. Some isotopes emit powerful gamma rays and must be handled with special precautions and be shipped in shielded containers.

Physical and Chemical Properties of Thorium

Thorium was discovered in 1817 by J. J. Berzelius, who named it after Thor, the Scandinavian god of war. The element was first produced in its metallic state

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[1] The Mines Branch of the Department of Mines and Technical Surveys, in collaboration with Eldorado Mining and Refining Ltd., continued its program of research into non-nuclear uses of uranium. This program was undertaken to help close the gap between Canada's uranium production capacity and the reduced demand for uranium as a result of the termination of uranium contracts with the United States Atomic Energy Commission. Results of this work to date appear promising. Experiments on a laboratory scale have shown that when small amounts of uranium are added to certain types of steel, the fatigue strength is increased substantially. The high-temperature strength and resistance to pitting corrosion are also increased. The possible improvements to commonly used steels could involve additions of from one-half a pound to one pound of uranium per ton of steel.

Late in 1960 a new organization—the Canadian Uranium Research Foundation—was formed by the uranium mines. The mining companies will provide funds for research to determine whether substantial amounts of uranium can be used economically for industrial applications.

in 1828. Its radioactive properties were recognized in 1898, two years after the discovery of radioactivity in uranium.

Thorium is a heavy, silver-grey metal having the hardness and general appearance of platinum. Upon exposure to the atmosphere, surfaces of the metal tarnish and eventually become black. Thorium has a density of 11.7, which is a little higher than that of lead. It melts at 1,842°C; has an atomic weight of 232.05, and the atomic number 90. Naturally occurring thorium has only one isotope, of mass 232. Thorium is produced by electrolytic reduction of thorium salts and by reduction of thorium oxide.

Thorium forms only one oxide: thorium dioxide (ThO_2). It forms compounds with the halogens, and with sulphur, nitrogen, carbon, boron, and silicon. It also forms intermetallic compounds with many metallic elements. The metal is dissolved by nitric acid and by aqua regia, and slowly by other acids; it is not attacked by strong alkalis. When heated in air it burns brilliantly, forming thorium dioxide, a white powder.

Uses of Thorium

A marked change in the technology of thorium occurred in 1957. For decades prior to that year thorium had been used chiefly in its oxide form in the manufacture of incandescent gas mantles, and there were only limited applications for the metal. In 1957 the consumption of the metal greatly surpassed that of the oxide. This reversal was due principally to the development of thorium-magnesium alloys, which, because of their great tensile strength at high temperatures, have found a place in the aircraft industry. These and other thorium alloys will probably find new uses and it appears that they offer the most-promising non-energy field for thorium.

Apart from its use as an alloying constituent there are few industrial applications for the metal at present. Hampel (1954) stated that low tensile strength, low elastic modulus, and poor resistance to atmospheric corrosion eliminate thorium from the list of structural materials. Thorium metal is used as a deoxidant in such metals as molybdenum and its high alloys, and also in electronic tubes and lamps, for controlling starting voltages and maintaining stability over their useful lives (Lilliendahl, 1957).

Thorium oxide continues to be used chiefly in the manufacture of incandescent gas mantles. These are made of thorium oxide containing 1 per cent cerium oxide, and are generally constructed in the form of a small mesh bag; they are familiar to persons who have used gas or gasoline lamps, in which the mantles give off a brilliant white light. Some thorium oxide is used in the manufacture of thoriated-tungsten compounds for the electronic and lighting industries. Thoriated-tungsten is also used in the fabrication of electrodes for welding operations and as non-consumable electrodes in the arc-melting of the transition metals (Hampel, 1954). Because of its extremely high melting point, thorium oxide has been used as a refractory material. Some thorium oxide is also used in the chemical industry, and some as a polishing compound. Thorium itself is not a nuclear reactor fuel but, as mentioned previously, any thorium present in a reactor is partly converted to a new fuel, uranium 233. Experiments have been conducted into the possibility of 'breeding' uranium 233 from thorium. The thorium-uranium 233 breeding cycle is said to be preferable, both metallurgically and chemically, to the uranium 238-plutonium cycle (Dunworth, 1955) but a large investment in uranium 235 or plutonium would be required to start the thorium-uranium 233 cycle (Cockcroft, 1958). It is not expected, therefore, that large quantities of thorium will be required for nuclear reactors in the near future.

Geochemical Data

Uranium and thorium are geochemically related elements which commonly occur together, in diverse geological environments. More geochemical data are available for uranium than for thorium, particularly in regard to geological abundance and distribution, but much basic research is necessary before the geochemistry of either element is fully understood. The subject is much too large and complex to be discussed in detail here; therefore a selection of the more significant data has been made and is presented as an introduction to the following sections. Much of the data that follow has been taken from Rankama and Sahama (1950).

General Geochemical Characteristics

Uranium and thorium are strongly 'oxyphile' elements, that is, they always occur in nature in combination with oxygen, such as oxides and silicates. They are never found in the native state, nor do they form such compounds as sulphides and tellurides. They may form synthetic sulphides, but Frondel (1956) considered that the formation of these compounds in nature is unlikely on thermochemical grounds. Uranium occurs in nature in the tetravalent (U^{4+}) and hexavalent (U^{6+}) states. So far as is known it is always tetravalent in primary uranium minerals and hexavalent in secondary minerals (Frondel, op. cit.); these minerals are discussed in the section on mineralogy. Thorium, on the other hand, always occurs in the tetravalent (Th^{4+}) state. Tetravalent uranium and thorium ions, which are simply atoms deficient in electrons, have nearly identical radii, that of uranium being 1.05 angstroms, i.e.: 1.05 X 10^{-8} cm, and that of thorium being 1.10 angstroms. Because of the similarity in their ionic radii they may substitute for one another in crystal lattices. For this reason most primary uranium minerals contain thorium, and most thorium minerals contain uranium. The tetravalent ions may also substitute for calcium ($Ca^{2\pm}$ 1.06 Å), for cerium ($Ce^{4\pm}$ 1.02 Å), and, to a limited extent, for zirconium ($Zr^{4\pm}$ 0.87 Å); they are therefore frequently found in certain minerals of these elements, such as apatite, titanite, monazite and zircon. Uranium and thorium ions are much larger than the ions of most common elements, however, and have higher valencies. Because of this they do not appreciably enter into the structures of the major rock-forming minerals. Although they may substitute for calcium they do not meet the co-ordination requirements of calcium in plagioclase structures.

Uranium has a close affinity for carbon. In many parts of the world, therefore, it is found in coal, lignite, peat, carbonaceous and bituminous shale, and other carbonaceous substances. Uranium does not appear to be genetically associated with carbon in such substances; its presence in most is believed to be due to secondary processes. Certain uranium-bearing coals and lignites, for example, appear to have precipitated or adsorbed their uranium from migrating solutions that have dissolved it from associated rocks, because of the natural affinity between carbon and uranium.

Geological Abundances of Uranium and Thorium

Earth's crust as a whole. Uranium and thorium are relatively common elements. They are 'lithophilic' in character, that is, they are concentrated in the upper part of the earth's crust, or lithosphere. Estimates of their abundances in the earth's crust, as compiled by Fleischer (1953), range from 0.00002 to 0.0009 per cent for uranium, and from 0.00073 to 0.002 per cent for thorium. Expressed as parts per million, these estimates range from 0.2 to 9 ppm for uranium, and from 7.3 to 20 ppm for thorium. On the basis of Fleischer's data, uranium is less abundant than copper, nickel or zinc, but more abundant than gold or silver. Thorium is about three times as abundant as uranium and more abundant than molybdenum. These estimates indicate that uranium and thorium are fairly common elements and that their minerals should be fairly common also. On the basis of these estimates a deposit containing 0.1 per cent uranium oxide represents a concentration of about 300 times the estimated average abundance of uranium in the earth's crust.

Igneous rocks. All igneous rocks contain at least traces of uranium and thorium. These rocks have received more attention than others because they constitute more than 90 per cent of the earth's crust and because they are genetically related, either directly or indirectly, to many uranium and thorium deposits. Larsen and Phair (1954) have summarized data on the abundance of uranium and thorium in gabbroic, intermediate and granitic rocks, which are reproduced in Table IV. The most significant observations to be made from these data are that thorium is consistently more abundant than uranium; that the thorium-to-uranium ratios are fairly constant, being around 3.5-to-1; that the elements show a progressive enrichment from basic to acidic rocks, that is, in general, from the early to the late rock differentiates; and that the greater concentrations are found in granitic rocks, these being generally high in silica and potash. In all but the very last stages of the magmatic cycle uranium and thorium behave as one element, both being present in concentrations of about the same order of magnitude, and because under the reducing conditions that would be expected to prevail they are both tetravalent, with similar ionic radii. Also, their low abundance not permitting them to form separate minerals early in the crystallization of the magma, and as, for reasons already explained, they do not appreciably enter into the crystal structures of the major rock-forming minerals, the elements become concentrated in residual magmatic solutions. They therefore tend to be enriched in the youngest, or latest-formed, rock differentiates. This progressive enrichment is apparently continued into and during the pegmatitic stage, as evidenced by the relatively greater abundance of discrete uranium and thorium minerals in well-defined, coarse-grained pegmatites, as contrasted to their scarcity in normal igneous rocks. Rankama and Sahama note that in pegmatites the uranium-rich minerals are formed during the late stages of deposition. The relatively high abundance of the elements in granitic rocks can be correlated, in part, with their presence as vicarious constituents in certain accessory minerals common to these rocks, notably zircon, titanite and allanite. In a detailed study of a massive granodiorite in Italy, for example, more than 95 per cent of the total radioactivity was found to be concentrated in the accessory minerals, which constituted only 0.1 per cent of the total volume of the rocks (Merlin, *et al.,* 1957). Laboratory experiments have shown, however, that much of the uranium and thorium in some igneous rocks may be leached by dilute mineral acids, indicating that the elements may also occur in some form other than insoluble accessory minerals. Neuerburg (1956) considered that uranium may occur in igneous rocks in the following ways: as discrete minerals; disposed in the structure of rock minerals by atoms or ions of uranium substituting for some other atom or ion, and in structural defects, such as along twin-boundaries; held in cation-exchange positions; adsorbed on the surfaces of crystals; and dissolved in fluid inclusions and in intergranular fluids. The distribution of the elements in granitic rocks is discussed more fully later.

Larsen and Phair (1954) postulated that during the late magmatic stage a change takes place that allows uranium to be carried off in the hydrothermal solutions, leaving thorium to crystallize in the final silicate-rich melt. They attribute this change to a shift in the oxidizing conditions at the late magmatic stage, in which uranium is converted to the hexavalent state, whose compounds are highly soluble in contrast to those of tetravalent uranium and thorium. Thorium, having only the one stable valence, is not affected by this change and remains behind. This may well account for the almost complete absence of thorium in hydrothermal pitchblende-type deposits.

Sedimentary rocks. Sedimentary rocks generally show wider variations in their uranium and thorium contents than do igneous rocks. According to Adams and Weaver (1958), the thorium-to-uranium ratios of sedimentary rocks range from less than 0.02 to more than 21, the ratios in many oxidized continental sediments being above 7-to-1, whereas the ratios in most marine sediments are much below 7-to-1. The diversity in the ratios of continental and marine sediments reflects an early separation of uranium and thorium in the sedimentary cycle, with proportionally more uranium reaching the oceans. This separation is believed to be due to the greater mobility of uranium in solution, and to the more refractory nature of thorium minerals. During the weathering of rocks some uranium and thorium is leached by surface and ground waters and some remains fixed in resistant minerals; these minerals may accumulate near their original source or may be reduced by attrition and be carried and deposited, largely, with clastic sediments, probably mainly in near-shore environments. Uranium that is leached from rocks forms soluble uranyl complexes that are fairly stable in an oxidizing environment; the element may therefore be carried far before being precipitated or becoming otherwise fixed in sedimentary rocks, and part ultimately reaches the ocean. On the other hand, thorium that is leached hydrolyzes easily and accumulates largely with the hydrolyzates, that is, shales and related rocks. A combination of the foregoing factors presumably accounts for the relatively larger concentration of uranium in ocean waters. Uranium that is carried in solution may be extracted and fixed in sediments in different ways. It may be precipitated as insoluble compounds; it may be adsorbed on clays and on the hydroxide gels of iron, aluminum and manganese, and silica gel; or it may substitute isomorphously for calcium in chemical precipitates, such as phosphorites. Carbonaceous matter is a particularly effective precipitant of uranium because it creates a strong reducing environment; it can also adsorb relatively large amounts of the element from solution. The role of humic acid in the geochemical enrichment of uranium has been discussed recently by Szalay (1958) and Vine, *et al.* (1958). Organisms are also believed to adsorb uranium. Recent data on the abundance of uranium and thorium in limestones, shales and sandstones are presented in Table IV. The data for limestones and shales represent a large number of analyses of North American and Russian origin. The contents shown for limestones are the limits of the mean contents of three different groups of rocks of different ages: North American individual samples, North American aggregates, and Russian Platform aggregates; the contents shown for shales are estimates for the average shale. The contents shown for sandstones are averages obtained from the analyses of fifteen orthoquartzitic, clay-free sands. Black, carbonaceous marine shales and marine phosphorites generally contain higher concentrations of uranium than do other sedimentary rocks. The average uranium contents of eleven black shale formations in the United States and Europe are reported by Bates and Strahl (1958) to range from 0.0003 to 0.0168 per cent, with one, the St. Hippolyte shale in France, containing 0.1244 per cent. The same authors also report that most of the uranium in the French shale and all of the uranium in the other shales are loosely held in the fine-grained, organic-inorganic matrix of the rock. Marine phosphorites commonly contain 0.005 to 0.03 per cent uranium (McKelvey, 1956).

Considering sedimentary rocks as a whole, it seems evident that much of their uranium and, more particularly, their thorium occur in resistant minerals in which the elements are essential or vicarious constituents, or contained as inclusions. This is because during the weathering of rocks uranium minerals alter to hydrated oxides that are sparingly soluble (Rankama and Sahama, 1950, p. 636); because thorium minerals are known to be strongly resistant to weathering, especially those of greatest abundance, such as monazite; and because many minerals in which uranium and thorium are nonessential constituents are refractory. Even in limestones and dolomites, Adams and Weaver (1958) have concluded that most of the thorium and approximately 20 per cent of the uranium occur in the detrital, acid-insoluble fraction. Because many uranium and thorium minerals resist weathering and possess a high specific gravity, concentrations of them frequently occur in placers.

Rivers and seas. Traces of uranium and thorium are present in the waters of rivers and seas. The contents in rivers are extremely variable, as would be expected, because they are affected locally and regionally by differences in the composition of the terrain. Koczy (1954) reported that the uranium content of rivers seems to range from 0.3 to 20, or more, micrograms per litre. The uranium contents of

Table IV

Uranium and Thorium Contents of Some Igneous and Sedimentary Rocks

	Uranium (ppm)	Thorium (ppm)
Igneous		
Gabbroic rocks		
Evans and Goodman (1941)	0.96 ± 0.11	3.9 ± 0.6
Keevil (1938)	0.94	2.83
Intermediate rocks		
Evans and Goodman (1941)	1.4 ± 0.2	4.4 ± 1.2
Senftle and Keevil (1947)	2.27 to 3.03	9.28 to 10.5
Granitic rocks		
Evans and Goodman (1941)	3.0 ± 0.3	13 ± 2.0
Keevil (1938)	2.77	7.94
Senftle and Keevil (1947)	3.84 to 4.02	13.1 to 13.5
Sedimentary		
Limestones		
Adams and Weaver (1958)	2.1; 2.2	1.1 to 2.4
Shales (average)		
Adams and Weaver (1958)	3.7 ± 0.5	12 ± 1
Sandstones		
Murray and Adams (1958)	0.45 ± 0.05	1.7 ± 0.1

seas are similarly small, but show considerably less variation. Analyses by Rona, *et al.* (1956) show a concentration of 3.1 to 3.5 micrograms of uranium per kilogram of sea water; Koczy (1956) proposed a value of 2±1 micrograms per kilogram. Determinations of the abundance of thorium are scarce, probably because of difficulties in analyzing for minute traces. The content of thorium in sea water is reported in Mason (1958) as 0.000001 to 0.00001 grams per ton. An interesting observation is that sea waters contain less radium than would be expected under conditions of equilibrium with their uranium content, whereas surface layers of deep-sea sediments contain abnormally high amounts of radium. Pettersson (1954) suggests that this anomaly is caused by the selective precipitation of Th^{230}, the parent of radium, which accumulates on the ocean floor.

Production and Reserves

Uranium

Production

Data on production and resources are far from complete because some countries disclose little or no information. A fairly satisfactory summary can be presented, however, because most of the 'western' countries that are believed to produce significant amounts publish at least some returns. These are sometimes stated as pure natural uranium, or as highly concentrated products, or as the amount of U_3O_8 contained in such concentrates.[1] As it is not always practical to convert such units, the following statements are usually couched in the terms used in the sources. Tons are listed as short tons of 2,000 pounds. Geological classes of deposits are here mentioned briefly, if at all; some of the principal foreign deposits are discussed elsewhere in this report.

The total production of 'western' countries in 1958 was estimated at 35,000 tons of uranium concentrates, and that for 1959, 42,000 tons (Johnson, 1958). This is obtained mainly from United States, Canada and South Africa.

In 1958, production in the United States, mainly from disseminations of pitchblende and other minerals in sandstone, was about 12,000 tons of U_3O_8, and the amount for 1960 is expected to be more than 16,000 tons. Canada produced about 13,000 tons of U_3O_8 in 1958 and is expected to yield about 15,500 tons in 1959.[2] The Union of South Africa produces about 6,000 tons of U_3O_8 annually as a by-product of the mining of gold-bearing conglomerate. Production figures are not available for the Soviet Union. The following estimate of mining there in 1957 and of future possibilities is quoted from a recent review (Paone, 1958a):

> Soviet Russia's major sources of uranium were (1) the Satellite countries, (2) the Ferghana region of the Central Asian Republics, (3) Northern Siberia, (4) Southern Siberia, and (5) Central Kamchatka. The most important source during the year was the

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[1] The term *concentrate* commonly refers to material concentrated by ore dressing, such as in flotation or separation by gravity, and *precipitate* refers to material precipitated chemically. In the uranium industry, however, there is a tendency to use *concentrate* also for precipitates from leaching plants.

[2] Canadian production in 1959 was 15,909 tons of U_3O_8, and in 1960 it was 12,517 tons.

> Ferghana field, where the carnotite deposits closely resemble those of the Colorado Plateau in the United States. At least half of the current Soviet production is believed to be from Ferghana.
>
> The fields in Northern and Southern Siberia and Central Kamchatka are less known to the western world, although much can be inferred from the geology. Main occurrences of uranium are in two geological regions in belts of ancient Precambrian rocks and in widespread areas of permeable sediments (such as the Ferghana field). Such rocks indicate either the existence or potential source of uranium. Two vast areas of Precambrian rocks exist in the U.S.S.R.—the Angara shield of Northern Siberia, and the whole of Southern Siberia and the Mongolian Peoples' Republic. Scientists of the Free World are convinced that considerable mining is being done in these areas and consider that by 1960 the Angara shield deposits and the Ukhta reserves of North Russian might well be producing 2,000 tons of metal a year.
>
> Another 2,000 tons of metal a year may be mined in Southern Siberia by 1960; in addition to 1,000 tons from the Mongolian-North China field. Mining was most intensive in the Lake Baikal area of Southern Siberia. At Slyudyanka, at the southern end of the lake, betafite deposits, containing uranium, calcium, columbium, and tantalum were mined. East of the lake uranium deposits were worked at Ulan Ude and at Vitim, 300 miles farther northeast on the Lena river. On the Yenisei River and about 1,000 miles west of Lake Baikal, 2 other fields are known—Yeniseisk and Minusinsk.
>
> Within the next 2 years possibly, the extensive Kamchatka area, northeast Soviet Russian, may be yielding some 1,000 tons annually. Another 800 tons may come from the Satellite countries—half from East Germany and Czechoslovakia and the remainder from Rumania, Bulgaria, and Hungary.

Substantial mining is believed to be carried on in Australia, Belgian Congo, Czechoslovakia, East Germany, France, India, Portugal and Rumania, as outlined in Table V. Argentina may also be in this category—twelve mines are reported to be in operation there, but their sizes are not known. At least three important mines are producing in Australia, but reserves data for only one are available. The famous Shinkolobwe mine in Belgian Congo was believed to be still in production in 1957. The Joachimsthal district of Czechoslovakia, which produced radium for many years, is understood still to be an important source of uranium. East Germany also is said to be producing important amounts. A plant in India is reported to extract uranium from monazite sands; monazite contains little, if any, uranium, but as the tonnages of sands are large, the aggregate production of uranium is no doubt important. Uranium has been produced from one district in Portugal for some time, and is reported to have been found recently in another district; no production figures are available. Rumania is said to have extensive mines, from which uranium is exported to the Soviet Union. Information on several other countries that are understood to be small producers is summarized in Table V.

Discoveries of uranium have been reported from many other countries. Indeed, the element is now known to occur under such a wide range of geological conditions that it could probably be found in small quantities in almost any country.

Table V

Summary of Available Data on Production and Reserves of Uranium

Country	Annual Production (Approx.)	Year	Principal Type(s)	Reserves (Approx.)	Year	Remarks
Argentina		1957	Supergene and peg.?			At least 12 producing mines and 2 plants reported.
Australia	1,000 tons of conc.	1958	Diss. pitch.; davidite in veins; met.	Pitch. deposits: 335,000 tons at 0.3%	1957	Reserves of other types not stated.
Belgian Congo	Former production 1,000–3,000 tons conc.					Producing, but reserves reported to be almost exhausted.
Brazil		1957				2 plants treating uraniferous zirconium ores.
Canada	13,000 tons U_3O_8	1958	Cong.; pitch. diss. and veins; peg.	340,000,000 tons mainly at 0.1%	1957	
Colombia						Planned production of 50 tons per month reported in 1957.
China						Mining reported in 1957.
Czechoslovakia		1957	Pitch. veins			Uranium reported a main export.
East Germany		1957	Pitch. veins			Reported leading producer in Europe.
France	300 tons of uranium	1957	Pitch. veins	100,000 tons at 0.2%	1957	Production estimated at 1,780 tons in 1958.
Hungary						Production estimated at 25 tons of ore daily.
India		1957				Uranium produced as by-product of monazite sands. Large uranium deposits reported.
Israel		1957				Production from phosphate rocks reported to be beginning.
Italy			Supergene minerals in veins	3,000,000 tons at 0.2%	1957	No production facilities in 1957.
Japan				117,000 tons at 0.8%	1957	Discoveries in other districts but reserves not reported.
Madagascar		1958	Uranothorianite ore	1,000 tons	1957	Also small quantity produced intermittently from supergene minerals in peat, clay and sand.
Mozambique	42 tons of conc.	1956	Davidite pockets			
Portugal			Pitch. veins			Medium producer but figures not available.

Rhodesia	6 months, 7,256 lb U_3O_8	1957				Export begun in 1957 as by-product of copper mine.
Rumania						Extensive mines reported.
South Africa	5,500 tons of conc.	1957	By-product of gold-bearing conglomerates	1,100,000,000 tons at 0.03%	1957	17 plants processing 20,000,000 tons of ore annually.
Sweden			Uraniferous shale			1 concentrator and 1 refinery.
United States	15,000 tons of U_3O_8	1958	Pitch. in sandstone	78,000,000 tons at 0.27%	1957	16 plants in 1957. By 1959 expected to be 25 plants with combined capacity of 20,400 tons of ore daily.
U.S.S.R.		1957	Carnotite and other types			Production in 1960 possibly 6,000 tons of uranium according to *Minerals Yearbook*.

Abbreviations:

Conc.	Concentrate	Diss.	Disseminated	Peg.	Pegmatite
Cong.	Conglomerate	Met.	Metasomatic	Pitch.	Pitchblende

Reserves

In 1957 reserves of uranium ore in the United States, mainly in the Colorado Plateau and adjacent regions, were estimated at 78 million tons averaging 0.27 per cent U_3O_8. Canadian reserves were estimated at 340 million tons, by far the greater part averaging 0.1 per cent U_3O_8 or slightly higher.[1] Reserves in South Africa were stated to be 1,100 million tons averaging 0.03 per cent U_3O_8. These estimates are thought to be conservative, although figures of different degrees of accuracy are included. Additional ore can probably be found by further exploration of some deposits, and other workable deposits can probably be found by further prospecting. At current rates of production the reserves of these three countries appear to be sufficient for roughly 20, 20 and 50 years, respectively. The average content of ores in the United States is the highest of those of the three leading countries, but this is offset to some extent by higher costs, because the conglomerate ores of the other two countries consume less reagents. It is interesting to note that the total contents of uranium in the Canadian and South African reserves are roughly similar, the higher grade of the Canadian ores approximately compensating for the much larger tonnage of the South African ores.

Of the other producing countries, figures for reserves are available only for Australia, France, India, and Italy (Paone, 1958a). The reserves in the Rum Jungle area in northern Australia as of 1957 were reported to be 335,000 tons averaging 0.3 per cent U_3O_8. Reserves for two other mines, the Radium Hill and Mary Kathleen, producing in the southern part of the continent, were not stated. France reported 100,000 tons carrying 0.2 per cent U_3O_8 in 1958. Reserves at one Indian deposit of monazite sands were reported in 1957 to be 3,300,000 tons, from which 10,000 tons of uranium concentrate containing 0.13 to 0.4 per cent U_3O_8 could be obtained; other large deposits of this kind are understood to be available. Deposits in Italy, believed to be of the vein class, are reported to contain 3 million tons averaging 0.2 per cent U_3O_8. The Atomic Energy Newsletter (2 September, 1958) quoted the first report of the Euratom Commission as stating that reserves at the Shinkolobwe mine in Belgian Congo are almost exhausted.

J. C. Johnson, Director of the Division of Raw Materials, United States Atomic Energy Commission, pointed out (1958) that uranium reserves fall into two broad economic categories. The most important of these, which apparently includes most of the reserves mentioned above, are ores from which uranium can be recovered profitably at a price of $10 per pound of contained U_3O_8, or less. The other category comprises ultra low-grade shales, phosphate rocks, and other deposits whose exploitation for uranium alone would require prices from three to six times greater than the foregoing. Johnson concluded his review as follows: "The knowledge and experience gained from extensive geological investigations and explorations indicate that there need be no concern about the availability of adequate supplies of nuclear fuels for current and future atomic power require-

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[1] At the beginning of 1960, Canadian reserves of ore were estimated at 308.5 million tons averaging 0.12 per cent U_3O_8.

ments." Sir John Cockcroft, in the concluding lecture of the Second International Conference on Peaceful Uses of Atomic Energy in 1958, in which he summarized the main features of all data presented on uses, fuel cycles and fuel supplies, estimated that the reserves of South Africa, Canada, United States and France are likely to contain at least 2 million tons of uranium, and that, on the basis of present geological data and the experience of the last 10 years, a like amount is probably awaiting discovery and proving. He pointed out that these estimates were two to four times higher than those made in 1955. He suggested that if it is assumed that the reserves of the Soviet Union, China and other countries are of the same order, world reserves of high-grade ore are likely to be about 10 million tons of uranium. He estimated that, at the 30 per cent rate of 'burn-up' which might be achieved by 'breeder' reactors, 10 million tons of uranium is equivalent to three times the world's estimated coal reserves, and predicted that "we are likely to have developed fusion power long before we run out of uranium".

Thorium

Production

For many years a plentiful supply of thorium for industrial uses in other countries has been obtained from monazite concentrates derived as a by-product of beach sands worked mainly for rutile and zircon in India, Brazil and Australia. An interesting feature of the Indian placers is that they are reported to be replenished annually by wave-action during the monsoon season, when mineral grains are transported from the continental shelf and deposited on the beaches. Some monazite was obtained from beach and stream placers in the United States, and from various deposits in other countries. In recent years France has been an important producer, apparently by refining concentrates derived from thorianite or uranothorianite ores mined in Madagascar, and large amounts of monazite have been obtained from a quartz-vein deposit in South Africa. Increased interest has been shown lately in the possibility of expanding ordinary industrial uses for thorium and using it as a fuel for nuclear reactors. In Canada, construction of a plant to recover thorium from certain of the Blind River uranium deposits was begun jointly in 1958 by the Rio Tinto Mining Company of Canada Limited and the Dow Chemical of Canada Limited. This plant, costing about a million dollars, began operation in March 1959 and was expected to reach its annual capacity of 100 to 200 tons of thorium compounds in mid-1959.

Few statistics are available for current production. France claimed to be the world's leading producer of thorium in 1957, with an output of 250 to 300 tons of thorium nitrate. Most of the thorium requirements in the United States and United Kingdom were supplied by South Africa. To date requirements in the United States have been amply supplied by thorium obtained as a by-product of the extraction of rare earths from monazite. Information available for these and other countries, obtained mainly from a recent review by Paone (1958b), is listed in Table VI.

Reserves

Economic reserves in ‘western’ countries may be about 500,000 tons of contained thorium (Johnson, 1958). These are principally in India and Canada. The best statistics available to the end of 1957 are shown in Table VI.

The principal Canadian reserves are in the uranium ores of Blind River area, which are estimated to contain an average of 0.05 per cent ThO_2. Some large deposits there probably average 0.1 per cent ThO_2. Smaller tonnages in the Bancroft area are estimated to contain 0.02 to 0.2 per cent ThO_2.

Table VI

Summary of Available Data on Production and Reserves of Thorium

Country	Annual Production (Approx.)	Year	Principal Type(s)	Reserves (Approx.)	Year	Remarks
Australia		1957	Monazite sand	Reported to be limited	1957	Production but no figures
Brazil		1957	Monazite sand	10,000 tons of ThO_2	1957	Probable production but no figures
Canada			Mainly monazite and other minerals in uraniferous conglomerate.	330,000,000 tons of potential ore at 0.05% ThO_2	1957	Possibly 200,000 tons of ThO_2
Ceylon	Small	1957	Monazite sand			Production but no figures
France	250 to 300 tons of thorium in thorium nitrate	1957	By-product of thorianite ore	Sufficient for few years only	1957	Believed to be refining in France of concentrates from Madagascar
India		1957	Monazite sand	One deposit reported capable of producing 330,000 tons of conc. containing 10% Th	1957	
Korea		1957	Monazite stream placers			Production but no figures
Madagascar		1957	Pegmatite	1,000 tons of uranothorianite at 60 to 70% ThO_2		Probable production but no figures
New Zealand			Iron-bearing sands			Production from large deposits expected
Nigeria		1957	Thorite in granite and placers			Probable production but no figures
South Africa		1957	Monazite in quartz vein	250,000 tons of monazite containing 6% ThO_2	1957	Largest source for U.S. and U.K., production not stated
United States		1957	Monazite sands and thorite ore	18,000 tons of ThO_2		
U.S.S.R.						Probably recovered as by-product of gold placers (Nininger, 1956a, p. 100)

PART II

GENERALIZATIONS

Mineralogy

Some minerals containing uranium or thorium have been known and described for more than a century, but until about 15 years ago they received relatively little attention because of their limited economic importance. Advances in atomic fission focused attention on them, research being greatly accelerated because of the need for more systematic studies and better understanding of their characteristics and classification. As a result much new information has accumulated for the previously known minerals and many additional ones have been discovered, named and described. The development of portable radioactivity detectors has played an important role because their use by prospectors and others has revealed thousands of new occurrences and provided a wealth of new material for study, both in Canada and in other countries. The literature is now extensive and ever-increasing, whole volumes having been devoted exclusively to uranium and thorium minerals; one of the most recent and authoritative of these is that of Frondel (1958). The subject is much too large and complex to be treated fully in this report, therefore the following is a summary—pertaining only to known Canadian species and varieties—of those aspects of the subject that are likely to be of concern to geologists, advanced prospectors and others who are not mineralogists. Further work may cause revision of some of the information given, and in time will undoubtedly add to the species described or listed here.

Minerals containing uranium or thorium are commonly called radioactive minerals because they emit alpha, beta, and gamma rays. These minerals contain uranium and thorium as the principal radioactive constituents, but also present are small amounts of radioactive disintegration products, or daughter elements, such as radon and radium. There are no separate radium minerals distinct from those of uranium. Strictly speaking, minerals containing certain naturally occurring isotopes of potassium, rubidium and other elements are also radioactive, but potassium is relatively insignificant in this regard and the other radioactive elements are unlikely to be encountered in detectable amounts. Potassium-bearing minerals or rocks may contain enough of the radioactive isotope of potassium (K^{40}) to be slightly radioactive and to cause misleading results to be obtained with portable detectors. For this report, however, radioactive minerals are considered to be those that contain uranium or thorium in amounts greater than 0.1 per cent. In the following sections minerals that ordinarily contain more uranium than thorium are classed as uranium minerals, and those that ordinarily contain more thorium than uranium are classed as thorium minerals. Only a few minerals, mainly Canadian ore minerals, are discussed individually. Some of the problems that arise in laboratory identification and classification are outlined to explain certain ambiguities and usages. Practical information is included on the field identification of those minerals that can generally be recognized.

Table VII lists the seventy radioactive minerals and varieties now recognized as occurring in Canada.

Table VII

Canadian Radioactive Minerals

Name	Composition	Per cent U_3O_8[1]	Per cent ThO_2[1]
Allanite	Complex silicate of rare earths, iron, aluminum and calcium	to 0.2	to 3.5
Meta-allanite[2]	Apparently a hydrated variety		
Autunite (S)	Hydrated phosphate of calcium and uranium	57	—
Bastnaesite	Fluo-carbonate of the cerium group of rare earths	trace	to 0.4
Becquerelite (S)	Hydrated oxide of uranium	89	—
Betafite	Oxide of, essentially, niobium, tantalum, titanium, uranium and calcium	18 to 27	to 1.3
Ellsworthite	Higher, generally, in calcium		
Hatchettolite	Higher, generally, in calcium and tantalum		
Beta-uranophane (S)	Hydrated silicate of calcium and uranium	66	—
Beta-uranotile	Synonym of beta-uranophane		
Brannerite[3]	Oxide of uranium and titanium	34 to 52	to 6
Britholite	Complex silicate and phosphate of rare earths and calcium	—	to 3
Calciosamarskite (*see* Samarskite)			
Carnotite[4] (S)	Hydrated vanadate of potassium and uranium	62	—
Cerianite (*see* Uraninite-thorianite-cerianite series)			
Coffinite[4]	Hydrated silicate of uranium	48 to 71 (on concentrates)	—
Columbite-tantalite	Oxide of niobium, tantalum, iron and manganese	to 0.5	trace
Toddite	High in uranium	11	0.5
Cuprosklodowskite (S)	Hydrated silicate of uranium and copper	64	—
Curite (S)	Hydrated oxide of lead and uranium	74	—
Cyrtolite (*see* Zircon)			
Davidite[4]	Titanate of iron, uranium and rare earths	1.5 to 9	to 0.2
Ellsworthite (*see* Betafite)			
Eschynite-priorite series	Oxides of, essentially, niobium, titanium and rare earths, with uranium and thorium, etc.	to 5.5	to 18
Eschynite	Rich in cerium group of rare earths and, generally, thorium		
Priorite	Rich in yttrium group of rare earths; also usually higher in uranium than eschynite		
Euxenite-polycrase series	Oxides of, essentially, niobium, tantalum, titanium and rare earths, with uranium and thorium, etc.	to 14	to 5
Euxenite	High niobium + tantalum member		
Lyndochite	Relatively high in calcium, low in uranium	0.7	5
Polycrase	High titanium member		

Table VII—*Conc.*

Canadian Radioactive Minerals—Conc.

Name	Composition	Per cent U_3O_8[1]	Per cent ThO_2[1]
Fergusonite-formanite series	Oxides of, essentially, niobium, tantalum, yttrium and erbium, with uranium and thorium, etc.	to 8	to 5
Fergusonite	Niobium-rich member		
Fourmarierite (S)	Hydrated oxide of lead and uranium	77	—
Gadolinite	Silicate of rare earths, beryllium and iron	to 0.5	to 2
Gummite (S)	Generic term for alteration products of uraninite and pitchblende	65 to 77	—
Hatchettolite (*see* Betafite)			
Kasolite (S)	Hydrated silicate of lead and uranium	48	—
Lessingite	Silicate of rare earths and calcium	(No analysis available)	
Liebigite (S)	Hydrated carbonate of calcium and uranium	40	—
Lyndochite (*see* Euxenite-polycrase series)			
Masuyite (S)	Hydrated oxide of uranium	87	—
Melanocerite	Fluosilicate of, chiefly, the cerium and yttrium groups of rare earths and calcium	—	to 3
Meta-allanite (*see* Allanite)			
Metatorbernite (S)	Hydrated phosphate of copper and uranium	60	—
Metazeunerite (S)	Hydrated arsenate of copper and uranium	55	—
Microlite (*see* Pyrochlore-microlite series)			
Monazite	Phosphate of the cerium group of rare earths, with thorium	to 0.7	1 to 15
Perovskite	Essentially calcium titanium oxide; some varieties contain niobium and rare earths	(No analysis available)	
Phosphuranylite (S)	Hydrated phosphate of calcium and uranium	69	—
Pitchblende (*see* Uraninite-thorianite-cerianite series)			
Polycrase (*see* Euxenite-polycrase series)			
Priorite (*see* Eschynite-priorite series)			
Pyrochlore-microlite series	Oxides of niobium, tantalum, calcium and sodium, with uranium, etc.	to 18	to 9
Pyrochlore	Niobium-rich member		
Uranoan pyrochlore	High in uranium		
Sabugalite (S)	Hydrated phosphate of aluminum and uranium	63	—
Saleeite (S)	Hydrated phosphate of magnesium and uranium	61	—

Samarskite	Oxide of, essentially, niobium, tantalum, rare earths, iron and uranium	4 to 17	to 4
Calciosamarskite	Relatively high in calcium		
Sklodowskite (S)	Hydrated silicate of magnesium and uranium	67	—
Soddyite (S)	Hydrated silicate of uranium	85	—
Studtite (S)	Hydrated carbonate of uranium	High	—
Thorianite (*see* Uraninite-thorianite-cerianite series)			
Thorite	Thorium silicate	to 5	50 to 80
Uranothorite[3]	High in uranium and water	5 to 21	40 to 60
Thorogummite (S)	Hydrated thorium silicate, with uranium	to 35	25 to 60
Thucholite	Hydrocarbon with uranium, etc.	variable	variable
Toddite (*see* Columbite-tantalite)			
Torbernite (S)	Hydrated phosphate of copper and uranium	56	—
Tyuyamunite[4]	Hydrated vanadate of calcium and uranium	59	—
Uraconite	Hydrated sulphate of uranium (discredited species, probably uranopilite or zippeite)		
Uraninite (*see* Uraninite-thorianite-cerianite series)			
Uraninite-thorianite-cerianite series			
Uraninite[3,4]	Uranium dioxide, with, usually, thorium and rare earths	65 to 95	to 10
Pitchblende[3,4]	Uranium dioxide, with no, or negligible, thorium or rare earths	60 to 85	less than 0.1
Thorian uraninite	High in thorium	45 to 65	10 to 35
Thorianite	Thorium dioxide, with, usually, uranium and rare earths	to 10	75 to 93
Uranoan thorianite	High in uranium	10 to 40	40 to 75
Cerianite	Cerium dioxide	—	5
Uranophane[3] (S)	Hydrated silicate of calcium and uranium	66	—
Uranopilite (S)	Hydrated sulphate of uranium	80	—
Uranospinite (S)	Hydrated arsenate of calcium and uranium	54	—
Uranothorite (*see* Thorite)			
Vandendriesscheite (S)	Hydrated oxide of lead and uranium	80	—
Xenotime	Phosphate of, essentially, yttrium and erbium	to 4	to 2.5
Zippeite (S)	Hydrated sulphate of uranium	76	—
Zeunerite (S)	Hydrated arsenate of copper and uranium	53	—
Zircon	Zirconium silicate	to 0.5	to 0.1
Cyrtolite	With water, rare earths, uranium and thorium	to 2	to 1

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[1] U_3O_8 and ThO_2 contents, which in some instances are theoretical, are taken from standard references and do not necessarily represent analyses of Canadian specimens.

[2] Names indented are those of members of series and of varieties of preceding species.

[3] Principal Canadian ore minerals.

[4] Principal ore minerals in other countries.

(S) Supergene minerals.

Problems of Identification

Few radioactive minerals can be identified specifically in the field because: many look alike and resemble certain non-radioactive minerals; few are separable by simple means such as blowpiping; and many deposits contain radioactive minerals in microscopic grains only. Uraninite and pitchblende can, however, commonly be identified if they occur in grains or masses of sufficient size, and supergene minerals can usually be recognized at least collectively. Otherwise, laboratory tests are generally required and these are often time-consuming, and in some instances ambiguous, for reasons explained below. The writers, however, recognize the fact that with practice, and on the basis of laboratory reports, persons may become proficient in identifying primary uranium and thorium minerals visually in a single deposit, or in a group of related deposits.

Fortunately, it is seldom necessary to have radioactive minerals identified unless and until a discovery shows definite signs of being of commercial size and content, or unless the occurrence is included in a research project. The widespread use of radioactivity detectors almost always provides the first indications of a prospect, and assays, which are easier and cheaper to perform, are generally more helpful than mineral identifications in distinguishing between uranium and thorium occurrences and providing an idea of quantity. Knowledge of the mineral or minerals involved is mainly useful later, in helping to determine the geological class of a deposit of some size, and whether or not it would be amenable to ore-dressing and metallurgical processes, or in connection with geological research. When laboratory identifications are desirable, an effort should be made to obtain pieces of the richest and least-altered material, preferably with the aid of a radioactivity detector, and to designate them as specimens rather than as samples.

Mineral separations. Radioactive minerals rarely occur in crystals or masses that are large enough to be readily separated in the field for identification. For this reason, and because more than one mineral may be present in a deposit, if it is desirable to identify the minerals selected specimens are generally taken in the field and the minerals separated in the laboratory. These separations may be simple or complex. Where the minerals occur in macroscopic grains their separation is more or less incidental to their identification, because fragments can usually be pried out, or they can be hand-picked, under a low-powered microscope, from part of the specimen that has been crushed. But where the minerals occur in grains that can be seen only under high magnifications, and particularly where two or more minerals are present in the same sample, their separation becomes a problem in itself, and one that in many instances consumes more time than the actual identifications. Samples containing fine-grained minerals must be carefully crushed and sized, and the separations carried out by special procedures that are based on differences in the specific gravities and the magnetic susceptibilities of the minerals. At the least these procedures take an hour's time for each sample, but ordinarily they require several hours, and not uncommonly they may take a day or more. In special research projects where absolutely pure samples of the minerals have been required for chemical analyses, the separation of a single radioactive mineral has been known to take 40 days to complete, most of this time being devoted to tedious hand-picking of the mineral grains from concentrates under a microscope. In some producing Canadian uranium deposits the minerals are so fine grained that they can rarely, if ever, be seen with the unaided eye, and in many instances they cannot be recognized even with the aid of a hand lens. Although mineral separation has been highly developed, some appreciably radioactive samples have been received by the Geological Survey that have contained minerals so finely dispersed, or so intimately admixed with one another or with the gangue minerals, that they have defied the most elaborate separation procedures. Work will be continued on these samples as time permits, but it is to be expected that similar samples will continue to be found in which the fine-grained nature of the minerals will hinder or preclude the identifications. For this reason, the identification of a radioactive mineral is commonly more restricted by grain size than by other factors.

X-ray tests. Some minerals, such as allanite and thucholite, may be identified in the laboratory by simple physical and chemical tests. Most minerals, however, can be identified positively only by elaborate techniques, commonest among which is the X-ray diffraction method. This is based on two main principles, namely, that minerals have an orderly internal crystalline structure, in which the atoms may be pictured as being arranged in a three-dimensional network of parallel planes, and that these atomic planes will reflect X-rays in much the same manner as a mirror reflects light rays. The X-ray diffraction method is applicable to the identification of most radioactive minerals, but it has a few limitations and there are certain problems associated with it. It provides a fairly reliable means of distinguishing between uraninite and pitchblende; fragments of both yield a UO_2 X-ray pattern, but because of certain differences the pattern of uraninite is 'spotty', whereas that of pitchblende consists of smooth arcs.

Metamict minerals. The atomic structures of radioactive minerals are continuously undergoing an internal bombardment by alpha particles emitted during the disintegration of the uranium and thorium atoms. This bombardment apparently has little effect on tightly bonded minerals with a simple crystal structure, such as uraninite, but in certain primary radioactive minerals that are weakly bonded and that usually have a complex structure, such as the radioactive niobate-tantalates, the alpha particles will dislodge the various atoms from their orderly position in the crystal lattice and in time will destroy the internal crystalline structure of the minerals. Such minerals, which by X-ray and optical studies are found to be amorphous, or noncrystalline, even though they may exhibit external crystal form, are said to be metamict. Many of the common radioactive minerals belong to this class, including most complex multiple oxides, as well as allanite, uranothorite, and brannerite. Metamict pitchblende has been reported by Conybeare and Ferguson (1950) but later work by Brooker and Nuffield (1952) suggests that this may have been due to the degree of the oxidation of the specimen. As their amorphous character precludes the use of X-ray diffraction and optical methods the identification of metamict minerals presents certain problems not ordinarily associated with other minerals. A crystalline structure may be restored for X-ray diffraction tests by igniting fragments of the minerals at a high temperature, but it is not certain whether the original crystal structure of the mineral is reproduced in the heating process, or whether a new structure is formed. This is the usual way of identifying the minerals, however, and it seems satisfactory for most. Also, the presence of impurities may be important, because they may be incorporated in the heating process and in extreme cases they may possibly react with the mineral under study to form a new compound altogether. The metamictization of minerals requires further study, and although it is believed to be due mainly to alpha particle bombardment, other factors may also be responsible.

Isomorphous series. Certain groups of elements, because of similarities in their chemical and physical properties, may substitute partly or completely for one another during the crystallization of a mineral, without altering the crystalline structure. This substitution is called isomorphism. Because of this phenomenon, groups of minerals occur in nature having identical structures but varying in composition between arbitrary limits; these are called isomorphous groups or, more commonly, isomorphous series. Multiple oxides of niobium and tantalum are the commonest examples of radioactive minerals that form isomorphous series. Because of their structural similarities, minerals of any one isomorphous series yield similar X-ray diffraction patterns after ignition except for slight dimensional differences; these differences are rarely sufficient to distinguish one member of a series from another. The identification of a mineral as a particular member of an isomorphous series, therefore, requires subordinate chemical or other forms of analyses in conjunction with X-ray diffraction, but because such analyses are both costly and time-consuming the X-ray identification is often all that is reported, and the mineral is designated simply by its series name. Identifications such as pyrochlore-microlite and euxenite-polycrase therefore frequently appear throughout this report, indicating that the mineral is a member of the series named, but that insufficient data are available to identify it as any one particular member. Uraninite, as will be explained later, is isomorphous with thorianite, but because these two similar-appearing minerals yield simple X-ray diffraction patterns with relatively large differences in their spacings, they can generally be distinguished from each other by X-ray diffraction alone.

Uranium Minerals

Uranium is known to occur as an essential constituent of approximately eighty different mineral species; it is also present as a major, but not essential, constituent in at least some specimens of about thirty-five additional species. For practical purposes, therefore, it may be considered that there are approximately one hundred and fifteen different uranium and uranium-bearing minerals. Actually, names for more than one hundred and sixty such minerals appear in the literature, but many of these are synonyms or varieties of well-defined species. In addition to the number already stated approximately thirty-five additional species, such as allanite and gadolinite, contain minor amounts of uranium, and a number of common minerals such as biotite and apatite often contain traces of uranium as impurities, either in chemical combination or as inclusions of radioactive minerals. Of the long list of uranium minerals only nine constitute the principal ore minerals in uranium mines throughout the world; a few of the remainder do occur in relatively small amounts in some ores, but most are rare and chiefly of scientific interest. The main ore minerals are: uraninite, pitchblende, coffinite, brannerite, uranothorite, uranophane, davidite and carnotite, and tyuyamunite which is related to carnotite. Davidite, carnotite and tyuyamunite are mined in other countries, but only small occurrences of davidite, coffinite and tyuyamunite, and no confirmed occurrence of carnotite, have been found in Canada. Carnotite is one of the principal uranium minerals in deposits worked in the Colorado Plateau region of the western United States, and coffinite is also important there. Davidite is the principal uranium mineral mined at Radium Hill, Australia.

Uraninite group. The uraninite group of minerals comprises uraninite, pitchblende, thorianite and cerianite. Uraninite and pitchblende, being more abundant and of greater economic importance than the others, are discussed most fully. Although thorianite is essentially a thorium mineral, it is included here because in its strict mineralogical classification it is a member of the uraninite group. Until a few years ago thorianite had been found at only a few places in Canada, but it has since been identified from several other localities. Cerianite has so far been identified at only one locality, and there it occurs in but small amounts.

Uraninite and its variety pitchblende are important minerals of uranium because (1) they are relatively abundant, (2) they contain large percentages of uranium, and (3) they are amenable to established extraction processes. One or the other is an ore mineral at every Canadian mine now producing uranium. Pitchblende was once considered to be a separate mineral species and was the first uranium 'mineral' known, its name being doubtless applied because of its usual pitch-like lustre, but its relation to uraninite has since been established by X-ray studies. Most mineralogists now regard it as a variety of uraninite, but some do not make a distinction and use the terms interchangeably; still others believe that the term pitchblende should be dropped altogether. The writers class it as a variety of uraninite because: it has separate and diagnostic characteristics, it occurs in virtually distinct kinds of deposits, and it is used widely in the Canadian literature.

Uraninite and pitchblende consist essentially of uranous oxide (UO_2) and uranic oxide (UO_3). Ideally, they both have the composition (UO_2), and may have originally been deposited as such, but because of oxidation, some of the UO_2 is changed to UO_3. This oxidation is generally attributed to a combination of weathering and auto-oxidation, the latter being a theory conceived by Ellsworth which proposes that as the uranium atoms decay their attached oxygen atoms become available to oxidize UO_2 to UO_3. It is also probable that some UO_3 was deposited when the minerals were originally formed. Regardless of the process, no UO_2 has been found in nature that is not oxidized to at least some extent, and the oxidation seems to increase with the age of the mineral. Pitchblende is usually more oxidized than uraninite. Both minerals also contain appreciable amounts of lead. Most, if not all, the lead is due to radioactive disintegration, but some of that reported in analyses may be of primary origin or be due to microscopic inclusions of lead minerals. The lead derived from radioactive disintegration is called radiogenic lead. Although uraninite and pitchblende have essentially the same compositions they display chemical and physical differences. Uraninite, almost without exception, contains several per cent of thorium and rare earths. Pitchblende, on the other hand, rarely contains more than a trace (less than 0.1 per cent) of these elements. Robinson (1955) stated that in concentrates from forty pitchblende specimens from one area X-ray spectrographic analyses failed to detect any thorium or rare earths. Specimens of apparently pure pitchblende may show wide variations in composition, but this is usually due to fine-grained admixtures of other minerals, such as quartz and hematite, which are observable only under high magnification. Typical uraninite is crystalline, occurring mostly as cubes and octahedra or in combinations of these forms. It is hard, steely black and has a metallic lustre; on alteration it becomes soft and black, with a dull lustre. The streak is black. Pitchblende is cryptocrystalline and almost always occurs as disseminations and masses whose forms show no external crystal faces, but which may be botryoidal, banded or colloform. It is generally black and hard, with a pitch-like lustre. Both minerals are characteristically heavy and strongly radioactive, and dissolve in nitric acid.

Among mineralogists who distinguish between uraninite and pitchblende, some base their distinction on origin, some on composition, and some on habit. The writers believe that all these criteria should be considered, but feel that no one is satisfactory in itself. For example, Robinson identified crystalline pitchblende from a Canadian deposit, and although this might well be regarded as a mineralogical curiosity it is nevertheless noteworthy. Also, the late H. V. Ellsworth told Steacy of a thorium-free crystalline uraninite that he had found in a pegmatite. Accordingly, uraninite is here regarded to be the macrocrystalline form of UO_2 that occurs typically as crystals in deposits formed at high temperatures and which contains in solid solution several per cent of thorium and rare earths. Pitchblende is regarded to be the cryptocrystalline form of UO_2 that occurs in deposits formed at lower temperatures, which typically shows no crystal form, and which contains no thorium or rare earths or contains them in negligible amounts.

Uraninite forms a complete isomorphous series with thorianite, its thorium analogue, ThO_2. Although the complete series has been demonstrated in the laboratory, there are some gaps that have yet to be filled by naturally occurring compounds. For example, and as well illustrated by Robinson and Sabina (1955) in their study of twenty specimens of uraninite and thorianite from Ontario and Quebec, a large gap has yet to be filled by uraninites containing from about 15 to 25 per cent ThO_2. The name uraninite is applied to those members of the series that contain more uranium than thorium, and the name thorianite to those members that contain more thorium than uranium; in other words, a division is made at a thorium-to-uranium ratio of 1 to 1. A mineral containing identical amounts of uranium and thorium is named uranothorianite, but so far as the writers are aware it has not yet been identified in Canada. Thorianites, rich in uranium—generally placed at 10 per cent or more—are named uranoan thorianite. Like uraninite, thorianite contains several per cent of lead and, usually, rare earths, in addition to its variable but always significant content of uranium. Thorianite closely resembles uraninite in most physical properties. It commonly occurs in small cubes and interpenetration twins of the cube, such twins being helpful in distinguishing thorianite. It is much less soluble than uraninite under normal weathering conditions.

Cerianite has been found in small dark greenish octahedral crystals at one locality (Graham, 1955).

Brannerite. Brannerite is essentially an oxide of uranium and titanium, containing minor but variable amounts of thorium, rare earths, calcium and iron. It occurs as masses, imperfect crystals, and rounded grains. Unaltered brannerite is black, with a vitreous lustre, and is about as heavy as pyrite. It closely resembles many of the complex multiple oxides, and like most, is metamict. Upon alteration it becomes brownish to pale brownish yellow, and the lustre then varies from resinous to dull. The mineral alters fairly readily to anatase with which it may be confused unless a radiometric test is made.

In heavy mineral separates of certain Canadian ores made by the Geological Survey of Canada brannerite grains were found invariably to be altered to anatase or rutile; they vary appreciably in colour from almost black, through brown to light tan, and they show wide variations in their radioactivity. Chemical analyses on hand-picked samples showed up to 41.3 per cent U_3O_8 and up to 6.1 per cent ThO_2 (Roscoe, 1959). The grains are metamict, and before ignition yield an X-ray diffraction pattern comparable to those for anatase or rutile. After ignition for several minutes at a high temperature the grains yield the characteristic pattern for brannerite. Because of these X-ray observations, as well as other considerations, the writers earlier thought the grains might be mixtures that formed artificial brannerite when ignited for X-ray diffraction tests, but studies to date appear to leave little doubt that brannerite is a definite mineral species occurring naturally in the ores.

Niobate-tantalates. Multiple oxides containing niobium, tantalum and titanium are among the most commonly occurring radioactive minerals in Canada. Approximately thirty such minerals are known, and of these seventeen have been identified from Canadian localities, about one half belonging to a few well-defined isomorphous series. The minerals contain several elements in complex combinations, and are popularly called radioactive niobate-tantalates. Their composition can be expressed by the generalized formula $A_xB_yO_z$, where A represents chiefly rare earths, uranium, calcium, thorium, ferrous iron and sodium; where B represents chiefly niobium, tantalum and ferric iron; and where O represents oxygen, hydroxyl and fluorine. The uranium content is generally less than 10 per cent, but specimens of some minerals, notably samarskite and betafite, have shown more. Specimens of samarskite have indicated up to about 17 per cent U_3O_8, and specimens of betafite (and its varieties ellsworthite and hatchettolite) 18 to 27 per cent. Ellsworthite and hatchettolite are listed in most publications as variants of pyrochlore but recent work by Hogarth (1959) has shown that they are more closely related to betafite and should be considered as varieties of betafite, as also should all pyrochlore containing more than 15 per cent uranium.

The minerals vary in colour from black through brown to yellow, the more prevalent colours being black and darker shades of brown. They have a brilliant lustre. They are hard, but extremely friable. Most are commonly found as rounded grains or small masses, but some betafite occurs as octahedral crystals, and imperfect crystals of some varieties, such as fergusonite, have been noted in some specimens received by the Geological Survey. The minerals are not soluble in acids and on this basis they may be distinguished from other common radioactive minerals such as uraninite, uranothorite and allanite. They may be distinguished from thucholite in that they show no apparent effect on ignition.

Thucholite. Thucholite is the name given to radioactive hydrocarbons, of variable composition, that occur in many pegmatitic and vein-type deposits. Detailed studies have shown that thucholite is not a true mineral species but a mixture composed of one or more hydrocarbons and uraninite or pitchblende, usually present as microscopic disseminations (Davidson and Bowie, 1951; Bowie, 1953). Because thucholite is fairly common, however, and because it has separate characteristics, it may for practical purposes be regarded as a separate mineral. The name was improvised by Ellsworth from the first letters of five main constituents of an occurrence near Parry Sound, Ontario, namely: thorium, uranium, carbon, hydrogen and oxygen. The name is now generally applied to any hydrocarbon that is significantly radioactive, though thorium may be entirely absent. Thucholite is jet black and commonly resembles a high-rank coal such as anthracite; in fact, the first recorded occurrence was described as coal. In such instances it is hard and brittle, and breaks with conchoidal fracture. The lustre may be dull on external surfaces, but is brilliant on fresh fractures. The 'mineral' is not dissolved by acids, though admixed minerals may be removed in the acid treatment. Powdered thucholite burns when ignited at a high temperature, and yields variable amounts of ash; this is usually light brownish, and is proportionally more active than the unburned material. Like coal, the mineral has a low specific gravity. Thucholite occurs as nodules or masses, or as intimate intergrowths with pitchblende and uraninite. It has also been recognized in a disseminated sooty form in some pitchblende deposits (Robinson, 1955). The origin of thucholite has not been completely resolved but it is generally attributed to the polymerization of fluid hydrocarbons by radiations from radioactive minerals.

Supergene minerals. Some uranium minerals, particularly uraninite and pitchblende, oxidize and decompose fairly readily under surface or near-surface weathering conditions—that is, in the zone of oxidation—to form a large number of secondary or 'supergene' minerals. One or more of these minerals therefore commonly occur on or near outcroppings containing primary uranium minerals. The decomposition is especially pronounced in the acidic environment resulting from the alteration of sulphides, such as in pitchblende deposits containing pyrite and chalcopyrite. Many of the species closely resemble one another and often two or more are intimately admixed in the same occurrence, therefore positive identifications usually require extensive laboratory tests. Because of the limited economic importance of the minerals, however, such tests are seldom considered necessary on routine samples, and for this reason the minerals are commonly referred to as 'uranium stain', 'uranium ochre', or collectively as 'secondary uranium minerals'. The different species identified from Canadian localities are listed in Table VII, uranophane and gummite being the commonest. Gummite has been shown by X-ray tests to be actually a mixture of several different secondary minerals, but the name has been retained because it is a useful term to describe collectively the alteration products of uraninite, and because it frequently appears in the literature. Supergene minerals of uranium are characterized by their bright colours, these being typically hues of yellow, orange, and occasionally green; by their relative softness; and by their strong radioactivity; also, some varieties fluoresce when exposed to the rays of an ultraviolet lamp. Because of their high uranium content they will produce a strong positive test for uranium by the fluoride bead method; this is probably the best single method for identifying them in the field because secondary iron stains or even lichen growths are known to have been mistaken for the minerals, and if such substances should occur on rocks containing thorium minerals misleading interpretations could be made from tests with a Geiger counter.

Thorium Minerals

According to Frondel (1956) only six minerals contain thorium as an essential constituent; these are the four silicates: thorite, huttonite, thorogummite and pillbarite; the silico-phosphate: cheralite; and the oxide: thorianite. Many other minerals, however, contain thorium as an accessory constituent, approximately sixty being listed by Frondel of which specimens have shown more than 0.1 per cent ThO_2. Thorium accompanies uranium in all its primary minerals except pitchblende, but is absent in its secondary minerals because in these uranium occurs in the hexavalent state. The principal thorium minerals in Canada are thorite, uranothorite, monazite, allanite, and the large family of niobate-tantalates. As opposed to uranium minerals, thorium minerals are chemically stable and strongly resistant to weathering; therefore very few supergene thorium minerals are known or described. In Canada, Traill (1954) records the presence of thorogummite at one locality, and thorium has been detected in samples of weathered radioactive rock in which it may be present in some secondary form, but these are the only examples known to the writers. The stability of thorium minerals is evidenced by their frequent occurrence in placers in many countries of the world.

Monazite. Monazite is essentially a phosphate of the cerium group of rare-earth elements. It generally contains between 4 and 13 per cent ThO_2, but only a few tenths of one per cent U_3O_8, although Roscoe (1959) described some monazites that show unusually high amounts of uranium. Monazite is commonly yellowish, reddish, or clove-brown, with a resinous lustre. It is brittle and has a good cleavage. The streak is almost white. The mineral typically occurs as crystals in primary deposits, and as rounded grains in detrital deposits. The crystals may be minute and poorly developed, and discernible only with a hand lens; as such they have been observed in biotite-rich samples from migmatites. But where large and well-developed in pegmatites the crystals are mostly thick and tabular, or they may be wedge-shaped like those of titanite; and where unaltered they are more or less translucent. Monazite is sometimes associated with uraninite, whose presence can usually be ascertained by panning finely crushed portions of the rock. Monazite is the principal ore of thorium and one of the principal sources of the lighter rare-earth elements. Because large deposits are already known additional occurrences are not likely to be of any interest in Canada unless the demand for thorium and rare earths should improve.

Uranothorite. Uranothorite is a hydrous, uranium-rich variety of thorite, thorium silicate. The name is used arbitrarily and sometimes loosely, because all thorites contain at least some uranium, but it here defines those species of thorite in which the uranium content exceeds 5 per cent. Specimens of thorite in which uranium has been detected but not measured are occasionally referred to as 'uraniferous thorite'. Most Canadian uranothorites contain between 5 and 15 per cent U_3O_8, although contents up to 20.73 per cent U_3O_8 have been reported by Robinson and Abbey (1957). Uranothorite is a non-metallic mineral with a greasy to resinous lustre. It is commonly black, but may be brick-red or yellow when free of miscroscopic inclusions. It is hard and brittle and yields a greyish powder that is soluble in heated nitric acid. It commonly occurs as ovoidal-shaped grains or irregular masses, and less commonly as crystals; these are usually slender, and square in cross-section. The strong radioactivity, brittleness, greasy to resinous lustre, and solubility are diagnostic features. Uranothorite is a subordinate ore mineral of uranium in some producing mines.

Allanite. Allanite is one of the commonest radioactive minerals in Canada. A separate description seems appropriate because persons prospecting for radioactive minerals commonly find it, and because masses or local concentrations will cause readings of several times the background count. Allanite is a complex silicate of rare earths, iron, aluminum and calcium; it may sometimes contain up to 3 per cent of thorium but rarely contains more than a small fraction of 1 per cent of uranium. It occurs as platy crystals, as masses, and as embedded grains that are usually cigar-shaped in cross-section. When fresh, the mineral is jet black with a vitreous lustre, but most specimens are altered around their margins to a dull brownish compound. It is hard and brittle. The powdered mineral is light brownish and is soluble, and gelatinizes, when heated in hydrochloric acid. Slender fragments of allanite will fuse and intumesce, or swell up, easily when held in a sufficiently hot flame; the intumescence of the mineral is remarkable and one of the best single distinguishing characteristics.

Types of Deposits

Including minor occurrences, uranium has been found in almost all the more common types of deposits that are characteristic of metals in general. At least minor examples of almost all these have been found in Canada. The number of types from which uranium is produced, both in the world as a whole and in Canada, is much smaller. Canadian uranium ores are of three broad classes: the most productive now being uraniferous conglomerate, and the others being pitchblende-bearing veins, stringer-systems and disseminations, and pegmatitic granite. Thorium occurs in much the same types of deposits as uranium; in fact, most classes of uranium deposits contain at least some thorium, the distinction being mainly a matter of degree rather than of types. There is, however, an important exception; pitchblende deposits do not contain significant amounts of thorium.

A classification is a necessary aid to description and arrangement of data, but no classification is entirely satisfactory or final. The producing deposits can be classified according to their importance, but the possible future importance of some nonproductive ones is uncertain; in any case, a classification of this kind would not be appropriate for geological discussion. The deposits can be classified according to their contained minerals, but several different types contain the same minerals. They can be grouped according to their form—that is, whether they occur as veins, disseminations, sedimentary beds, etc.—but such groupings fail to take into consideration several other important characteristics. Deposits can be classed according to the kinds of host rocks in which they occur, but excepting the conglomerates, deposits otherwise similar occur in such a wide variety of rocks that such a system does not seem well suited to Canadian purposes. The writers consider, therefore, that a classification based primarily on origin—that is, a genetic classification—provides the best treatment for the present discussion and for the needs of Canadian prospectors and geologists.

Table VIII

Genetic Classification of Canadian Radioactive Deposits

	Types		Characteristic Elements	Characteristic Uraniferous Minerals	Other Characteristic Minerals
IGNEOUS AND RELATED TYPES	Granite, Syenite (including pegmatitic facies)		Th U Zr Si (Ce Fe P F)	Uraninite, uranothorite, thorite, zircon, monazite	Magnetite, sphene, allanite, fluorite
	Pegmatite		U Th Nb Ta (Zr Si Ce P Fe F Ti Mo C)	Uraninite, pyrochlore, betafite, euxenite, samarskite, thucholite, brannerite	Molybdenite, biotite, magnetite, allanite
	Metasomatic	General	U Th Ce P Si (F Mo Fe S)	Uraninite, thorianite, thorite, monazite, rare-earth silicates	Biotite, apatite, pyrite, fluorite, molybdenite, magnetite
		Fenites	U Th Nb (Ta Ce P F Ti Fe S)	Pyrochlore, betafite, perovskite	Calcite, soda pyroxene and amphibole, apatite, biotite, magnetite
	Hydrothermal	With simple mineral associations	U C Fe	Pitchblende, 'thucholite'	Hematite, quartz, calcite
		With complex mineral associations	U C Fe (Cu Co Pb Se V Ni As Au Pt)	Pitchblende, 'thucholite'	Hematite, quartz, calcite, chlorite, chalcopyrite, galena, pyrite, arsenides, selenides, nolanite

SEDIMENTARY	Placer	Th U Ce P Zr Fe (Nb Ta Ti W Sn)	Monazite, uraninite, pyrochlore, zircon	Magnetite, garnet, ilmenite, pyrite, etc.
	Conglomerate	U Th Ti Ce P Fe (Cr Zr C)	Brannerite, uraninite, monazite, uranothorite, zircon	Pyrite, anatase, chromite, traces of common sulphides, hydrocarbon, etc.
	Sandstone	U Ca P	Autunite, phosphuranylite	Hematite
	Dolomite	Th U Fe	Monazite	Hematite, zircon
	Phosphate rock[1]	U Ca P C	Unknown	Collophanite, bitumen
	Carbonaceous	U C H	Unknown	Bitumen, lignite
SUPERGENE	Cappings	Fe U Si Se V As S Al Mn (Pb Cu Co Ni)	Uranophane, liebigite, zippeite, gummite, etc.	Limonite, erythrite, malachite, etc.
	Formed by percolating water	U Si S	Uranophane, secondary (?) pitchblende, 'thucholite' (?)	Barite, gypsum

Types now in production are underlined.

[1] Only known examples in amounts below 0.05% U_3O_8 or ThO_2.

A tentative genetic classification was used in the first edition of this report, but soon required revision in the light of further research and additional uranium discoveries. A revision was made by Robinson (1958); this was revised further by Robinson and Lang (Griffith, *et al.,* 1958); and with a few additional changes is the one shown in Table VIII. This is still far from satisfactory, because several deposits are border-line cases representing deposits in a succession that blends from one fairly distinct type into another fairly distinct one, instead of being divisible into sharply defined categories. For example, some deposits have all the characteristics of pegmatites except that their average grain-size is smaller than that of rocks strictly classable as pegmatites; petrographically these rocks are granites or syenites, or pegmatitic granites or syenites, but in form and mineral associations they are more closely related to pegmatites than to large bodies of granite or syenite. Again, certain deposits apparently formed at fairly high temperatures have most of the characteristics of veins, but partly resemble pegmatite in appearance and mineralogy. Another serious disadvantage is that the origins of certain types, most notable the conglomeratic, are not yet fully known. Problems of origin are outlined in the discussions of various types.

Most of the principal divisions of the classification are arranged as nearly as possible in descending order of temperature of formation, beginning with granitic deposits, which are formed at high temperatures, and ending with supergene deposits, which are products of alteration by surface waters. Regardless of whether large bodies of acid igneous rocks are derived from magma in the classical sense, or from deep-seated alteration of crustal rocks, they appear to be the first stages in cycles that include most of the various types of deposits. Most of the uranium and thorium in an acid 'magma' appear to remain uncrystallized during the main stages of rock formation and to be expelled later to form pegmatites, veins and other deposits, successive fractions containing increasing amounts of uranium (Everhart, 1958). Some uranium and thorium, however, crystallize in accessory minerals in granitic rocks. Everhart (op. cit.) pointed out that Machin and others have suggested in a personal communication that "at least some of the uranium in the Miocene magmas of the Great Basin of the western USA may have been incorporated into rock-forming and accessory minerals *early* in the process of crystallization and released into interstitial fluid of the rocks by endomorphic alteration late in the consolidation process. This implies that uranium may be released from a magma in both early and late stages during its consolidation, and thus any fraction may contain uranium concentrations."

Certain types are included for completeness although the only known Canadian examples contain uranium or thorium in amounts far below the quantity of 0.05 per cent, which is, in this country, usually considered to represent an occurrence.

Granitic Deposits

Plutonic rocks. Large bodies of granitic rocks in the earth's crust as a whole have long been known to contain small amounts of uranium and thorium, and allanite, uraninite and a few other radioactive minerals have been described as accessory minerals in them. Uranium and thorium also occur as substitutes for other elements in the crystal lattices of minerals that do not contain uranium or thorium as essential constituents. The elements may also be deposited in the interstices between mineral grains in igneous rocks in quantities too small to be detected microscopically. Uraninite has not been reported as an accessory constituent of Canadian examples of undoubtedly plutonic granitic rocks, although it occurs in special classes of granitic rocks. This lack of information on uraninite may be partly because most attention has of necessity been devoted to richer kinds of deposits, and probably also because the opaque characteristics of most radioactive minerals render them difficult to detect during ordinary microscopic studies; autoradiographs, or mineral separations on bulk samples, or both are required for thorough investigations.

The emphasis placed on richer deposits has also limited greatly the amount of analytical data on the uranium and thorium contents of Canadian plutonic rocks. Studies of radioactivity by ordinary methods are inconclusive because radioactivity may be caused by the potassium in feldspar as well as by uranium or thorium, therefore, further tests are necessary to indicate the source of radioactivity.

Slack (1949) studied the radioactivity of the Round Lake, Elzevir, and Cheddar batholiths in Ontario and the Bourlamaque batholith in Quebec. He found that the central parts of all four showed least radioactivity, and that the rims or parts of the rims were most radioactive.

In a study of the Preissac-Lacorne batholith, Dawson (*in preparation*) found that the mean uranium content did not vary greatly from the abundance values of Rankama and Sahama (1950) for igneous rocks as a whole. He found that concentrations of uranium are distributed irregularly, with highs of up to 10 parts per million; that there is no evidence of concentration in peripheral zones; that there is a slight increase from intermediate to acidic facies; and that the Preissac and La Motte massifs are more homogeneous than the Lacorne.

In connection with a study of North American igneous rocks Senftle and Keevil made analyses on four composite samples from about nine hundred localities in Canada, the results being tabulated in Table IX. This was an interesting and stimulating study, but the following points should be noted: (1) the number of localities from which samples were obtained is relatively small in proportion to the large regions involved; (2) the specimens tested may have included some from dykes or other non-plutonic bodies; and (3) although the thorium analyses were made by the thoron-line method, which is believed to be the most reliable, the uranium contents were calculated from analyses for radium. This could permit inaccuracies if the precautions taken to account for disequilibrium (*see* p. 17) were not entirely effective (the fluorimetric method of uranium analysis has since been considered most suitable for low-grade samples).

Table IX

Analyses of Certain Canadian Igneous Rocks

(after Senftle and Keevil)

Region	Rocks	No. of Localities	Uranium (ppm)	Thorium (ppm)	Th/U Ratio
Ont. and Que.	Acid	396	2.90	8.89	3.06
Labrador, Maritime Provinces, etc.	Acid	123	4.98	19.8	3.98
Alta., Sask., Man., Yukon, N.W.T.	Acid	126	4.68	11.2	2.40
B.C., and Alaska Panhandle	Acid	92	3.52	12.2	3.47
Ont. and Que.	Intermediate	72	2.09	7.95	3.81
Labrador, Maritime Provinces, etc.	Intermediate	31	3.80	8.86	2.33
Alta., Sask., Man., Yukon, N.W.T.	Intermediate	23	3.70	12.9	3.50
B.C., and Alaska Panhandle	Intermediate	49	2.56	7.42	2.90

In connection with the origin of uranium deposits at Blind River, Roscoe and Steacy (1958) collected and studied thirty-two samples of granites and granitoid rocks. Twenty samples were found to contain zircon in amounts up to 0.1 per cent by weight. Allanite was present in five samples in amounts up to 0.3 per cent. Four samples contained up to 0.06 per cent monazite. One sample contained 0.1 per cent thorite. Uranium and thorium determinations were made on twenty-seven of the samples, uranium being determined fluorimetrically and thorium by the thoron-line method. These determinations showed ranges of 0.0003 to 0.0030 per cent U_3O_8, and 0.0005 to 0.0095 per cent ThO_2. By plotting the results graphically the mean averages were estimated to be 0.0008 per cent U_3O_8, and 0.0022 per cent ThO_2. The ThO_2-to-U_3O_8 ratios of the twenty-six samples ranged from 0.6 to 5.0, two-thirds of the ratios being between 2.0 and 4.0; the mean ratio was estimated to be 2.8. In contrast to the uranium and thorium contents, this mean ratio is somewhat lower than the ratio for granitic rocks as a whole; it may indicate deuteric emplacement of uranium and that lower-than-normal ratios may be expected within uranium provinces; or it may indicate that there is a preferential enrichment of uranium in deeper parts of plutonic masses.

As a result of studies of pegmatitic deposits in the Parry Sound area, Ontario, Ellsworth became interested in the radioactivity of a body of granite on and near lot 7, concession X, Conger township. The granite is red, fine grained, and mainly gneissic. It contains streaks of rock that is much coarser grained but not sufficiently coarse to be regarded as pegmatite in the strict sense of the term. Preliminary studies showed that the granite possessed a fairly uniform radioactivity of 0.01 per cent U_3O_8 equivalent. Because of the unusually high activity additional samples were collected by Steacy. A radiometric assay on a 100-pound grab sample indicated 0.010 per cent U_3O_8 equivalent. Radiometric assays on separate samples showed the gneissic rock to be more radioactive than its coarser grained inclusions.

More detailed analyses showed that the gneiss contained 0.0063 per cent U_3O_8 and 0.0042 per cent ThO_2. In the outcrops examined the granite contains a pegmatite dyke that was once worked for feldspar and that contained local, but small, concentrations of radioactive minerals. At one end of this dyke the granite is only slightly gneissoid. A representative sample of this showed 0.0037 per cent U_3O_8 and 0.0040 per cent ThO_2. It is interesting to note that although the thorium contents of both types of this granite are almost identical, the uranium content of the rock adjacent to the dyke is roughly one half that of the gneissoid material taken at a distance of about 75 feet from the dyke. A test showed that 70 per cent of the radioactivity was lost after leaching with hydrochloric acid, suggesting that at least most of the uranium is not in refractory minerals but in soluble minerals or films on mineral grains. Nearby pegmatites contain uraninite, euxenite and probable monazite, but radioactive minerals have not yet been isolated from granitic samples.

A study of a sample from a body of red, fairly fine grained granite near Essonville, some 20 miles west of Bancroft, Ontario, was made by Brown and Silver (1955). The total uranium content of the sample was 2.74 parts per million. Most of the uranium was in zircon, an intermediate amount was in titanite (sphene) and apatite, and very small amounts were found in magnetite, perthite, plagioclase and quartz.

'Pegmatitic' granites and syenites. Several radioactive deposits have some of the characteristics of granitic rocks and some of the characteristics of pegmatites. They have the forms—dykes, sills, lenses and irregular masses—of pegmatites, and their radioactive and associated minerals can be matched by those of definite pegmatites. Their average grain size is, however, smaller than that of typical pegmatites, which, the writers believe, can be considered to be an inch or more. On the basis of grain size, Robinson and Hewitt (1958) classed several deposits in the Bancroft area, including those of the producing mines, as granites and syenites. The writers concur with this, but because the deposits are so much like pegmatites except for their grain size and are so different in form from large plutonic masses, they are here called 'pegmatitic' granites and syenites. The main characteristics of the principal deposits of this kind in Bancroft area are: only certain deposits that have average uranium contents of about 0.1 per cent U_3O_8 have thus far been considered economic; commonly several bodies are sufficiently close to one another to form parts of a single mining operation; the bodies are mostly lenticular and irregular; they are not zoned in the technical sense; most are granites but some are syenites; soda feldspar is generally more abundant than potash feldspar; most bodies contain ore shoots as well as parts that are too lean to mine, in some instances rich shoots being used to bring low-grade material up to an economic average; the richest shoots contain relatively much pyroxene, magnetite and biotite; the principal radioactive minerals are uraninite and uranothorite, others being allanite, betafite, zircon and fergusonite. Some deposits or parts of deposits appear to be typical fracture fillings, whereas others show evidence of replacement of wall-rocks or earlier granitic phases, and some deposits contain patches that resemble metasomatic deposits more than pegmatites or granites. The deposits are described more fully in Part III.

Other examples of these deposits occur in Saskatchewan, where some of the bodies usually called pegmatites and migmatites are, strictly speaking, coarse-grained granites. Uraninite-bearing deposits of this kind are fairly common in the Charlebois Lake area, occurring along contacts between granite-gneiss and meta-sedimentary rocks. They have not been productive, but are described briefly in Part III.

A few of the deposits listed as pegmatitic in Part IV are probably granites, and vice versa, as the distinction is arbitrary and, also, because some deposits are not known in sufficient detail to permit an accurate estimate of average grain size.

Pegmatites

Pegmatitic deposits containing one or more radioactive minerals are common in many parts of Canada. They are of several kinds, some of which would probably not be called pegmatites by specialists in these deposits, but which seem to be best called pegmatites for general geological purposes. They are coarsely crystallized; most are roughly tabular; they are composed of minerals that crystallize at high temperatures; and metallic minerals are relatively minor constituents.

The most typical, and probably most abundant, pegmatitic deposits are simple, unzoned granite pegmatites. These are so well known that little description is required. Many were worked for feldspar or mica during periods of favourable demand for these minerals. Radioactive minerals, if they occur at all, are commonly allanite or uraninite, generally scattered as minor accessory constituents. Although these minerals may cause radioactivity detectors to react strongly, and yield selected samples from which high assays may be obtained, no deposits of this kind have become producers of uranium, except certain of the finer grained bodies classed and described above as pegmatitic granites and syenites. Ellsworth (1922, 1932) pointed out a tendency for radioactive minerals to occur in pegmatites that were worked or investigated for their contents of mica or feldspar, whereas those of possible interest for lithium or beryllium rarely contained radioactive minerals. This generalization is still fairly applicable. Another rough generalization is that many pegmatites contain uraninite or uranothorite, or both, as the only or principal uraniferous minerals, whereas others contain complex uraniferous minerals such as euxenite, pyrochlore and fergusonite; pegmatites of the latter type carrying complex minerals are commonly zoned.

Many pegmatites consist of well-developed or partly developed zones or 'shells' having different textures or mineral contents, or both. In some the zones are clearly visible, whereas others require careful mineralogical investigations. A deposit of this kind—the Richardson—is described in Part III as an example. Another, at Drope Lake, Saskatchewan, has been described by Mawdsley (1958). It is one of a group of pegmatites and, probably, pegmatitic granites on the property of La Ronge Uranium Mines Limited which that company estimates to have a large aggregate tonnage averaging 0.083 per cent U_3O_8. Most of the uranium is in supergene minerals. Other radioactive zoned pegmatites have been described by Robinson (1955, 1958), Ford (1955), Satterly (1957), and Mawdsley (1958).

In addition to fairly typical unzoned and zoned pegmatites there are several unusual types of deposits that are difficult to classify. Some have certain characteristics of granites, metasomatic deposits, or veins, and probably represent gradations between pegmatites and one of these types. Their principal features and the reasons the writers group them under the general heading of pegmatites are outlined below, and examples of several are described briefly in Part III.

Many deposits seem best described as migmatites. They comprise interbeds of schistose or gneissic rocks and lenses or bands of pegmatite or pegmatitic granite. Some of the pegmatitic bands resemble ordinary injections, but many appear to be of metasomatic origin. Because of this uncertainty the writers have designated them as 'Charlebois type' in the tables in Part IV, because many occur in the Charlebois Lake area of Saskatchewan, including those on the Row claims which are described in Part III as examples. The writers believe that these deposits represent a 'border-line' case between pegmatitic and metasomatic deposits, and discuss them here under the general heading of pegmatites because they have many characteristics of pegmatites and are so-called in much of the literature.

Several occurrences near the East Arm of Great Slave Lake are considered to be 'intermediate' or 'basic' pegmatites because of the coarse crystallization of the dominant mineral, which is actinolite. Apatite, magnetite, calcite, fluorite and uraninite are present in minor quantities. The Rex occurrences are described in Part III as the best-exposed examples.

Several deposits in the Haliburton-Bancroft region of Ontario have been described in other reports, including the first edition of this one, as calcite pegmatites and calcite-fluorite pegmatites. Ellsworth (1932, p. 216) suggested two theories to account for the abundance of calcite: one, that ordinary pegmatitic solutions reacted with limestone country rock and dissolved more calcium carbonate than could be assimilated by chemical combination, so that calcite crystallized from the excess; the other is that the calcite bodies are partly recrystallized and pegmatized inclusions of limestone. Robinson (1958) and Satterly (1957) who have studied the deposits more recently consider most to be metasomatic rather than pegmatitic, and Satterly considers some fissure fillings to be hydrothermal veins. The writers consider most to be metasomatic, and that those that are called veins or vein-dykes, such as the Cardiff described in Part III, represent 'border-line' examples between metasomatic and hydrothermal deposits.

Metasomatic Deposits

General. As already intimated, several deposits that have some of the characteristics of pegmatites, and which contain some of the same radioactive minerals as occur in pegmatites, are now considered to be of metasomatic origin. They are formed by either solutions or gases, or both, that emanate from igneous bodies and replace or react with country rocks, notably those of limy composition. The deposits so formed are commonly more irregular in shape than most pegmatites and veins, but this is not so in some instances where a definite bed or series of beds of sedimentary rock is affected. Deposits of this general class are called contact metasomatic or contact metamorphic by some writers because they commonly lie at the contact between igneous and invaded rocks. Others call them pyrometasomatic, in allusion to their high temperature of formation. The writers omit the word 'contact' because all deposits are not immediately at contacts, prefer 'metasomatic' to 'metamorphic' because the latter term usually implies re-arrangement of elements already in a rock rather than introduction of elements, and prefer 'metasomatic' to 'pyrometasomatic' because it is shorter.

Some of these deposits, particularly those that seem to be mixtures of types or border-line examples, have already been mentioned. Others are characterized by salmon-coloured calcite, sugary diopside, and commonly, by uraninite higher in thorium than is usual (Robinson, 1958); the Yates deposit described in Part III is an example containing uranothorite instead of uraninite. Still others, which commonly contain molybdenite, occur in lime-rich amphibolites (Robinson, 1958).

Fenites. Another group, termed fenites, are associated with alkaline igneous rocks that commonly form complexes of several rock types in roughly circular arrangement. The principal radioactive mineral in these deposits is pyrochlore. Some extensively explored deposits of this kind have shown large tonnages of niobium-bearing material with a smaller content of uranium; none is yet in full production but a pilot plant has been operated in connection with the Beaucage near North Bay, Ontario. The deposit of Quebec Columbium Limited near Oka, Quebec, is described as an example in Part III.

Hydrothermal Deposits

The term 'hydrothermal' seems the most appropriate one to apply to the large class of vein and disseminated uranium deposits that are believed to have been formed by hot solutions at temperatures usually, if not always, lower than those at which pegmatitic and metasomatic deposits were formed. By derivation, the term implies only 'hot waters'. Certain difficulties arise in using the term, however, because in its classical sense it implies that the solutions and their dissolved metals emanated directly from a primary magma. Modern theories require that other possibilities be considered. Magmas may be formed from crustal rocks by processes of granitization; thus there may be cycles in which metals are eroded from early mineral deposits, transported to sedimentary basins, consolidated with the enclosing sediments into crustal rocks, and these converted into igneous rocks. It seems possible that, in modified cycles, metals contained in crustal rocks are not incorporated in magmas during processes of granitization, but are dissolved from crustal rocks, transported, and deposited as veins or disseminations by hydrothermal solutions or other agencies derived from the process of granitization. Another possibility is that surface waters percolating through crustal rocks leach metals from them, are heated by proximity to molten or cooling igneous bodies, and deposit veins and disseminations. These theories, although imperfectly developed, may help to acount for the fact that, in the principal pitchblende-bearing areas of Canada, it has been impossible to relate the deposits genetically to any exposed bodies of granitic rocks. According to the classical concept, in such cases the parent granitic bodies are assumed to lie at depths not yet exposed by erosion. If the uranium in the present pitchblende deposits was re-cycled by a process only remotely connected with igneous processes, the lack of exposed related igneous rocks may be accounted for more readily. In any event, most or all the deposits here classed as hydrothermal seem to be related at least remotely to igneous processes and to have been deposited by hot solutions.

Uraninite-bearing veins. A few vein deposits in central British Columbia appear to belong to the hypothermal (high-temperature) class of hydrothermal deposits (Stevenson, 1951). Parts of the veins, however, contain pegmatitic material, suggesting that the deposits either represent 'border-line' cases between pegmatites and hydrothermal deposits, or are 'telescoped' deposits formed partly under pegmatitic conditions and partly at lower temperatures. The deposits are characterized by the presence of crystalline uraninite, monazite, and allanite, together with cobalt-nickel sulpharsenides, molybdenite and other metallic minerals, and by hornblende as a gangue mineral.

Pitchblende-bearing veins, disseminations, etc. Veins, stringers, lenses, pods, stockworks, breccia-fillings, disseminations and combinations of these forms, all containing pitchblende, are numerous. Many of the disseminations seem to have been formed by the filling of open spaces in crushed or brecciated rock, but some may have resulted from replacement. Most deposits appear to have been formed under mesothermal (medium-temperature) or epithermal (low-temperature) conditions, but Robinson (1955, pp. 97-100) presented evidence that some of the early pitchblende in Beaverlodge area may have been deposited at temperatures as high as 500°C. Many deposits were evidently formed at successive stages, in part by solution and redeposition of earlier pitchblende. Some 'sooty' pitchblende may be supergene.

Excepting thucholite and related hydrocarbon materials which are not strictly minerals and which occur relatively scarcely, pitchblende is the only primary radioactive mineral in these deposits. With respect to associated metalliferous minerals the deposits are divisible into two broad groups which, although not completely separate, constitute a useful distinction. In most pitchblende deposits hematite is the only other abundant metalliferous mineral (it appears to be completely lacking in a few deposits). Such deposits commonly contain occasional grains or masses of sulphide or selenide minerals. The other class comprises very complex mineral associations, including, as well as hematite, abundant cobalt-nickel sulpharsenides, and, in some deposits, native silver, selenides, vanadium minerals, gold and platinum. The complex type is rarer than the simple type, and is best represented by the veins of the Eldorado and Nicholson mines. In most deposits of both simple and complex types the principal gangue minerals are quartz, carbonates, or chlorite, all three not occurring in all deposits.

The so-called 'giant quartz veins' common in parts of the Northwest Territories are an interesting and unusual variety of the simpler mineralogical type. They are large stock-works composed of quartz stringers and silicified wall-rocks, commonly occupying major fault zones and being traceable for miles. Some can be seen readily from the air or on air photographs because of their resistance to erosion and their light colour. Some appear to be barren of radioactive minerals, and others contain scattered streaks and pods of pitchblende and hematite. The Rayrock mine (*see* p. 193) is related to one of these deposits.

Recent Placers

It is, perhaps, inconsistent to begin the discussion of sedimentary deposits and those possibly of sedimentary origin with unconsolidated placers of Recent age instead of with deposits in consolidated rocks, but certain matters that pertain to the latter can best be explained by first describing Recent placers.

Radioactive minerals have been found in several stream placers in British Columbia and Yukon Territory, and in some instances the lodes or rocks from which the minerals were eroded and deposited in sand or gravel are evident. Pyrochlore, allanite and monazite are the most common radioactive minerals. To date, only one group of placers, at and near Bugaboo Creek, British Columbia, are known to have been investigated as possible commercial sources of radiocative minerals; these were explored as possible sources of niobium and, perhaps, of other metals as by-products. Radioactive minerals reported are: a member of the pyrochlore-microlite series, a member of the euxenite-polycrase series, allanite, uraninite and uranothorite. The deposits are described further on page 198.

Uraninite is commonly considered to be a rare constituent of placers because of its brittleness and solubility, but the following evidence indicates that it may not be as rare as hitherto supposed. Another occurrence, at Nation River, British Columbia, has been reported by Steacy (1953) from concentrates sent to the Geological Survey. An attempt made to find this occurrence for further investigation failed as the prospector who sent the sample had left the country. Steacy recently separated a few microscopic, euhedral grains that gave a spotty UO_2 pattern by X-ray tests, from concentrate collected by R. W. Boyle of the Geological Survey from the Barker Placer on Haggart Creek in Yukon Territory. A recent study by Koen (1958) on the attrition of uraninite in a laboratory mill showed that after grains were worn to small size little further attrition took place.This suggests that the common failure to find uraninite in placer concentrates may be due partly to its presence in fine rather than in coarse fractions. The study by Koen also showed that uraninite is slightly more resistant to dissemination than monazite. This suggests that, apart from grain size, the scarcity of uraninite in placers is more a matter of solubility than brittleness.

A small low-grade thorium placer probably containing monazite was found at the shore of Yamba Lake, Northwest Territories, where wave action has concentrated material from an esker. It is described further on page 211.

Conglomeratic Deposits

Precambrian conglomerates containing uranium and thorium in the Blind River area are now Canada's principal uranium ores. Associated with the conglomerate in a general way are smaller amounts of quartzite and other rocks containing uranium and thorium minerals. The ore conglomerates contain tightly packed, moderately rounded quartz pebbles in an arkosic matrix in which pyrite is abundantly disseminated. These rocks lie on, or short distances above, a prominent erosion surface which distinguishes early and late Precambrian times. The matrix of the ore conglomerate contains relatively small amounts of brannerite, uraninite and monazite, almost always in grains of microscopic sizes, and several other minerals of apparently minor economic significance which are listed in the more detailed description of the deposits in Part III. The ores average about 0.1 per cent U_3O_8 and about 0.05 per cent ThO_2. Many other beds and lenses of similar conglomerate in the area contain smaller amounts of uranium and thorium, and some beds low in uranium appear from preliminary sampling to contain as much as 0.1 per cent ThO_2.

Evidence regarding the origin of the conglomeratic ores is conflicting. The hypotheses put forward by different geologists and mineralogists are, briefly: (1) that the ores are simply ancient placers derived from the erosion of earlier Precambrian terrain and subsequently lithified; (2) that the ores went through an alluvial (placer) stage but were later modified by diagenetic processes that did not greatly affect the bulk composition of the placers; (3) that the ores are entirely epigenetic, all the uranium and other metals having been introduced by hydrothermal solutions or some other metallizing process; and (4) that the ores resulted partly from alluvial processes but were much modified, probably with introduction of certain metals as well as sulphur, and that these changes were caused hydrothermally or by some other process.

Superficially it would appear that the theories of origin outlined above would be easy to prove or disprove, but many factors that seem to indicate sedimentary origin can be used also to point to sedimentary features that would favour the entry of mineralizing solutions and resulting crystallization of epigenetic minerals. These problems are by no means restricted to the Blind River ores. They have been debated for a much longer time in connection with the gold-uranium conglomeratic ores of the Witwatersrand in South Africa, which are analogous in many respects, the main differences being that the latter are essentially gold ores, from which uranium is recovered as a by-product, and that they contain uraninite but not brannerite.

The writers are not specialists on the origin of the Blind River deposits, although Steacy has done much laboratory work in connection with a special field and laboratory study undertaken by S. M. Roscoe of the Geological Survey. All that is attempted here is to record the following list of what appear to the writers to be the main factors respecting syngenetic and epigenetic origins, and combinations thereof, and to state their present opinions regarding the most plausible explanations.

Factors suggesting syngenetic detrital origin. 1. The ores are unquestionably related to sedimentary features. The most notable of these features is the conglomerate itself, which strengthens the concept of detrital origin.

2. Most of the mine geologists, who are able to study the deposits as they are developed day by day and whose opinions must therefore be respected, believe in detrital or modified detrital origin and say that successful mine geology requires a detrital outlook.

3. Many of the minerals in the conglomeratic matrix are heavy or resistant minerals (or both) occurring in rounded or subrounded grains. Many of these minerals are typical constituents of Recent placers.

4. The deposits are on or close to a widespread erosional surface. Samples from rocks beneath this surface show small contents of uranium and thorium.

5. ThO_2/U_3O_8 ratios of samples from basement rocks and overlying conglomerates are more or less comparable. The ratios are considerably lower than ratios for the earth's crust as a whole, thus suggesting a genetic relationship between the basement rocks and the conglomerates.

6. The uraninite is of the variety high in thorium and rare earths, typical of granitic and pegmatitic deposits, not the pitchblende variety typical of hydrothermal deposits.

7. Virtually no signs of macroscopic veins or replacement by quartz or metalliferous minerals have been found.

8. Little sign of the red alteration typical of Canadian hydrothermal uranium deposits has been reported from outcrops, drill-cores, or underground workings. This factor is not entirely cogent because red alteration is much less noticeable in the Theano Point pitchblende area some 100 miles to the northwest than in the pitchblende areas of Saskatchewan and the Northwest Territories.

9. Monazite and thorite have been found both in basement rocks and in conglomerates. Although monazite is reported to occur with pitchblende in the Belgian Congo, it and thorite are characteristic of granitic and pegmatitic rocks; they are fairly heavy and resistant.

Factors suggesting epigenetic or modified detrital origin. 1. Pyrite seems to be present in much larger quantities than in Recent gold-bearing and other placers, and it is relatively unoxidized. It is characteristic of many epigenetic deposits. However, some of the pyrite occurs as rounded grains.

2. Magnetite is virtually absent, whereas it is abundant in most Recent placers. The absence of magnetite seems to be more contradictory of a detrital origin than is the abundance of pyrite.

3. The Blind River area lies between the great epigenetic sulphide deposits of the Sudbury area, and formerly large although less important epigenetic copper deposits at Bruce Mines. Many smaller epigenetic deposits lie in the intervening terrane, which includes a zone of prominent faults. The Blind River deposits are thus situated so that hydrothermal or other epigenetic origins are plausible geographically.

4. Uraninite is fairly brittle and soluble and has seldom been reported from placers. Three occurrences in Recent placers in Western Canada have, however, been reported. Furthermore, a recent study mentioned above in connection with unconsolidated placers suggests that fine-grained uraninite is more resistant than monazite to attrition.

5. Uraninite and brannerite have not been found in samples from basement rocks. The sampling of basement rocks, however, has not been exhaustive. The source may have been farther from the site of the ores, and was undoubtedly at horizons that were reduced by erosion.

6. Factors that suggest sedimentary deposition of ore minerals can also be considered favourable for epigenetic mineralization. Roscoe and Steacy (1958) stated, however, that sharp, very large, contrasts in uranium content cannot be correlated with large differences in permeability.

7. In at least one specimen a veinlet of pyrite cuts a quartz pebble. This is not a vital factor because it could be an accidental veinlet unrelated to the pyrite of the matrix; or it could be formed by subsequent migration and recrystallization from matrix pyrite.

Tentatively, the writers consider that the factors outlined above suggest deposits that were in part detrital but which later underwent considerable changes. They believe that the main problems are the amount of these changes, and whether they involved only rearrangement of elements within the sediments or included introduction of elements. It appears almost certain that magnetite was converted to pyrite, but this could have been by processes of low-grade regional metamorphism (Roscoe and Steacy, 1958) rather than by hydrothermal action. Most or all of the thorium seems most plausibly explained by detrital origin. All the uranium may have been contributed to the sediments in detrital mineral grains which have not since been altered or which may have been partly recrystallized. On the other hand, some or most of the uranium may have been introduced hydrothermally, or uranium may have been carried into the sedimentary basin as impurities in other minerals, or in solution in surface waters and later been deposited as films on mineral grains; subsequent metamorphism or hydrothermal action would then be postulated to have transported the uranium slightly and crystallized it as uraninite or brannerite, or both. 'Brannerite' shows evidence, as mentioned in the section on mineralogy, of being a mixture of two minerals, but such mixtures could have been deposited detritally. The writers are not so favourable to the suggestions as to the need for transforming magnetite to pyrite, but believe that serious consideration should be given to them because some uraninite is fairly sharply crystalline rather than rounded.

Deposits in Sandstone

Deposits comparable to the important deposits in sandstone characteristic of the Colorado Plateau region in the United States have not yet been found in Canada. A deposit in sandstone, containing autunite and phosphuranylite at Middle Lake, Saskatchewan is of this general type. It is uncertain whether this deposit is syngenetic, epigenetic, or supergene. Robinson (1958) suggested that it may have been formed by deposition in sand before its consolidation.

Several radioactive occurrences associated with carbonaceous material in sandstone are mentioned below.

Deposits in Dolomite

A few low-grade deposits near the south shore of Great Slave Lake, Northwest Territories, contain a little fine-grained monazite and uraninite (or pitchblende). It is uncertain whether these deposits are of syngenetic or epigenetic origin. Their association with structures that appear to be algal suggests that they may be of biogenic origin. On the other hand, a pitchblende vein deposit and several occurrences described above as pegmatites of intermediate composition have been found in the same area, therefore it is not unreasonable to conjecture that the radioactive minerals were introduced into the dolomite epigenetically. The largest known occurrence, the McLean Bay, is described on page 201.

Phosphate Rocks

Although phosphate rocks of Jurassic age, more or less comparable to those mined for uranium in the northwestern United States, occur in the Fernie formation of the Canadian Rocky Mountains, virtually no uranium has been found in them. Only brief reconnaissance investigations have been made on uranium deposits of this kind in Canada, however, because of the low grade of the deposits in the United States. A few samples taken by Lang from the Fernie area showed up to 0.005 per cent U_3O_8 equivalent, and up to 0.0045 per cent U_3O_8 by fluorimetric analysis. Robinson (1958) found that the radioactivity is associated with collophanite.

Carbonaceous Deposits

A few small or low-grade occurrences of uranium associated with carbonaceous material found in Canada are briefly described below. It may be of interest to note incidentally that preliminary tests on certain drill-cores from the Athabasca tar sands showed no significant radioactivity, and that twenty of twenty-one samples showed traces to 0.002 per cent U_3O_8 equivalent, which is within the range of activities found for common rocks and sands. One sample, supplied by A. W. Norris of the Geological Survey, showed 0.0043 per cent U_3O_8 equivalent; the ash of its extracted oil showed 0.07 per cent U_3O_8 equivalent, but this represented an activity of only 0.00002 per cent in the tar sand sample itself. A heavy mineral concentrate made from the sample was found to contain some grains of monazite. This preliminary sampling is, however, not exhaustive.

Marine shales. Radioactive logs of wells drilled for oil and gas in the Great Plains show black carbonaceous shale of the Exshaw formation to be the most radioactive rock, but it is only slightly radioactive. From samples collected by Lang, from several occurrences of such shales in Alberta and British Columbia, the highest assays obtained by fluorimetric analyses were 0.0070 per cent U_3O_8 for a sample from the Banff formation, and 0.0047 per cent U_3O_8 for a sample from the Exshaw. Five samples from the Exshaw showed up to 0.005 per cent U_3O_8 equivalent (Haites, 1959).

Radioactive nodules in shale. Small weakly radioactive nodules were found by T. L. Tanton in specimens of mudstone and shale he collected from the Sibley series, considered to be of late Precambrian age, near Nipigon, Ontario (Tanton, 1948). The radioactivity, which was detected by means of autoradiographs, is concentrated in small black spots at the core of the nodules. The writers understand that uranium was detected chemically but that because of the slight amount no quantitative tests were made. The nodules are similar in some respects to radioactive, vanadiferous nodules in Permian red clay near Budleigh Salterton, Devon, described by Carter (1931) and Perutz (1939).

Coal and lignite. Many deposits of coal and lignite in various parts of Canada were tested with a scintillation counter by B.A. Latour of the Geological Survey. Radiometric assays on the ash from 355 samples from the most radioactive localities gave the following results:

Number of samples	*Per cent U_3O_8 equivalent (beta)*
107	0.001 or less
139	0.002
66	0.003
27	0.004
8	0.005
2	0.006
4	0.007
2	0.008

Some of the radioactivity of the samples mentioned above may be caused by potassium or thorium. However, the fact that much of it is due to uranium is shown by the following results of fluorimetric analyses for uranium made on five of the samples, which were from seams in Alberta and Saskatchewan:

Per cent U_3O_8 equivalent	*Per cent U_3O_8*
0.007	0.008
0.007	0.006
0.006	0.004
0.005	0.001
0.005	0.001

A sample of ash from a coal seam in the Eastend area of Saskatchewan, sent to the Geological Survey by the Saskatchewan Department of Mineral Resources, showed 0.057 per cent U_3O_8 equivalent. As a result of further tests it was concluded that most of the radioactivity of this sample was caused by uranium.

Hydrocarbon in fault zones. Uranium-bearing hydrocarbon occupies fault zones at the Hampton property in New Brunswick (Gross, 1957, pp. 6, 12-14). The hydrocarbon is believed to have migrated from oil shale of the nearby Albert formation. Analyses show the presence of uranium in fairly pure hydrocarbon, but no uranium mineral could be isolated. The source of the uranium is not clearly evident, but it may have been leached by ground water from sedimentary rocks and have been precipitated by the hydrocarbon.

Hydrocarbon in felsite dykes. Very finely disseminated pitchblende or uraninite has been found in specks and veinlets along the borders of felsite dykes cutting black carbonaceous slate and argillite, at Coxs Brook, New Brunswick (Gross, 1957, pp. 4, 6, 11). Gross stated that the hydrocarbon was probably derived from the slate during cooling of the dykes, but that the dykes are believed to be the source of the uranium. A somewhat similar occurrence was found in the same general region at the contact of a quartz-feldspar porphyry dyke with black slate (Gross, 1957, p. 10).

Deposits associated with fossil carbon in sandstone. Occurrences of uranium associated with fragments of fossil wood and 'trash pockets' in carboniferous sandstone have been found at Shippigan Island, New Brunswick, and Black Brook, Nova Scotia (Gross, 1957, pp. 6, 17-21). In places, the uranium is associated with chalcocite, pyrite, and hematite or malachite in the woody material. A little uraninite or pitchblende associated with hematite was isolated in material from Shippigan Island. No uranium mineral could be isolated in specimens from Black Brook and it is thought that the uranium may be present in the ionic state instead of as a distinct mineral. The copper and uranium are believed to have been precipitated from circulating ground water.

Supergene Deposits

The outcrops of most Canadian uranium deposits contain cappings of supergene (secondary) minerals, but these rarely extend to significant depths. This is probably because the fairly cold climate retarded supergene action and because glaciation removed some supergene accumulations. The supergene minerals are, therefore, rarely separate deposits but are surface and near-surface phases of primary deposits. They are commonly important as guides in prospecting because of the bright yellow, orange, and green colours of the supergene minerals, but as a rule do not occur in large quantities. The most common Canadian supergene uranium mineral is uranophane. Supergene thorium minerals are rare.

Exceptions to the above statement are the Gunnar and Fish Hook Bay deposits in Beaverlodge area, Saskatchewan, where large amounts of uranophane as well as some sooty pitchblende persist to depths of a few hundred feet. This unusual mode of occurrence, so far as Canadian deposits are concerned, is evidently caused by movement of artesian surface water through porous rocks and mineral deposits. The Gunnar deposit is described on page 158.

A few deposits comprise supergene minerals transported laterally from their primary sources. Examples of this kind that have misled prospectors have been found in the Northwest Territories and Saskatchewan. They comprise thin films of yellow minerals on smooth glaciated outcrops that appear to have been painted yellow. Uranium has evidently been leached from lean occurrences by rain water or meltwater which has then stood in ponds long enough for the contained uranium to crystallize out. The deposits are spectacular, and because of their lateral extent they cause strong reactions on radioactivity detectors, but the rock beneath is barren or only slightly radioactive. A larger transported supergene deposit on the Bolger claims at Beaverlodge is described on page 198.

Very low-grade supergene uranium occurrences, associated with chalcocite, in carbonized plant fragments in the Pictou formation of Nova Scotia are described by Brummer (1958).

Radioactive Springs and Related Deposits

A type of radioactive deposit that apparently contains little or no uranium or thorium is exemplified by several springs in various parts of Canada, and by tufa deposited around some of them. Satterly and Elworthy (1917) reported that water from several springs contained a little radon and that some contained a little radium, but not in amounts likely to be recoverable commercially. They attributed the presence of these elements to solution of small amounts of radium contained in common rocks. The writers are indebted to S. S. Holland of the British Columbia Department of Mines for informing them that at the Liard hot springs in northeastern British Columbia high counts were obtained at the springs themselves, from pannings from several of the pools, and from tufa deposited around them. A specimen of tufa tested by the Geological Survey was fairly radioactive but X-ray fluorescence analyses showed no uranium or thorium; special radiometric tests indicated that the radioactivity was probably due mainly to the radium group of elements. These springs are in the Liard Plateau and in a Provincial Reserve that is withdrawn from staking. Holland also stated that an extensive area of radioactive tufa occurs at the east side of Deer River about 5 miles north of the Liard, and that this area is not reserved. It should be noted that insignificant amounts of radium could cause high readings with radioactivity detectors, or fairly high radiometric assays.

Geochemical Associations

Elements that are geochemically associated with uranium in Canadian deposits may be roughly divided into three classes: (1) those that commonly occur as inherent constituents of uranium minerals, (2) those that may occur either as inherent constituents or as separate but closely associated minerals, and (3) those that occur only as separate but closely associated minerals. Elements of class (1) include thorium, rare earths, niobium, tantalum, zirconium and phosphorus; those of class (2) include titanium, arsenic, iron, vanadium and carbon; and those of class (3) include nickel, cobalt, silver, selenium, fluorine and molybdenum. Uranium occurs in its minerals as the simple oxide (UO_2) and as multiple oxides with niobium, tantalum or titanium, or with two or more of these elements; these oxides frequently contain significant amounts of thorium and rare earths. Uranium also occurs as hydrated silicates and oxides, and less commonly as hydrated phosphates, arsenates, sulphates, carbonates and vanadates; these are mostly free of thorium and rare earths, presumably because of the hexavalency of the uranium ion. The strongest geochemical associate of uranium is thorium (the geochemistry of these two elements has already been discussed in Part I of this report). The geochemical association of zirconium is mainly represented in zircon and its variety cyrtolite; zirconium has been reported also in some analyses of uraninites, thorianites and multiple oxides. In addition to its presence in multiple oxides, titanium minerals, such as anatase and rutile, are present in many deposits. Iron is ubiquitously associated with uranium and next to thorium it bears a stronger geochemical relationship than all other elements listed. Cobalt and nickel arsenides and silver are together associated with uranium in some pitchblende and uraninite deposits. Vanadium and selenium are represented by certain of their minerals in pitchblende deposits; also, carnotite and tyuyamunite have been reported from a few localities. Associations with fluorine and molybdenum are represented by fluorite and molybdenite, respectively. Emmons (1953) suggested that fluorine may be genetically associated with uranium. So far as is known no uranium-molybdenum minerals have been identified in Canada, although they are reported from other countries. Carbon as hydrocarbon is associated with uranium in many classes of deposits; also, as calcite or other carbonate minerals, it is common in the gangue of pitchblende deposits. A more detailed discussion of these associations is given by Robinson (1958). Elements that are associated with thorium, either as inherent constituents of radioactive minerals or as separate but closely associated minerals, include uranium, rare earths, phosphorus, niobium, tantalum, titanium, iron and carbon. Thorium is conspicuously absent in hydrothermal deposits but otherwise its associations with the elements listed are markedly similar to uranium. Thorium occurs principally as silicate, phosphate, and as multiple oxides with niobium, tantalum, and, usually, titanium; most of these carry uranium and rare earth in various amounts. Thorium occurs less commonly than uranium as the simple oxide (ThO_2). Whereas both thorium and uranium are frequently associated with rare earths, thorium appears to favour the cerium group and is therefore a common constituent of rare-earth minerals rich in cerium, such as monazite and allanite.

Mineral Associations

Studies both in the field and in the laboratory have disclosed certain characteristic associations with non-radioactive minerals, some of which may be useful guides in prospecting. Probably the most outstanding association is that of pitchblende with hematite. Hematite is associated with pitchblende in most, if not all, Canadian deposits and in many it is the most abundant metallic mineral. It may occur within a deposit as either discrete grains or intimately admixed with the pitchblende, or forming the 'red alteration' described in a later section. Other minerals associated with pitchblende have been mentioned in the discussion of hydrothermal deposits. Uraninite is associated variably with fluorite, magnetite and molybdenite, and occasionally with pyrrhotite, ilmenite, scheelite, columbite-tantalite and beryl. Associations with magnetite are fairly common in coarse-grained granites and pegmatites. In these the uraninite occurs typically as minute cubes closely associated with the magnetite masses or enveloped by the magnetite. Where fluorite is associated with uraninite, it is generally dark purple to almost black. Associations with molybdenite and, less commonly, pyrrhotite have been noted in some pyroxenites. Also, associations with molybdenite and scheelite have been noted in samples from deposits that have some of the characteristics of both hydrothermal and pegmatitic deposits. Uraninite has been identified with columbite and beryl in one pegmatite (Robinson, 1958) but this association is not common. Two associations of uraninite with common rock-forming minerals are worth recording. In one, uraninite occurs with magnetite, fluorite, and other minerals in a coarsely fibrous, dark greenish actinolite. Also, a few occurrences of high thorian uraninite occur in metasomatized zones in limestone that are typified by salmon coloured calcite, tremolite, and sugary diopside. Brannerite is associated with anatase, rutile and uraninite. Uranothorite is frequently associated in pegmatites and in coarse-grained granites with magnetite, and has been observed enclosed in crystals of allanite. The common affinity of uranium for carbon, as explained in the sections on geochemistry and mineralogy, accounts for many occurrences where uranium is related to carbonaceous material, although not forming true minerals.

Distribution of Deposits

Geographical Distribution

Although producing uranium mines are at present restricted to a few areas, occurrences of the metal are numerous and widespread. The distribution is sketched in Figure 1 and illustrated in more detail on a separate map (1045A-M1). Thorium occurrences follow much the same pattern except that this metal does not occur in significant amounts in pitchblende deposits or in areas where these are the only uranium deposits found. Canada is divided into five principal physiographical and geological regions: the Canadian Shield, the Appalachian Region, the Cordilleran Region, the Interior Plains, and the Innuitian Region—a mountainous terrain in the northern Arctic islands. Uranium occurrences in amounts of 0.05 per cent or more are known in large numbers in the Canadian Shield, and are fairly numerous in the Cordilleran and Appalachian Regions. Only the very low-grade (below 0.05 per cent) lignites and shales mentioned previously are known to occur in the Interior Plains. No occurrences have been reported from the Innuitian Region. Below, the distribution of uranium occurrences in general is discussed first, then the distributions of occurrences for which there are productive examples are described at greater length. The following explanations of the usages regarding occurrences and mining properties, although explained elsewhere, may bear repetition in this connection.

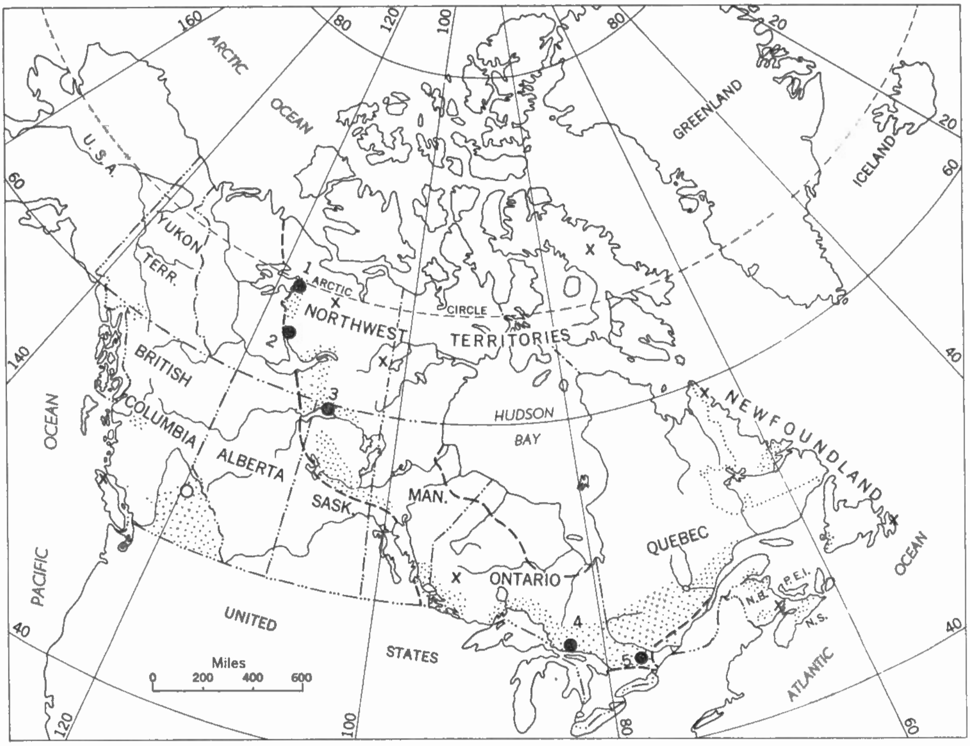

Figure 1. *Distribution of known Canadian uranium occurrences. Areas containing more than one occurrence shown by dotted pattern; isolated occurrences shown by crosses. Locations of one or more producing or previously producing mines shown by solid dots; 1, Port Radium; 2, Rayrock; 3, Beaverlodge; 4, Blind River; 5, Bancroft. A production contract has been made for Rexspar mine, shown by open circle. Boundary of Canadian Shield shown by broken line.*

Definitions and statistics. Regulations provide for the reporting of a mineral discovery containing more than 0.05 per cent by weight of uranium or thorium. This figure was decided upon by taking the mean between 0.1 per cent, about the lowest grade thought likely to be mineable, and 0.01 per cent, an amount that seemed too small for mandatory report. For the compilation of records, the Geological Survey adheres essentially to this but considers a radioactive occurrence to be any separate body from which an assay of 0.05 per cent or more of U_3O_8 or ThO_2 is obtained (because assays are usually reported as U_3O_8 or ThO_2) or from which is identified a uranium or thorium mineral that normally contains at least this amount of U_3O_8 or ThO_2. This convention is arbitrary and does not distinguish between size or importance of occurrences, but it seems the most practical one and compilations based on it are believed to be useful.

A mining property is regarded as a single claim or a group of adjoining claims held by one owner. A few unstaked occurrences are considered properties, for statistical purposes. At the end of 1957, since when there has been no significant change in the totals because of the decline in prospecting and exploration for uranium, the number of properties on which one or more radioactive occurrences had been found totalled 1,249 (*see* Table X). Of these only about fifty were reported as purely thorium properties, but a few others are probably in this class. Most, however, are entirely or mainly uranium properties and probably about 1,200 contain at least a little uranium. In some earlier publications the total of radioactive properties was estimated at about 1,500, but careful checking showed that many were reported more than once under different names.

Some properties contain hundreds of individual discoveries. The exact total cannot be calculated because it is required to report only the first discovery on a claim or group of claims and, later, to report the results of any diamond drilling, underground operations, or large-scale surface exploration. Therefore the records for some properties are more complete than for others. Another source of error is that some properties were divided and transferred to different owners, and it has been impracticable to keep track of all the individual occurrences involved. The total number of uranium occurrences found is estimated with reasonable accuracy to be about 10,000.

Canadian Shield. In 1950, 93 per cent of the properties were estimated to be in the Shield. At the end of 1957, although the number of properties had tripled, the percentage in the Shield was still 93 per cent (*see* Table XI). On the basis of individual occurrences rather than on that of properties, the proportion in the Shield is about 99 per cent, because all properties with large numbers of occurrences are there.

As pointed out in earlier publications, almost all discoveries in the Shield are in a broad peripheral belt, mainly along the western and southern margins. There has been little change in this broad pattern during the past few years despite a great increase in the number of discoveries and a great change in emphasis on certain areas. Figure 1 shows the locations of virtually all finds known. The areas containing occurrences are slightly schematic because of the scale of this and other figures. Some prospectors do not wish locations to be revealed, but almost all such locations are within general areas outlined by other occurrences. The zone in which uranium discoveries are numerous begins at the northeast corner of Great Bear Lake and extends to the north arm of Great Slave Lake. After a gap in the vicinity of Yellowknife, it resumes near the east arm of Great Slave Lake and extends southward to Lake Athabasca, where the belt widens because of numerous occurrences in the Charlebois Lake area, about 250 miles east of the border of the Shield. From a point about 150 miles south of Lake Athabasca occurrences again become numerous, particularly in the vicinities of Foster Lakes and Lac la Ronge.

Table X

Estimated Distribution of Properties by Types and by Provinces and Territories (1958)

Province or territory	Conglom-eratic		Hydro-thermal		Pegmatitic		Replace-ment		Granitic		Metaso-matic (General)		Metaso-matic (Fenites)		Dolomite, Sandstone, etc.		Placer		Totals		
		?		?		?		?		?		?		?		?		?		?	
Yukon									1								3		4		4
N.W.T.			86	6	7	3			4		2	1				2	1	2	100	14	114
B.C.			10	9	10	4		2	1	4	2	1	2	4	1		12		38	24	62
Alta.			4		13	1										1			17	2	19
Sask.			196	14	128	4	1		11	14					2	2			338	34	372
Man.				1	9	3													9	4	13
Ont.	48	8	54	13	75	7			241	2	5	11	2			2	2		427	43	470
Que.			1	2	123	24			1	1	9	5	2	3					136	35	171
N.B.				2			1								2				3	2	5
N.S.			1		1										1				3		3
Nfld.			14		2														16		16
Totals	48	8	366	47	368	46	2	2	259	21	18	18	6	7	6	7	18	2	1,091	158	1,249

Note: Columns headed (?) list occurrences for which the reports do not clearly indicate the type.

Table XI

Estimated Distribution of Properties by Types and Main Geological Regions (1958)

Region	Conglomeratic		Hydrothermal		Pegmatitic		Replacement		Granitic		Metasomatic (General)		Metasomatic (Fenites)		Dolomite, Sandstone, etc.		Placer		Totals		
		?		?		?		?		?		?		?		?		?		?	
Cordillera	....	....	10	9	10	4	....	2	2	4	2	1	2	4	1	1	16	....	43	25	68
Canadian Shield	48	8	351	36	356	42	1	....	257	17	16	17	4	3	2	6	2	2	1,037	131	1,168
Appalachian	....	....	5	2	2	....	1	....	....	....	....	....	....	....	3	....	....	....	11	2	13
Totals	48	8	366	47	368	46	2	2	259	21	18	18	6	7	6	7	18	2	1,091	158	1,249

Note: Columns headed (?) list occurrences for which the reports do not indicate the types clearly.

The belt then swings eastward, where a few occurrences have been found in the Flin Flon and Herb Lake areas in Manitoba. Several have been found near the southeast end of Lake Winnipeg, and this part of the belt continues into Ontario in the Lake of the Woods and Rainy Lake districts. A few occurrences are known near Port Arthur, and from there they are fairly numerous throughout the territory north of lakes Superior and Huron and the St. Lawrence River, as far east as Seven Islands, Quebec. In eastern Ontario and western Quebec the general belt is about 250 miles wide, extending northward from the southern boundary of the Shield to the Timiskaming and Chibougamau areas. In Labrador, several occurrences are now known in the Seal Lake and Makkovik areas, north of Goose Bay.

Cordilleran and Appalachian regions. The known occurrences in the Cordilleran region are mainly in the southern interior of British Columbia, in the part extending from the east flank of the Coast Range to the Rocky Mountain Trench. A few have been found near Hazelton and near Atlin in northern British Columbia, and in the adjacent part of Yukon Territory. One has been reported from the eastern Cordillera but its position may not be revealed.

Most of the occurrences in the Appalachian region are in New Brunswick, where a few have been found in the northern part of the province, together with one occurrence near Cross Point in Gaspé. In the southern part of New Brunswick, a few occurrences have been found at and near Harvey Mills and Hampton. A few have been found in Nova Scotia and Newfoundland.

Conglomeratic type. Productive deposits of this kind occur in a fairly small area a few miles east of the town of Blind River at the north shore of Lake Huron (*see* Figure 1). Scattered occurrences of the same general type, which have so far not been proved to be of workable size or grade, have been found in conglomerate and quartzite beds higher in the Proterozoic succession, as far west as the vicinity of Bruce Mines, and eastward in the area between the Blind River mines and Sudbury, and a few miles east of Sudbury; thus the larger area embracing occurrences as well as orebodies is about 175 miles long.

Hydrothermal type. Most of the known occurrences of veins and related types of deposits are in the northwestern part of the Shield. The most northerly concentration of such discoveries begins near the Arctic Circle and extends past Marian River almost to the north arm of Great Slave Lake. It is at the west edge of the Shield, has a maximum width of about 40 miles east of Great Bear Lake (although most occurrences are much closer to the shore of the lake), and it tapers southward in the Marian River area. Another large concentration extends along the north shore of Lake Athabasca. This area includes a few occurrences in Alberta between Fort Chipewyan and the Saskatchewan border, several thousand in the Beaverlodge region, and a few between there and Black Lake, which lies about 200 miles east of the margin of the Shield. At Beaverlodge, this belt extends northward about 30 miles. One vein occurrence is known near the east arm of Great Slave Lake, and a few have been found near Nonacho Lake between Great Slave and Athabasca Lakes. In Ontario, one pitchblende deposit has been reported from a property south of Lake Nipigon, and a little of this mineral was found on about fifty properties some 70 miles north of Sault Ste. Marie. A few occurrences of the vein type that have yielded uranium assays but for which it has been impossible to isolate a uranium mineral, have been found in the Kenora region, at Port Arthur, near New Liskeard, and at the Opemiska mine in Quebec. Several vein occurrences have been found in the Seal Lake and Makkovik areas in Labrador (Beavan, 1958).

Pegmatitic type. Pegmatites and other 'high-temperature' occurrences account for the largest number of known Canadian uranium occurrences. They have been found in many parts of the Canadian Shield and are fairly common in southern British Columbia; a few have been found in Nova Scotia and Newfoundland. Most are in a large area extending from Lake Huron through southeastern Ontario and the part of Quebec lying north of the St. Lawrence River; this area comprises a large part of the Grenville 'geological province' of the Shield. Many occurrences have been found also in the Charlebois Lake, Foster Lakes, and Lac la Ronge areas of Saskatchewan. They are fairly common close to the north shore of the east arm of Great Slave Lake, and in the area between Great Slave and Athabasca Lakes, in the Herb Lake and Bird River areas of Manitoba, in the Lake of the Woods district of Ontario, and near the north shore of Lake Superior.

Some of the radioactive minerals of the pegmatitic and related types of deposits are distributed widely; others are fairly restricted to the Grenville 'province'. Uraninite and allanite are widespread. On the other hand, the accompanying table based on a recent review of the records shows the extent to which uranothorite and certain other minerals are characteristic of the Grenville. It should be noted, however, that many of the occurrences in the Grenville contain uraninite together with one or more of the other minerals, and that others contain uraninite as the only radioactive mineral.

Table XII

Distribution of Complex Minerals, by Properties

Mineral	Total in Canada	Total in Shield	Total in Grenville
Uranothorite	69	67	53
Betafite	7	7	5
Euxenite-polycrase series	44	41	39
Fergusonite	25	22	19
Pyrochlore-microlite series	43	38	30
Samarskite and calciosamarskite	5	5	5

Discussion of Geographical Distribution

Main regions. In a broad sense, uranium has been found in the geological regions that are characterized by metal deposits in general. The Shield has been for years the principal metal producing region of the country, and almost all the remaining production has come from the Cordilleran and Appalachian regions.

The preponderance in the Shield as a whole is readily explained, as the rocks of this region represent five sixths of geological time and have been subjected to much orogeny, igneous activity and erosion. The western part of the Cordilleran region and the Appalachian region are also the sites of fairly old orogenies and of deeply eroded mountains and plutonic rocks. The eastern Cordillera represents a younger orogenic belt in which metal discoveries have been comparatively rare. The distribution of uranium discoveries in the southern part of the western Cordillera resembles the situation respecting all metals there, and may result largely from greater population and better facilities for transportation. The reason for the scarcity of uranium discoveries to the west of the eastern boundary of the Coast intrusions is uncertain but may be related to the inaccessibility of many parts of the Coast mountains.

Despite the fact that many uranium deposits contain iron, copper, cobalt, nickel, silver and other metals, almost all the large producers and former producers of these metals, as well as the gold mines, have been tested for uranium with negative results. Exceptions are the Opemiska copper mine and the Box gold mine, where a little uranium has been found. Most of the gold, copper, lead-zinc, nickel, and iron camps, to say nothing of their main deposits, have yielded no uranium occurrences or only a few minor ones. This may be partly because deposits of pegmatitic and conglomeratic types, which account for so many uranium occurrences, are not commonly sources of other metals. Also, some uranium deposits of the hydrothermal class show signs of having been formed at lower temperatures than were many deposits of other metals; therefore, zoning may account for the position of some uranium deposits. Another probable factor is that uranium has a strong tendency to form oxides and never forms sulphides; therefore, although sulphides of iron and other metals are commonly present in uranium deposits, conditions that permitted the formation of large deposits of massive sulphides, such as constitute many copper, nickel, lead and zinc orebodies, might not have been suitable for the deposition of uranium.

Few metal deposits are known in the plains areas of Canada. Important uranium deposits have been found in plains and plateaux in the United States, south of the plains that stretch from Alberta to Manitoba. The possibility that such deposits might also be found in the Canadian plains should not be ignored, for, although preliminary investigations have not yielded significant results, detailed searches were not undertaken because of the successful results obtained elsewhere. The Canadian plains do not appear to be as favourable, however, because the principal deposits found in the United States are related to uplifts and folds that have not been found, comparably, in Canada, and because the eastern Cordillera of Canada does not appear to contain many uranium deposits whose erosion could contribute uranium to the sedimentary rocks of the flanking plains. Such deposits are more plentiful in the mountains bordering the Colorado Plateau and the Great Plains of the United States.[1]

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[1] See also: On the Uranium Possibilities of the Southern Interior Plains of Canada, *by* J. A. Chamberlain; *Geol. Surv., Canada,* Paper 59-16.

Marginal distribution in Shield. Concentration of the known uranium occurrences in the Shield along a wide marginal belt has been apparent since 1930. Subsequent prospecting has but accentuated this pattern. In attempting to explain the reasons for this it is necessary to consider the human factors of accessibility and fashions in prospecting, as well as geological reasons.

The striking relationship between this marginal belt and the accessibility provided by many large lakes and rivers at and near the border of the Shield has been mentioned in other publications. The first uranium discovery in Canada was made about a century ago, apparently by the captain of a schooner plying Lake Superior. The discovery of the Eldorado deposit at Great Bear Lake followed a reported occurrence of cobalt and copper found by geologists making a reconnaissance of the shores of the lake. Several other occurrences found before the use of aircraft made other parts of the Shield more accessible are attributable to nearness to these main water routes and to the relative abundance of roads and railways in the southern part of the Shield. There is, also, a tendency for independent prospectors and supervisors of organized prospecting ventures to choose areas where important deposits of the kind sought are already known, or at least where minor occurrences have been found, and also to choose an accessible area because a discovery would be more likely to be exploitable. These factors undoubtedly caused many additional discoveries at and near Great Bear Lake from 1930 to about 1935, and later in Saskatchewan, southern Ontario and southern Quebec. However, as interest in prospecting for uranium grew, lesser amounts of searching were done in other parts of the Shield, with few results. This included considerable work in remote sections by prospectors working for companies and by parties engaged in geological mapping. It is possible that searchers in these areas were, on the whole, more experienced and did not report as many minor occurrences as did novice prospectors in the more accessible and more fashionable areas, but this does not appear to have been a strong factor.

Certain considerations suggest, however, that parts of the marginal belt are geologically more favourable than others for the occurrence of uranium. In some other continents uranium discoveries are concentrated in the margins of shields, and although accessibility seems to have been responsible in some of these instances it does not seem so in others. Another consideration is that many vein deposits are of fairly low temperature origin and probably were deposited relatively close to the surface of the Precambrian landmass. This was covered at least partly by seas in the Palæozoic era, and sediments were deposited. Much of the resulting sedimentary strata, as well as much of the underlying Precambrian rocks, have since been removed by erosion. Some parts of the Shield near the present Palæozoic contact have probably been eroded less deeply than many other parts, hence there might be more chance there for fairly low temperature veins to have escaped destruction by erosion. This is far from a completely satisfactory explanation because some deposits appear to be mesothermal, because areas of fairly young Precambrian strata have been preserved in central parts of the Shield, and because no uranium deposits have been reported from near the Palæozoic contact that extends south of Hudson Bay (this area has probably been only cursorily prospected), and because it offers no explanation for the position of pegmatitic deposits, formed at high temperatures and greater depths, in the marginal belt. Other possible geological explanations for the positions of deposits are mentioned in later sections of this paper; these explanations, however, offer few reasons why such possibly favourable geological conditions should be most abundant near the periphery of the Shield. Also, it should not be overlooked that Precambrian rocks similar to those of the Shield have been encountered in many deep wells drilled for oil and gas in the interior plains (Burwash, 1957). The boundary of the exposed part of the Shield is therefore an erosional feature, and it does not seem probable that parts of the Shield favourable for uranium mineralization would end abruptly at this boundary.

Segregation of main types. The fairly complete segregation within the Shield of discoveries of the three principal types is not surprising, in view of the differences in their modes of origin. This segregation seems related largely to the subject of 'provinces' discussed later, but it is desirable to mention the following points here.

The distribution of discoveries of the conglomeratic type cannot yet be explained fully, because of uncertainty regarding the origin of the deposits. The ores may have resulted entirely from erosion of rocks relatively high in uranium and from localization of detrital sediments. If so, other places that fulfill this condition may be found in the Shield, or even in other regions. But if the ores are partly a result of subsequent alteration or deposition, their position may be related to the general belt of epigenetic gold and base-metal deposits extending from Lake Huron to the Chibougamau area.

Hydrothermal deposits have been found principally in strata classed as Proterozoic, which have been folded and faulted. This was pointed out several years ago by Bateman (1949), Jolliffe (1950), and Lang (1949). The conglomeratic deposits of Blind River have also been found in one of these areas. These belts of strata and their associated faults mostly strike northeast. Older Precambrian rocks are also exposed in some of these belts, and some of the veins occur in them but are considered to be contemporaneous with the younger veins.

Most younger rocks are less metamorphosed and less intensely folded than their older neighbours, and commonly consist of well-sorted sediments of 'shelf' type. Some of the younger strata may be Archæan, bearing only structural and lithological resemblance to true Proterozoic strata, as pointed out by Gill (1955). To allow for this possibility, they are referred to in this paper merely as 'younger Precambrian'. Uranium discoveries in younger Precambrian rocks have been almost completely restricted to those in northeasterly trending belts. This suggests that these belts and their continuations, and others like them, may be favourable for deposits of the vein type. Such belts may include those mapped near Rankin Inlet, Cape Smith, Port Arthur, north of the Grenville boundary between lakes Huron and Mistassini, and at Seal Lake, Labrador. Younger Precambrian strata occur also in northerly and northwesterly trending belts, such as at Belcher Islands and in the Labrador Trough, and in large, relatively flat lying, bodies. Although these strata have not been prospected as thoroughly as some of the northeasterly trending belts, considerable unsuccessful searching has been done. With regard to the folded belts, S. M. Roscoe (personal communication) noted that there are two types. One, as exemplified by the Labrador Trough and the Bruce series, has one margin resting unconformably on older rocks and the other grading through increasing metamorphism into rocks of younger or contemporaneous age. The other type, exemplified by the Athabasca series at Beaverlodge, and the Keweenawan and Seal Lake groups, has both margins resting unconformably on older rocks. Deposits of the vein type have been found only in belts of the latter kind, but it is not yet clear whether this is a valid generalization or why it should be so.

Hydrothermal deposits are related to the northeasterly trending faults and fault zones at Great Bear Lake, Beaverlodge and elsewhere. Similar structures in otherwise favourable areas, as shown on geological and tectonic maps, offer theoretically promising areas for further prospecting. If the effect of such structures was only in causing zones of crushing, brecciation, or fracturing favourable for mineralization, there seems little reason why zones of equal intensity striking in other directions would not be equally favourable. Perhaps, however, further knowledge will show that certain northeasterly trending zones were formed or reopened when mineralizing processes were active, or that intersections of faults striking in different directions resulted in particularly favourable conditions. Also, it can be speculated that some of the more prominent northeasterly trending zones may have penetrated deeper and have allowed upward movement of all or part of the material required for mineralization.

The abundance and wide distribution of the pegmatitic type seems explainable by the facts that pegmatites and related deposits are common where granitic rocks have been eroded sufficiently to expose them, that these conditions prevail in many parts of the Shield, and that such deposits commonly contain accessory amounts of high-temperature uranium minerals. The fairly complete segregation of pegmatite and vein types is reasonable, because all uranium available may have gone into pegmatites in some areas, and if both pegmatites and veins were deposited in other areas, most of the veins would probably be destroyed if erosion reached pegmatitic levels. However, some overlapping of contemporaneous deposits could occur, and both types could readily be present in the same area if pegmatites were formed there at a much earlier time.

Metallogenic and Geological Provinces

Uranium deposits resemble those of other metals in a tendency to be most abundant in 'metallogenic provinces' which may or may not correspond to geological or petrographic provinces containing distinctive kinds or ages of rocks or structures. Metallogenic provinces may be characterized by only one metal or class of deposit, but more commonly they contain a distinctive group of metals or classes of deposits. Although the existence of such provinces is accepted widely, the reasons for them are uncertain and have been the subject of many theories, which are summarized briefly in the next two paragraphs because the literature is extensive and scattered and may not be available to all readers.

The theories are of three main classes, suggesting that the original distribution of metals in the earth was heterogeneous, or that it became heterogeneous as a result of processes distinct from the geological ones that operate at the surface or at depth, or that the distribution evolved by geological processes. The idea of provinces was introduced by De Launay (1913) in describing regions where deposits in general are abundant, without much regard to kinds of metals or origin of deposits. Spurr (1923) confined the related expression 'metallographic province' to regions characterized by a particular metal or group of metals; he believed they were related to zones that tapped a heterogeneous source of metals beneath the earth's crust. Theories of the second kind have been suggested by Bateman (1950), Sagui (1951), and Skerl (1957). Bateman and Sagui speculate that some elements, under conditions prevailing in the depths of the earth, may have undergone atomic changes that caused a particular metal to be available when conditions favoured mineralization. Skerl suggests that irregular distribution of metals may be a result of showers of meteorites of different compositions falling on the earth early in its history. As an example, he cites the alignment of the Blind River orebodies in a direction crossing the fold pattern; there is, however, much evidence that this alignment results from channels in which conglomerate was deposited, and that the source was to the northwest (McDowell, 1957; Roscoe, 1956). Theories of the third, geological, kind are exemplified by the writings of Niggli, who relates metallogenic provinces to kinds and stages of magmatic differentiation and to tectonic events (1929, 1954). In a recent review, Turneaure (1955) regarded metallogenic provinces as "strongly mineralized areas or regions containing ore deposits of a specific type or groups of deposits that possess features suggesting a genetic relationship". He commented that, whatever theory is favoured, the ultimate source of the metals is in the deeper layers of the earth; that many provinces show a broad similarity of ore types, bespeaking a certain uniformity in metal distribution and processes of concentration; but that some provinces suggest notable difference in the composition of various segments of the crust.

In reviewing uranium provinces of the world Kerr (1956) concluded that the boundaries of a province may be ill defined, that it may cover a large part of a continent or a few hundred square miles, and that many complexities of mineralization are included. A province may persist for long periods, resulting in the formation of many types of uranium deposits. He suggested that differences in the thickness of the crust under shields, young folded belts and suboceanic belts, and vertical boundaries between such segments, would lead to inhomogeneities in metal content. Klepper and Wyant (1956) summarized world-wide data on uranium provinces and considered that most important deposits are clustered in broad, indefinitely defined areas; that the initial concentration probably occurred early in the earth's history; and that, subsequently, geochemical and orogenic processes redistributed the uranium and further concentrated some of it to form exploitable deposits. They considered that tectonic events at late stages in magmatic processes probably determine largely whether most of the uranium in residual magmatic fluids crystallizes in late igneous rocks such as pegmatites, or in veins, or in both; that if most of the uranium is drained off to form deposits, the related rocks may not be abnormally uraniferous; and that the best opportunity for concentration of uranium occurs during and following the secondary stage of mountain building, because uranium-bearing shales and phosphorites may accumulate in the marginal parts of secondary geosynclines and because highly differentiated intrusions associated with this stage may be important bearers of uranium.

The distribution of uranium discoveries in Canada is well segregated and seems definitely to corroborate the concept of metallogenic provinces (Lang, 1958a,b), although many of the boundaries are still undefined and the reasons for the distribution are only partly understood. Furthermore, within the Shield the three main types of uranium occurrences are sufficiently segregated to suggest that distinct areas are characterized by vein, conglomeratic, or pegmatite deposits. Some of the areas correspond almost exactly with geological provinces or sub-provinces, and others correspond partly. The subject of these geological divisions, and the closely related subject of age determinations, are largely beyond the scope of this report but the following short synopsis is included to permit relating the data on distribution of uranium.

Divisions of Shield. Progress has been made in dividing the Shield on the basis of kinds and ages of rocks, structural trends, and dating of orogenies. Some writers regard the entire Shield as a geological 'province' and call its major divisions 'sub-provinces'. Most authorities now regard the Shield as too large to be classed as a single province, and call the main segments 'provinces' and smaller segments within them 'sub-provinces'. The first divisions recognized were the Grenville and Timiskaming, which were named 'belts' by M. E. Wilson (1918), and later 'sub-provinces' (1939, 1941). Today the tendency is to regard the large Grenville region as a province. M. E. Wilson suggested names for other provinces in the Shield, based partly on geographical features and partly on kinds and ages of rocks.

Gill (1949) divided the Shield into provinces and several sub-provinces based largely on ancient mountains and younger sedimentary and structural features.

Lord (1951) recognized distinct metallogenic provinces in the northwestern part of the Shield. Jolliffe (1950) divided this region into sub-provinces on the basis of kinds and ages of rocks and associated metal deposits; he concluded that the segregation of metals may reflect heterogeneities that persisted since the consolidation of the crust and that the sub-provinces "functioned as more or less independent segments, each with its own unique geologic history".

The dating of mineral deposits and rocks by isotopic analyses has already yielded information that aids in the understanding of the subdivisions of the Shield and the ages of radioactive deposits and their host rocks. This subject is now very large, and in a 'state of flux' because of the need for further research to evaluate various methods and results. It is almost entirely beyond the scope of the present publication. Summaries of the problems and the results to date are available in papers by Collins, *et al.* (1952), Cumming, *et al.* (1955), and in reports of the Committee on Precambrian and Related Dating published in the *Transactions of the Royal Society of Canada* for 1955 and later years.

J. T. Wilson and several associates have added to knowledge of the subject by extensive studies of structural trends shown on air photographs, by performing many age determinations, and by compiling data on these and other determinations (1949, 1956). They considered that the Shield is divisible into 'basement provinces' separated by fault zones, and that at least two of the oldest provinces, called Yellowknife and Keewatin (or Superior), were formed about 2,500 million years ago and acted as nuclei around which younger provinces grew, by stages of sedimentation and mountain building, into areas of gneissic rocks containing pegmatites. They place the age of the Grenville orogeny at 1,100 to 800 million years, and the ages of other provinces between this and the age of the nuclei. They believe that the Grenville represents the roots of a primary mountain system and that the 'Huronian' and other strata flanking the Grenville were derived from erosion of the Grenville mountains and were later uplifted and folded to form secondary mountains. Some of these proposals are based on age determinations made by methods that are considered reliable within relatively close limits, and in some cases different methods have yielded relatively close dates. As the authors themselves point out (1956, p. 557), other proposals are based on less certain methods of dating and sampling, on widely scattered samples, and on preliminary structural studies. They provide inspiration and challenge for greatly augmented studies and interpretation.

The authors mentioned above agree on the boundaries and naming of certain divisions and disagree on others. For many parts of the Shield no division into sub-provinces has yet been attempted. In Figure 2 the writers have shown divisional names that are unquestioned; have chosen others from conflicting nomenclature; and have added a few tentative sub-provincial names. Some boundaries are omitted because of the small size of the map, and others because of uncertainty. This is largely a tentative classification to aid in the following discussion.

Relation of uranium to provinces and sub-provinces. In the Slave province, as mentioned by Jolliffe and Lord, uranium discoveries are scarce in the Yellowknife sub-province and abundant in the Great Bear. One pitchblende occurrence has been reported in the Yellowknife, at Contwoyto Lake, and several pegmatitic occurrences lie close to the boundary of the East Arm sub-province. The Great Bear sub-province is underlain largely by rocks that have been classed as Proterozoic, and the uranium discoveries are almost exclusively of vein type. These include the veins of the Eldorado mine, from which specimens have consistently yielded ages of about 1,200 to 1,400 years, suggesting that, although the host rocks are younger than the rocks of the Yellowknife sub-province, they may be late Archæan instead of Proterozoic. Uranium occurrences are fairly numerous

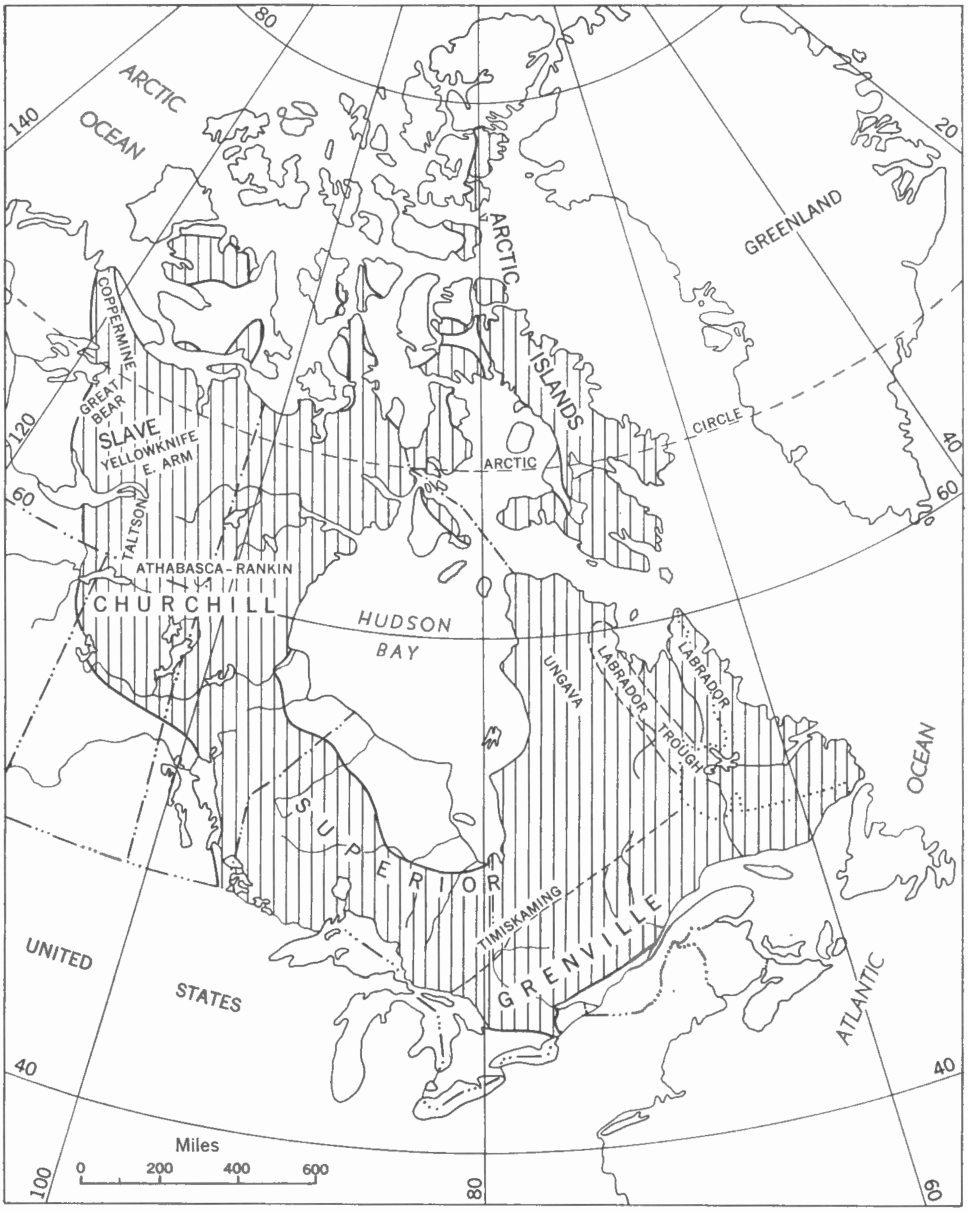

Figure 2. ***A scheme for dividing the Canadian Shield into geological provinces (shown by large type) and certain sub-provinces (smaller type).***

in the East Arm and Taltson sub-provinces, which are also marked by belts of younger Precambrian strata. Ages on specimens from the East Arm also suggest that the strata there may be late Archæan; no ages are available for the Taltson occurrences. Vein and pegmatitic types are somewhat intermixed in the East Arm and Taltson sub-provinces, but the pegmatites are mainly on the west flank of the younger belt in the Taltson.

The writers have followed Gill in including in the Churchill province the belt of folded younger Precambrian strata at Beaverlodge, north of Lake Athabasca, in which deposits of vein type predominate. This belt is linked tentatively with one near Rankin Inlet from which uranium has not yet been reported. A large area south of Lake Athabasca, called the Athabasca Plain by Gill, is underlain by flat-lying sediments in which is only one uranium property containing secondary minerals (Blake, 1956, p. 11). Some geologists consider these sediments to be of Palæozoic age. Blake (1956, p. 9) believed they are Precambrian, although possibly younger than the folded strata at Beaverlodge. The scarcity of uranium occurrences in the Athabasca Plain may be due to its extensive cover of glacial deposits, to lack of deformation, or to blanketing of deposits by younger sedimentary rocks. South of the Athabasca Plain, pegmatitic occurrences are numerous in the western and southern parts of the remainder of the Churchill province. The writers follow Gill and J. T. Wilson in drawing the southern boundary of this province near Nelson River, on the basis of marked changes in structural trends.

M. E. Wilson drew the Churchill boundary farther south, near the south end of Lake Winnipeg, and classed the remainder of the southeastern part of the Shield including the Grenville, as "St. Lawrence province". The writers prefer the name Superior, as used by Gill and J. T. Wilson, because of the size of the Grenville and its nearness to the St. Lawrence River. J. T. Wilson, *et al.,* use the name Keewatin instead of Superior in certain papers, but, although there is historical justification for this, it does not seem so suitable because of its usage for an administrative district in the Northwest Territories. The western part of the Superior province contains many pegmatitic occurrences, some of which have been found to be very old by different methods, thus supporting the view of Wilson, *et al.* that this part of the province is a primitive part of the Shield. Vein occurrences are unknown west of a belt of younger strata near Port Arthur and Lake Nipigon. In the southeastern part of the Superior province, the conglomerate occurrences and several vein deposits are present in a belt of younger rocks that J. T. Wilson, *et al.* have more recently included in a "Secondary Grenville or Huronian province" which corresponds with the eastern part of M.E. Wilson's Timiskaming sub-province.

The extension of the Superior province into northern Quebec is uncertain. M. E. Wilson and Gill regard the northern territory of Quebec and Labrador as an 'Ungava province' but are in doubt about its southern boundary, because of scarcity of geological information. The writers use the term for a sub-province west of the Labrador Trough because of shortage of names, but usage for a more inclusive province has priority. The only known uranium occurrences in this region are those near Seal Lake and Makkovik, and the province or sub-province to which they should be assigned is not yet clear. Two age determinations on a specimen from one of these deposits showed dates of about 1,000 million years by the Pb^{206}/Pb^{207} method (R. W. Wanless, personal communication), suggesting that the belt of younger strata in this area may be fairly old.

The widespread distribution of numerous pegmatitic occurrences in the Grenville province and the lack of discoveries of vein type have already been discussed. The distribution of radioactive properties in the Grenville and Timiskaming 'provinces' is illustrated by Table XIII.

The distribution of known occurrences thus provides data from which metallogenic provinces for uranium can be outlined, fairly completely in some instances and partly in others. The writers consider it reasonable to make further distinctions into conglomeratic, pitchblende, and pegmatitic provinces, in which deposits of these general kinds are exclusively present or are the prevailing type. These provinces correspond to a large degree with geological provinces and sub-provinces. The writers believe that many uranium provinces can be explained by geological events, and that original inhomogeneity of the earth's crust, or other causes, should not be invoked except as last resorts. However, some barren areas, and associations such as the concentration of complex minerals in the Grenville, may prove to be best explained by inhomogeneity. The pattern in the Shield seems largely explainable on the basis that pegmatite occurrences are found mainly in the deeply eroded remnants of primary mountains, and vein and conglomeratic occurrences mainly in belts of secondary orogeny. The favourableness of the latter may be due only to faulting and fracturing associated with veins, to deposition of uranium-bearing conglomerate, and to less severe erosion of secondary folded belts, with resulting preservation of vein and conglomeratic deposits. Further favourableness would exist if uranium was transported from a primary to a secondary belt by erosion and sedimentation, and later supplied to veins, and perhaps to pegmatites, by granitization, leaching, or diffusion.

The concentration of discoveries around the margin of the Shield is believed to result largely from the relative accessibility of many such areas. There are, however, geological reasons such as the situation of the Grenville, the location of belts of secondary orogeny represented by the Great Bear, East Arm, Taltson and Athabasca sub-provinces, and, perhaps, the effect of parts of the Palæozoic cover in preventing deep erosion of veins. These reasons, however, do not preclude the possibility of discoveries in other suitable parts of the Shield.

Relation to Rock Types

Data on the uranium content of rocks in areas containing uranium deposits are scanty because prospectors found deposits in such numbers that the relatively few geologists available were soon involved in other tasks. The rocks of some areas show abnormally high radioactive backgrounds, but few analyses are available to indicate the extent to which this is caused by uranium, thorium, or potassium. Because of the size of the Shield it will be many years before sufficient data of this kind will permit generalizations on the possible relation of metallogenic provinces to trace amounts of metals in rocks. Studies of sample areas would be a desirable preliminary step.

Evidence for relationship between Canadian uranium deposits and kinds of igneous rocks is also scarce. It has been suggested that uranium deposits in the United States are commonly affiliated with rocks rich in alkalis (Kerr, 1956, p. 10). Some corroboration for this is evident in connection with certain Canadian pyrochlore occurrences. Several of the uraninite-uranothorite pegmatites near Bancroft occur in areas containing nepheline syenite, but no direct relationship is apparent; however, the pegmatites themselves are rich in albite (S.C. Robinson, personal communication). Direct genetic relationships have not been established for Canadian hydrothermal uranium deposits. Many such deposits at Beaverlodge, however, are associated with a form of wall-rock alteration rich in albite, as explained below.

Rock Alteration

The wall-rocks of most pitchblende deposits of the vein type are considerably altered, as are fragments of rock within the deposits themselves. The most typical kind of alteration is reddish in colour, thus providing a conspicuous and important clue for prospecting and exploration. This type of alteration is also present in and near some pegmatitic deposits. Rock alteration is not a conspicuous feature of the conglomeratic deposits. Because of the visibility of the red alteration it is a useful guide for prospectors and miners who do not require special mineralogical and petrographic knowledge in order to make use of it. Therefore this type of alteration is discussed first and at greater length than the other forms. None of the types is discussed exhaustively because further information is contained in the description of individual deposits and districts, and still further details are available in special publications.

Red Alteration

The red alteration in the Beaverlodge region was studied in detail by K. R. Dawson, and the following description is summarized from his report (1956, pp. 37-40):

> The colour in different deposits is bright red, yellowish red, or brown and results from a concentration of hematite veinlets, iron oxide stain on minerals, and evenly disseminated red or yellow dust. In some cases the hematite veinlets increase in width and numbers as a radioactive vein is approached from the walls and accordingly the intensity of red coloration increases. Potash and plagioclase feldspars, carbonates, quartz, and barite are reddened. Of the feldspars, reddened albite probably is the most widespread and this mineral is especially plentiful in alaskite and mylonite. In these rocks the albite is an intense red, and in the wall-rocks of some deposits the intensity of red coloration increases noticeably close to the veins due to dusty red hematite that forms around the boundaries of white albite grains, and penetrates these along microfractures until the whole grain becomes an earthy red aggregate of hematite. Carbonates are from pink to dark red in colour and reddened carbonates are not so widespread in their occurrence as the feldspars. Quartz is rarely reddened and it does not show the colour intensity of either the feldspars or the carbonates.
>
> Earthy red dust stains the wall-rocks of some radioactive deposits, particularly those in the Athabasca series feldspathic sandstone and basalt and Tazin group chert. In these

> rocks the red dust is distributed through the intergranular spaces and is not concentrated within a particular mineral. The staining material in the matrix, and where present within the grains is a yellowish red dust consisting of particles less than 0.001 mm. in diameter. These particles are translucent with yellow birefringence and they are not tabular nor do they show other plane geometric shapes. The particles have no detected preferred orientation and their distribution in abundance at grain boundaries and along microfractures is characteristic. These particles may be alpha hematite, as suggested by the results of differential thermal analysis (Forman, 1952).
>
> The feldspars are characteristically red in some rocks, especially granite and pegmatite, and various explanations of this have been advanced. To check the idea that the red coloration may be the result of the presence of a larger than normal content of some element, the relative abundance of trace elements of feldspars from different regions was determined . . . Assuming iron a cause of the red coloration, the analyses indicate this varies in quantity 0.01 to 1.0 per cent and that the red feldspars, Nos. 16 to 20 inclusive, contain much more iron than white feldspars, Nos 1 to 3 inclusive. Other trace elements that might influence the colour of the feldspar, as manganese and magnesium, are more plentiful in some red than in white feldspar . . .
>
> The red dust and stain in the matrix and certain minerals of the wall-rocks at some radioactive deposits in Goldfields region could result from auto-oxidation, exsolution, alumina metasomatism, simultaneous breakdown and crystallization of mafic silicates, and the introduction of the red material by solutions from which the radioactive veins were deposited. Auto-oxidation was proposed by Ellsworth (1932) to explain the occurrence of hematite beside radioactive minerals in pegmatites. The uranium in these minerals gives off radon gas, alpha and beta particles, gamma rays, and nascent oxygen, under which circumstances ferrous iron might have become ferric iron and this combined with any nascent oxygen present to form hematite. This could happen in wall-rocks, as gabbro or basalt, where magnetite, hornblende, biotite, and chlorite were altered to supply ferrous iron, but such rocks and minerals as chert, alaskite, some mylonite, quartz, feldspar, and carbonates contain a limited supply of ferrous iron. Auto-oxidation furthermore is regarded as taking place at a fixed rate after the radioactive minerals were deposited and the formation of hematite and the staining of the wall-rocks are best interpreted as a result of alteration effected during the deposition of the veins containing the radioactive minerals.

Exsolution and alumina metasomatism apply especially to the feldspars. Both exsolution and alumina metasomatism require that the feldspar retain some iron in the alumina lattice positions at low temperatures. Faust (1936) states that orthoclase is the only iron-bearing feldspar known to occur naturally, and as albite or sodic oligoclase are the principal stained feldspars known in the Goldfields region, this process apparently is not applicable.

> In certain wall-rocks most of the hematite probably resulted from the alteration of silicates in the rocks beside the veins. Some of this was trapped as microscopic inclusions in minerals, such as calcite, albite, quartz, that grew from the products of the alteration. Hematite inclusions without discernible crystallographic orientation in clear albite of veins crossing the altered rocks may be thus explained. Modal analyses of mafic unaltered and altered rocks adjoining radioactive veins indicate an increase in the hematite content of the altered rock that can be correlated with the decrease in the quantity of mafic silicates present as compared with that of the nearby unaltered rock. This probably is an important source of hematite. Chemical analyses, however, indicate that iron is added in some cases and removed in others and hematite locally intergrown with and staining gangue minerals of the veins suggests that the solutions from which the veins were deposited were capable of transporting iron and depositing hematite. Such solutions also were capable of penetrating microfractures and intergranular spaces of minerals of the wall-rocks and depositing hematite in these situations. Hematite was deposited in chert beside veins and also some was added to altered amphibolite and the movement of iron and the deposition of iron is supported at many radioactive deposits by the occurrence of hematite along fractures, and as encrustations on carbonate, quartz, and feldspar grains.

Table XIII

Estimated Distribution of Properties by Types, in Grenville and Timiskaming Regions (1958)

Region	Conglomeratic		Hydrothermal		Pegmatitic		Replacement		Granitic		Metasomatic (General)		Metasomatic (Fenites)		Dolomite, Sandstone, etc.		Placer		Totals		
		?		?		?		?		?		?		?		?		?		?	
Grenville (Ontario)......	....	....	7	8	63	4	....	....	200	1	5	10	1	....	....	1	....	....	276	24	300
Grenville (Quebec).......	....	....	....	....	118	24	....	....	1	1	9	5	2	3	....	....	....	....	130	33	163
Total Grenville.............	....	....	7	8	181	28	....	....	201	2	14	15	3	3	....	1	....	....	406	57	463
Timiskaming (Ontario)	48	8	47	5	12	3	....	....	41	1	....	1	1	....	....	1	1	....	150	19	169
Timiskaming (Quebec)	....	....	1	2	5	1	....	....	....	....	....	....	....	....	....	....	....	....	6	3	9
Total Timiskaming......	48	8	48	7	17	4	....	....	41	1		1	1			1	1		156	22	178

Note: Columns headed (?) list occurrences for which the reports do not clearly indicate the type.

Much the same kind of alteration is a feature of the Eldorado mine at Great Bear Lake. Murphy (1946, p. 432) described the alteration there, as follows: "The envelope of reddish 'jasperoid' enclosing the veins is the most intense form of alteration. Within four or five feet of the vein there are seldom even recognizable remnants of the wall-rock. Although the width of the altered zone is roughly proportional to the width of the vein, there are examples of unusual penetration, probably on numerous small mineralized fractures. The red alteration may mark areas in which veins are concealed and is therefore a useful guide in exploration." Kidd and Haycock (1935) in describing the alteration of this mine pointed out that it was accompanied by widespread feldspathization. Dawson (1956, p. 7) indicated that the fine-grained, red cherty alteration found in parts of the Beaverlodge area is probably analogous to Murphy's jasperoid.

At Beaverlodge and Great Bear Lake the red alteration has proved a useful guide both for surface prospecting and in connection with diamond drilling and underground exploration. Rocks containing the alteration are not always indicative that a pitchblende occurrence will be found within or beneath them, still less are they indicative of ore, but the relationship has been demonstrated sufficiently often to cause prospectors and geologists experienced in these areas to place considerable faith in them. Thus, if alteration is found at the surface, additional surface exploration or even drilling may be warranted if the alteration is fairly intense and occurs over a fairly large area. If it is encountered in diamond-drill core over a considerable length, additional drilling may be warranted nearby, even if the assay returns from the sections first encountered are negligible. In underground exploration the presence of considerable red alteration may influence a decision to slash or drive farther than otherwise would have been the case.

Ellsworth (1932) reported that many of the radioactive pegmatites that he studied in Eastern Canada showed red alteration. This is more difficult to use as a reliable generalization, because many of the pegmatites themselves contain large masses of pink or red feldspar with calcite. The examples that the writers have seen in connection with pegmatitic deposits are more commonly haloes within the pegmatite itself, surrounding a crystal or a nest of crystals of uranium minerals, than large areas of altered wall-rock adjoining the pegmatite. Such haloes may be in the form of a deeper colour in reddish or pink feldspar.

Other Types of Alteration

Other types of alteration found at many deposits of the general vein class are silicification, chloritization and argillic alteration. These are not as spectacular as the red alteration described above, but in some instances one or more of these types may be more widespread than the red alteration, and attention paid to them by specialists may prove valuable guides in the search for ore. At the Eldorado mine at Great Bear Lake argillic alteration is the most common type and affects all rock types, tending to transform them to a fine-grained, greyish, clayey rock; chloritization, most common in mafic rocks, is generally superimposed on the argillic alteration at Eldorado mine (Donald, 1956, p. 79).

Ellsworth (1932, p. 63) pointed out that rock surrounding radioactive minerals in pegmatites commonly displays fractures that radiate out in all directions from the radioactive minerals. These show best on freshly broken surfaces and may be difficult to recognize on weathered outcrops. It is not clear whether this fracturing is caused by the pressure of growing crystals of radioactive minerals, or whether it is related in some way to the radioactivity, but the fact that it appears to be more commonly associated with radioactive minerals than with other minerals suggests that the radioactivity may be at least partly responsible. This fracturing can be an important clue in prospecting, as evidenced by the fact that the prospector who found the Bicroft deposit in Ontario reported that he did not have a Geiger counter and was led to investigate the discovery further because he first noted the radial fractures and the presence nearby of purple fluorite; he stated that he had learned of both clues by reading the manual *Prospecting for Uranium in Canada.*

Economic Considerations

Explorations and mining for uranium differ only in details from explorations and mining for other metals and minerals. The fundamental economic principles concerning mining are well known to experienced persons and need not be discussed at length here, but they are outlined because this report will probably be used by some who are not familiar with them. These principles are: (1) Mining is, in general, subject to the same principles of supply and demand that control other industries. (2) A mine that does not reproduce is a 'wasting asset', therefore financing has to be done with this in mind. (3) Only a small proportion of mineral discoveries are suitable for profitable mining. (4) A relatively small proportion of mines ship ore directly or after it has been sorted by hand, but most mines treat fairly low-grade material, which must be concentrated or completely processed, at or close to the mine, in order to avoid paying freight on a large amount of worthless gangue. (5) Metals that occur in relatively small amounts with the principal metal being mined may be recovered as by-products, but it is rarely possible to recover economically the very small amounts of metals that accompany the principal metals in most deposits. Many reports of assays list elements occurring in amounts of hundredths of one per cent or less, but such amounts are generally not significant. (6) The costs of transportation, ore treatment, construction, labour and other factors vary. As these factors greatly affect the cost of mining, every deposit has to be evaluated not only according to its inherent qualities but also to the marketing and cost conditions prevailing at the time. Certain deposits that are not economically mineable, or that do not appear to be economically mineable at a given time, may be reviewed in a more favourable light later, if metal prices increase, if transportation facilities are improved, if the costs of labour and supplies are lowered, or if improved treatment or mining methods allow a lower cost of operation or an improved recovery; conversely, lowering of metal prices may force suspension of operations or eliminate certain reserves that were formerly classed as ore.

Mining for radioactive metals in Canada differs from general mining in that, since 1943, the Canadian government has controlled the sale of products. Until recently all the uranium produced in Canada was sold to the United States Atomic Energy Commission and was covered by similar guarantees between the Canadian and United States authorities. During the last few years Canada also undertook to supply smaller amounts of uranium to the United Kingdom, West Germany and Japan. When the temporary ban on private mining for radioactive metals was removed late in 1947, Eldorado Mining and Refining Limited was appointed the buying and marketing agency of the Canadian government. In 1958 private Canadian uranium companies were authorized to negotiate directly with potential foreign buyers for sale of uranium precipitates, subject to export control by the Canadian authorities.

The guaranteed prices for uranium included all radioactive elements in a shipment, for which no additional payment was provided, because: the amount of radium and related elements in a shipment of uranium ore or concentrate is minute; the demand for radium had declined; and thorium is not a significant constituent of pitchblende ores or of the uranium precipitates produced from other ores that may carry thorium.

No figures are available at the time of writing for the production or revenues from the plant recently completed to produce thorium from certain uranium ores in Blind River area. Quotations for monazite in the United States early in 1959 were 15 cents a pound for sands containing 55 per cent total rare earth oxides and thorium oxide, and 20 cents for the 68 per cent grade.

Marketing

Published schedules of prices. On March 16, 1948, the first schedule of prices that the government was prepared to pay for acceptable ores or concentrates was announced. This provided for payment of $2.75 per pound of contained U_3O_8, f.o.b. rail, in ores or concentrates normally required to contain 10 per cent or more U_3O_8. Later, development and milling allowances were added that brought the maximum price up to $7.25 a pound of contained U_3O_8, and the period during which these prices would apply was extended to March 31, 1962. It is notable, however, that excepting small test shipments no ore was submitted under these schedules.

Special price agreements. The published schedule of prices was intended to cover shipments of raw or sorted ore of fairly high grade, or of concentrates from relatively simple concentrating plants. As prospecting and the testing of discoveries proceeded, it became apparent that certain fairly large lower-grade deposits that would require treatment in costly leaching plants would probably be mineable economically at special prices. Accordingly, in 1953, the president of Eldorado outlined the following two conditions under which special prices would be considered: (1) a property with a proven tonnage of substantial dimensions but in such a location and having a grade such that production would not be worth while under the present prices; (2) a property for which there were plans to produce a high-grade mill product but which could reach this stage only after large expenditures for plant.

Special agreements were negotiated by several mining companies, having deposits in different parts of the country. Those with individual treatment plants are listed in Table XIV and a few additional companies shipped ore to some of these plants. The agreements provided for sales of uranium precipitates to a value of about one and a half billion dollars. The agreements between Eldorado and the private companies concerned were for purchase of uranium to be delivered by Eldorado to the United States Atomic Energy Commission without profit to Eldorado. Most of the aggreements will terminate on March 31, 1962, but a few that were negotiated later allowed for a full 5 years' operation of the mine, extending into 1963. The contracts with the United States authority provide that the Government of Canada could at any time divert production for use in Canada. The prices paid were based on tonnage of ore, recovery, and estimated preproduction, operating and capital costs. The exact prices were not published officially,

Table XIV

Companies With Treatment Plants, Holding Agreements For Sale of Uranium at Special Prices, 1958

Company	Location	Agreement $	Nominal Capacity (tons per day)	Commencement of Production
Algom (Quirke)	Blind River	206,900,000	3,000	1956
Algom (Nordic)	Blind River		3,000	1956
Can-Met	Blind River	79,350,000	2,500	1957
Cons. Denison	Blind River	201,250,000	5,700	1957
Milliken Lake	Blind River	94,500,000	3,000	1958
Northspan (Lacnor)	Blind River	275,000,000	4,000	1957
Northspan (Panel)	Blind River		3,000	1957
Northspan (Spanish Am.)	Blind River		2,000	1958
Pronto	Blind River	55,000,000	1,500	1955
Stanleigh	Blind River	90,400,000	3,000	1957
Stanrock	Blind River	95,200,000	3,000	1958
Eldorado	Beaverlodge	168,500,000	2,000	1953
Gunnar	Beaverlodge	[1] 76,950,000	2,000	1955
Lorado	Beaverlodge	64,400,000	700	1957
Bicroft	Bancroft	35,800,000	1,000	1956
Dyno	Bancroft	34,900,000	1,000	1958
Faraday	Bancroft	29,750,000	1,000	1957
Greyhawk	Bancroft	20,350,000		
Eldorado	N.W.T.	33,500,000	300	1933 (before contract)
Rayrock	N.W.T.	15,800,000	150	1957

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[1] A supplementary contract brought this to $119,300,000.

but were stated in the press to be about $10 per pound of contained uranium. Contracts were reported to include options that would permit the United States authority to purchase uranium up to the end of 1966 if it desired.

Values of contracts are listed in 'round numbers', and the rated capacities of plants are listed. The tonnages of ore actually treated daily fluctuate to some extent. In some instances production was begun with smaller plants which were later increased to the capacities shown.

The Minister of Trade and Commerce announced in August 1955 that it was unlikely that Eldorado would be able to negotiate contracts at special prices after March 31, 1956, because of improvement in the situation respecting supplies of uranium in the United States. This forecast was essentially borne out by subsequent events, the only difference being that several agreements for which applications were made before March 31, 1956 were completed shortly after that date.[1]

Production

Concentrates and crude ore produced at the Eldorado mine, Great Bear Lake from 1934 to 1939 were reported to be worth $7,639,764, being mainly of value for radium, copper, silver and cobalt. From 1939 to 1955 publication of data for production of uranium in Canada was not permitted, nor have the full figures been released subsequently. The production for 1956 was $39,577,000, and this was reported to be an increase of about $13,500,000 over the total for 1955. The production for 1957 totalled 6,557 tons of uranium oxide valued at $133,035,853, and in that year production from Ontario exceeded that of Saskatchewan for the first time. The production for 1958 was 13,537 tons valued at $274,416,000. The figures quoted are preliminary, and are subject to slight amendments when final statistics are compiled.

Mining and Treatment

The subjects of mining and ore treatment are almost entirely beyond the scope of this publication but it is desirable to outline a few fundamental matters because of their important bearing on the appraisal of prospects.

Mining. All mining for uranium in Canada has been done by companies. Some persons were led by exaggerated ideas of the value of uranium and by accounts of small-scale mining in parts of the United States, where the kinds of deposits and other factors permitted it, to hope that small operations conducted by one or two men would be possible in this country, but this did not prove to be so. Even the smaller shipping operations that have been carried on were at substantial daily tonnages. Furthermore, some of these were 'salvage operations' on deposits that were explored extensively with the hope of proving sufficient ore to warrant construction of treatment plants, and which, when this did not materialize, were mined with the hope of recovering as much ore as possible. Some of the other shipping mines, however, are fairly large and successful ventures.

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[1] Arrangements were made later to permit producers to 'stretch out' the remainder of their undelivered uranium under firm contract until 1966; to permit transfer of contracts between companies; and to permit private producers to make their own arrangements for sale of surplus uranium under certain conditions.

Mining of Canadian uranium ores is done in one of three ways: by open-pit methods, by conventional underground mining in which track haulage and electric locomotives are used, and by trackless mining in which trucks and other vehicles powered by diesel or electric motors are used. The Gunnar is the only open-pit mine, this being possible because the orebody is roughly circular in plan and its upper part is close to the surface. Most mines use conventional methods and track haulage. Trackless mining is used at some of the Blind River mines because it is considered speedier, and perhaps cheaper, where deposits are large, flat, and otherwise suitable (Barrett, *et al.,* 1958, p. 2). These authors summarized mining costs, based on experience to early 1958, as follows: open-pit mining, $2.50 per ton; normal underground operations, $4.00 to $6.00 per ton; high-cost operations on narrow, rich veins, $10.00 to $15.00 per ton. These figures include the costs of true mine development, such as stope preparation and late-stage exploration to extend orebodies, but not the original exploration or testing of the deposit carried out to learn if an orebody existed.

Several companies have published their total production costs, including milling and other expenses. Some of these, with the year or month concerned stated in parentheses, are: Algom Uranium Mines Limited, $11.33 (1958); Bicroft Uranium Mines Limited, $11.42 (1957); Consolidated Denison Mines Limited, $10.77 (1958); Faraday Uranium Mines Limited, $9.97 (1957); Pronto Uranium Mines Limited, $11.59 (1958). Two companies published further details, as follows:

Faraday (1957)

Development	$ 2.30
Mining	3.73
Ore conveyance	.25
Milling	3.69
	$ 9.97

Bicroft (1957)

Development	$ 2.79
Mining	3.78
Milling	3.79
General expense	1.06
	$11.42

Treatment. Canadian uranium ores are treated almost exclusively by leaching, in plants commonly costing several millions of dollars each. The Eldorado mine at Great Bear Lake was originally equipped with a plant for making concentrates by gravity methods. This, however, failed to yield good recovery, largely because pitchblende is so friable that 'slimes' are formed when it is ground finely, and these are carried away by the waste water of the plant. Leaching equipment was, therefore, added to the plant at Great Bear Lake. Electronic sorting was used for one stage of the operations there, and a recent development of this kind has been tested at the Bicroft mine.

Tests on material from certain pegmatitic deposits that contain fairly coarse crystals of uraninite that separate freely, somewhat analogously to free-milling gold ores, indicated that good recoveries could be expected by treating such material by gravity concentration, but deposits of this kind were not shown to contain commercial tonnages.

All ore from producing uranium mines developed since the Eldorado mine at Great Bear Lake has been treated in leaching plants at the mines or within shipping distances. The Ace plant at Beaverlodge was designed for basic leaching under pressure, because of the high carbonate content of the ore. Further research showed that leaching could be done successfully at atmospheric pressures, and when the plant was enlarged such equipment was installed. Acid leaching is used at the other plants, separation of uranium usually being accomplished by ion exchange, followed by precipitation. Sulphur is brought in for manufacture of sulphuric acid at Great Bear Lake and at the Gunnar mine in Beaverlodge area; part of the acid for the Lorado mine is made from pyrite associated with the ore. Much of the acid used in the plants at Blind River is made by Noranda Mines Limited at the nearby town of Cutler, using sulphur derived from pyrite concentrates from the Horne mine at Noranda, Quebec; other acid is supplied by the plant of Canadian Industries Limited at Sudbury. Plants in the Bancroft area use acid transported by tank trucks. The products of the leaching plants are high-grade uranium compounds (precipitates) called 'yellowcake', which are either processed further at the Port Hope refinery, or sold to U.S. authorities without further processing in Canada.

A consideration of possible importance in appraising discoveries is that the extraction of uranium from some uranium minerals is more difficult and costly than from others. Uranium can be dissolved fairly easily from ores or concentrates containing pitchblende, uraninite, or uranothorite. Some other minerals, such as euxenite and pyrochlore, are called 'refractory minerals' because it is more difficult to dissolve the uranium contained by them.

Gow (1959) estimated that the treatment costs per ton of ore were $4.00 for plants in Blind River and Beaverlodge (acid leaching) areas, and $3.00 for plants in Bancroft area.

Grades of ores and scales of operations. Important relationships between the grade of ore, the scale of operation, and the accessibility of the site are apparent for the mines equipped with their own treatment plants. The Eldorado mine at Great Bear Lake was begun as a high-grade operation on veins that in places are almost pure pitchblende, in a remote region. The average uranium content of mill feed was reduced somewhat as the size of the operation was increased and treatment methods were improved, but it is still a relatively high-grade mine, with a nominal daily mill capacity of 300 tons of ore, the reserves in 1959 being reported to average 0.58 per cent U_3O_8. The Rayrock mine, also in a remote area and having a mill capacity of 150 tons a day, is operated on fairly massive pitchblende ores estimated by the company to average 7 to 8 pounds of U_3O_8 per ton, that is, about 0.4 per cent.

When the Eldorado discoveries at Beaverlodge were being appraised concern was felt because the higher grade deposits offered disappointingly low tonnages, whereas the larger tonnages that offered hope for average grades in the range of 0.2 to 0.3 per cent U_3O_8 seemed lean for that rather remote area, and for the treatment methods available at the time. Research resulted in improved treatment methods, and by mining first at 500 tons a day and later at 2,000 tons a successful operation was developed. The Gunnar deposit is estimated by the company to average 3.4 pounds of U_3O_8 per ton (0.17 per cent) for open-pit ore, and 4 pounds for ore for which underground mining is planned. Thus, ores averaging about 0.2 per cent U_3O_8 are required at Beaverlodge for mines operating at rates of about 1,000 to 2,000 tons of ore a day.

When the pioneer deposits of Blind River area showed indications of averaging 2 pounds of U_3O_8 per ton, or about 0.1 per cent, it was considered that, despite their fairly accessible locations and the improved treatment methods then available, the grade was about at the economic limit and would require large and low-cost operations. The plants built range in capacity from 1,500 to 5,700 tons a day. Deposits of about the same grade are mined in Bancroft area at rates of about 1,000 tons a day.

It is impossible to make simple generalizations regarding the economics of deposits or to state the smallest sizes and grades of deposits that would be mineable at a given price for uranium, because so many variable factors are concerned, because several of the mines now producing have not been in operation long enough to yield full details, and because full analysis is in the field of accountancy rather than geology. The following brief conclusions, however, seem to indicate the principal points. The Eldorado companies did not pay dividends on the early operations for radium, and later used profits from the production of uranium at Great Bear Lake to help in financing work at Beaverlodge. A dividend of $3,525,000 was paid by Eldorado to the Canadian treasury in 1957; as the Beaverlodge operation is much larger than that at Great Bear Lake, it can be assumed that most of this dividend is attributable to the Beaverlodge deposits. Gunnar Mines Limited declared its first dividend, of $1.25 per share, in 1958. Thus it seems clear that at least the larger deposits in Beaverlodge area are economic, and that, as the profits are not excessive, and as lower-grade material is available but not mined, the grades are approximately minimal for deposits of those sizes under the conditions now prevailing at Beaverlodge.

Pronto Uranium Mines Limited declared a dividend of 75 cents a share in 1958. Other uranium mines in Ontario have not yet yielded dividends, possibly because they came into production later than those at Beaverlodge.[1] Some have shown operating profits, but pre-production costs had to be covered. Others have had financial difficulties, attributed largely to the higher costs necessitated by rapid

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[1] Faraday Uranium Mines Limited, Rio Algom Mines Limited, and Denison Mines Limited declared dividends later.

building programs and speedy mining methods instituted because of the relatively short time intervening between the indicating of orebodies warranting sales agreements and the expiry of these agreements. Thus events have confirmed the opinion that 0.1 per cent U_3O_8 is approximately the minimum grade that can be mined under present conditions at rates between 1,000 and 5,000 tons a day in an accessible part of Canada.

Ore Reserves

The following terminology is used in this report in connection with reserves:

1. Ore is a mineral substance that is expected to be mineable at present at profit to the operator.
2. Measured (proven) ore: Ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, or drill-holes, and for which grade is computed from adequate sampling. The sites for inspection, sampling and measurement are so closely spaced, on the basis of defined geological character, that the size, shape, and mineral content are well established.
3. Indicated (probable) ore: Ore for which tonnage and grade are computed partly from specific measurement, samples, or production data, and partly from projection for a reasonable distance on geological evidence. The openings or exposures available for inspection, measurement, and sampling, are too widely or inappropriately spaced, to outline the ore completely or to establish its grade throughout.
4. Inferred (possible) ore: Ore for which quantitative estimates are based largely on knowledge of the geological character of the deposit and for which there are few samples or measurements. Estimates are based on assumed continuity or repetition for which there is geological evidence.
5. Potential material: Material that has been shown or partly shown to average somewhat less than would be considered ore grade for the district and type of deposit concerned, but to be in substantial quantity. It might become ore in future if prices are raised or if treatment, transportation, or other costs are lowered.

The writers summarized the reserves of measured, indicated, and inferred ores estimated by the companies that had obtained sales contracts, with the following results:

Table XV

Summary of Canadian Uranium Ore Reserves
(*short tons*) (*end of 1957*)

Type	Measured	Indicated	Inferred	Totals
Conglomeratic	31,300,000	279,200,000	45,200,000	355,700,000
Pegmatitic	300,000	9,600,000	980,000	10,880,000
Veins and related deposits	180,000	10,100,000	28,000	10,308,000
Totals	31,780,000	298,900,000	46,208,000	376,888,000

The above figures are based on totals available at the end of 1957. Since that time little additional ore has been outlined because of the decline in exploration for additional uranium deposits. Mine development has to a minor degree added to measured ore at the expense of indicated ore. Consumption totalled about 15 million tons of ore in 1958 and is expected to be roughly at this rate until 1962.

The measured ore included in the above table was partly mined ore in stockpiles or underground workings, and partly deposits that were sampled along underground workings or by closely spaced diamond-drill holes. Indicated ore, which constitutes the largest reserves, is almost entirely material that has been sampled by diamond drill holes spaced reasonably closely, having regard to the nature of the deposit and to previous experience with deposits of that class; estimates of this kind were accepted for the negotiation of contracts. Inferred ore is material that appears to be of present mineable grade for the district in which it occurs, and to occur in significant quantities, but which requires much further exploration. This is regarded as a minimum figure because further exploration or entirely new discoveries could in all probability add substantially to it. The content of the conglomeratic and pegmatitic ores is approximately 0.1 per cent U_3O_8. The pitchblende-bearing veins and related deposits carry from about 0.2 to 0.5 per cent U_3O_8, most ore averaging about 0.2 per cent.

The estimate of 355,700,000 tons of ore in the Blind River deposits agrees well with an estimate made independently by Roscoe (1957). He estimated a total of 320 million tons averaging 0.1 per cent U_3O_8, in beds at least 10 feet thick, and at depths not exceeding 3,700 feet. His estimate did not include the Pronto deposit, which is in a separate part of the region. The rated capacities of plants now operating in the Blind River region total about 35,000 tons per day or 12,775,000 tons per year. Thus the reserves estimated for the Blind River mines should furnish ore at the expected rates for about twenty years, after allowing considerable margin for dilution in mining, for pillars and other sections that it may not be desirable to mine, and for the possibility that some sections might be lower in uranium content than was predicted.

Much potential uranium-bearing material is available but satisfactory figures cannot be presented because exploration is usually suspended when a deposit shows signs of being below present economic grade for its district or of lacking suitable dimensions. The possibilities are discussed in general terms in a later section.

The principal known deposits of thorium in Canada are the uranium ores of Blind River. These are estimated to contain an average of 0.05 per cent ThO_2. Some large deposits in this district appear to average about 0.1 per cent ThO_2. The ores now being mined near Bancroft are estimated to carry about 0.02 to 0.2 per cent ThO_2, but less sampling has been done for thorium there than at Blind River. Certain deposits at Bancroft that are not being mined for uranium appear to carry considerably more thorium.

Outlook

Future demands for uranium. The feasibility of nuclear power plants based on uranium has been amply demonstrated and the number of such installations is growing. Much uncertainty exists, however, regarding the degree of future demand for uranium because of the large amounts of ore available in Canada, the United States and South Africa; because of the intensive search for additional deposits being carried on in several countries; because the economics of nuclear power is not yet well attested by experience with commercial installations, and the amount of competition by conventional sources of power as well as by thorium and thermonuclear energy is difficult to assess at present, and because military demands are unpredictable.

In 1955 the President of Atomic Energy of Canada Limited stated:

> It is impossible to say at this time what the demand for uranium will be after March 31, 1962, the present expiry date of the guaranteed market. The military demand may continue at the present rate or may cease altogether. On the other hand, we may have a situation in which there is still government buying but on a reduced scale. Whatever happens, it can be safely predicted that there will be some requirements for uranium for use in atomic power programs in the early sixties. It is evident, however, that the demand for uranium in the early stages of a Canadian atomic power program will take up only a small part of our potential production. Consequently, if the military requirement ceases or is cut back substantially, Canadian producers may have to look to export markets and should expect to meet the same conditions which prevail in the case of other base metals which are not in short supply.

In summarizing the situation regarding resources of nuclear fuel in 1958, Johnson (1958) estimated that the ore reserves of South Africa, Canada, the United States, and France, are likely to contain 1,100,000 tons of uranium which at present production costs could be produced for $10.00 per pound or less.

Early in 1959 the President of Eldorado Mining and Refining Limited presented the following authoritative outline of the Canadian situation:

> It has been stated many times that the world's ability to produce at the end of the existing contracts would be well in excess of the world's ability to absorb. One of the most recent educated guesses states that production at that point in time will exceed requirements by a ratio of three to one. However, by the late 60's and early 70's requirement should be in balance with productive capacity, barring any expansion of the latter in the interim. These are the cold facts of the problem and the question as to how the gap is to be bridged is becoming daily of more concern. The change in the climate from one of scarcity to one of plenty in a period of little more than two years has effectively freed the planners of our atomic power programs from the worry that was a very real one up to a short time ago, that the limited supply of uranium would effectively interfere with the development of atomic power on a large scale; but the recent efforts of the world's producers and developers have made it apparent that the world can go forward with these projects confident that there will be no shortage of fuel in the foreseeable future, assuming that future discovery will be as productive as it has been in recent years.
>
> The next ten years are going to be difficult but we have built something that most authorities agree has a future and all parties must make a strong and concerted effort to maintain a healthy core during the difficult period of limited demand.

A point that may be of considerable importance after 1962 is that the agreements with private producers allow for some amortization of plants. Therefore, those mines that have additional ore or which are within shipping distances of other deposits may be in strong positions to take advantage of future demand for uranium, whereas deposits that would require construction of new plants would be at a disadvantage unless they were much richer.

Possibilities for additional ore. The possibilities are in general good for the development or discovery of additional supplies of uranium and thorium in Canada if or when required. There are possibilities of revealing extensions or satellites to proved orebodies; of successful exploration of prospects already discovered; of new discoveries; and of deposits now in the potential class, which might become more attractive because of changed conditions.

The figures listed for inferred ore are conservative, not being carried far beyond present exploration. Some of the mines in Blind River area have indicated and inferred reserves in excess of contracts. Because of the limiting, basin-like structure of the main part of Blind River area great extensions of known orebodies beyond these tonnages cannot be expected, but some extension is probable. The larger deposits in Beaverlodge area are not bottomed and the ore-bearing structures are strong, therefore substantial extensions in depth are possible. The more persistent deposits or structures in Bancroft area likewise are not bottomed, and offer possibilities for expansion.

Some prospects would warrant further exploration in the event of demand for still more uranium ores. The history of mining in general indicates that relatively few prospects can be expected to contain commercial tonnages and average grades. Work was stopped at several properties, however, because of the rapid growth of tonnages in Blind River area, and some of these might respond to furthur testing. It would not be fitting for the writers to indicate their opinions regarding individual properties in this category or in the potential class mentioned below, but the references given in the tables in Part IV of this report and on Map 1045-M1, as well as other accounts in the mining press, will provide descriptions from which interested persons could select prospects in the light of future requirements.

Many areas in which the geology is favourable in a general way have not been prospected exhaustively for uranium, and offer opportunities for additional worth while discoveries. These possibilities are outlined below in the section on prospecting.

Considerable amounts of potential ore not far below present ore grades have been partly revealed. No attempt has been made to compile figures for such deposits because exploration was generally stopped short of providing accurate figures, as soon as the average grade became apparent. It is sufficient for present purposes to point out that considerable tonnages of pitchblende-bearing material along the St. Louis fault in Beaverlodge area probably average from 0.1 to 0.2 per cent U_3O_8; that substantial tonnages of conglomerate in Blind River area probably average between 0.05 and 0.1 per cent U_3O_8; and that several large deposits of pegmatitic granite and migmatite in Saskatchewan probably carry averages of 0.05 and 0.1 per cent U_3O_8. As mentioned in the descriptions of types of deposits, there are also indications of ultra-low-grade deposits carrying less than 0.05 per cent U_3O_8, but it is unlikely that these would be utilized when substantial amounts of higher grade material are available.

In addition to the reserves of thorium in Blind River and Bancroft areas, several deposits appear to contain large tonnages of very low grade thorium-bearing material. Some of these are described briefly in Part III of this report. The known occurrences of thorium in Canada were found incidentally to prospecting and exploration for uranium, virtually no prospecting and little testing of prospects having been done directly for thorium. If this should be warranted in future it seems probable that other large deposits, perhaps more suitable than those already known, may be found.

Prospecting

Prospecting, exploration, development, and mining are fairly distinct phases of the mining industry which overlap to some extent. In this report the usages of Peele (1948, p. 10-03) are adopted, whereby prospecting is the search for minerals; exploration is the work of exploring a mineral deposit when found, to gain knowledge of the size, shape, position, characteristics, and value; and development is the driving of openings to and in a proved deposit for mining and handling the product economically. Prospecting includes both the original search for a prospect, and work done later at an established mine to search for additional ore, but it is sometimes difficult to separate the latter from exploration and development. The term 'exploration' is sometimes used in connection with prospecting in remote places and in connection with the geophysical search for ore, but 'prospecting' is less confusing in these circumstances. The term 'development' is often used in some reports for the testing of prospects, but that usage has been avoided here.

It is not always possible to distinguish sharply between prospecting and exploration. For example, the preliminary testing that a prospector must commonly do himself is an intermediate step between prospecting and the more extensive testing of prospects that is usually supervised by a geologist or mining engineer. Also, a radioactivity survey may be undertaken as a form of prospecting, or as a preliminary step in the exploration of a prospect.

Prospecting and exploration for radioactive minerals differ only in details from prospecting and exploration for metals in general. The basic principles are discussed at considerable length in *Prospecting in Canada,* a companion volume to this one in the Economic Geology Series, and few are repeated here. The present discussion is limited so far as possible to matters that are peculiar to work in connection with uranium or thorium. Information on this subject was published in 1952 in the handbook *Prospecting for Uranium in Canada,* much of which is now out of date. These matters are brought up to date in the present publication, and others are included, so that it is unnecessary to refer to the handbook in the event of further prospecting for radioactive minerals. If the handbook is available, however, it will be found that certain matters are explained in more elementary and extended ways. The handbook not only contains certain statements regarding regulations and services that have since been altered, but also, because it was prepared fairly early in the period of interest in uranium geology and uranium prospecting, it was to be expected that although many topics stood the test of time, others were wrongly emphasized. These matters are explained briefly below, in the light of later experience and knowledge. The writers are, however, keenly aware that present knowledge of uranium deposits, and techniques and clues for prospecting, are far from being final.

Prospecting Systems and Services

Prospecting may be undertaken either by private enterprises or by government agencies. In Canada, prospecting for uranium was done in both of these ways and both were successful. Government prospecting was done during and immediately after World War II when special measures were required for security and secrecy. This was undertaken by Eldorado Mining and Refining Limited, and, to a lesser extent, by the Geological Survey of Canada. The two organizations jointly examined known occurrences of radioactive minerals and decided on favourable areas. Eldorado engaged prospectors, mining engineers, and geologists with experience in prospecting for gold and other metals or in supervising prospecting for these metals. These men quickly learned the special features related to uranium. Teams of prospectors worked in localities selected by the supervisors, who checked the results periodically and moved the teams when that seemed advisable. The Survey undertook more detailed geological mapping in as many favourable areas as staff permitted, and prospectors were attached to some of the parties. The Survey and the National Research Council jointly undertook the testing, developing, and building of portable Geiger counters, and much of what now seems standard practice regarding the use of counters and their design was worked out during this period, when more than one thousand pitchblende occurrences were found in the Beaverlodge area alone. These subjects are reviewed at greater length in two papers by Lang (1953a, b).

When the ban on private staking for radioactive minerals was removed at the end of 1947 the Geological Survey ceased adding prospectors to mapping parties, although many parties were still equipped with Geiger counters for incidental use. For a time Eldorado continued prospecting and acquiring claims, but gradually withdrew from these activities and relinquished many claims. Private prospecting was begun in 1948 and reached a peak about 1953 when, for a few years, more persons were prospecting for uranium than for any other metal. Private prospecting was financed and, in some instances, organized in different ways. Some prospectors, particularly amateurs, relied entirely on their own resources. Others were backed by syndicates or companies, but worked with little or no supervision. Some companies, however, conducted organized campaigns for prospecting unstaked areas, or groups of claims, or concessions, under the supervision of a geologist or mining engineer. In some of these campaigns one or more prospectors worked in a roving way within a specified area, and in others prospecting was done along parallel lines commonly 100 to 500 feet apart. Although only a few discoveries became producing mines, all the systems yielded at least one producer. The Bicroft deposit was found by a man working entirely on his own resources. The original discovery of radioactivity that led to the Pronto mine and to the establishment of the Blind River camp was made by a prospector grubstaked by a hotel owner. The other producers were found later by organized prospecting, including the drilling of drift-covered favourable zones. The Gunnar deposit was found by two prospectors sent out by a gold-mining company but working without supervision. The Rix Athabasca deposits were found by prospecting a concession in an organized manner.

The Canadian Government encouraged private prospecting and mining by guaranteeing a price for uranium, by special services outlined below, by conducting geological and metallurgical research, and by free treatment tests on bulk samples. They did not, however, help to finance private prospectors, pay rewards for discoveries, nor undertake to buy claims. Several provincial mining departments assisted prospectors in the usual way by assaying samples, examining certain discoveries, doing geological mapping, and conducting classes for prospectors. Under certain circumstances the governments of British Columbia and Saskatchewan assisted prospectors who were residents of the province concerned, by providing funds or equipment.

After 1947 the Geological Survey continued geological mapping in uranium areas, without including prospectors on parties, and continued research on the geology and mineralogy of uranium deposits. It also undertook to provide, as agent for the Atomic Energy Control Board and because of the urgency to find workable uranium deposits, certain services to prospectors and companies that it does not undertake to provide in connection with other metals. These were: to receive and file notifications of discoveries and reports of work done on properties, as required by regulations of the Board; to collate this information and to augment it by examining as many discoveries as possible, for the purpose of preparing annually a confidential inventory of Canadian deposits of uranium and thorium; to assay radioactive samples free of charge (no other assaying is done for the public by the Geological Survey) and to identify radioactive minerals in such samples; to advise uranium prospectors and companies by interviews or correspondence; and to sell small specimens of pitchblende. At first virtually all discoveries were examined, but the number of insignificant occurrences and the limitations of staff soon made this impracticable. Thereafter, discoveries were selected for examination on the basis of the samples or reports received. It was realized that a few significant occurrences might be passed over in this way, because of inadequate sampling or reporting, but this risk had to be taken because there were soon about one thousand prospectors as compared to a maximum of about ten Survey geologists working on uranium, most of whom were engaged in mapping rather than in studying deposits. At first, all samples submitted by the public were assayed radiometrically, because virtually no other organizations were prepared to do this work, but as the number of samples became excessive and as other facilities became available, the number accepted was limited to six, and only if from a new discovery and submitted by the discoverer. After a few years, identifications of radioactive minerals were undertaken only if the sample or report seemed to warrant it. The sale of pitchblende specimens was discontinued in 1959. The giving of individual advice to prospectors and companies was gradually replaced by pamphlets and other publications.

Regulations of the Atomic Energy Control Board. Although some of the regulations of the Atomic Energy Control Board respecting prospecting and mining were described in the historical section of this publication, they are summarized here together with others not mentioned previously.

The Regulations and certain Orders were made by authority of the Atomic Energy Control Act and have the effect of laws. The administration of the regulations is designed to give all possible freedom to prospecting and mining, although the reporting of information is required and restrictions are placed on the removal of bulk samples and the disposal of ores and concentrates. The reporting of radioactive discoveries and of advanced work done on deposits is needed for scientific compilations and in case of expanded future demand for uranium or thorium. All data so reported are treated in strictest confidence unless and until released in writing by the sender or published in a newspaper or other publication outside the control of the Atomic Energy Control Board and the Geological Survey of Canada. The importance of reporting information is shown by the first and present editions of this report, based largely on non-confidential data reported by discoverers and property-owners; the first edition called attention to many occurrences that would not otherwise have been known to financiers and companies, and contained generalizations useful to geologists and prospectors which were based partly on numerous occurrences that would not have been known without the provisions for reporting.

Copies of the full Regulations and Orders can be obtained from the Secretary, Atomic Energy Control Board, Ottawa, but the following information will serve most needs of prospectors and mining companies unless there are changes.

The regulations do not replace the laws governing prospectors' licences, staking of claims, mine safety, etc. Control of these matters is vested in the provincial governments and in the administration of the Northwest Territories and Yukon. Information on these subjects, for the respective jurisdictions, can be obtained from the Departments of Mines (or their equivalents) of the provinces concerned, and from the Northern Administration and Lands Branch, Department of Northern Affairs and National Resources, Ottawa, for the Northwest Territories and Yukon.

A summary of these laws, for all Canada, called *The Mining Laws of Canada,* can be obtained from the Mines Branch, Department of Mines and Technical Surveys, Ottawa. The regulations of the Atomic Energy Control Board, summarized below, are additional to the provincial and territorial laws.

No special permission from the Board is needed to authorize prospecting for uranium.

No special permission is required for the removal, or shipping within Canada, of the following: uranium-bearing hand specimens; specimens of reasonable size and number for display purposes; grab samples; chip samples; or channel samples.

Shipments of specimens and samples to other countries require export permits, for which forms and information can be obtained from all Collectors of Customs.

Anyone who has reason to believe that he has found a deposit containing 0.05 per cent or more of uranium or thorium must report the particulars, including the exact location, to the *Director, Geological Survey of Canada, Ottawa,* who for this purpose acts for the Board. A reasonable time to permit staking, usually a month, is allowed before sending this information. Any desired publicity may be given to a discovery by the discoverer or owner after the Geological Survey has been notified. If envelopes are addressed to "The Director, Geological Survey of Canada, Ottawa, Ontario", with the words "Attention Economic Geology Division", placed beside the address, the reports will be opened and seen only by a minimum of specially selected personnel. If a sample from a new discovery is being sent to the Geological Survey for radiometric assay or mineralogical test time and trouble will be saved if the locality and other particulars are reported at the same time. Reports should include: (1) name of property or claim if it has a distinctive name; (2) statement of ownership of mineral rights; (3) statement of locality, preferably by township, concession (or range) and lot or by direction and distance to nearest named geographical feature. Localities should be described accurately enough to permit a geologist to find the occurrence without a guide if the Geological Survey should wish to examine it; sketches are often helpful in this regard; (4) statement of the kind of sample or samples concerned (chip, channel, selected, or grab) and the width(s) for which the sample(s) are representative; (5) any information known regarding the geological type of occurrence or of the mineralogy; (6) statement as to whether or not information is to be kept confidential.

To ensure receipt of information on discoveries all Canadian assayers and analysts were formerly required to send to the Geological Survey copies of reports of assays or analyses for uranium or thorium showing more than 0.05 per cent. This requirement was discontinued by the Board after the number of assays for 'development' samples exceeded the number from new discoveries. The entire onus for reporting discoveries is thus now on the discoverers or their employers; it is to their advantage to comply because failure to do so can result in refusal to undertake further assays or tests or to issue exploration or mining permits if these should be required later.

A little stripping or trenching may be done on claims containing uranium or thorium without special permission from the Board. Exploration permits are required, however, for work that goes beyond the stage of ordinary prospecting. In general, work will be considered as going beyond the prospecting stage if it includes diamond drilling, underground work, removal of bulk samples, systematic traversing with Geiger counters or other geophysical instruments, or trenching to the extent of more than 300 man-days. Such permits are issued readily and promptly, free of charge, their main purpose being to ensure receipt of the information needed to keep the inventory of uranium resources up to date and to increase as rapidly as possible the geological information available to prospectors and operators. Applications for permits should be made to the *Secretary, Atomic Energy Control Board, Ottawa,* and should give the following information:

1. The full name and address of the applicant, and, if the applicant is a corporation, the manner of its incorporation and the names and addresses of all of its directors and officers.
2. The name and address of the person who will be in charge of the work on the ground.
3. A complete and accurate description, preferably by lot and concession number, township, county or district, and province or otherwise by claim number, district, and province, of all property intended to be covered by the permit.
4. A general description of the work contemplated.

A permit stipulates that complete and accurate annual reports showing the work done at the property, and its results, must be sent promptly to the *Director, Geological Survey of Canada, Ottawa*. Such reports are treated as confidential until released by the property owner. The property owner is free to publish his results, after having notified the Geological Survey.

If work is stopped temporarily for seasonal or other reasons, the Geological Survey should be notified so that reporting may be suspended, and it should again be notified when resumption of work is planned. These notifications are necessary because failure to send reports may invalidate a permit. If abandonment of the property is planned the *Secretary, Atomic Energy Control Board* should be asked to cancel the permit.

No further permit is required until a property nears production, when a mining permit will be required to provide for control of material and information.

No provision is made to have notifications of discoveries or reports of work accepted or forwarded by mining recorders or resident geologists, but most of these officials can advise regarding the correct procedure.

On March 31, 1959, the number of exploration permits in force was 379 and the number of mining permits was 22. The largest number of exploration permits was in 1955-56, when a total of 422 were in force. Most of the companies holding exploration permits in 1959 were inactive.

Personnel

Prospecting for uranium was done in Canada by persons of widely different training and experience. Canada has a highly regarded group of skilled prospectors who are not engineers or scientists, but who have spent much time learning their craft by attending special classes in the winter, by home study, and by working under experienced prospectors, engineers, or geologists. Prospecting is the sole calling of many such men. Others work at such occupations as trapping and mining during part of the year, but would nonetheless be considered 'professional' prospectors. When prospecting for uranium was undertaken by the Government during the last war, several such men who had previous experience in prospecting for gold and other metals were employed and taught to recognize a few uranium minerals and to use counters. Later, when private staking was resumed, a much larger number of the same kind of men turned their attention to uranium and were largely responsible for the success that has been attained during the last few years. Many geologists, geophysicists, and mining engineers were also engaged, either in supervising conventional methods of prospecting, or in prospecting by special methods.

There are also competent amateur prospectors. The word 'amateur' is here used to describe a man who engages in the search as an avocation apart from his means of livelihood. As in most other hobbies, however, amateur prospectors need to acquire much knowledge and experience either by taking instruction or by study and practice by themselves. The word 'amateur' is sometimes used to describe a 'beginner'. For several years most of those searching for uranium in Canada were beginners—tourists, vacationers, week-enders, farmers, and others. Most of these were misled by glamorous publicity on uranium to assume that possession of a Geiger counter avoided the necessity of knowing anything about prospecting. Indeed, many did not obtain counters, but merely sent for testing specimens collected at random. The Geological Survey may have contributed to this misunderstanding by stating in the opening of the booklet *Prospecting for Uranium in Canada*: "the amateur searching for uranium by means of modern equipment has a chance of finding a uranium deposit even though lacking the expert knowledge and experience of the professional prospector". Later experience showed that it should not have been assumed that readers would understand that they would have to distinguish between traces of radioactivity or small radioactive occurrences and ones that showed some promise. This statement was, however, a minor contributing factor, the main one apparently being that, as in gold rushes, many persons became obsessed and failed to consider the technical and business matters involved and the chances of success. It is true that the number of insignificant radioactive occurrences reported aided in outlining areas containing at least small amounts of radioactive minerals, but this was offset by the great amount of time devoted to individual attention to elementary inquiries that were adequately covered in the literature available, and to assaying worthless samples. There is no wish to belittle the efforts of the less worthy amateurs; it seems important, however, to point out the pitfalls in case of another wave of popular prospecting for uranium. From 1948 to 1958 a very large number of radiometric assays were made on prospectors' samples by the Geological Survey. For a time these numbered about one thousand a month. Year after year about 85 per cent of these samples yielded less than 0.05 per cent U_3O_8 equivalent, indicating that despite the great amount of correspondence and elementary literature disseminated, many persons either were still attempting to find uranium without using radioactivity detectors or, if they had them, were not using them properly.

Mines that became producers were found by all the above-mentioned types of prospectors except the unqualified amateurs. The Eldorado mine at Great Bear Lake, the Ace at Beaverlodge, the Gunnar, the Pronto and some other mines at

Blind River, and the Faraday at Bancroft were found by experienced 'professional' prospectors who had spent considerable time searching for gold or other metals before turning their attention to uranium. Other producing deposits at Blind River lie beneath overburden or barren rock and were found by diamond drilling done to test theories formed by geologists on the basis of published geological maps and knowledge of the manner of occurrence of deposits already found. The early Bicroft discoveries were made by a competent amateur prospector who carefully studied and intelligently applied information contained in the booklet *Prospecting for Uranium in Canada*. The multitude of incompetent amateurs found many minor occurrences of radioactivity, but the nearest approach to success known to the writers, who have followed the subject with interest for years, is an instance whereby a vacationist is said to have found a radioactive occurrence that showed promise, and which was explored extensively by a company although it did not become a producer. The discoverer is said, however, to have told another person about his find, and this person is rumoured to have staked it and sold the claims.

Selection of Areas for Prospecting

The selection of a field of operation is an important subject which offers much scope for theories, preferences, and luck, as well as for careful study of all pertinent data. Obviously, it cannot be discussed fully here, because many of the topics throughout this publication bear upon it, to say nothing of the more detailed information contained by local reports and maps. All that is attempted here is to summarize certain important considerations and to indicate some more speculative possibilities, without implying that these are the only approaches to the problem. All the suggestions must be interpreted in the light of the current demand for additional deposits of uranium. Areas favourable for thorium are not discussed specifically because some of the types of uranium deposits also contain important amounts of thorium.

The producing uranium camps offer opportunities for further prospecting, because of favourable geological environment, and because treatment plants may be available. The more accessible camps would have advantages, but these might be offset by higher-grade ores in the Beaverlodge area and the camps in the Northwest Territories. Because of the availability of plants the search for extensions of known orebodies and for additional orebodies at properties now producing would be especially attractive. This would probably require specialized prospecting because little, if any, opportunity for ordinary outcrop prospecting remains on producing properties. Several other areas offer possibilities for both outcrop and subsurface prospecting. Some are areas where occurrences have already been found, and others are areas where the geology is analogous to that of producing areas but where occurrences have not yet been found. Some such places are mentioned in the section on distribution, and also are outlined on the metallogenic map in pocket.

The influence of the various types of producing deposits on the selection of areas in future cannot be fully assessed at the time of writing but should be considered in the light of demands, costs, treatment methods, transportation, and other factors. Conglomeratic deposits have the advantages of accessibility, size, and uniformity, and the disadvantages of marginal grade and the limiting structure of the Quirke Lake Basin (*see* p. 127). Although there are possibilities for extending some known orebodies and of discovering others within this basin, present indications are that considerably less material of present ore grade than has already been outlined remains to be found within the basin. Other possibilities, both for deposits at analogous stratigraphic positions and at other positions, may exist in regions underlain by Huronian sedimentary rocks, where prospecting and drilling have been less intense. The possibilities of conglomerates of other ages, in other parts of Canada, are even more difficult to predict. One way of searching would be to test any conglomerates regardless of theories of origin of the Blind River deposits. Or, if the deposits are regarded as being entirely or partly of detrital origin, basement rocks might be investigated to seek areas where such rocks showed abnormally high radioactivity or where accessory uranium or thorium minerals could be found in them, then search could be made for conglomerates or other detrital sedimentary rocks in or near such areas. On the other hand, if the deposits are regarded as being formed entirely or significantly by hydrothermal or other epigenetic processes, conglomerates could be sought and tested in other areas favourable for the operation of these processes, such as places where other kinds of hydrothermal occurrences have been found, or places where wall-rock alteration or zones of fracturing or faulting occur. Such conditions would be particularly attractive if within areas regarded as metallogenic provinces for uranium on the basis of the present limited knowledge of this subject.

Areas favourable for the occurrence of pitchblende deposits would have the advantage that discoveries would probably be higher in grade than those of other types. The pitchblende areas now productive are, however, more remote than other producing areas. Moreover, most pitchblende discoveries, although high in grade, are too small or erratic to be of commercial value unless uranium is in such demand that small ‘pockets’ would be worth gleaning here and there. On the other hand, the larger producing orebodies of the pitchblende type offer opportunities for the discovery of extensions in depth or laterally, and additional deposits of these magnitudes may be found.

The Bancroft area offers possibilities for discovery of extensions of presently known orebodies or of additional deposits. The chances of successfully developing known pegmatitic occurrences and of discovering important new ones in other areas seem less favourable than for deposits of the pitchblende type because radioactive minerals are usually only accessory minerals in pegmatitic deposits, and even the productive pegmatitic deposits are, in general, more difficult to interpret, follow, and mine than the principal pitchblende deposits. The Bancroft operations indicate that pegmatitic prospects and areas favourable for pegmatitic occurrences should not be rejected too arbitrarily but present indications are that even more experience and caution would be required in appraising their possibilities than in the case of conglomerate or pitchblende prospects or areas.

Searching for deposits of types that are not now represented by producing mines in Canada also offers possibilities. The most intriguing types in this category seem to be those that provide large quantities of uranium in fairly flat lying sedimentary rocks in the Great Plains and adjacent basins of the west-central United States. There, deposits have been found in strata ranging in age from late Palæozoic to Tertiary, and largely in Triassic and Jurassic beds. Common host rocks are sandstone, limestone, and conglomerate. Many deposits are disseminations of carnotite, pitchblende, or other uraniferous minerals. Other deposits are beds of uraniferous coal and lignite. Many of the mines in west-central United States have the advantages of grades substantially higher than the Blind River deposits, the average tenor of uranium ore reserves in the United States in 1958 being 0.27 per cent U_3O_8. Also, most are mineable by open-pit methods or by relatively shallow underground operations. The possibilities of finding commercial deposits of these kinds in the Interior Plains of Canada do not seem so attractive as in analogous parts of the United States, for the following reasons. Although there are conflicting criteria and theories regarding the modes of origin of the American deposits, it is commonly considered that the erosion of uranium-bearing lodes comparable to those now found in the front ranges of the Rocky Mountains in the United States supplied uranium to some of the sediments being laid down farther east, and that the uranium deposits now present are related directly or indirectly to these conditions. The front ranges of the Canadian Rocky Mountains contain no known uranium deposits with the possible exception of very low-grade phosphate rocks and shales, and they contain few metalliferous deposits of any kind. Another consideration is that most of the principal American deposits are in areas where igneous intrusions and upwarping of strata took place, thus causing beds to be exposed by erosion around the edges of uplifts, and providing conditions favourable for primary hydrothermal mineralization or for migration and modification of earlier sedimentary deposits. In the Canadian plains there is less evidence of uplifting although there are such features as the disturbed belt near the Foothills, and the Sweet Grass Arch in southeastern Alberta. Lang tested for radioactivity and searched for other signs of radioactive minerals at many outcrops in the plains of Alberta, Saskatchewan, and Manitoba, and as an additional check he took many samples that were tested for radioactivity. No significant results were obtained. Many wells drilled for oil or gas have been logged radiometrically for stratigraphic purposes by private concerns. These logs have been studied by officers of the Geological Survey, the most radioactive unit so far found being the Exshaw shale or its equivalent, which is only slightly radioactive (*see* p. 65). Also, Steacy tested in groups more than one million samples of oil-well cuttings stored by the Survey, without detecting significant radioactivity. Many samples of coal and lignite have also been tested, the ash of only one yielding more than 0.05 per cent U_3O_8 equivalent (*see* p. 65). On present knowledge, the possibilities of the Interior Plains do not seem particularly promising, but they are not exhausted and the beds may merit further investigation. Much information on the geology of the American deposits will be found in publications on the International Conference on Peaceful Uses of Atomic Energy, and by the United States Geological Survey, and the United States Atomic Energy Commission.

It should also be borne in mind that several other types of occurrences are represented by nonproducing examples and might repay further investigation; and that uranium in recoverable amounts may yet be found in some large deposits of iron, copper, or other metals; and that, awaiting discovery, may be types of deposits now unknown, and formations or conditions not yet realized to be favourable for types that are known. Use of radioactivity detectors for routine tests probably would render the search for such deposits, formations, and conditions easier and less dependent on theories than if the search were in connection with non-radioactive metals.

Methods of Prospecting

Most of the knowledge and skill desirable in prospecting for uranium are common to prospecting in general. These fundamentals are discussed in the separate publication *Prospecting in Canada* (Lang, 1956) and are not repeated here. It is commonly thought that if a man has a Geiger counter or other instrument he does not need to know any of the usual lore of the prospector, but although a counter gives a completely unskilled person an outside chance of finding an important deposit, there are so many weakly radioactive rocks and other pitfalls that it is almost essential to have not only a sound knowledge of prospecting in general, but also of the special considerations discussed in the following sections. Most of the prospectors who found productive uranium deposits in Canada could make practical use of geological maps and reports, recognize common rocks and possible zones of faulting or fracturing, recognize pitchblende and uranium stain or at least be sufficiently alerted for practical purposes, use a counter properly to distinguish adequately between prospects and mere occurrences, and carry out preliminary exploration of prospects. Some made good use of panning or radiometric surveys.

Narrowing the search. Unless a large area is to be tested in a completely routine way it is desirable to narrow the area down on the basis of published or observed geological data. Few country-wide generalizations can be offered in this regard but the following points are worth noting. It is impossible to generalize broadly regarding favourable host rocks because these vary in different uranium districts and with different types of deposits, but there is a tendency for pitchblende occurrences to favour dark coloured rocks high in magnesia and iron, rather than light coloured rocks largely composed of quartz or feldspar. Many exceptions to this have however been found. Many pitchblende deposits are in areas containing numerous northeasterly trending faults, but it is not yet clear whether there is any genetic reason why this direction should be more favourable. Places where red, hematitic alteration of rocks is extensive may be worth special attention. Many pitchblende deposits and some pegmatitic ones were formed in rocks that were much fractured or crushed, and they contain relatively soft or soluble minerals. Both conditions permit more rapid erosion of the deposits and the rocks most closely associated with them than of harder or less deformed rocks. Depressions in areas that are otherwise favourable may, therefore, be worth careful prospecting. They may contain a few rock exposures, or contain radioactive bedrock or rock fragments or secondary minerals not buried too deeply to be detected with a counter. Water in a depression overlying a deposit may occasionally contain enough uranium to cause a significant reading with a counter, but this possibility should not encourage persons to test lakes or streams with a counter, or to send water from swamps or springs for investigation unless the liquid sample causes a strong count when tested at a place where the background is normal, in the same way as is recommended for solid samples (*see* p. 114). Soil, water, or plants in depressed places may also be tested by experienced persons using geochemical techniques as outlined on page 117.

Portable radioactivity detectors. Early instruments for detecting radioactivity, such as electroscopes and scintilloscopes, have been so superseded by Geiger counters and scintillation counters that they are not discussed here. Information on the principles, use, and care of Geiger and scintillation counters is available in several publications, including *Prospecting in Canada* and manuals that may accompany particular instruments, therefore the following discussion is limited to a brief description of counters and to what are considered to be the most important principles in their use for prospecting. Strictly speaking, a Geiger-Mueller counter contains a tube having a thin wire stretched along its axis to act as one electrode, whereas a Geiger counter contains a tube having a needle for this purpose. The two terms are, however, now commonly used interchangeably and the shorter term is used here regardless of the kind of tube. The wall of a tube is penetrated by gamma rays, and also by beta rays in the case of special tubes with thin walls. These rays cause ionization of the gas that fills a tube, and a certain proportion of these reactions are amplified by the circuit so as to produce a 'click' in an earphone, an indication on a meter, or a flash on a light-bulb. Most varieties of tubes wear out with use and may give misleadingly high reactions shortly before they 'die'. Most circuits are amplified by tubes analogous to radio tubes, but transistors, having the advantages of compactness and lightness, are being increasingly substituted. Waterproofed sets have advantages but are not essential for most Canadian conditions. Some models are equipped with a probe which contains the Geiger tube; this permits mobility without moving the entire counter, but is of more service in geological or mineralogical investigations than in prospecting. A semicylindrical lead shield can be placed over a probe to make the instrument more directional by screening rays striking the probe from the side, but the weight of such shields has kept them from being used widely in Canada. The detecting unit of a scintillation counter is a crystal instead of a tube. When a gamma ray strikes the crystal a light-emitting particle is struck off, which registers on a photomultiplier tube (the so-called 'electric eye'). This reaction is generally interpreted by means of a meter.

Geiger counters are of many different makes, models and prices, the last ranging from about $50 to $300. The simpler types equipped only with earphones are quite satisfactory for ordinary prospecting and are commonly lighter. Their relative cheapness permits many persons to have two of them, which is desirable because even the best counters may get out of order or be damaged unexpectedly. It has been found, however, that the cheapest models get out of order more frequently than those of moderate price, and experience of the Geological Survey, as well as of prospectors who have been consulted, has been that the counters in the price range of about $100 to $150 are most suitable for ordinary prospecting. The still larger and more expensive Geiger or scintillation counters equipped with meters are almost indispensable for making radiometric surveys and are more useful in many respects for engineers and scientists in examining discoveries; they are as suitable for ordinary prospecting as the simpler ones, except for cheapness and lightness. Scintillation counters may be used for any kind of prospecting, radiometric surveys, or examination of discoveries, but their expense is an unfavourable feature. They are particularly useful when dealing with low-grade deposits, when attempting to detect through as much overburden as possible, or when making very precise radiometric surveys. Some persons believe that the greater sensitivity of scintillation counters permits them to detect radioactivity through much more cover than by means of a Geiger counter. Generally speaking, however, about 4 feet of water or overburden, or 10 feet of snow will successfully mask the radiation from a radioactive source when a scintillation counter is used. These distances are about 30 per cent smaller when a Geiger counter is used. Where radioactive minerals have been found through much greater thicknesses of overburden as a result of surface indication detected by a Geiger or scintillation counter this is attributed to the presence of radon, or of secondary uranium minerals deposited by percolating water, or of uranium carried in solution in such water, or of small specks of primary minerals that became mixed in the overburden, within a few feet of the surface.

The most important matters concerning the ordinary use of radioactivity detectors are to walk or otherwise move the counter slowly or to keep it stationary for a time, so as to give the detector time to react, and to allow for 'mass effect'. Many common rocks contain minute quantities of potassium, thorium, or other radioactive elements, and rays coming from several square feet or more of such rock cause a cumulative effect on the counter, so that it registers what appears to be a significant reaction of several times the normal 'background' count coming from common rocks, soil, or cosmic rays. This 'mass' effect is still further accentuated if the counter or its probe is held in a crevice, trench, underground mine working, or diamond-drill hole, when rays will reach the counter from several directions, thus adding to the number of counts. To allow for the possibility of mass effect in ordinary prospecting, it is always necessary to use the counter in two steps, first as a detector, and second as a means of testing a specimen or sample. During the first step the counter is held about 6 to 12 inches away from the surface of the ground or from the surface of an outcrop or cliff, and is moved slowly over it. If a count of two or three times the background is heard, or seen on the dial of a Geiger counter, or if a fairly high count is registered on a scintillation counter, this may be considered an indication worth further checking. In using the earphone-type counter, as the normal background count is usually about 30 counts per minute and as counts of about 100 per minute or more register as a continuous buzz rather than as discrete individual counts, it is usually safe to consider that if the clicks can be counted they may be disregarded and that attention should be paid as soon as the counts become a buzz. If what seems to be a significant count is detected, stage two must be followed. This consists either of detaching a hand specimen from what appears to be the most radioactive spot or of chipping several small pieces to form a chip sample that is fairly representative of a width of from 1 foot to 3 feet of radioactive rock, taken across the strike of the radioactive zone if this is apparent. If it seems wider than 3 feet, separate samples may be chipped. Then the specimen or sample is carried away from the radioactive locality to a place where the background is normal, and is held against the side of the counter, preferably the side that is closest to the tube; if the counter has a probe it is placed against the sample or specimen. In most instances, because of the prevalence of mass effect, it will be found that the sample or specimen does not significantly raise the count and it can be discarded. If several trials of this kind are unsuccessful, the reaction can confidently be assumed to be nothing more than mass effect, and the prospector can continue on his traverse. If, however, the sample or specimen does raise the count three or four times the background or gives a comparable count on a scintillation counter, it should be sent for assaying by one of the methods explained later, unless the prospector has learned from previous experience that still higher counts are necessary with his instrument and manner of using it to indicate material that will yield a significant assay. It is impossible to state definitely what constitutes a significant assay because so much depends on demand, size of deposit, and location, but in recent years in Canada it was considered that under the most favourable conditions 0.05 to 0.1 per cent U_3O_8 might suggest a place warranting further search, and that 0.1 per cent U_3O_8 or more might represent ore. While waiting for the report of assay the prospector has two choices. If the count seems fairly low he will probably be wise to continue prospecting and not to arouse his expectations, but if the count is high, and particularly if he can from one or more of the field indications mentioned elsewhere form a fair idea of whether he is dealing with uranium or thorium, he may proceed to explore the occurrence in a preliminary way.

Ordinary radioactivity detectors are generally used in prospecting in one of two ways, which may be called 'roving' and 'systematic'. In either case their use is combined with geological observation and other arts of prospecting, unless the operator is completely inexperienced. In the roving method he moves slowly over outcrops, and more or less at random from outcrop to outcrop. In the systematic method he takes readings at specific intervals along lines commonly 100 to 400 feet apart, the lines being surveyed by one of several methods, commonly by pace and compass or picket-line and compass. In either roving or systematic prospecting, the counter should be turned on and observed while walking between outcrops or 'stations'. In some organized schemes places where strong radioactivity was detected or where other observations were made, were marked by paint on rock, blazes on trees, or other means. Another method of prospecting with a counter, which may be called routine, consists of testing old mine dumps, trenches, and other workings or exposures, or collections of specimens, samples or drill-cores.

Car-borne detectors. Early in the search for uranium some prospecting was done along a railway using a special radioactivity detector mounted on a hand-car. Considerable prospecting has been done in other countries with special scintillation and other detectors in jeeps and other automobiles. This has not been done to any extent in Canada, probably because most of the prospecting was in parts of the Canadian Shield where roads are scarce. Use of an ordinary scintillation counter held in the open window of an automobile moving slowly along country roads was reported to have led to the discovery of a niobium-uranium deposit that later was tested extensively.

Aeroradiometric prospecting. Experiments in measuring natural radioactivity with airborne detectors have been conducted in Canada by organizations of the federal government since 1947, being continued whenever new equipment appeared capable of providing additional information. Prospecting for uranium provided the main impetus to the studies. Instruments and techniques that are useful under certain conditions have been developed in this country and abroad by industrial and government groups. Because of the recent decrease in interest in prospecting for uranium there has been a marked reduction in aeroradiometric surveys in Canada both by governments and industry.

The general aeroradiometric technique is based on use of a sensitive gamma-ray detector (usually a scintillation counter) in an aircraft especially chosen for the 'target' and survey conditions. Two general flight patterns are used: the survey technique is used in exploring large areas of virgin country for geological information and radioactive sources of large exposure. Heavy fixed-wing aircraft with complex instruments are utilized and flight clearances are about 500 feet or greater. Lines are usually spaced at regular intervals. The prospecting technique is used in local exploration for radioactive sources of small exposure. Helicopters or light aircraft with simple instruments are utilized and flight clearances are about 200 feet or less. A random flight path is followed at the discretion of the geologist-observer. Essential data recorded are: the detector signal, the terrain clearance (vertical separation of aircraft and terrain), and a positioning filmstrip of the flight track. These data are interpreted on the basis of previous experience and known empirical relationships. With the helicopter technique, anomalies may be evaluated in flight or by landings and the data need not be recorded.

The interpretation of aeroradiometric data is complicated by many variables. The main variations in the recorded signal intensity are:

(1) An increase with increase in the percentage of radioactive elements present in the source material.

(2) An increase with increase in the area of a given source material exposed on the surface of the ground.

(3) A decrease in intensity with increasing air distance between source and detector.

(4) A decrease with increasing velocity of movement of detector relative to a small source.

Airborne radioactivity detectors measure gamma radiation from thorium and potassium, as well as from the radium decay products of uranium. Occasionally, atmospheric contamination from nuclear explosions and possibly secondary gamma rays from cosmic radiation may interfere with measurements of the natural terrestrial radioactivity.

Most rocks are very weakly radioactive and have low radiation backgrounds despite their large area of exposure. Many granitic rocks and some shales and sandstones are more radioactive, although they are only weakly to moderately radioactive in comparison to uranium and thorium ores. The cumulative radiation from large exposures of such rock, however, commonly causes anomalies similar to those from veins of uranium and thorium. Such veins are rarely exposed over areas larger than about 4 feet by 100 feet. Most overburden is fairly inactive; 3 to 5 feet of such material will effectively absorb the radiation from sources beneath it. Similarly, 1 foot to 2 feet of solid, non-radioactive rock will effectively shield underlying sources from detectors.

Varying degrees of success have been experienced in different countries in finding radioactive mineral occurrences from the air. Sedimentary and pegmatitic deposits were readily located but there were no significant discoveries of vein type deposits. False anomalies resulting from the mass effect of large exposures of weakly radioactive rock and from sudden clearance changes are common, especially in rolling Precambrian terrain. In Canada, where most aeroradiometric prospecting has been in the area underlain by the Canadian Shield with its Precambrian granitic and metamorphic complexes, less than ten of the thousands of radioactive occurrences showing 0.05 per cent or more of U_3O_8 or ThO_2 were reported to have been found by aeroradiometric means, and no orebodies were directly attributed to this form of prospecting. In two instances, however, the exploration of properties that became productive was said to have been aided by aeroradiometric surveys.

The relative success of aeroradiometric survey techniques depends upon the geological environment in which the desired sources are located. The sedimentary-type uranium deposits of the United States commonly have a moderately large exposure and thus relatively high intensity; they occur in sediments with a low radiation background. In contrast, pitchblende veins have a very small exposure and thus a relatively low intensity. They generally occur in metamorphic and igneous complexes with a variable, and usually high, radiation background. This background would overwhelm the anomaly from a significant vein deposit and make it difficult to detect except at relatively short air distances (i.e. low elevations). Because of these characteristics, successful location of vein-type occurrences is considered to require passage of the detector within 200 to 300 feet of the deposit (i.e. a useful flight elevation of about 100 feet or less). For sedimentary and pegmatitic occurrences, limitations are much wider and a useful flight elevation is considered to be about 300 to 500 feet depending upon the size of the exposure and sensitivity of the detector. However, low elevation flight provides greater radiation contrasts and significant anomalies are more readily recognized, providing the speed is not too great. In summary, aeroradiometric surveys may be useful in prospecting for certain kinds of deposits occurring under certain geological and topographical conditions, and for guiding the exploration of properties, but it does not appear to be as simple or as universally applicable as is sometimes supposed.

The literature on aeroradiometric techniques and surveys is extensive. The earlier Canadian papers are listed by Griffith (1956), and the work in other countries has been summarized by Nininger (1956b, pp. 155-191). Recent publications include those by Boyle (1958), Brownell (1959), Gregory (1960), Mackenzie (1956), and Sakakura (1957).

Other geophysical methods. Various geophysical methods other than those based on radioactivity have proved useful in searching for or outlining non-radioactive deposits. They have not been used to any extent in Canada in prospecting for uranium deposits, except that airborne magnetometer surveys were sometimes combined with airborne radioactivity surveys. Possible uses of other geophysical methods in connection with the search for uranium were mentioned several years ago (Lang, 1952); their general lack of application in the past in Canada can be attributed largely to the successes obtained from use of radioactivity detectors on the ground, and also to the fact that the type and environment of orebodies so far found in Canada may not be so amenable to other geophysical methods. The results of tests of a wide variety of geophysical methods in the United States by the United States Geological Survey have been summarized by Nininger (1956b, pp. 193-201); seismic-refraction and electrical resistivity methods are reported to have been particularly applicable to deposits in the Colorado Plateau region. These or other methods might be useful in future prospecting by companies in Canada, particularly in searching for additional deposits in established producing areas; they would probably have fewer applications for prospecting by individuals.

Geochemical methods. Geochemical methods of prospecting, based on field or laboratory chemical tests for traces of metals in water, soil, rock, or plants, have not been used extensively in searching for uranium deposits in Canada. Senftle

(1946) made a preliminary study of the radium contents of waters near the Eldorado mine at Great Bear Lake, and S. C. Robinson (personal communication) conducted a trial study of the uranium contents of trees and plants in Beaverlodge region (Lang, 1952). Both investigators concluded that further work was warranted, but although at least one company began it, no resulting discoveries were reported. This was doubtless due to the successful uses of radioactivity detectors on the ground, to the glaciated nature of much of Canada, although this does not necessarily preclude use of geochemical methods, and to the wane in searching for additional uranium deposits. Geochemical methods may be used more extensively in Canada in future, and would appear to be particularly useful in searching for deposits hidden beneath low, and possibly swampy, ground. In that case papers, too numerous to list here, based on wider and more thorough applications in other countries are available in the proceedings of the first and second International Conferences on Peaceful Uses of Atomic Energy. The papers of the first conference, together with other pertinent literature, have been summarized by Nininger (1956b, pp. 202-255). Methods used in the Colorado Plateau region of the United States are described by Cannon (1957).

Appraisal and Exploration

Most matters regarding the appraisal and exploration of radioactive discoveries are common to mineral deposits in general. As these matters are discussed at some length in *Prospecting in Canada,* only the special considerations that apply to radioactive occurrences are discussed here.

The prospector must generally decide for himself which discoveries are worth attention, unless he is a member of a group for which all discoveries are checked by a supervisor. For this reason no sharp distinction can be made between prospecting and exploration. It is commonly necessary for the prospector to decide whether radioactivity is due mainly to uranium or thorium, as explained in the previous section, to decide whether the occurrence appears to be large enough and of sufficient average content of uranium or thorium to be worth further investigation, and, if so, to do a little stripping or trenching to prepare it for the first examination by a geologist or engineer. Most work of this kind is done later, if at all, under the supervision of a geologist or engineer. Prospectors may also make radioactivity surveys. A few have done a little preliminary diamond drilling with light drills.

Ground Radiometric Surveys

Ground radiometric surveys have proved useful for preliminary work on and near certain radioactive discoveries that appear to be fairly extensive and that are not too deeply covered. These surveys are made by recording readings of a meter-equipped Geiger or scintillation counter, on a grid with intervals usually from 5 to 100 feet apart. A base line is usually surveyed, stakes or other marks being placed at the intervals selected, or if two tapes are available, one is left on the base line and moved in stages. A tape is generally used to measure the stations along side lines, but pacing may be substituted for rough surveys. A common method is for one man to stand at the base line acting as recorder, and to pay out the tape for the instrument man who calls out the readings; the recorder would move along a side line if the area to be covered were wider than the length of the tape.

The instrument is placed on the ground or on two sticks if the ground is wet, and should be oriented in a constant direction; a plastic bag may be tied over the bottom of the instrument to keep it clean and dry. Readings may be recorded in a notebook, but a time-saving method is to record directly on squared paper fastened to a board or 'spring binder'. Readings may be either counts per minute, millirontgens, or expressed as convenient multiples of the background count if a Geiger counter is used; useful surveys have been made in both ways, but the present tendency is to prefer direct counts because of variations in background and because of increased use of scintillation counters. Lines analogous to contour lines, called isocounts, are then drawn through points of equal radioactivity, convenient intervals being selected according to the range of radioactivity detected and the amount of detail desired. Areas between isocounts may be coloured on the plan.

Surveys of this kind are only semiquantitative, because some parts of the area may be covered by more overburden than others, and because radioactive minerals are generally scattered irregularly in bedrock. Nevertheless, such surveys are useful as a guide to where to begin, and how to space, stripping, trenching, sampling, or diamond drilling. If the area or areas of highest radioactivity yield favourable results, places in the next range are tested, and so on, until the body or the part of it that appears to be of significant grade is outlined. So far as the writers can learn, attempts to relate readings directly to uranium content have not been successful in Canada, although deposits in other countries may have been so well exposed and so evenly mineralized as to permit this.

If possible, radiometric surveys should be made before any blasting is done in the vicinity, because radioactive particles may be scattered widely by blasting. Scattering may, however, be minimized by placing logs over the rock to be blasted.

Examples and descriptions of radiometric surveys made in Canada are included in a paper by Brownell (1950).

Distinguishing Between Uranium and Thorium

The question of whether a radioactive mineral discovery consists mainly or entirely of uranium or thorium is best determined by special radiometric assays or chemical analyses on samples sent to a laboratory. The time required for this in Canada is commonly not prohibitive because of good mail and bush-aircraft services. It is, however, always desirable for the prospector to form an opinion on this matter if possible without waiting for reports of laboratory tests. Under such circumstances, the most useful guides are mineralogical. In many instances the presence of bright yellow or orange uranium stain associated with strong radioactivity is sufficient indication, because thorium minerals do not produce such stains. Also, it is usually possible to distinguish crystalline uraninite fairly readily and pitchblende often can be identified with reasonable certainty. This is about all that can be done by most prospectors to identify radioactive minerals. Laboratory tests to identify these minerals are commonly more difficult and costly than assays or analyses, and are rarely required until the questions of geological type of occurrence, or treatment possibilities, arise. Red alteration surrounding a radioactive discovery is a moderately reliable indication of uranium. Some Geiger counters are equipped with tubes or probes that permit both the screening of beta rays and the counting of combined beta and gamma rays. On this basis it is theoretically possible to form an opinion of the relative abundance of uranium and thorium, because the ratios of beta to gamma rays differ with the two elements. In practice, however, this does not appear to have been of much use. Certain scintillation counters are equipped so as to permit comparisons between the energies of gamma rays emitted by uranium or thorium, but this method of distinction is not known to have been much used.

Uranium and thorium can also be distinguished sufficiently for most practical purposes by the fluorescent-bead test described below.

Fluorescence tests. Unaltered pitchblende, uraninite, or other primary uranium and thorium minerals do not themselves fluoresce under ultraviolet light, but may by alteration give rise to thin patches or coatings or tiny crystals of secondary minerals that will fluoresce under shortwave ultraviolet light such as is produced by a portable ultraviolet lamp or 'mineral light'. Deposits of secondary uranium minerals may fluoresce similarly. The usefulness of radioactivity detectors renders it unnecessary for a prospector or geologist to carry such a lamp unless he intends to make bead tests, but lamps were used successfully in helping to outline, at night, a deposit of autunite.

The fluorescent bead test is based on the fact that a fused bead of sodium fluoride or lithium fluoride, in which a little uranium is dissolved, will fluoresce under ultraviolet light. It is useful because it will work with all important uranium minerals, and is sensitive enough to detect the presence of very small amounts of uranium in most cases. However, minerals such as monazite and allanite, containing only very small amounts of uranium with much cerium, will not yield fluorescent beads by this test.

The equipment required consists of:

(1) Wire, to hold the bead, and wire-cutting pliers. Iron stovepipe wire, obtainable at most hardware stores, is satisfactory. Platinum wire, of course, is better, but expensive.

(2) Means for producing a small, hot flame, such as a pressure gasoline stove or torch. The use of an alcohol lamp and mouth blow-pipe has also been suggested. Alcohol torches that have been tried do not give enough heat to be satisfactory.

(3) A supply of sodium fluoride or lithium fluoride. These are dry powders obtainable from chemical supply houses. They are poisonous if taken internally, so should be well labelled and kept apart from baking soda or similar materials used in foods.

(4) An ultraviolet light.

The specimen to be tested is finely powdered and well mixed. A loop with an inside diameter of an eighth of an inch or a little more is formed on the end of a piece of wire, heated, dipped into the fluoride powder, and again heated until the fluoride melts. This is repeated until the loop is completely filled with the melted fluoride 'bead'. While still hot, the bead is brought into contact with the sample powder so that some adheres to it. The bead is then reheated until the sample powder is thoroughly melted into the bead. After the bead has cooled it is examined under ultraviolet light. This may be done in darkness, or in daylight by placing the bead on the glass filter of the lamp and viewing it through a small cardboard tube held closely against the glass to exclude daylight. A tube about 1¼ inches in diameter is suitable; its length should be such that the bead can be seen clearly when the operator's eye is applied closely to the open end, usually 6 to 12 inches. The inside of the tube should be blackened; this may be done with charcoal. If significant uranium is present the bead will fluoresce with a bright yellow-green colour.

In the case of radioactive materials occurring as very fine grains disseminated in rock, it may be advisable to concentrate some of the heavy material in a tail by panning, remove magnetic materials with a magnet, and make a bead test on the residue.

In making tests, suitable precautions must be observed to prevent contamination of the wire or fluoride powder with uranium-bearing material from previous assays.

Minerals containing tungsten or niobium (columbium) will also yield fluorescent beads, but the fluorescence caused by these elements is less intense than that by uranium. Tests with the tungsten mineral scheelite, for example, caused a bluish white fluorescence with lithium fluoride and a pale yellowish fluorescence with sodium fluoride. The common tungsten minerals, however, are not radioactive and this in itself should serve to avoid any confusion. Pure niobium compounds fluoresce only with sodium fluoride, the colour being bluish white. It is to be noted, however, that most niobium minerals contain at least some uranium, and even columbite-tantalite was found to cause a yellowish green fluorescent bead with sodium fluoride.

Diamond Drilling

Diamond drilling was used extensively in exploring uranium prospects and in the further testing of orebodies at producing mines. It was reported to have been done at a total of three hundred and fifty-nine uranium properties. Most drilling was from the surface, but much was also done from underground stations at some properties. Drilling was also used successfully as a means of prospecting for buried orebodies in geologically favourable places, particularly in Blind River area. The spacing of holes depended on the nature of the deposit; this therefore does not permit of much generalization. Preliminary drilling was commonly done at 400- or 500-foot intervals, and later at closer intervals (as close as 25 feet at some mines) in places where favourable indications were obtained by earlier drilling. At some properties in Blind River area holes were spaced more than 500 feet apart after the nature of the deposits in the area was established. There was a strong tendency to depend on drilling rather than on rock trenching for early-stage exploration. This was partly because of the availability and popularity of diamond drilling in Canada, partly because of the difficulty of obtaining unaltered samples from trenches or test-pits, and partly because of the high cost of labour. Preliminary drilling was therefore sometimes advocated if the geological conditions were favourable although surface showings were small, or were fairly extensive but yielded only low assays; the successful outcome of such drilling at the Gunnar and Pronto properties testifies to the soundness of this principle when conditions warrant, but it could readily be overdone.

Most drilling at uranium properties was for cores about 1 9/32-inch diameter (AX or AXT sizes) because this provides a larger sample and commonly permits better recovery of core. Drilling for cores about 29/32-inch diameter (EX or EXT) was, however, done at some properties, and at some drilling was begun at the larger size and then changed to the smaller if good recovery was obtained, because of cheaper costs. Most drilling was done by contract at prices from $4.50 to $7.50 a foot, dependent on location, number of mines, number and depths of holes, and other factors. Drilling done from underground stations is usually cheaper than that done from the surface. A little short-hole drilling was done by prospectors, and for assessment work, by light drills of the so-called 'X-ray' type. These were said to have given poor results when used with the customary small 'X-ray' bits, but better results were reported from use of drills converted for 'EX' or 'EXT' bits.

In general, results of later underground sampling checked well with results obtained from drilling; at some mines the underground results were a little better than the drill indications.

Radiometric logging. In addition to the customary geological logging of cores, most of the cores were logged for radioactivity. This was usually done with an ordinary portable Geiger or scintillation counter, but Eldorado Mining and Refining Limited used an apparatus developed for more convenient logging of a large amount of core from its work in Beaverlodge area. This consisted of a bench in the core-house, a Geiger tube set transversely a short distance above the bench and shielded with lead blocks at the top and sides of the tube, a meter, and a loudspeaker. The height of the tube and the setting of other components were adjusted by trial and error so that meter indications and buzzing of the loudspeaker began when core emitting significant radioactivity was in position. Boxes of core were pushed slowly under the tube until significant indications were obtained, then parts of each row of core in the box were placed in a special holder and placed under the tube, until the entire radioactive section was determined and logged. Most companies tested all core for radioactivity but some companies working in Blind River area are understood to have tested only core from the ore-bearing formation. Core that was considered to warrant it was split, one half being assayed and the other kept, at least for a time to permit further study.

So far as the writers could learn the logging of core at Canadian prospects was only semiquantitative, as a means of selecting core to be assayed. Many Canadian deposits appear to be unsuited to attempts to replace assaying by radiometric logging of core or of drill-holes, but some may have their radioactive minerals distributed sufficiently evenly to render applicable some of the methods developed recently in the United States (Casey, *et al.,* 1958; Nininger, 1956b, pp. 268-276; Tanner, 1958; Vaughan, *et al.,* 1958). The amount of core assayed varied considerably. At one property, at least, all core that showed twice the background count or more was assayed. At some properties in Bancroft area all core containing pegmatitic or related rock was assayed, and at some properties in Blind River all quartz-pebble conglomerate, or all such conglomerate and the quartzite interbedded with it.

Radiometric logging of drill-holes by means of waterproofed probes attached to long insulated cables was used in connection with many exploration programs for pitchblende deposits in Beaverlodge area and elsewhere, but was not used extensively at properties in Blind River or Bancroft areas. The main reasons for its use in connection with pitchblende deposits was that core-recovery was commonly poorer than for other types of deposits, because of the friable nature of pitchblende and some of the gangue minerals and host rocks, and that masses and grains of pitchblende in a deposit commonly vary greatly in size and distribution. If core was lost, or if the hole barely missed a mass of pitchblende, probe readings would supply semiquantitative information to permit rough 'weighting' of the calculations. As mentioned in the previous paragraph, instruments and techniques developed more recently might provide more quantitative results even for Canadian deposits, including those that were previously considered not to require probing. The logging done at Beaverlodge commonly consisted of readings with the probe stopped at 5-foot intervals; the meter could also be observed while the probe was being moved. The probe was pushed along flat or 'up' holes by means of slotted metal rods suggested by the Geological Survey and developed by Eldorado. These were tubes 5 feet long, having a slot along one side so that successive rods could be laid over the cable and joined to the preceding rod, somewhat after the manner of diamond-drill rods. If holes were to be probed during cold weather or in areas of permafrost this was done immediately after drilling, before ice formed in the hole.

Underground Exploration

Although diamond drilling is, strictly speaking, a form of underground exploration, this expression is used for exploration in the form of adits, shafts, levels, raises and winzes. Most Canadian uranium prospects that yielded favourable results by diamond drilling were explored further by underground means, to provide better exposures for study and sampling, the latter generally including bulk samples for fuller estimates of average uranium content and for ore-dressing or metallurgical tests. Underground exploration was done at one hundred and seventeen uranium properties. Results from drilling some deposits, however, were considered to be sufficiently consistent to warrant plans for production without confirmation by underground exploration. These deposits were the Gunnar and many of those drilled in Blind River area after certain deposits there had been explored underground.

The underground exploration of Canadian uranium prospects differs little from standard procedures, which do not require explanation here. Special attention should be paid to ventilation because of the possibility that harmful concentrations of radon or radioactive dust might otherwise accumulate. Further information on health precautions dealing mainly with producing mines, is contained in papers by Cipriani (1955) and Yourt (1955). Radioactivity detectors may be used underground to help to outline places to be followed or sampled, and to form an opinion as to whether a pile or car of broken rock should be classed as waste or 'stockpiled'. Desirable features of detectors for underground use are compactness, lightness, sensitivity, meters to avoid the necessity of using earphones in noisy places, and absence of canvas cases as these may be contaminated by dust or mine water. In using a detector underground it may be necessary for the operator to become accustomed to a higher background than would be present on the surface, and to check the instrument occasionally to ensure that it does not become contaminated by the lodging of radioactive material in crevices.

Assaying

Radiometric assays. The radioactivity of samples containing uranium or thorium, or both, permits methods of assaying that are cheaper and quicker than many of the methods used for non-radioactive metals, and which are sufficiently accurate for many purposes. Approximations of the combined content of uranium and thorium, if both are present, can be made in remote places by simple equipment comprising a mortar and pestle or other means of grinding a sample, a small tray to hold a constant volume of samples, a few radioactive standards, and a meter-equipped radioactivity detector. A small balance for weighing samples may also be included. The radioactivity from a sample is measured for a constant time, and the 'U_3O_8 equivalent' is calculated by using factors obtained from tests on standard samples. Rejects from samples assayed in a laboratory provide suitable standards. The method is described more fully by Senftle (1949). It is not known to have been used by prospectors, but it has been used by geologists and other personnel connected with remote operations that did not warrant more elaborate equipment, to obtain tentative results pending receipt of laboratory reports or to decide which samples should be sent for laboratory assays.

More precise radiometric assays are made in laboratories by commercial assaying firms, mining companies, and government organizations. Almost all producing uranium mines have a laboratory for this purpose, and some prospects where extensive exploration was being done have been so equipped. The basic principles of radiometric assaying are similar to those described above, the equipment, which can be bought commercially, being much more refined and expensive. The simplest laboratory assays do not distinguish between uranium and thorium, and are inaccurate if the sample is out of equilibrium (*see* p. 17), but are useful to screen samples that are too low in content to warrant further tests, or for assaying a large number of samples from a single deposit when the thorium content and equilibrium have been established and if a proportion of control samples are analysed by a more complete method. Because the ratio of beta to gamma rays differ for the uranium and thorium series, more elaborate tests that measure these rays separately indicate fairly accurately the contents of uranium in samples, and less accurately the contents of thorium. Earlier methods employed a Geiger tube for measuring the gamma rays, but a later method, described by Eichholz, *et al.* (1953) uses a thallium-activated sodium iodide crystal that detects gamma rays more efficiently than a Geiger tube and so permits greater accuracy on lower-grade samples. Such assays are designated in some reports of the Geological Survey by "beta-gamma" or "calc.", the latter referring to the fact that the uranium or thorium content is calculated and not analysed separately. The assays are also designated in some later reports of the Geological Survey by "equil" or "equilibrium", because the method is self-correcting for any dis-equilibrium conditions of the sample in uranium assaying, and because the equipment described by Eichholz (op. cit.) was installed by many mining companies and commercial assaying firms and became popularly known as the equilibrium counter, and the method as the equilibrium method.

For a few years after 1947 the Geological Survey undertook to make radiometric assays free of charge on any samples sent by prospectors or companies, as an encouragement for uranium discoveries. This was done because commercial assaying firms did not have the necessary equipment. In 1954, because commercial firms were able to do this work and because the number of samples being sent to the Survey was more than could be handled, the Survey limited the service to not more than six samples from a single discovery or from a group of claims if it yielded more than one discovery. It was considered that six samples should be accepted at least for a time as a service to those prospectors who did not know where else to send samples or who could not afford commercial fees, and that if one or more significant assays were obtained from properly taken samples a prospector should have little difficulty in obtaining backing to provide for commercial assaying of further samples. Samples of drill-core were declined because it was felt that a prospector or company able to do diamond drilling would know where else to obtain assays and would be in a position to pay for them. The Geological Survey at the time of writing first assays samples by the simpler method that does not distinguish between uranium and thorium. If this assay shows 0.1 per cent U_3O_8 equivalent or more another assay is made by the 'beta-gamma' method, from which the uranium content of the sample is calculated. The assay results are mailed promptly, usually within 24 hours of receipt of samples.

Radiometric assays for thorium may be made by the thorium emanation method developed by Zimmerman and Bouvier (1955).

Chemical and other analyses. Analyses for uranium or thorium may be made by spectrographic, spectrochemical, fluorescence, X-ray fluorescence, and chemical methods. Some of these are described in a recent manual by Ingles (1959). Several producing uranium mines use the fluorescence method, which is commonly spoken of as a variety of chemical analysis, because it is rapid and accurate in the range of uranium content common in Canadian mines. Some mines also use other chemical methods when dealing with high-grade samples. Considerable variation is practised in the number of samples checked chemically (including fluorimetrically) by Canadian uranium-producing mines, at least one doing all samples both radiometrically and fluorimetrically, one checking one in five samples fluorimetrically, another checking one in twenty fluorimetrically, and at least two checking one per hundred fluorimetrically.

PART III

DESCRIPTIONS OF AREAS AND DEPOSITS

Blind River Area

An area of some 200 square miles in Ontario immediately north of Lake Huron is now Canada's leading uranium field. It is variously referred to as the Algoma, Blind River or Elliot Lake area. Strictly speaking, Algoma is the name of a large district including this area but extending westward to the east shore of Lake Superior. Blind River is a town at the north shore of Lake Huron, 12 miles west of the nearest producing uranium mine. As this town was the nearest sizable settlement to the uranium mines during the early stages of activity, it became the popular name for the mining camp. The new town of Elliot Lake has recently been established about 18 miles north of Lake Huron, close to all but one of the producing mines, and this name is now also used for the area, particularly for its northern and most important part.

The area is roughly 100 miles west of Sudbury and the same distance east of Sault St. Marie. The Soo Line of the Canadian Pacific Railway and highway 17 have for many years extended near Lake Huron between these cities. Large-scale lumbering operations, particularly for pine and spruce, were conducted in the region north of Lake Huron for about 60 years, and were largely responsible for the existence of the town of Blind River. Some lumbering, as well as farming in selected sites, is still done. The area was thus very accessible and close to established settlements when activities for uranium were begun. Most of the early work was serviced by float-equipped aircraft, the nearest being based at Algoma Mills, about 10 miles west of Blind River. When the importance of the deposits had been demonstrated, branch roads from the highway were built to all now-producing deposits and to the townsite of Elliot Lake.

The area is one of steep rocky ridges and rolling hills, up to 300 feet above the surrounding valleys which contain many lakes. The drift is thin and outcrops are fairly numerous. The climate is temperate, with pleasant summers and reasonably mild winters. The lakes usually freeze between November 15 and December 15, and the ice generally melts between March 15 and April 15.

History

The Blind River area lies between the famous Sudbury nickel area and the abandoned Bruce mines, where the first copper was mined in Ontario in 1848. Consequently the area was prospected for copper, gold, and other metals from time to time long before the present interest in uranium. This interest stems from a prospecting rush late in 1948 when pitchblende was rediscovered north of Sault Ste. Marie. Although this has been mentioned in Part I, the Blind River area is now so important that its history warrants fairly detailed recounting here.

The first recorded Canadian uranium discovery was the subject of an article by J. L. LeConte, a distinguished American geologist (1847). He described what he considered a new mineral, called coracite, from a collection made by the captain of a schooner engaged in the fur trade on Lake Superior. The locality was said to be at the shore of Lake Superior about 70 miles north of Sault Ste. Marie. A further article repudiated the mineral coracite and claimed that the mineral was merely pitchblende (Genth, 1857). These accounts were repeated in several publications of the Geological Survey, notably those by Logan (1863) and Ellsworth (1932), and various attempts were made by Survey officers and prospectors to find the occurrence. These were, however, unsuccessful because of lack of precise description and because of the unavailability of radioactive detectors. In the winter of 1947-48, Robert Campbell, an experienced prospector, studied the old reports and formed a syndicate to search for the occurrence with the help of a Geiger counter. In September 1948 he found a pitchblende occurrence which corresponded fairly closely with the original description; several other pitchblende occurrences were soon found in the area, however, and one of these seems more likely to have been the original discovery, although there is no doubt that Campbell rediscovered the general locality. The finds in this area did not become productive, but the interest aroused by them had more far-reaching effects.

Late in 1948 Karl Gunterman, a prospector backed by Aime Breton, tested with a Geiger counter old specimens displayed in the mining recording office at Sault Ste. Marie, and discovered that a piece of conglomerate labelled "Long Township" was radioactive. He found and staked an occurrence on a ridge in that township, where similar pyritiferous conglomerate was exposed in a few pits that had apparently been dug by a prospector years before in a search of gold or copper. Several geologists and engineers examined the showings and were impressed with their tonnage possibilities, but were disappointed by low assays. The occurrence was described in a paper by Kesten (1950) and, under the name Breton, in the first edition of the present report.

In the autumn of 1949 an employee of a contracting company engaged in re-routing the highway prospected with a Geiger counter in his spare time and sent six samples for assay; these were reported to contain from 0.025 to 0.15 per cent U_3O_8. Because the locality was not reported, as the Atomic Energy regulations required, the Geological Survey wrote asking for the locality and was told that the samples were from "Location X, south of highway, township of Long". A letter asking for a more precise location was unanswered. Location X is an old mineral grant in Long township, along the shore of Lake Huron. When the first edition of the present report was being prepared, permission to publish the assays and location was obtained and the information was included in the report. Franc Joubin, a geologist experienced in prospecting and exploration for various metals in several parts of Canada, who had devoted much attention to uranium, was one of those who had examined and sampled the Gunterman-Breton discovery. He stated (personal communication) that when the above-mentioned report was published he noted the higher assays from Location X, and that these caused him to take a renewed interest in the Gunterman-Breton occurrence. By this time the German prospector had been drowned (Roberts, 1955, p. 6).[1]

Joubin theorized that because the exposures at the Gunterman-Breton occurrence were strongly radioactive but samples showed little uranium or thorium, these elements might have been leached from the outcrops, leaving strongly radioactive daughter elements. He obtained financial backing from J. H. Hirshhorn, found that no claims were then in force and with associates staked thirty-six claims, including the conglomerate occurrence, in May 1952 (Roberts, 1955, p. 7). Peach Uranium Syndicate (later Peach Uranium and Metals Limited) was formed to explore these claims by diamond drilling, which was begun in April 1953. The first three holes gave results only slightly better than surface sampling, but later holes were reported to indicate an average of 0.13 per cent U_3O_8. Although this was low-grade the possibilities were intriguing because of the tonnages suggested by the geology and confirmed as drilling progressed. Tests on a composite sample of drill-core were carried out by the Mines Branch, and a small adit was driven to obtain a bulk sample. In 1954 sufficient tonnage was indicated to permit negotiation of a contract for sale of uranium precipitates to the value of about $55 million. Pronto Uranium Mines Limited was organized as a subsidiary company to mine the deposit. By the end of the year a shaft had been completed and construction of an acid leaching plant was well advanced. Operation of this plant was begun in September 1955 and it was opened officially in the following month, inaugurating what has proved to be a most important chapter in the history of Canadian mining.

Before releasing news of the results of the early drilling Joubin, Hirshhorn and their associates decided to prospect extensively in the area, in the hope of finding additional deposits. The Gunterman-Breton discovery consisted of pyritic quartz-pebble conglomerate at the base of a quartzite formation—the Mississagi quartzite—which unconformably overlies older granitic and metamorphic rocks. Accordingly, the search was concentrated in areas underlain by the Mississagi formation. Their attention was soon drawn to an extensive area of Mississagi formation north of the Gunterman-Breton discovery. A geological map issued by the Geological Survey about 30 years earlier (Collin, 1925) showed the extent of the formation, and the position of its contact with the underlying granites for a distance of about 80 miles. With the help of the staff of the Preston East Dome gold mine, of which Joubin was a director, teams of prospectors were flown to lakes along the contact. Flights were made from the Porcupine district which is far to the north, so as not to attract attention. This prospecting quickly resulted in discovery of several zones of radioactive conglomerate and the staking of more than 1,400 claims, which were apportioned to the Pronto and Preston East Dome companies and to several companies controlled by Hirshhorn interests. Extensive

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[1] Later, C. Baycroft stated (personal communication) that he had traced the report of the occurrence in Long township, and found a radioactive occurrence near the shore of Lake Huron; he donated two specimens to the Geological Survey from this occurrence, one of which was found to contain pitchblende and the other thorite.

programs of diamond drilling were begun which resulted in negotiation of a large contract for sale of precipitates from the Quirke and Nordic mines. The Quirke deposit was found virtually at the surface, although the actual ore is just below an outcrop of conglomerate. The Nordic was found by diamond drilling in a drift-covered area near a contact shown on the geological map, on claims staked along the extension of a surface discovery. Algom Uranium Mines Limited was organized to operate both mines, and plants built at each began production late in 1956.

Publication in the summer of 1953 of the results of drilling on the Peach claims, and accounts of the later staking and discoveries, caused the greatest staking rush in the history of Ontario, participated in by experienced prospectors and companies, and by many novices, the last causing considerable confusion and overlapping of staking. Thousands of claims were staked between Sudbury and Sault Ste. Marie, but although many radioactive occurrences in conglomerates and other sedimentary rocks were found, only certain occurrences in the northern part of the Blind River—or Elliot Lake—area became productive. It was clear from the geological map mentioned above that there were good possibilities of finding more deep-seated occurrences of conglomeratic ore in certain geologically favourable areas. Many deep diamond-drill holes were put down to test these possibilities. This drilling gradually narrowed down the best possibilities and resulted in the awarding of contracts for eight additional mines, namely: Consolidated Denison, Spanish American, Panel, Stanrock, Can-Met, Stanleigh, Milliken Lake and Lacnor, at each of which plants were built, the last coming into production in 1958. In 1956 the Rio Tinto group bought the Hirshhorn interests in the district, thus acquiring control of the Pronto, Quirke, Nordic, Panel, Lacnor, Spanish American and Milliken Lake mines.[1]

Activity was spurred by the expiry of contracts in 1962 or 1963, necessitating the speedy proving of deposits, sinking of shafts, construction of plants, and provision of housing and services. Men and companies experienced in mining for uranium or other metals in Canada or other countries took part. The regularity of the deposits favoured rapid development, as they did not require very detailed exploration and permitted closely similar treatment methods. Advantage was taken of contracting for such specialized services as diamond drilling, shaft sinking, catering, and plant design and erection. Rapid and low-cost methods of mining were adopted at several of the mines. A plant for producing sulphuric acid for

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[1] In 1960 four companies, Algom Uranium Mines Ltd., Milliken Lake Uranium Mines Ltd., Northspan Uranium Mines Ltd. and Pronto Uranium Mines Ltd., were amalgamated to form a new company called Rio Algom Mines Ltd. The merger involved the closing of Northspan's Lacnor mine in June, Pronto in April, and the Algom Quirke mine in December. The Pronto mill was converted to treat ore from the nearby Pater copper property and Pronto is expected to begin operating as a copper producer early in 1961. In June 1960, Preston Mines Ltd., which is managed by the Rio Tinto organization, acquired the contract held by Stanleigh Uranium Mining Corp. Ltd. and in November Stanleigh was shut down. Early in 1960, Can-Met Explorations Ltd. amalgamated with Consolidated Denison Mines Ltd. to form a new company called Denison Mines Ltd. Under this arrangement Can-Met transferred the remainder of its contract to Denison and the Can-Met mine ceased operating. Stanrock Uranium Mines Ltd. received offers for its contract but decided that it would be to the company's advantage to continue production as before.

use in the treatment plants was erected in the southern part of the area. Thus eleven mines with plants ranging in capacity from 1,500 to 6,000 tons of ore a day, and one shipping mine were brought to production. The combined capacities of the plants in the area is about 34,000 tons of ore a day, and the combined contracts for sale of uranium precipitates are valued at a little more than $1,000,000,000. A plant built by Rio Tinto Dow Limited for recovery of thorium from waste liquors or uranium plants commenced regular production in May 1959. It is adjacent to the Quirke plant of Algom Uranium Mines Limited.

Geology

Geological investigations. The Blind River and neighbouring areas were studied by Logan and Murray—the first officers of the Geological Survey of Canada—from 1847 to 1858, being among the first districts on the continent to be investigated in some detail, thus providing a foundation for much of later knowledge of the Canadian Shield. Later studies were undertaken by several officers of the Survey and of the Ontario Department of Mines, and others. The work of the 'pre-uranium period' culminated in the report and maps by Collins (1925) mentioned earlier, which, although inevitably subject to certain revisions, are widely recognized as classics and which greatly aided in the searches for uranium.

After the first promising results were obtained at the Peach property, the Ontario Department of Mines revised some of the surface geological mapping (Abraham, 1953, 1956) and sponsored a petrological study of the Mississagi formation (McDowell, 1957). From 1954 to 1958, Roscoe studied the uranium deposits in detail for the Geological Survey, paying particular attention to mode of occurrence, distribution, origin, stratigraphy and subsurface mapping; preliminary results (1956, 1957) aided in the planning of the deeper drilling projects and in the estimation of ore reserves; in addition to laboratory work by Roscoe much supporting work of this kind was supervised by Steacy, the preliminary results being incorporated in a paper (Roscoe and Steacy, 1958). Important information has resulted from studies by Joubin (1954, 1956) and by several geologists attached to the mines; the latter have published a number of papers, the principal information of which is now available in symposia prepared for the Canadian Institute of Mining and Metallurgy (Joubin and James, 1957; Hart, Harper, *et al.,* 1957; Holmes, 1957), and the Sixth Commonwealth Mining and Metallurgical Congress (Holmes, *et al.,* 1957).

Studies of the mineralogy of the ores were made by Nuffield (1954) and Traill (1954), by Hughson and Kaiman of the Mines Branch in connection with treatment tests, and by Steacy of the Geological Survey in connection with samples from prospectors and Survey officers.

Stratigraphy and lithology. The rocks underlying the Blind River area are divisible primarily into an early Precambrian complex commonly referred to as the 'basement', overlain with marked unconformity by a younger, more gently folded sequence of sedimentary strata collectively called 'the Huronian'. The

Huronian has been divided into the Bruce series and the still younger Cobalt series on the basis of a lesser unconformity, and each series has been divided into formations. The Blind River area is part of the 'type locality' of the Huronian, the sequence just outlined being largely responsible for the classical concept of the Precambrian Shield as primarily divisible into Archæan and Proterozoic eras separated by a principal and widespread erosional interval. Many geologists now consider this concept to be an oversimplification, and some have proposed changes in the correlations and nomenclature of the strata north of Lake Huron. These problems do not greatly affect the present account of the ore deposits, although they might be important if additional deposits should be sought in other districts. The following brief descriptions are, accordingly, confined mainly to the basement rocks and the strata immediately and a short distance above them.

The oldest recognizable basement rocks are greenstones and a little cherty iron-formation. Apart from these the basement is composed mainly of granodiorite, with other gneissic, pegmatitic and granitic rocks. Roscoe and Steacy have shown that the granodiorite and related rocks carry uranium contents ranging from 0.0003 to 0.003 per cent and have average thorium contents about three times those of uranium, and that much of the radioactivity is associated with accessory minerals such as zircon, titanite and monazite.

The unconformity is sharply defined at some places and at others is represented by as much as 50 feet of arkosic rock that appears to have been consolidated from residual soil. Collins named his lowest formation of the Bruce series the "Mississagi quartzite", which has already been mentioned. It is a thick sequence composed mainly of quartzite and including the apparently residual arkose mentioned above, together with lenses of conglomerate and banded argillite. Lenticular zones of conglomerate, some containing two or more bands of conglomerate separated by quartzite and conglomeratic quartzite, are up to 100 feet thick. At some places conglomerate rests on or almost on the basement, and at others a thick succession of quartzite rests directly on the basement. Many of the beds of conglomerate, particularly at or near the base, consist almost entirely of fairly closely packed and fairly rounded pebbles of vein quartz in a matrix composed chiefly of angular grains of quartz and feldspar. Roscoe (1957, p. 7) has proposed that, as detailed work has added to knowledge of the thick Mississagi unit of Collins, it be divided into four formations, for the lowest of which he proposed the name 'Matinenda'. This unit, which includes all the known ore zones, varies greatly in thickness and thickens notably from north to south, being absent in some places and as much as 700 feet thick in others. Roscoe considered that these variations are related to the original topography of the basement surface.

Dykes and sills of quartz diabase intrude the Huronian strata. In the southeastern part of Blind River area a large body of granite locally cuts Huronian strata and quartz diabase, and was considered by Collins to be related to the Killarney granite occurring farther east. Dykes of olivine diabase occur at many places in the region; as some intrude the Killarney granite all are usually considered to be of very late Precambrian age.

Structural geology. The greenstones and related rocks of the basement are much folded, a condition which, coupled with their place in the succession and their association with abundant granitic rocks, indicates that they are the roots of ancient mountains.

The Huronian strata are folded into broad anticlines and synclines trending east and west, and plunging gently westward. The relationship of the present erosion surface to these folds causes the contact between the Huronian and pre-Huronian rocks in Blind River area to take roughly the form of a huge reversed 'S' (*see* Fig. 3). Thus in the northern part of the area Huronian strata lie in a synclinal 'basin', now commonly called the Quirke Lake basin or trough, which is about 12 miles wide at its widest, western part, where the depth from the present land surface to the basement is approximately 4,000 feet. On the north limb dips range from 20° to 40°S, and on the south limb they range from 10° to 15°N. Although the general structure is on this grand scale, minor irregularities, drag-folds and crumples are present locally. The forces that folded the Huronian strata no doubt affected the basement rocks as well, but the configuration of contacts and the present distribution and thickness of certain Huronian beds are probably also due to undulations of the ancient land surface on which they were deposited.

The anticlinal area lying south of the main syncline is terminated by the Murray fault, a regional thrust extending in a general east and west direction near the shore of Lake Huron. At least two fairly extensive thrust faults cut the strata in the synclinal trough. These are described as follows by Holmes, *et al.* (1957): "The surface trace of one thrust is found near the north side of Quirke Lake and dips south a few degrees steeper than the bedding. The thrust fault trends nearly parallel with the strike of the strata and intersects and repeats the conglomerate ore at a depth of about 3,000 feet at the Spanish American and Stanrock Uranium Mines. It would appear that the direction of net slip has been northeast for about 1,300 feet. Another thrust strikes about north from Pecors Lake and movement has been up on the west side." Small normal faults are common, and a larger one trending northwest has been found.

Radioactive zones. Beds containing at least a little uranium and thorium have been found at several stratigraphic horizons in Huronian strata in Blind River area and at localities farther to the east and west. Most of these are in conglomerate, but some are in grit, quartzite and other rocks. The only deposits known to contain uranium in sufficient tenor and tonnage to be classed as ore, however, are in the lower part of the Mississagi (Matinenda) formation, within roughly 100 feet of the basement. With the exception of the Pronto deposit all are in two areas, one on the north and one at the south limb of the main syncline or 'Quirke Lake trough' (*see* Fig. 3). These are areas where the lower Mississagi is thickest and contains abundant conglomerate; they may be 'valley structures' representing channels in the early Huronian drainage system. The northern one rakes southeastward for about 5 miles from the surface exposures of the Quirke deposit and

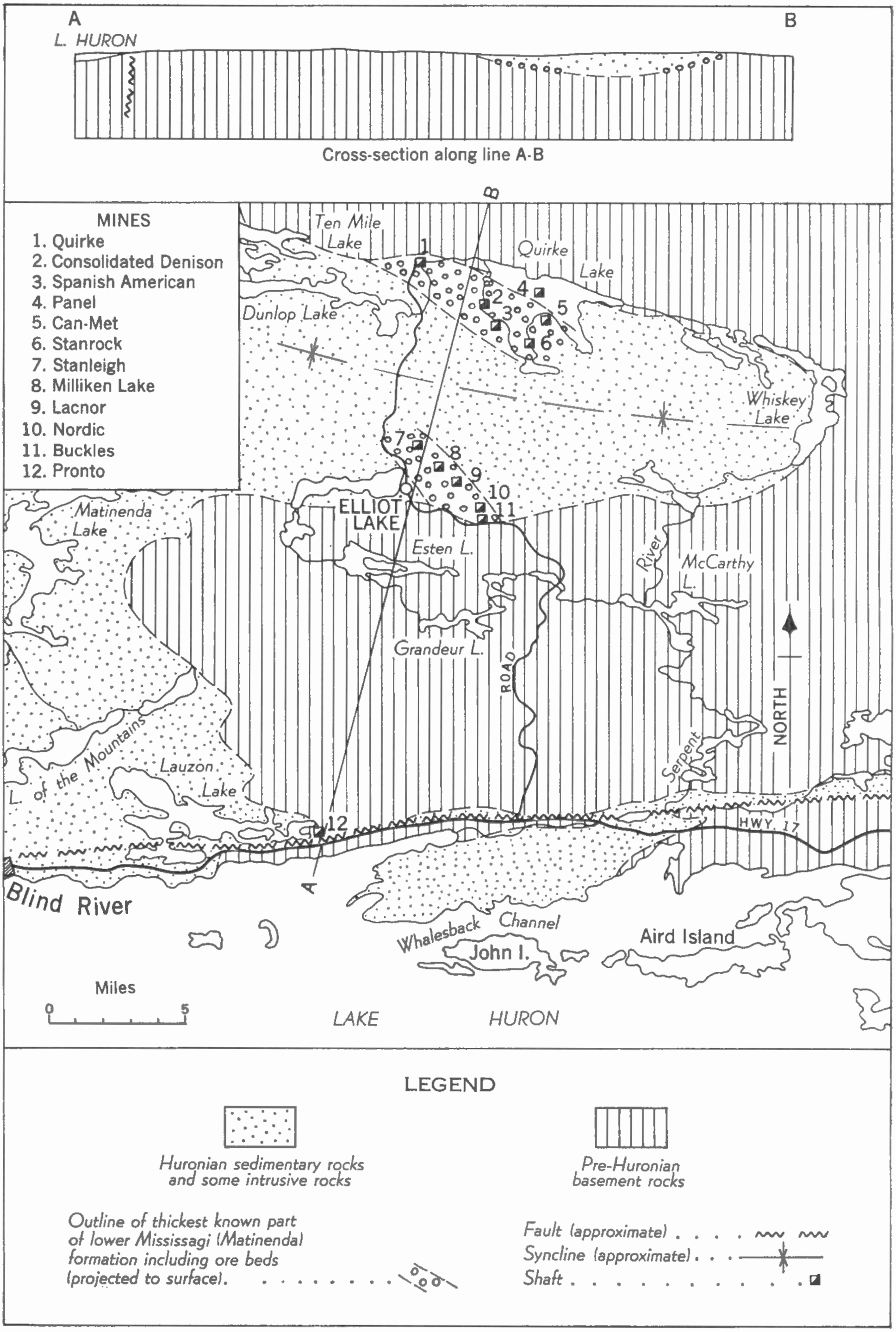


Figure 3. **Diagrammatic geological plan and cross-section, Blind River area, Ontario.**

includes the Consolidated Denison and four other productive deposits. The southern one rakes northwestward for about 4 miles from the Nordic and Buckles deposits and contains three other productive deposits. The boundaries of these areas are indistinct because they are gradational between dominantly conglomeratic to dominantly quartzitic facies. Drilling from the surface to probe the strata lying between these two areas has not revealed ore; it is not yet clear whether the areas represent a single drainage channel with a marked change in direction, or separate channels.

Individual beds and lenses in the ore zones vary in size, extent and lithology (*see* Fig. 4), although some beds have been traced for hundreds of feet and by intermittent drill-holes for apparent distances of thousands of feet. The thicknesses of ore zones are commonly about 10 feet, and range from about 7 to 35 feet. In some deposits these thicknesses comprise a single bed of conglomerate or grit, or two beds of conglomerate separated by lean quartzite that may be mined as part of the ore; elsewhere the ore sections comprise fairly intricate lenses of conglomerate and lean quartzite. Typical ore conglomerate is composed mainly of subrounded pebbles of vein quartz from ¼-inch to 2 inches in diameter (*see* Pls. I, II, III). The average uranium content of the ores of the area as a whole is about 2.4 pounds of U_3O_8 a ton (0.12 per cent), the lowest grade material mined to maintain an economic average carrying about 0.06 per cent U_3O_8. The uranium content of individual layers varies greatly, usually necessitating careful sampling to delimit ore zones.

Mineralogy. After quartz and feldspar, the most abundant mineral is pyrite disseminated in small grains in the matrix and around the borders of pebbles. Roscoe and Steacy described the pyrite grains as euhedral to spheroidal, mostly about 0.5 mm in diameter. Pyrite generally constitutes less than 6 per cent of the rock by weight, but locally may form as much as 20 per cent.

The principal uranium minerals are brannerite and uraninite (*see* pp. 43-46). Brannerite is believed by Roscoe and Steacy to be the most abundant ore mineral in the area as a whole, but to be rare or absent in low-grade conglomerates with high thorium to uranium ratios. It is generally in ovoid aggregates about 0.3 mm in diameter that also carry anatase or rutile. Uraninite generally occurs as subhedral grains about 0.1 mm in diameter. In the southern part of the Quirke Lake trough certain beds of conglomerate with low thorium to uranium ratios, and some pyritic seams in quartzite, contain more uraninite than brannerite. In the Pronto deposit a few thin streaks contained abundant uraninite. Pitchblende has been reported from some of the Blind River ores but has not been identified in samples studied by the Geological Survey or the Mines Branch; the writers believe that these reports may be based on terminology different from that used here, that narrow seams rich in uraninite may have been confused with pitchblende, or that there may be some secondary pitchblende.

Other minerals listed by Roscoe and Steacy as found in minor quantities in the ores or other radioactive conglomerates of the area are hematite, magnetite, monazite, zircon, uranothorite, coffinite (S. Kaiman, personal communication), sphene, anatase, rutile, chromite, spinel, epidote, sericite, chlorite, amphibole, apatite, cassiterite, fluorite, barite, pyrrhotite, chalcopyrite, galena, sphalerite, molybdenite, marcasite and gold (assays have shown trace amounts of gold, silver, chromium, nickel and vanadium). These minerals commonly occur in rounded grains. Thucholite or other hydrocarbon material "is common along fractures in the ores and also in rocks a considerable distance away from the ore conglomerate beds" (Roscoe, 1957, p. 19).

Thorium-uranium ratios. By means of much sampling, hundreds of analyses, and careful interpretation, Roscoe and Steacy provided comprehensive information not only on the thorium and uranium contents of the ores and other rocks of the district, but also on the areal and stratigraphic variations in ratios. They showed that the ores are unusual deposits relatively high in uranium, whereas most of the radioactive Huronian rocks are much richer in thorium. In ore zones ratios of ThO_2 to U_3O_8 vary from 0.1 to 4.0, both laterally and from bed to bed in an ore section. Elsewhere, certain conglomerates with uranium contents below ore grade are high in thorium, with ratios up to 16. In general, high uranium contents are related to abundant pyrite.

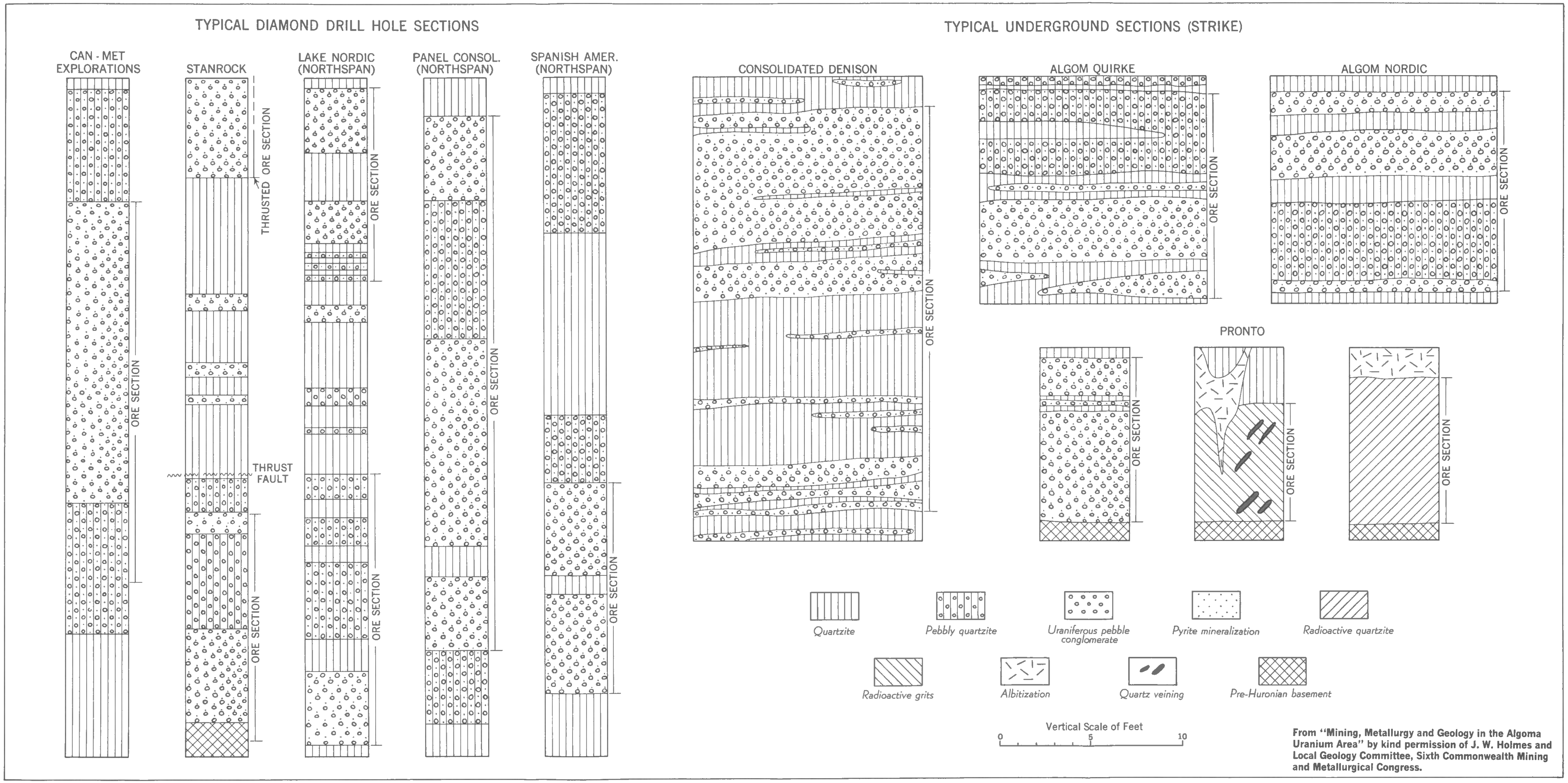
Buckles Mine

The Buckles mine is at the south side of the Quirke Lake syncline, less than a mile south of the Nordic property. The claims were held by Buckles Algoma Uranium Mines Limited, and acquired by Spanish American Mines Limited in 1955. In that year reserves indicated by diamond drilling and a test shaft were reported to be 486,500 tons averaging 0.124 per cent U_3O_8, in a zone about 10 feet thick found 75 feet beneath the surface. After the plant at the Spanish American mine was completed in 1958 ore from the Buckles was trucked to it for treatment at a rate of about 500 tons a day.

Can-Met Mine

History. The Can-Met mine, on the south shore of Quirke Lake, is in township 144, about 15 miles by road from Elliot Lake. Part of the property was staked by C. Mattaini as favourable ground. The present owners, Can-Met Explorations Limited, reported that eleven diamond-drill holes, totalling 24,346 feet, were completed in 1957. All holes were said to have intersected ore-bearing conglomerate with an average thickness of 15.7 feet. The ore reserves were reported by the company in 1958 to be 6,642,380 tons of partly proven ore in the main orebody, with an average grade of 1.832 pounds of U_3O_8 a ton, after allowing 10 per cent for dilution. The total tonnage, including all categories of ore, was reported to be 8,362,069 tons.

Two shafts, about 500 feet apart, were sunk to depths of 2,127 feet and 2,395 feet respectively. A plant rated at 3,000 tons of ore a day was completed in October 1957, and the first shipment of precipitate was in December of that year.



From "Mining, Metallurgy and Geology in the Algoma Uranium Area" by kind permission of J. W. Holmes and Local Geology Committee, Sixth Commonwealth Mining and Metallurgical Congress.

Figure 4. Detailed stratigraphy of ore horizons, Blind River area, Ontario.

Geology. The following account is in part after a brochure prepared for the Sixth Commonwealth Mining and Metallurgical Congress, in 1957. The deposit is on the north limb of the main trough. It is bordered on the west by the Consolidated Denison, on the north by the Panel, and on the south by the Stanrock mine. The depth of the ore below surface is from 1,500 feet in the north to 2,000 feet near the shafts. The average strike is N40°W, with dips ranging between 0° and 15°S. The average thickness of ore is 15.0 feet. Extensive faulting of the orebody has been encountered underground. A major easterly striking, high-angle reverse fault, and many minor normal and reverse faults, transect the ore. In the early stages of development these created a mining problem.

The orebody, which consists of two beds of conglomerate, is in one of the 'fringe' areas of the major ore shoot located on the north side of the trough. The orebody rests on the basement rocks at the north end and is 70 feet above the basement at the south end. The foot-wall contact is an 'assay wall', but the hanging-wall contact is sharp. The main radioactive minerals are brannerite, monazite and uraninite. A company official stated that a band of altered rock, cut in a drillhole, was found to be of ore-grade; this may be analogous to the chloritic rock found at the Algom Nordic mine.

Consolidated Denison Mine

The property of Consolidated Denison Mines Limited is in the north belt of uranium mines, in townships 144 and 150. It is about 10 miles by road north of the town of Elliot Lake. The holding is bordered on the north by the Quirke property of Algom Uranium Mines Limited, on the east by the Panel and Can-Met properties, and on the south by Spanish American and Stanrock claims.

Production at the Denison Mine officially began in September 1957. Plant capacity is 6,000 tons of ore a day. The average production for 1957 was reported by the company (annual report, 1957) to be 2,676 tons a day and the average grade of the ore milled in the same year was 2.63 pounds U_3O_8 a ton.

History. The claims were staked as being geologically favourable, in the summer of 1953, by A. W. Stollery, F. H. Jowsey, and associates, as a sequel to discoveries at the properties now owned by Pronto Uranium Mines Limited and Algom Uranium Mines Limited. The claims were acquired in 1954 by Consolidated Denison Mines Limited, when this company was reorganized from North Denison Mines Limited, a company interested in copper and nickel prospects. Geological studies were begun and in July 1954 the first diamond-drill hole was spotted to try to intersect the downdip extension of the Algom (Quirke) orebody. This hole intersected uraniferous conglomerate of marginal to submarginal grade. Subsequent drilling was done on a grid pattern with holes drilled at approximately 900-foot by 600-foot spacing. All these holes intersected mineable widths of strongly radioactive conglomerate, and sufficient ore was blocked out to qualify for a contract. Other more widely spaced holes indicated that the orebody was of still greater size. In 1957 the company estimated reserves at 136,787,400 tons averaging 2.78 pounds of U_3O_8 a ton. These figures do not include a secondary zone of lower grade 100 feet above the main zone. Shaft-sinking was begun in 1955, the No. 1 being sunk to 1,856 feet, and the No. 2, half a mile to the south, being completed to a depth of 2,766 feet in 1957. A plant rated at 5,700 to 6,000 tons of ore a day was built, the first 3,000 ton unit being in operation in May 1957.

Geology. The Denison mine is on the north limb of the Quirke Lake trough. The ore zone, averaging 16.7 feet in thickness, is found from 10 to 100 feet above the pre-Huronian basement rocks. The zone comprises an upper and a lower 'reef' of conglomerate as much as 14 and 12 feet thick respectively, separated by a 3-to-6-foot band of pebbly quartzite. Locally the beds pinch, swell and branch, causing variations in the stratigraphic sequence. Although the uranium content of the interbedded quartzite is low, the entire section is mined, in most places, as a single zone. The parts of highest grade are nearly always in beds where the pebbles are closely packed. Abundant pyrite is also used as a guide to higher-grade ore. A second, discontinuous reef of uraniferous quartz-pebble conglomerate was found about 100 feet above the main ore reef but this has not yet been mined; it may be the downdip extension of the main reef at the Algom (Quirke) mine.

The depth of the ore zone is about 1,000 feet at the north end of the property and 3,000 feet at the south. It strikes S65°E, and dips 10° to 30°S, the average dip being 19 degrees. The channel structure containing the uraniferous conglomerate beds crosses the Denison property from northwest to southeast and appears to continue into the adjoining properties of Panel, Can-Met, Stanrock and Spanish American. Faults are encountered but are reported not to cause serious mining problems.

Lacnor Mine

History. The Lacnor or Lake Nordic mine is on the south limb of the Quirke Lake syncline. The mine site is in township 149, about 4 miles by road from Elliot Lake. The property is bounded on the south by claims of Algom Uranium Mines Limited (Nordic mine), on the west by those of Milliken Lake Uranium Mines Limited, and on the north by those of Stanleigh Uranium Mines Limited. The property was acquired by Northspan Uranium Mines Limited, which is controlled by the Rio Tinto group. Diamond drilling in November 1954 indicated ore and led to negotiation of a sales contract. Two shafts were sunk to depths of 2,754 and 2,720 feet, respectively. A plant rated at 3,800 tons of ore a day was built and the first shipment of precipitate was made in November 1957. The plant was designed to handle 4,000 tons a day. Ore reserves were reported in 1957 to be 8,289,207 tons averaging 0.101 per cent U_3O_8.

Geology. Two principal beds of conglomeratic ore were found, the average thickness of the upper being 11 feet, and of the lower 12 feet. They are separated by a 14-foot bed of pebbly quartzite that is radioactive but not of ore grade. The strata strike about N70°E and dip about 18°N. The beds are apparently the northwesterly downdip continuation of the Algom Nordic deposit, crossing the boundary between the two properties at a depth of about 2,200 feet.

Milliken Lake Mine

History. The Milliken Lake mine is in township 149, about 1¼ miles by road from Elliot Lake. The holdings are bounded on the south and west by the Nordic property of Algom Uranium Mines Limited, on the north by that of Stanleigh Uranium Mines Limited, and on the east by that of Lake Nordic Uranium Mines Limited. The property was staked in 1953 and acquired by Milliken Lake Uranium Mines Limited in 1954. Rio Tinto Mining Company of Canada Limited assumed control in 1956.

Production was begun in March 1958 and the first shipment of uranium precipitates was made on April 28. Plant capacity is 3,000 tons of ore a day.

The company reported in 1957 that diamond drilling had indicated 7,269,846 tons averaging 0.098 per cent U_3O_8, and that the "additional tonnage potential for the property is estimated at from 14,000,000 to 18,000,000 tons".

Geology. The Milliken Lake orebody is on the south limb of the Quirke Lake trough. The strike of the ore beds is N70°W, and the dip is from 10° to 14°N. No evidence of faulting has been found. At the southwest corner of the property the depth to ore is about 1,200 feet, and at the southeast corner it is 2,400 feet.

The company reported that the production shaft, 3,400 feet deep, intersected two ore beds which were separated by 5 feet of quartzite, at a depth of 3,008 feet; the upper bed averaged 7 feet in thickness and contained 1.42 pounds of U_3O_8 a ton, and the lower bed was 12 feet thick, averaging 2.51 pounds U_3O_8 a ton; the service shaft, 3,070 feet deep, intersected the upper ore bed at 2,892 feet, where it carried 3.52 pounds U_3O_8 a ton across 7.5 feet; the lower bed was there separated from the upper one by 2 feet of quartzite; the lower bed was 6.6 feet thick, assaying 2.43 pounds U_3O_8 a ton; these beds had a combined average thickness of 15.6 feet carrying 2.75 pounds U_3O_8 a ton.

At the times of the writers' visits to the district sufficient underground work had not been done at this mine to permit study. The following description is quoted from a company report by Messrs. Ringsleben and Burns:

> Lying immediately above the basement rocks are several beds of quartzite and pebble conglomerate of which the economically most important member is a bed or reef of conglomerate up to 80 feet above the basement. At Milliken this bed, with some associated quartzite, is up to 60 feet thick. The finely divided uranium-bearing minerals in the conglomerate are predominantly brannerite and uraninite which are associated with disseminated pyrite and lesser amounts of pyrrhotite. The higher uranium values at Milliken occur in the upper portion of the bed although some sections may make ore across the full width of the bed. Intersections in some holes show an upper and lower ore bed separated by 10 to 20 feet of low grade material. Only the upper bed has been used in calculating ore reserves. Thirteen drill-holes in the southeast part of the property have cut economic values in the conglomerate, and drilling on Stanleigh and Norsynco near Milliken's north and northwest boundaries indicates continuation of the bed in a northerly and northwesterly direction. In the drilled area the thickness of the ore in the upper pebble bed is 8.5 feet to 15 feet. The dip is flatly to the north at 12 to 15 degrees.

Nordic Mine

History. The Nordic property of Algom Uranium Mines Limited is in township 149, 3 miles east of the town of Elliot Lake.

The property was staked in 1953 on the basis of geology, by prospectors for the Preston East Dome and Technical Mines Consultants companies. Algom Uranium Mines Limited was formed to explore this ground, the Quirke property to the north, and the Pecors Lake claims to the east. As the Nordic claims are largely covered by drift, radioactive outcrops were not found. The orebody was discovered and outlined by diamond drilling in 1953 and 1954. The spacing of surface diamond-drill holes was about every 200 feet along strike and the maximum spacing was about 1,000 feet. During the early drilling the samples were tested radiometrically, and every tenth sample was assayed chemically. The subsequent underground results checked well with assays and widths of diamond-drill core.

A shaft was completed at a depth of 890 feet in 1955, and production was begun in January 1957 in a plant rated at 3,000 tons of ore a day. Control of the company was acquired by Rio Tinto Mining Company of Canada Limited.

In 1958 the owners reported that "indicated ore reserves of the Nordic property at December 31, 1957 were estimated at 11,258,000 tons. Of this amount 2,237,000 tons, having an average diluted grade of 2.65 pounds U_3O_8 per ton, were fully or partly developed ore. These figures do not include unexplored potential reserves within the claim area of the property".

Geology. The Nordic mine is on the south limb of the Quirke Lake trough. The conglomerate orebody has been outlined along its easterly strike for a distance of 6,000 feet near the surface. It is a single, sheet-like bed, raking northwesterly, with a uniform dip of 17°N, and an average width of 10 feet. Near its eastern end the orebody is about 40 feet above the pre-Huronian basement; it rests unconformably on the basement rocks at the western limit. The depth of the ore below surface is 50 feet at the south boundary of the property and 2,000 feet at the north boundary. Beds of submarginal grade have been found above and below the main body. A bed 50 feet thick, reported to average about 0.05 per cent U_3O_8, lies above the main body, and is ranked as possible ore; the extent of this bed is not known. The walls or limits of the ore are well defined, consequently the ore is easy to follow without the aid of a counter. Diabase dykes of the Keweenawan type cut the Mississagi rocks. An ore zone containing chloritic rock was found beside a diabase dyke. It is contiguous with the conglomeratic ore and appears to have replaced the conglomerate, as remnants of pebbles have been found in the chloritic rock. This type of rock presents milling difficulties.

The Nordic deposit differs from the Quirke in that at Nordic most of the quartz pebbles in the conglomerate are larger, the grade is higher, and the uranium to thorium ratio is about 6 to 1, which is higher than that of the Quirke deposit. The chief geologist (personal communication) stated that some narrow (⅛-inch) stringers of 'pitchblende' cut across the bedding of the sedimentary rocks.

Only one fault, with a small displacement, was encountered.

Panel Mine

History. The Panel mine, in township 144, is on the north limb of the Quirke Lake syncline. It is bordered on the west by Algom (Quirke) and Consolidated Denison, and on the south by Can-Met. The plant is about 13 miles by road north of Elliot Lake. The property was staked in 1953 and held for a time by Emerald Glacier Mines Limited. It was acquired by Panel Consolidated Uranium Mines Limited in 1955, and later by Northspan Uranium Mines Limited, which is controlled by the Rio Tinto group. After an orebody had been indicated by diamond drilling two shafts were sunk to depths of 1,102 and 1,250 feet, a plant rated at 3,000 tons of ore a day was built, and production was begun in 1958. Ore reserves were reported in 1956 to be 6,033,000 tons averaging 2.12 pounds of U_3O_8 per ton.

Geology. The orebody lies entirely beneath Quirke Lake and was found by drilling, on the basis of favourable geology, by means of drill set-ups on the ice of the lake in winter. The shafts were sunk in two small islands, and a causeway was built to connect one of these with the mainland. The main ore bed is about 12 feet thick, strikes N75°W, and dips 14°S. The depths of drill intersections ranged from 1,100 to 1,700 feet below the surface.

Pronto Mine

The Pronto deposit is in and near lot 3, concession II, of Long township, 11 miles east of the town of Blind River. It is close to highway 17 and the Canadian Pacific Railway.

This is the original discovery in the Blind River area, its early history having already been discussed. The main shaft was sunk to about 650 feet, and four levels at 100-foot intervals were developed. In 1958 the shaft was deepened to permit development down to the seventh level. The original 1,250-ton-a-day treatment plant was expanded to a capacity of 1,500 tons.

Geology. The Pronto property contains the only orebody found to date on the south limb of the large anticlinal structure south of Elliot Lake. The ore is in a 'reef' of quartz-pebble conglomerate that strikes east, dips 15° to 20°S, and unconformably overlies pre-Huronian granitic rocks. The orebody has a strike length of about 3,500 feet and an average thickness of 7½ feet. It has been explored downdip by drill-holes for a slope distance of about 3,600 feet (a vertical depth of about 1,000 feet). At about this depth the 'reef' is intersected by a reverse fault that appears to dip 45°S; no exploration has been done south of this fault. Minor faults, which appear to be more numerous in the deeper underground workings, offset the ore.

Typical ore consists of a single, compact bed of quartz-pebble conglomerate composed chiefly of large pebbles, cobbles and abundant pink chert. Two other varieties of ore are present and are particularly abundant in lower levels of the mid-central part of the orebody. These have not been studied closely but for convenience have been called 'radioactive grit', and 'radioactive quartzite'. The 'grit' is a dark chloritic rock containing quartz and feldspar. The 'quartzite' is pink, fine grained and siliceous. These rocks are gradational into each other and into conglomerate, and everywhere occur at the same stratigraphic horizon as conglomerate. The mineralogy of these ores is not known to the writers, but the 'radioactive grit' is commonly peppered with yellow flecks that may be thorogummite.

The wall-rocks and ore beds appear to have been bleached or altered to pink in many places, particularly near joints and faults.

It is interesting to note how the underground results checked with the surface diamond drilling results with regard to grade and tonnage. The average underground grade was reported to be 84 per cent of the average grade calculated from diamond drilling results. The volume of ore was greater by 14 per cent but this included dilution figures.

Quirke Mine

History. The Quirke property of Algom Uranium Mines Limited, in township 150, is about 9 miles north of the town of Elliot Lake. The mine is about 2½ miles west of the northwest corner of Quirke Lake. The property was staked in 1953 after radioactive conglomerate was found in the manner described earlier. Surface trenching and sampling were done in the same year, and diamond drilling was begun about the same time. A total of 87,548 feet of diamond drilling was completed in 203 holes, spaced 200 feet apart along the strike of the conglomerate. Subsequent underground results checked closely with drilling results. The orebody was outlined to a slope depth of 2,000 feet, and in one area to a depth of 3,000 feet. The sinking of a five-compartment shaft was begun in 1954 and completed in 1955 at a depth of 864 feet. Six levels were established. A plant rated at 3,000 tons of ore a day was built, and production was begun in September 1956.

In the annual report of the company for 1957 ore reserves were described as follows: "Indicated ore reserves of the Quirke property at December 31, 1957 were estimated at 17,942,000 tons. Of this amount 1,409,000 tons having an average diluted grade of 2.31 pounds of U_3O_8 per ton were fully or partially developed ore. These figures do not include unexplored potential reserves within the claim area of the property.

Geology. The mine is on the north limb of the Quirke Lake syncline. The ore beds are interbedded with narrow beds of quartzite. The main bed or reef, termed the 'upper conglomerate' (Pountney, 1956), has a delimited east-west surface strike length of 7,500 feet. The beds have been explored by diamond-drill holes to a vertical depth of about 1,400 feet and about 7,500 feet along a southeastward rake. The 'upper conglomerate' reef dips 25°S but flattens with depth. It is about 100 feet above the pre-Huronian basement rocks and has an average thickness of 12 feet. Pountney stated that the orebody is entirely 'open' down the dip. A 'lower conglomerate' bed lies 10 to 15 feet below the 'upper' bed. This was described by Pountney as a persistent and extensive horizon, but is of lower grade material and consequently is not being mined at present. The extension of the radioactive beds of conglomerate may possibly continue downdip into the adjoining property of Consolidated Denison Mines Limited.

One major normal fault and numerous smaller, steeply dipping faults and fractures have been encountered in the underground workings. The displacements of the ore along these faults range from a few inches to 40 feet. An easterly striking thrust fault has displaced the main reef vertically about 15 feet.

The conglomerate is composed of well-rounded, densely packed quartz-pebbles mostly 1¼ to 1¾ inches in diameter. The uranium to thorium ratio is about 4 to 1. The cut-off grade was reported by Pountney to be about 1.30 pounds of U_3O_8 per ton. The walls of the orebody are poorly defined, the upper limit being an 'assay wall' that must be located with a counter or by sampling, or both.

Spanish American Mine

History. The Spanish American mine, in township 150, is on the north limb of the Quirke Lake trough. It is bordered on the north by Consolidated Denison and on the east by Stanrock. The plant is about 9 miles by road northeast of Elliot Lake. The claims were staked by P. Westerfield, who arranged for the drilling of two diamond-drill holes. After completion of these the claims were acquired by Spanish American Mines Limited, and later by Northspan Uranium Mines Limited, which is controlled by the Rio Tinto group. Two shafts were sunk to depths of 3,200 and 3,400 feet. A plant rated at 2,000 tons of ore per day was constructed, the shipment of precipitate beginning in May 1958. Ore reserves were reported in 1957 to be 6,251,726 tons averaging 0.097 per cent U_3O_8.

Geology. The orebody, which may be the downdip extension of the Denison deposit, is at depths ranging from about 2,400 feet at the north boundary to 3,500 feet at the south boundary. Much of the ore is beneath the southwest corner of Quirke Lake. The ore bed is about 10 feet thick, striking N70°W and dipping 17°S. A flat, south-dipping thrust fault causes a repetition or overlapping of the ore zone.

Stanleigh Mine

History. The Stanleigh mine, in township 149, is 2 miles by road northeast of the town of Elliot Lake. In the last part of 1953 and the early part of 1954, H. S. Strouth, chief of the mining division of Standard Ore and Alloys Corporation and now President of Stanleigh Uranium Mining Corporation, acquired by staking and purchase a contiguous block of 108 claims adjoining the properties now held by Milliken Lake Uranium Mines Limited and Northspan Uranium Mines Limited (Lacnor mine). Diamond drilling was undertaken, mainly at 900-foot intervals. Seven diamond-drill holes intersected uraniferous quartz-pebble conglomerate of ore grade forming a zone 6,900 feet long. Two shafts were begun in April 1956.

The production shaft, which is 3,790 feet deep, intersected the ore reef at a depth of 3,415 feet. This is probably the deepest horizon in the lower Mississagi formation (or Elliot group) so far explored underground. The service shaft is 3,690 feet deep.

Geology. The mine is on the south limb of the Quirke Lake trough, being the deepest and most northerly mine on this flank of the structure. The ore horizon was found at a depth of about 3,500 feet near the southern end of the property and it is probably at a greater depth at the north end. The ore is in two beds that strike east and dip 8° to 10°N. Each bed or reef is about 10 feet thick, separated by a bed of barren quartzite which ranges from 5 to 22 feet in thickness. No major faulting has been encountered. The east and west boundaries of the ore beds have not been definitely established and the extent of the beds downdip is not known. The ore consists of typical quartz-pebble conglomerate of the Blind River type, in which brannerite, uraninite and monazite have been reported.

Stanrock Mine

The Stanrock mine is at the south side of Quirke Lake, 14 miles by road from Elliot Lake. The property is bounded on the north by Consolidated Denison Mines Limited, on the east by Can-Met Explorations Limited, and on the west by the Spanish American property of Northspan Uranium Mines Limited.

History. This property, known formerly as the "Z-7 group", was purchased from Zenmac Metal Mines Limited in 1954 by Stancan Uranium Mines Limited, an American corporation which formed a Canadian subsidiary, Stanrock Uranium Mines Limited, to operate the property. In 1955 and 1956 Stancan carried out an extensive diamond-drilling program that indicated a probable commercial uranium deposit on the claims. Construction of a mining plant rated at 3,300 tons of ore a day was begun in 1956, when reserves were estimated by the company at 5,077,800 tons of drill-indicated ore averaging 0.109 per cent U_3O_8 before dilution, and an additional 4 million tons of probable ore before dilution.

Geology. The Stanrock deposits are near the north limb of the Quirke Lake trough and are probably the down-plunge extension of the uraniferous conglomerate beds on the properties of Spanish American and Consolidated Denison to the northwest. The Stanrock orebodies are in the 'fringe' area of the main Quirke Lake belt of conglomerate. Two areas of ore-bearing conglomerate have been outlined by diamond drilling but it is possible that these two areas may be one large deposit.

The ore was intersected at a depth of about 3,200 feet in the No. 1 shaft and at about 2,700 feet in the No. 2 shaft. The ore reefs strike N67°W and dips range from 14° to 18°S. The thickness of the ore is about 10 feet. A major thrust fault, which is found on adjoining properties, causes an overlapping or repetition of the ore beds. Other types of faults have been encountered.

Beaverlodge Area

The Beaverlodge area of northern Saskatchewan was, from 1953 to 1957, Canada's leading uranium-producing district. However, its output of about 2,000 tons of uranium precipitate in 1957 was only 34 per cent of the national total because of rising production from the Blind River mines. Beaverlodge is now the commonly accepted name for the uranium area midway along the north shore of Lake Athabasca. It is also called the Athabasca or Goldfields or Uranium City area, but Athabasca more properly refers to a much larger region; Goldfields, the name of an abandoned gold-mining settlement, is now falling into disuse; and Uranium City, although the name of the commercial town established in 1952, does not seem to the writers to be as appropriate as Beaverlodge because this name was in use for several years before Uranium City was founded. For the first edition of the present report 'Beaverlodge' was used in a more restricted sense than 'Goldfields', but that usage has waned.

The area is about 450 miles by air north of Edmonton, Alberta, and Prince Albert, Saskatchewan. Access for passengers and express is now mostly by Canadian Pacific Airlines from Edmonton or by Saskatchewan Government Airlines from Prince Albert to a government-controlled airstrip about 6 miles east of Uranium City, or to a private airstrip near the Gunnar mine. Air-freight rates from Edmonton and Prince Albert averaged 14 cents a pound in 1957. Heavy freight is usually transported by barge in summer from a railhead at Waterways, Alberta, for about 265 miles, to the shore of Lake Athabasca, at rates that averaged one cent a pound in 1957; some heavy weight has been transported in winter by tractor trains. Plans are being made to build a motor road from the present Saskatchewan highway system, probably at Lac la Ronge, to the Beaverlodge area. Travel within the area is now largely by a system of motor roads linking the landing at Bushell, Uranium City, the government airstrip, and several mines, and by small aircraft equipped with floats or skis which are based on Martin Lake near Uranium City.

The summer weather is generally clear and sunny with little rainfall; the winters are fairly long and cold, but not greatly different from that of several Canadian cities. The temperatures range from extremes of minus 60°F in the winter to 90°F in July and August. The mean daily temperature in July 1956 was 62°F and in January 1956 it was minus 11°F. 'Break-up' usually occurs late in May, although the ice on Lake Athabasca and in protected areas sometimes remains until mid-June. 'Freeze-up' begins about the end of October on the smaller lakes. The prospecting season is from May 1 until the end of September.

History

The region of Lake Athabasca received attention from prospectors in and after 1910 but productive deposits were not found until 1934 when gold was discovered at Lodge Bay. This led to the establishment of the low-grade Box mine by the Consolidated Mining and Smelting Company of Canada, Limited, which also installed a hydro-electric plant and transmission-line. It also caused the nearby town of Goldfields to spring up. Production was begun at the Box mine in 1939 but rising wages and other costs forced suspension in 1942, after which the town was abandoned.

In 1935 pitchblende was found by prospectors at the Nicholson copper prospect near Goldfields; this find was examined in that year by a Geological Survey party working in the area because of the activity for gold; the mineral was confirmed by Ellsworth from specimens submitted to him; and an account was published in the report of the survey (Alcock, 1936). A decade later, when Eldorado Mining and Refining Limited and the Geological Survey began intensive work to try to find and develop additional sources of uranium, this was the only known Canadian occurrence of pitchblende apart from the Great Bear-Hottah Lakes region and the then unconfirmed occurrence at Lake Superior. There was another unpublished clue, for in 1942 an officer of the Consolidated Mining and Smelting Company had sent a specimen from the Box property to the Geological Survey, where Ellsworth identified thucholite from it. Accordingly, in 1944, Richard Murphy of Eldorado and A. W. Jolliffe of the Geological Survey examined the Nicholson and Box showings and advised prospecting and staking in the area. This was begun in 1945 by establishing a base camp at Fish Hook Bay 3 miles east of Goldfields; by sending out teams of prospectors experienced in searching for metals other than uranium, who were equipped with early Geiger counters and trained in their use and otherwise supervised by Eldorado engineers and geologists; by more detailed geological studies and mapping undertaken by the Geological Survey; and by attaching prospectors to the Geological Survey parties. By 1949 about one thousand pitchblende occurrences or places where radioactivity was high but where the mineral was not identified had been found by these means, and Eldorado had staked a large number of claims. From then on as private prospecting became more active, the company gradually abandoned many of these claims, now holding one large and two small blocks.

Many of the occurrences found during the period of government prospecting were stripped and trenched, many of the more promising ones were tested by diamond drilling. By 1952 Eldorado had done 200,000 feet of drilling in the area. Three showings were selected for underground exploration, an adit being driven at the Martin Lake claims in 1948, and shafts being sunk at the Ace and Eagle claims in 1949 and 1950 respectively. Underground exploration of the Ace deposit, coupled with more detailed drilling from surface and underground stations, gradually indicated that the Ace was probably the most important uranium discovery known in Canada at those times. It was more erratic and much lower in average grade than the Eldorado deposit at Great Bear Lake, but these disadvantages were partly offset by shorter distance from railhead and by better climate. Serious treatment problems were gradually overcome by research. A decision to prepare the Ace for production was reached in 1951, this work being completed in 1953.

The base camp was moved to the north shore of Beaverlodge Lake, not far from the Ace showings, early in 1949. Modern buildings and homes were afterwards erected there by Eldorado. At first personnel and perishable goods were flown in float-equipped aircraft from Fort Smith, where the nearest airstrip was situated. Freight was brought by barge to a point on the shore of Lake Athabasca, portaged a short distance by truck, and taken across Beaverlodge Lake by a small barge and tug. When the scale of operations increased, the Department of Transport built an airstrip near the Beaverlodge camp. A 12-mile road was built from there to a new landing (Bushell) on Lake Athabasca, financed by the federal and provincial governments and several companies. Nearly 900 tons of freight were trucked over this road in one day in 1952, and the total for that year was about 35,000 tons. Early in 1952, before freight could be brought by barge, Eldorado flew 2,400 tons of building materials from Edmonton to speed work. The power plant mentioned previously was acquired, a branch line being constructed to the Ace operation.

Removal of the ban on private staking and mining for radioactive materials caused considerable private activity in the area during 1948 and early 1949, when some of the deposits that later became small producers were found and staked. In 1949 the provincial government withdrew the unstaked part of the area, and auctioned forty-two concessions, most being 25 square miles in size. These required a minimum expenditure of $50,000 each on prospecting or exploration, and were valid until 1952, after which 20 per cent of the concession could be retained as claims. Some were prospected systematically, this work resulting in many discoveries, others were tested less thoroughly, and a few were abandoned before expiry.

In 1952 much ground became open for prospecting and staking when concessions expired. This caused a rush which, although it was participated in by a number of individuals and companies, was exaggerated in the press and other media. The most important find of that year was the Gunnar showing, found close to the shore of Lake Athabasca by a team of prospectors financed by Gunnar Gold Mines Limited on a concession that had been inadequately prospected. Diamond drilling soon showed this to be an unusually large and regular deposit that could be mined initially by open-pit methods. Development was rapid, being aided to some extent by the regularity of the deposit, its nearness to barge transportation on Lake Athabasca, and the fact that certain buildings at the Box mine could be bought and moved, on the ice, to the Gunnar camp. The company built a private airstrip near the mine. Because of these facilities a road was not built to join the road extending between Bushell and the Beaverlodge airstrip. Other activities in the area, however, caused the provincial authorities to lay out a townsite midway between Bushell, on the one hand, and the Beaverlodge airstrip and Eldorado operations, on the other, called Uranium City, which has become the trading centre of the district.

A large treatment plant built by the reorganized Gunnar Mines Limited began production in 1955. Several other deposits were shown to contain substantial tonnages, but not enough to justify individual plants. After the Eldorado plant was built this company announced its willingness to buy custom ore for treatment if it could be accommodated. Beginning with shipments trucked from the Rix Athabasca mine in 1954, ore was produced and treated in this way from the Rix, Nicholson, National Explorations, and Eagle-Ace mines. Lorado Uranium Mines Limited developed a deposit near the south shore of Beaverlodge Lake which alone did not seem to warrant a plant. Arrangements were made to treat ore from several other mines, and a plant was completed in 1957. Ore has since been shipped to it from the Cayzor, Lake Cinch, National Explorations, Black Bay, and Rix mines.[1]

Geology

Geological work. The first geological report on the region was that of Tyrrell, who made a reconnaissance around Lake Athabasca for the Geological Survey in 1892 and 1893 (1896). A geological reconnaissance that included the northwestern part of what is here classed as the Beaverlodge area was carried out by Camsell in 1914 (1916). In 1935 Alcock made more systematic studies of a large territory along the north shore of Lake Athabasca, publishing a report (1936), three maps on the scale of 1 inch to 4 miles, and a map on the scale of 1 inch to 1 mile of the area around Beaverlodge Lake, which were of great value when activities for uranium were begun. Cooke (1937) studied in detail a small area at Goldfields. Beginning with detailed mapping of a small area at and near the Nicholson claims by Jolliffe in 1945, the Geological Survey has carried out extensive studies and mapping almost without interruption to the time of writing. Two areas including Beaverlodge Lake were mapped in 1947 and 1948 by Christie, preliminary maps being published quickly and the formal edition being published on the scale of 1 inch to 1 mile (1953). This work was continued to the east by Blake (1955), and to the west by Hale (1954a, b, 1955). Fraser mapped a small area at and near the Gunnar discovery in the same way (1954).

Because of the relationship of the uranium deposits of Beaverlodge area to complex geological features, particularly structural features, it soon became apparent that the area required mapping in greater detail. Surveys were made for new base maps by the Topographical Survey, including 50-foot contours. Tremblay from 1952 to 1957 carried out painstaking geological surveys on the scale of 1 inch to 400 feet over much of the area, the results being published in a series of seven maps on the scale of 1 inch to 800 feet (1955, 1957a, 1957b, 1958a, 1959); he has also described his findings in two papers (1957c, 1958b). C. K. Bell (1959) did similar work in the tract between the Gunnar and Lorado mines from 1954 to 1958.

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[1] In 1960, Gunnar Mines Limited arranged to supply the unfilled parts of contracts held by Rayrock Mines Ltd. and Canadian Dyno Mines Ltd. Lorado Uranium Mines Ltd. sold its contract to Eldorado Mining and Refining Ltd., causing closure of the Lake Cinch, Cayzor, Rix-Athabasca, and several smaller mines. At the end of 1960 only the Eldorado and Gunnar mines were in operation.

Robinson made detailed studies of the mineralogy of many deposits from 1949 to 1951 (1955). Dawson made a special study of wall-rock alteration in 1950 and 1951 (1956). Lang (1952a; 1952-56) and his associates studied many of the deposits, with particular reference to economic geology, from 1948 to 1956.

Much important geological work was done by company geologists, in private mapping of certain holdings and in studies of drill-cores and underground workings. Several resulting papers are not mentioned here because they are listed in a bibliography (Griffith, 1956). More recently, company geologists have contributed valuable papers in two symposia (Anon., 1957; Buffam, *et al.*, 1957; Joubin and James, 1957; Jolliffe and Evoy, 1957).

General geology. The area is rugged, with many hills and steep northeasterly trending, rocky ridges up to 700 feet above the intervening, generally drift-filled valleys. Rock exposures total about 15 to 60 per cent of the terrain.

Bedrocks are divisible into three main groups: (1) much metamorphosed sedimentary and volcanic strata comprising the Tazin group; (2) granitic and related rocks; and (3) relatively unmetamorphosed sedimentary and volcanic strata comprising the Athabasca group. The Tazin group is generally considered to be of Archæan age. Many of the granitic rocks are evidently granitized Tazin strata; Tremblay considered that all were formed in this way. Contacts between granitic rocks and less-altered Tazin strata are commonly gradational and difficult to map. The Athabasca group in the Beaverlodge area, except for exposures on islands in Lake Athabasca, is usually considered to be of Proterozoic age; it was, however, originally classed as Cambrian and the age of the group as a whole has not yet been definitely established and may be of more than one age.

The Tazin group consists mainly of quartzite, granitized quartzite, quartz-feldspar gneiss, argillites, amphibolite, chlorite schist, ferromagnesian schist, and garnetiferous schist. Ferruginous and dolomitic quartzites, dolomite and conglomerate are less abundant, occurring particularly in a belt that extends for about 10 miles in the southeastern part of the area. Most of the Tazin rocks have undergone feldspathization, silicification, chloritization, epidotization or hematitization.

Besides rocks resembling typical granite and pegmatite there is much granitic banded gneiss and other 'hybrid' rocks, which are believed to represent various stages in granitization and variations in the nature of the original rocks.

The Athabasca group[1] is a succession of beds of arkose, arkosic sandstone, conglomerate, siltstone, and flows of basalt and andesite. The lavas are most abundant immediately northwest of Beaverlodge Lake. The Athabasca strata rest unconformably on Tazin and granitic rocks, having a basal conglomerate composed of angular fragments of these rocks. The Athabasca rocks were deposited on a rugged erosion surface and now occur as remnants forming basins and synclines; they may, however, have been local accumulations rather than a connected succession.

The youngest rocks are dykes and sills of gabbro and basalt.

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[1] The Athabasca strata north of Lake Athabasca have been re-named the Martin formation.

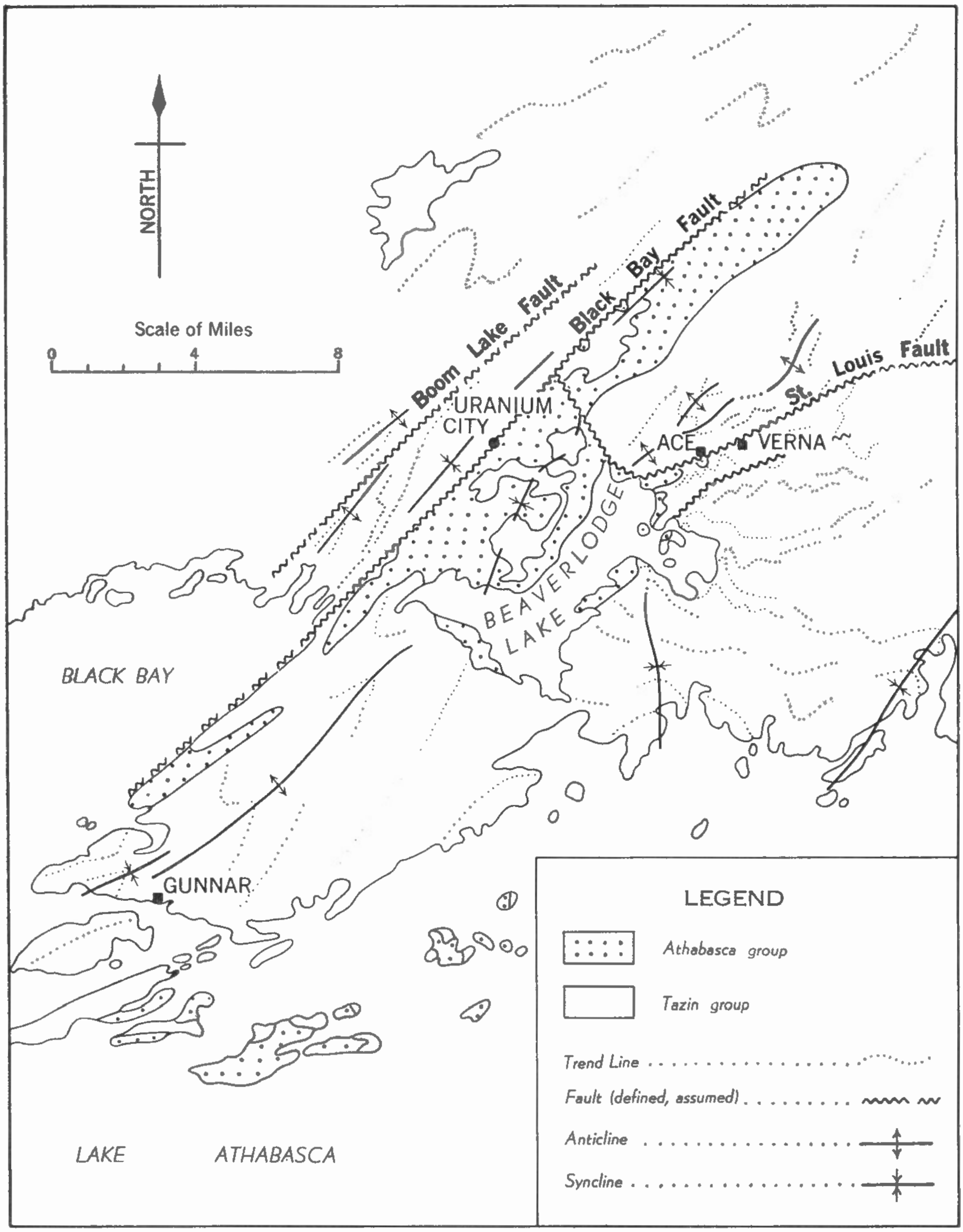


Figure 5. **Generalized geology, Beaverlodge area, Saskatchewan. After L. P. Tremblay, 1958.**

Geological structures. The Tazin strata are intricately folded, with axes trending generally northeast, but there are many local variations that cannot be interpreted fully because of patchy preservation of the less-granitized remnants.

The Athabasca strata are less severely folded, possibly as a result of both subsidence and regional folding. Within Beaverlodge area, they occur in two principal synclinal 'troughs' bounded in part by faults.

Faults ranging from small slips to major structural features are common. Many strike northeast roughly parallel with the trend of the strata, such as the prominent Black Bay and St. Louis faults (*see* Fig. 5 and Pl. IV A); others are perpendicular to this trend, and still others strike easterly. Most dip steeply southward. Some are left-handed and some are right-handed. Many faults curve, and many have branches. Tremblay has shown that there were two main periods of faulting, the earlier following granitization of the Tazin rocks, and the other following deposition of the Athabasca strata. Zones of fracturing, brecciation and mylonitization are common. Many are along major faults, but Tremblay considered that most were not caused by faults that can now be mapped, because most of the mappable faults are late. He considered that the zones are related to the earlier period of deformation or faulting. He stated also that many such zones of brecciation are related spatially to the flexures and to the noses of folds.

Mineral deposits. Although uranium is the only metal now mined in the area, two deposits consisting of gold-bearing quartz veins and stringers in granite were mined about 1940, and other deposits were tested for their contents of gold, iron, copper or nickel.

Roughly three thousand uranium occurrences of the 'vein' class have been found, pitchblende having been identified from many and doubtless being present in microscopic amounts at the others. No reliable pattern suggesting concentrations of minor occurrences in the vicinity of orebodies is apparent. In addition to pitchblende occurrences several radioactive migmatitic and pegmatitic occurrences have been found.

Pitchblende deposits occur in Tazin, granitic and Athabasca rocks. Although it is theoretically possible that all are post-Athabasca and that those in older rocks were merely deposited in openings in them, there is some evidence from isotopic datings to suggest two periods of mineralization (Robinson, 1955). No evidence relating the granitic rocks genetically to the earlier period has been found.

The occurrences are of many sizes and forms, including microscopic disseminations and veinlets, coarser disseminations, stringers, pods, irregular masses, lenses and true veins. The two most important productive deposits are: a large disseminated deposit (Gunnar), and complexes of disseminations and stringers, lenses and small veins spaced closely enough to form orebodies (Ace-Verna). Most occurrences are much too small and scattered to be mined profitably. Most concentrations are related to zones of fracturing, mylonitization and brecciation. Some of the more vein-like deposits cut disseminations; the former are the only kind found in Athabasca rocks. Most of the productive deposits are related spatially to prominent faults, but are almost invariably in secondary structures close to the major faults rather than in or immediately adjoining them. No significant post-mineral faulting has been detected.

No universal generalizations can be made regarding favourable host rocks, but affinities for the more mafic rocks such as basalt, amphibolite, argillite and rocks regarded as originally argillaceous quartzite are common. Excellent examples can be seen at the Martin Lake property, where veins of pitchblende occur in lava, and virtually unmineralized fractures extend from them across interbedded arkose. It appears that precipitation of uranium is favoured by presence of chlorite, amphibole or pyroxene in mafic rocks. There are, however, exceptions to this generalization, such as the deposits at the Black Bay mine, which are in fairly pure quartzite.

The distribution of several pitchblende deposits in Tazin or granitic rocks not far from their contact with the Athabasca series led to a theory that the unconformity may have been a factor in localizing deposits, either as a channel for solutions or as a means of providing a cover of relatively unfavourable rocks. The writers consider that although one or other of these factors may locally have been effective, there are no grounds for a broad generalization.

The most important deposits have been found beneath low-lying areas covered or largely covered by overburden. They were indicated by diamond drilling, usually in the vicinity of small pitchblende-bearing outcrops, the drilling being planned on the basis of structural conditions or radioactivity surveys. Erosion evidently was aided by the faulting and brecciation so commonly associated with pitchblende mineralization, by the relative softness of some mafic rocks as compared to the purer forms of quartzite, gneiss and granite, by the brittle, soluble and oxidizable nature of pitchblende, and by the softness of carbonate gangue. The histories of the discovery and exploration of the Ace, Gunnar, Lorado, Lake Cinch and certain other orebodies are ample testimony to the importance of low ground, in otherwise favourable localities, for any further prospecting that may be undertaken in the area.

Mineralogy. Pitchblende is by far the dominant uranium mineral in almost all deposits of the vein and related class. Robinson (1955a, pp. 60-64) has shown that it is cryptocrystalline and occurs in four main forms: colloform, massive, sooty and euhedral. Some pitchblende is brecciated and cemented by later pitchblende. The mineral is mostly adulterated by inclusions of other minerals, even masses that appear pure to the unaided eye carrying calcite, chlorite or hematite. Thucholite or related material has been identified from seven properties in Beaverlodge area. Robinson lists fourteen supergene uranium minerals, liebigite and uranophane being much the commonest. Supergene minerals generally extend only a few feet or less below the surface, except along the major fault zones where it is common to find supergene minerals down to 400 feet. In the Gunnar deposit they extend at least beyond a depth of 400 feet. The Bolger claims (*see* p. 198) contain an unusual example of transported supergene material.

Robinson identified a large number of metallic minerals from certain pitchblende deposits. In addition to common minerals like pyrite and chalcopyrite, unusual features are the selenides in several deposits, a new vanadium mineral—nolanite—in a few, and tiemannite, a mercury selenide, at the Nicholson property.

Metallic minerals other than pitchblende and hematite are usually in accessory amounts, if at all, but nolanite is fairly abundant in a few deposits. Calcite and chlorite, and, to a lesser extent, quartz, are the principal gangue minerals. Feldspar is also present, but is considered a phase of the red alteration.

There is no definite proof of mineralogical zoning, either within deposits or areally. It is worthy of note, however, that nolanite is more abundant in the lower levels of the Ace mine. It may also be significant that the more complex deposits, including the Nicholson with copper, cobalt, nickel, lead, zinc, mercury, platinum and gold minerals, and the Ace, Fish Hook and Pitche vanadium-bearing deposits, are all in the southern part of the area.

Various migmatitic and pegmatitic occurrences have been reported to contain uraninite, pyrochlore-microlite, fergusonite, allanite, thorite or monazite.

MINES WITH PLANTS

Ace-Verna Mine

Eldorado Mining and Refining Limited is producing from the Ace and Verna deposits, which are up to 2 miles apart and connected by underground workings. These operations are in a large block of claims extending about 6 miles northeastward from the north shore of Beaverlodge Lake.

History. Pitchblende occurrences were found on these claims in 1946 by P. St. Louis and E. Laurum, a team of prospectors working for Eldorado in the program mentioned earlier. Among other discoveries, St. Louis found veinlets of pitchblende in brick-red rock above what became the Ace deposits. The prospectors noted that the veinlets were near a contact and a long depression that probably marked a prominent fault, and considered that these features made the find attractive. They staked claims and stripped moss from the outcrops, and called the occurrences the "Ace". R. Murphy, geologist for Eldorado, examined the discoveries in 1946 and reported:

> Several pounds of rock showing these veinlets assayed 1.20 per cent U_3O_8. Following the draw west for a thousand feet, a second and similar occurrence is found on a low knoll. Here two samples were taken of relatively rich material which assayed 1.53 per cent and 4.06 per cent U_3O_8. These assays represent small pockets of pitchblende for which extensions are unlikely, but they may point to more important deposits in the break underlying the draw.

Geiger-counter surveys and a little trenching were done. Diamond-drill holes spaced 400 feet apart probed the fault and its walls at depths of 175 and 300 feet beneath the surface. This suggested the presence of two bodies of commercial sizes, but far below the grade of the ores at Great Bear Lake. Drilling was continued between the first holes, at intervals of 100 and 200 feet, the results being sufficiently encouraging to warrant underground exploration. An inclined shaft was sunk in 1949. In the following year drifting was done on two levels and many diamond-drill holes 25 and 50 feet apart were run from the drifts. The shaft was deepened later, and four additional levels were established.

By 1950 drilling had outlined several other deposits lying at intervals for several miles along the fault, and in other parts of the area. The Ace deposits appeared to be the most promising, although the average grade was disappointingly low by the standards of that time, and the large amount of carbonate in the ore made acid-leaching undesirable. A carbonate-leaching method was developed, however, and as no large deposits of better grade were known, production was decided upon. A treatment plant rated at 500 tons of ore a day (later increased to 2,000 tons) and a vertical, operating shaft were commenced in 1951 and completed in 1953. The plant was begun as a carbonate-process plant, but acid-leaching was later undertaken as well. The shaft, called the Fay, was placed 4,000 feet southwest of the Ace shaft because a good site for a shaft and plant was available there, and because it would permit underground exploration of showings called the "Ura" which had been found between this site and Beaverlodge Lake. The Ura deposits proved to be of still lower grade than the Ace, however, and they have not been mined. The Fay shaft was eventually sunk to a depth of 2,297 feet to permit sixteen levels. The two shafts were connected by a haulageway at the sixth level, and a similar haulageway at the thirteenth level was begun.

Meanwhile further drilling was done to test showings found on the Bolger claims more than a mile northeast of the Ace shaft. The results were sufficiently encouraging to cause sinking of a shaft, begun in 1954 and called the "Verna", 6,000 feet northeast of the Ace. It is connected to the Ace-Fay workings on the sixth level, making an underground operation about 2 miles long. In addition to producing from Eldorado ground, the Verna mine is extended into ground owned by Radiore Uranium Mines Limited (the NW—GC—Lee group described in the first edition of this report). Eldorado leases this ground and pays a royalty of 50 cents per pound of U_3O_8 mined, because the Verna zone extends into Radiore ground for a distance reported to be about 20 per cent of the total. In the last nine months of 1957 the plant was reported to have treated an average of 93 tons of Radiore ore a day, carrying 2.4 pounds of U_3O_8 a ton. This, together with ore from the Eldorado part of the deposit, accounted for the total of 1,200 tons of Verna ore treated a day in 1957. This compared with 800 tons a day from the Ace mine. In 1957 the plant produced 2,171,284 pounds of U_3O_8, including 289,336 pounds from purchased ore. The total reserve of proved and probable ore at the end of 1957 was 3,484,000 tons averaging 0.21 per cent U_3O_8.

At the end of 1957 Eldorado had 903 employees at Beaverlodge. Most were housed at Beaverlodge Lake, and 249 resided at Uranium City.

General geology. The rocks near the Ace orebodies are northeasterly striking Tazin strata, chiefly thinly bedded chloritic argillite, interbedded with siliceous argillite and perhaps quartzite, uncertainty existing as to whether some beds are true quartzite or products of silicification. These rocks form a band about 1,200 feet wide. Farther from the deposits are banded gneisses and granitic rocks. The gneisses are overlain locally by synclinal remnants of Athabasca conglomerate containing minor interbeds of feldspathic sandstone and siltstone.

Structural geology. The dominant structural feature is the St. Louis fault, named after its discoverer. Extending the length of the claims, and beyond, it strikes about N70°E near the Fay shaft and N60°E near the Verna, and it dips 50°SE. The actual fault is marked by a seam of gouge averaging 3 inches thick with a maximum of 10 inches. Zones of intense fracturing and brecciation occurring in the wall-rocks were probably caused by earlier movement related in a general way to the fault. The Tazin rocks have been folded as well as fractured, but the latter, together with subsequent alteration, obscures the folding in many places. Tremblay (1958, p. 12) stated that at the Ace "A slight flattening of the bedding occurs at depths below 1,000 feet (300 m), causing the belt of argillite and quartzite to narrow there. The strata are on the southeastern limb of a broad northeasterly-trending anticline that plunges southwest. On a smaller scale the beds are much flexed, and many minor open folds plunge about 50°SW. Many of the ore zones are related to such flexures and folds." Tremblay described the structural features at the Verna mine as follows:

> The general trend of the strata east of the shaft is easterly, at an angle of about 40° with the fault, which here strikes N60°E and dips 50°SE. West of the shaft and near the fault the strata seem to swing northerly into the fault; their dip is generally less than 60°S. These strata appear to be near the trough of a broad syncline plunging southerly and extending southward to Lake Athabasca. They are much flexed, and contain some minor folds and many fractures. A minor anticline in the mine area trends about parallel with the strike of the fault and plunges southwestward from around 50° east of the shaft to 20° and less west of the shaft. A zone of intense fracturing and shattering is closely associated with the approximate position of the axis of this anticline and marks the position of the pipe-shaped zone of altered argillaceous rock mentioned above. Most of the Verna ore zones are related to this zone of intense fracturing and alteration, and consequently to the crest of the anticline. Although this relation is readily apparent west of the shaft, it is less so east of it, where later cross-folds and fractures have much modified the attitudes of the ore zones.

Orebodies. The Ace orebodies are tabular, irregular-shaped bodies (*see* Figs. 6, 7, and Pl. V) containing disseminations, veinlets and small veins in much fractured and brecciated rock that appears to have been argillite, altered by processes related to granitization as well as by hydrothermal action. These bodies lie in the foot-wall of the fault at irregular intervals along a length of about 7,000 feet, and within 300 feet of the gouge seam. They have been found as low as 1,100 feet, some not yet being bottomed. They are classed as 'breccia' orebodies, composed of breccia cemented by pitchblende, quartz, calcite and chlorite, and commonly also contain short pitchblende-bearing fractures, and as 'vein' orebodies composed of networks of stringers and small veins carrying pitchblende. The breccia-type orebodies occur close to the gouge seam, and the vein type from 100 to 300 feet from it. The bodies vary in size, as illustrated by Figure 7. One of the larger breccia orebodies is 650 feet long, 5 to 30 feet wide, and is partly explored to a depth of 1,800 feet. Many orebodies grade out into sparsely mineralized rock, their limits being based on assays and mining practicability, thus accounting for some of the straight-line limits shown on Figure 8.

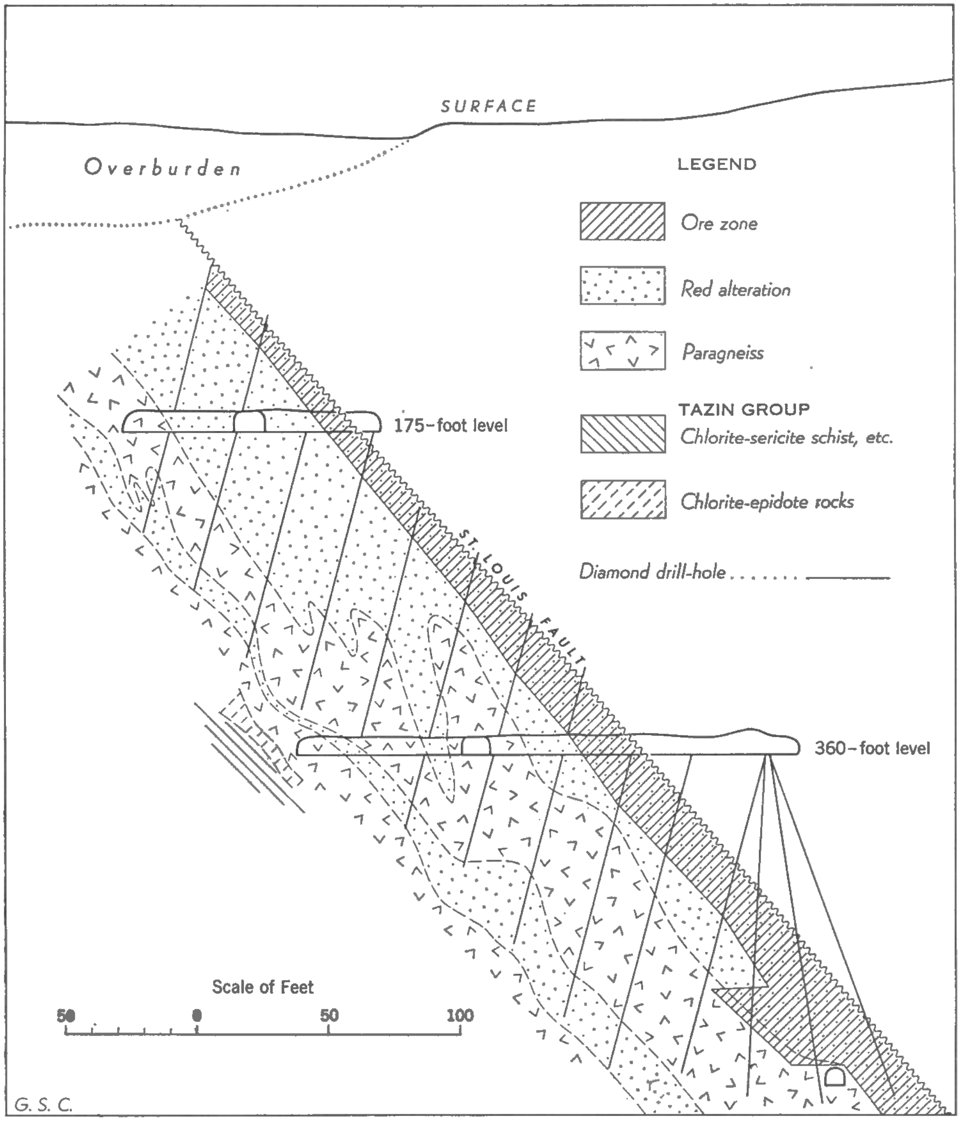
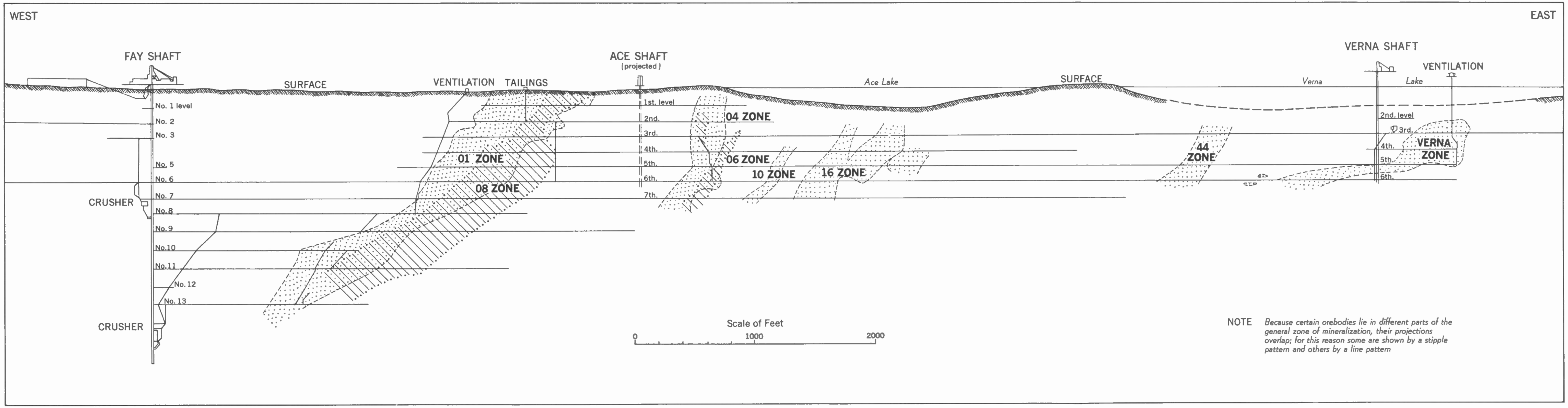


Figure 6. **Vertical cross-section through upper levels, Ace mine (befoie stoping). From plan by Eldorado Mining and Refining Limited.**

Robinson (1955, p. 21) estimated the order of abundance of metallic minerals in the Ace ores to be hematite, pyrite, pitchblende, chalcopyrite, galena, clausthalite, bornite, nolanite, ilmenite, marcasite and sphalerite. Nolanite was found only in lower parts of the mine. Calcite is the principal gangue mineral, along with oligoclase which appears to be related largely to the period of rock alteration rather than that of the formation of disseminations and veins. Other gangue minerals are chlorite and quartz.



NOTE *Because certain orebodies lie in different parts of the general zone of mineralization, their projections overlap; for this reason some are shown by a stipple pattern and others by a line pattern*

Figure 7. ***Vertical longitudinal section through Fay and Verna shafts showing projections of orebodies. From drawing by Eldorado Mining and Refining Limited, January 1958.***

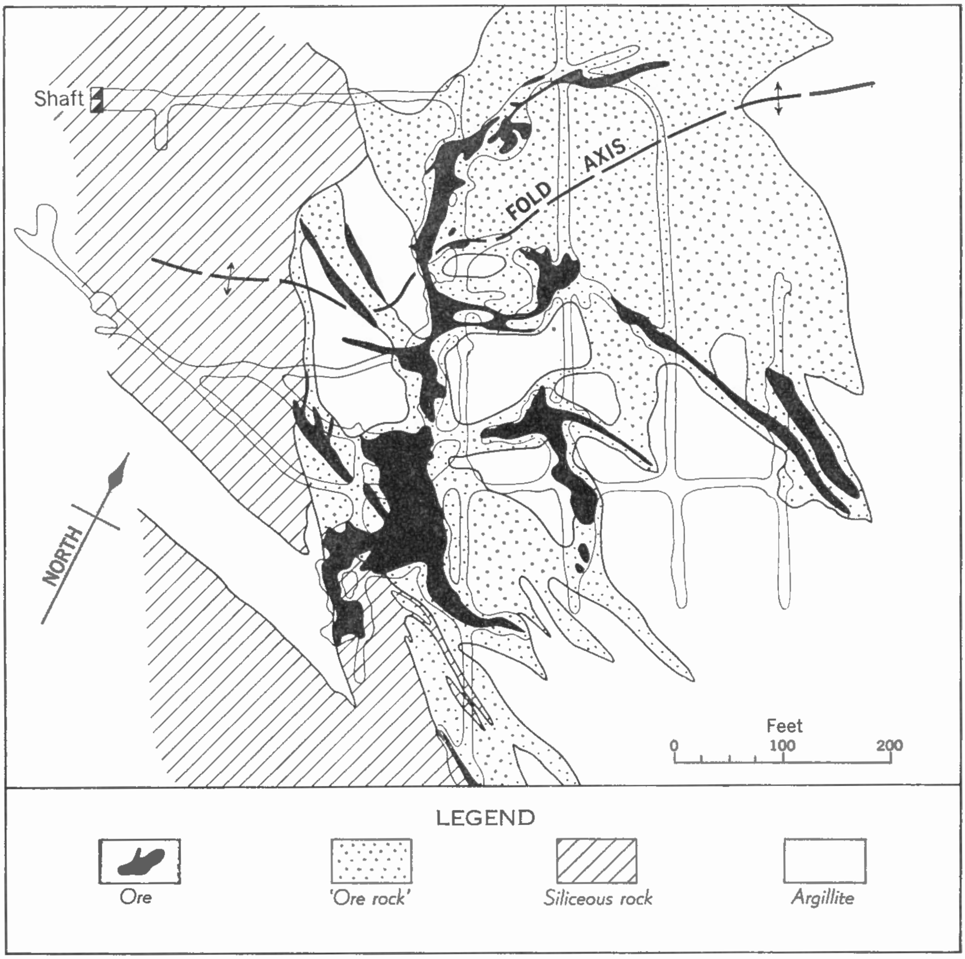


Figure 8. ***Geological plan of fourth level, Verna mine.*** **From plan by Eldorado Mining and Refining Limited.**

The Verna orebodies are in a wedge-shaped band of argillite altered by feldspathization and hematitization (locally called 'ore rock'). They occur in the hanging-wall of the St. Louis fault, in contradistinction to the Ace orebodies, and their average position is about 400 feet from the gouge seam. Most are tabular bodies, dipping 20° to 50°SW, and branching or joining one another in places. These are zones containing sufficient pitchblende, in fractures from microscopic in size to 4 inches wide, to constitute ore. The orebodies are disposed in *en échelon* fashion to one another because of a southwest rake in a zone of shearing and silicification with which they are associated. The mineralogy of the ores appears to be much similar to that of the Ace ores, except that nolanite and some of the other minerals found in Ace ores have not been described from Verna ores;

it should be noted, however, that these deposits were opened after Robinson had completed his detailed mineralogical field work and were therefore not discussed by him.

Gunnar Mine

The Ed-Bon and Arch claim-groups of Gunnar Mines Limited, at the south shore of Crackingstone Peninsula of Lake Athabasca, contain one of the largest uranium mines in Canada and the only one operated by open-pit methods. The company established its own air and water transportation services and a community for about 750 persons.

History. In the spring of 1952 Gunnar Gold Mines Limited sent two prospectors, A. O. Zeemel and W. J. Blair, to work in Beaverlodge area. They went to the Crackingstone sector because ground previously held under concession there had already come open for staking, as the holders had yielded it before expiry after what proved to be incomplete prospecting. After finding several minor occurrences, Zeemel followed a radioactive fracture to its disappearance under overburden and obtained strong readings with his Geiger counter over a swampy area. A large area proved to be radioactive, although containing only one strongly radioactive outcrop and a few pieces of radioactive rock brought to the surface by frost action (Zeemel, 1956). Zeemel and Blair staked twelve claims, and Zeemel made a competent preliminary radioactivity survey by pace, compass and Geiger counter. Later in the season a more detailed survey was made by scintillometer, at 50-foot intervals. Preliminary diamond drilling was done, but little trenching or surface sampling was attempted. Detailed diamond drilling, with vertical holes on a 75-foot grid-system was begun. Hole after hole yielded significant sections, until a body that appeared at least 450 feet in diameter was outlined to a depth of about 1,000 feet. A total of 70,000 feet of drilling was done in 169 holes. The results were estimated to indicate 4 million tons averaging 0.2 per cent U_3O_8. Later work showed still more ore. The results of drilling were sufficiently consistent to suggest that confirmation by underground exploration would not be necessary, and a contract for sale of precipitates to a value of some $77 million was arranged with Eldorado in 1954. This contract was increased later. Preparations for open-pit mining were begun and a leaching plant was completed in 1955 and later increased to a capacity of 1,650 tons of ore a day.

General geology. The Gunnar property is underlain by a succession of altered strata, composed chiefly of quartz and feldspar (Tremblay, 1957b, p. 220), which in most places strike about N75°E and dip 45°S. Most of these rocks are gneissic and all are regarded as altered sedimentary strata of the Tazin group. Some are considered paragneisses, and others as granitized sediments. All rocks called granite or syenite here are considered by the writers, and several other geologists, to be phases of granitization. The rocks at and near the mine are locally called paragneiss, granitic paragneiss or granite-gneiss, and syenite (Jolliffe and Evoy, 1957, p. 241). Although rocky ridges extend in the neighbourhood, rocks are poorly exposed near the mine, except in the pit. The following account has been condensed largely from the papers of Jolliffe and Evoy, and Tremblay, whose information is much more complete than was permitted by the short studies the writers were able to make.

Structural geology. The deposit is on the east limb of a large anticline that has been traced along the full length of Crackingstone Peninsula, and which plunges southwest.

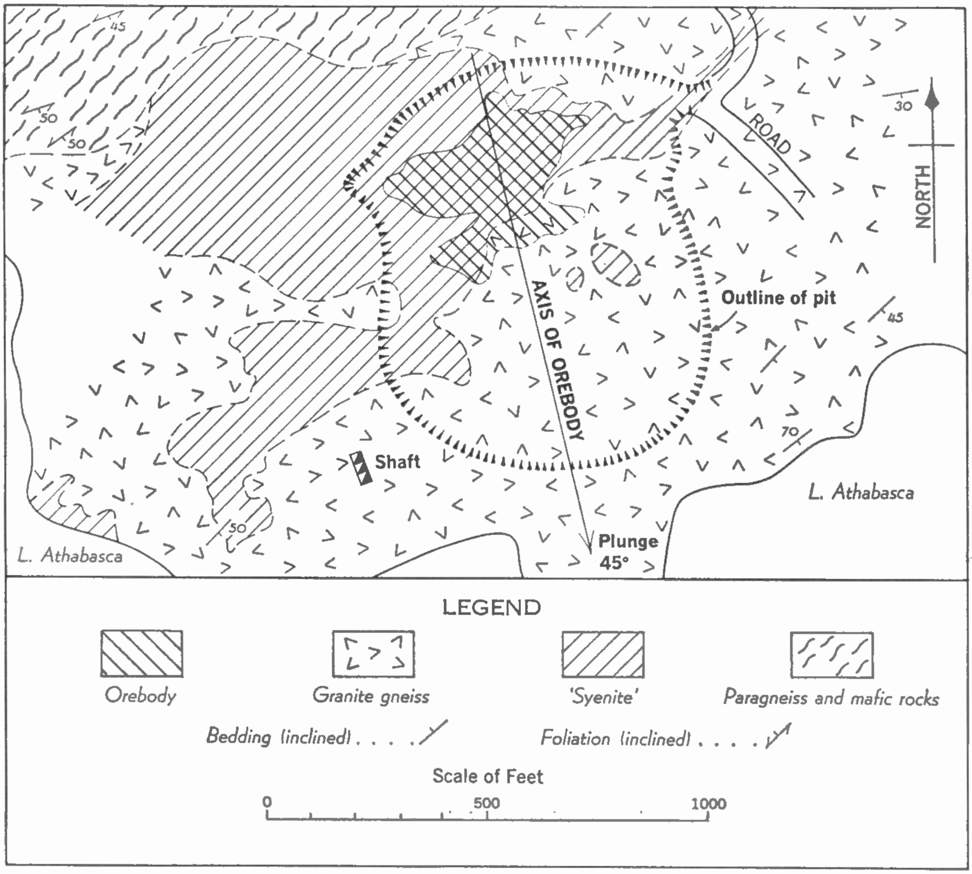


Figure 9. Geological diagram of near-surface features, Gunnar deposit. After plan by Gunnar Mines Limited.

Two sets of major faults have been recognized, one striking northeast and dipping southeast, and the other striking east and dipping south. Minor faults are also in two sets, one striking east-northeast about parallel with the foliation but dipping south more steeply, the other set striking slightly west of north and dipping vertically. Ore is confined to much-brecciated syenite in the eastern corner of a triangular mass of this rock, which was apparently the type that fractured most suitably. The location of the deposit close to the northeasterly striking Zeemel

Creek fault and the easterly striking St. Mary's Channel fault (Tremblay, 1958, p. 15) suggests that the brecciation was related to movement along one or both of these faults; it may also be attributed partly to drag-folding. The Zeemel Creek fault may have been mainly responsible, because it bends sharply near the orebody.

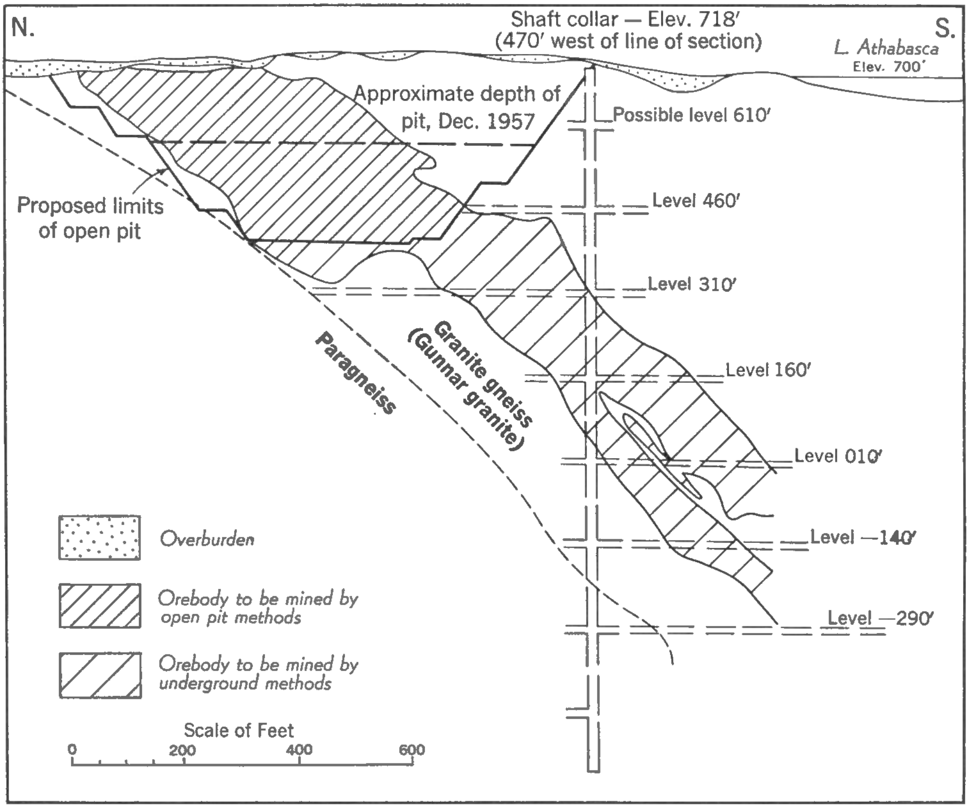


Figure 10. **Generalized longitudinal section along axis of Gunnar orebody, looking east. Based on drawing by Gunnar Mines Limited with additions by the writers.**

Orebody. The orebody is 'pipe-like' in shape (*see* Figs. 9, 10), plunging 45°S. It has been probed by drilling to indicate a depth, along the plunge, of about 1,400 feet, and appears to continue farther. Between depths of 250 and 350 feet the plan of the body changes from roughly circular to the shape of a 'figure eight', the north circle of the 'eight' becoming smaller and disappearing, and the south part enlarging and continuing to plunge southward. This gives the appearance of a bend or offset in the 'pipe'. The ore occurs in a rock approaching syenite in composition, but containing much carbonate. Various names have been applied to this rock, such as soda granite, albite monzonite, carbonated syenite, carbonate-feldspar rock, albite rock and "sponge rock" (from its pitted weathered surface). For simplicity, it is referred to here as 'syenite'. It forms irregular masses of various sizes and shapes within the mass of granitic gneiss and, like it, is foliated in a northeasterly direction. The 'syenite' is a much-crushed, porous, alteration product of the granitic gneiss. It contains much feldspar and, locally, small amounts of secondary quartz. The granitic gneiss contains little or no carbonate, more quartz, and shows less fracturing and brecciation. Members of the staff of Gunnar Mines Limited stated that both field and laboratory evidence suggest that the 'syenite' was derived from the granitic gneiss by replacement of quartz by carbonate. Bell (personal communication) believed that there was a third step in the replacement process in which the original quartz was replaced by feldspar and that some of the feldspar in turn was replaced by carbonate.

The ore minerals are pitchblende and uranophane. Most of the pitchblende is disseminated finely (*see* Pl. VI). Robinson (1955, p. 33) showed that it occurs principally as rims on grains of albite, and is commonly associated intimately with chlorite and iron oxides. Ore boundaries commonly require demarcation by assays. Uranophane is unusually abundant, apparently because of circulation of artesian water in the porous host rock, as some of the diamond-drill holes for a time emitted water under pressure. Uranophane accounts for roughly half the uranium in much of the ore, and has been reported from the deepest intersections, yet there is no evidence of supergene impoverishment or enrichment. Other metallic minerals are hematite and traces of pyrite, chalcopyrite and galena. Non-metallic, introduced, minerals are calcite, dolomite, chlorite and quartz. The ore is pink, mauve, red or brown, depending on grain size and degree of hematitization. Red alteration is common but is not always a guide to ore.

It is planned to mine the deposit by open-cut methods to a depth of about 350 feet. The pit is about 800 by 1,000 feet at the surface. A shaft has been sunk to 1,242 feet to permit underground mining later, and eight levels have been established. In 1957 the average milling rate was 1,647 tons a day, and ore reserves at the end of that year were reported to be 1,375,810 tons of open-pit ore averaging 3.4 pounds of U_3O_8 a ton, and 1,800,000 tons of underground ore, to the seventh level, averaging 4 pounds a ton.

Lorado Mine

The Alco group of seven claims is at the southwest end of Beaverlodge Lake. It is reached by a 12-mile road from Uranium City.

The claims were staked in 1950 for Noranda Mines Limited on part of the former BB concession. Early work was discouraging, and in 1953 the claims were sold to Lorado Uranium Mines Limited which had been incorporated in the previous year. About 25,000 feet of diamond drilling was then done, indicating a few scattered occurrences. A vertical shaft was begun in 1954 to test some of these. The shaft was eventually sunk to 610 feet, three levels and three sublevels being driven. A deposit that did not extend to the surface was explored. Although this did not itself appear to contain enough ore to warrant construction of a treatment plant, custom arrangements were made with certain other companies, as mentioned elsewhere. A plant rated at 500 tons of ore a day was completed in 1957, and increased to a capacity of 800 tons. Ore reserves at the Lorado mine were reported in 1956 to be about 150,000 tons, the tenor being unstated. The property covers part of the east limb of a major northeasterly striking anticline extending along Crackingstone Peninsula. The orebody occupies a position with respect to the anticlinal axis analogous to that of the Gunnar orebody 10 miles to the southwest. The claims are underlain mainly by quartzites, phyllites and schists of the Tazin group, striking northeast and in most places dipping 50° to 60°SE. A small amount of Athabasca conglomerate is present at the north end of the property near the shore of Beaverlodge Lake. Local drag-folds are present in the Tazin metasedimentary rocks. Faults parallel with the strike of the strata are suggested by topographic lineaments.

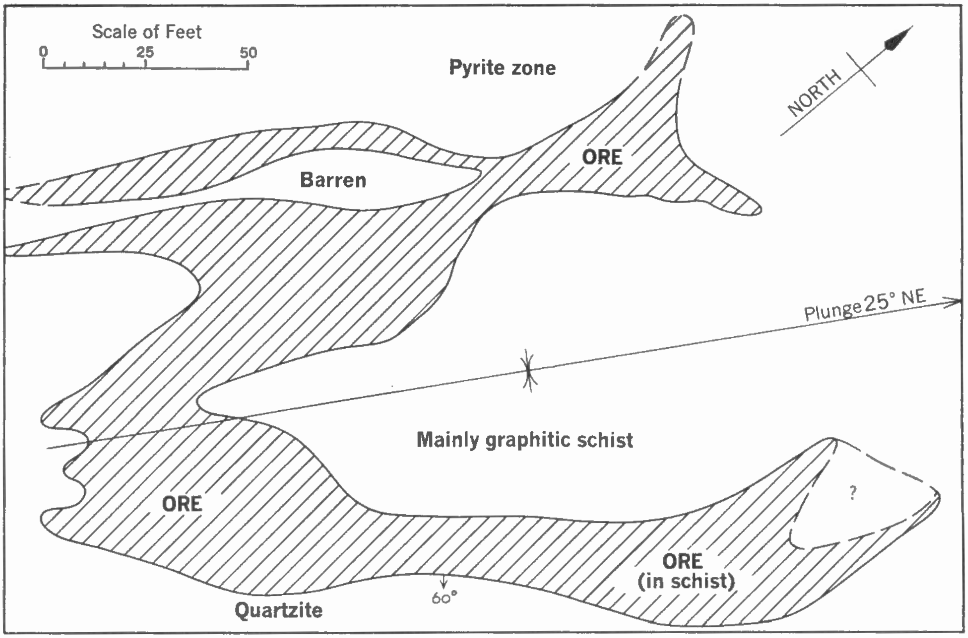


Figure 11. Generalized outline of orebody on first level, Lorado mine. Sketched from company assay plan.

Ore shoots occur in a band of much contorted graphite schist and chlorite schist, bounded on the east by quartzite and on the west by a pyritized shear zone (*see* Fig. 11). All rocks strike roughly northeast and dip steeply to the southeast. The main structural feature in the mine area appears to be a syncline in the schists which plunges about 25°NE. Irregular pitchblende-bearing shoots up to 250 feet long and 50 feet wide were formed in the folded schist zone, the best ore mostly being on the limbs of the syncline within about 100 feet of the bottom of the fold. The main orebody does not seem to extend below the second level. The principal structural control of ore deposition appears to have been fracturing along the base and limbs of the syncline. The graphitic zone seems to have been formed in a bed, possibly of slaty composition, lying between two relatively competent beds of quartzite. Smaller ore shoots were found outside the synclinal structure. A feature of much of the ore is the absence of hematite and feldspar, common in other parts of the area.

Pyrite in the foot-wall zone is mined to provide a source of sulphur for the manufacture of sulphuric acid used in the leaching plant. The zone varies from a few feet to 100 feet in width and has been traced for more than 700 feet. The rock appears to have been originally conglomerate, and to have been pyritized after shearing took place.

SHIPPING MINES

Black Bay Uranium Mine

Black Bay Uranium Limited shipped stockpiled ore from its Gretta group to the Lorado plant. The property is near the south shore of Murmac Bay of Beaverlodge Lake, and is underlain by quartzites and mafic rocks of the Tazin group striking generally east.

Four main pitchblende-bearing zones, designated A, B, C, and D, were found in an area about 100 feet wide and 500 feet long in sheared reddish quartzite near a sinuous contact with mafic rocks. The contact is marked by a zone of graphitic schist that is locally radioactive, movement along which has caused a complex of shear zones and minor folds. The contact dips about 30°S, with mafic rocks overlying quartzite. La Prairie (1955) stated that the most radioactive places are concentrated along the contact, mineable widths occurring along or near the synclinal axis of an overturned fold that plunges southeasterly from the surface contact zones. Short irregular ore shoots lie in shear zones as much as 3 feet wide and in subsidiary fractures extending not more than 30 feet from the contact. La Prairie described the dimensions and average grades of the A, B, and C zones, as indicated by surface trenches, as "45 feet by 3 feet, 0.47 per cent U_3O_8; 75 feet by 4.8 feet, 0.72 per cent U_3O_8; and 20 feet by 15 feet, 0.91 per cent U_3O_8, respectively." Radioactive minerals are pitchblende and secondary minerals, including kasolite. These are commonly associated with hematite and graphite.

In 1954 an adit was begun and about 6,000 feet of crosscutting, drifting and raising was done, including a sublevel, and a winze was sunk. By these means the zone was explored to a depth of 500 feet. About 13,000 feet of diamond drilling was done from surface and underground stations. Most of the ore in the A, B, and C zones, above the adit level, averaging about 0.2 per cent U_3O_8, was reported to have been mined and stockpiled when work was suspended in 1956. In March 1958 it was reported that 345 tons had been shipped to the Lorado plant.

Cayzor Mine

The mine of Cayzor Athabaska Mines Limited is on the east shore of Jean Lake about 1½ miles northwest of Uranium City. The property was formerly part of the DD-2 concession on which prospecting and radiometric surveys were done by and for W. N. Millar from 1949 to 1951. Scintillometer traverses on the ground resulted in the discovery of one hundred and forty-eight radioactive localities, and a few additional ones were found by low flying. About twelve were considered worth immediate stripping and trenching.

In 1951 the DD-2 concession was held by Azor Mines Limited. This company staked sixteen claims in 1951 to cover part of the concession and these were recorded as the Azor group. A showing on the east side of Jean Lake, presumably the one that was mined later, was diamond drilled. An X-ray type drill was used and eight holes were put down, with poor core recovery. After the showing was exposed it appeared to continue under Jean Lake. Further diamond drilling was done on the ice of the lake, along the apparent strike, by the reorganized present company. The results of this drilling indicated several high-grade fractures under Jean Lake and the swamp to the southeast. In 1954 a three-compartment vertical shaft was sunk to a depth of 670 feet and levels were established at 170, 320, 445 and 570 feet. Shipments of up to 250 tons of ore a day were sent to the Lorado plant after it was in operation.

The claims are underlain by altered Tazin rocks, the principal host rock of deposits, locally called 'meta-argillite', being quartz-feldspar-chlorite schist. Other rocks are chloritic quartzite, amphibolite, and granitic gneiss. These strata mostly strike northeast and dip from 30°S to vertically. Two main faults or shear zones a few hundred feet northwest of the workings are assumed to cross the claims in a northeasterly direction. These may be continuations of structures called the Boom Lake fault and the Jean Lake shear zone (Leonard fault) on nearby properties, and are so called. Numerous minor faults or fractures have been found, striking northeast, northwest and east; most have steep southerly dips.

Ore occurs mainly in fractures in 'meta-argillite' and chloritic quartzite. In the early stages of underground work ore was found in the hanging-wall of the Jean Lake shear zone. Locally, the ore zones can be related to a fault or fracture zone striking nearly perpendicularly to the Jean Lake shear zone, which consists of several faults or fractures that strike east and dip 40° to 80°S, and intersect and merge with one another. Ore also occurs along northeasterly striking and northwesterly striking faults or fractures that branch from the main easterly trending system; the richest and widest ore zone is at the intersection of two of them. In a few cases, fine-grained basic dykes, which cut all other rocks, appear to have influenced the concentration of ore along fault planes. All fault movement is believed to be pre-ore. Individual ore shoots vary in length from about 20 to 300 feet, with widths up to 12 feet. A company assay plan indicated one of the best ore-bearing fractures on the first level to be 247 feet long, averaging 3.8 feet in width with an average uncut grade of 0.525 per cent U_3O_8.

Pitchblende and thucholite are distributed at random in short, discontinuous bodies, together with a little pyrite. The gangue minerals include chlorite, kaolin and carbonate. There is little red alteration of the wall-rocks except in the vicinity of carbonate veins.

Eagle-Ace Mine

Nesbitt-Labine Uranium Mines Limited holds the Jam-Maj group of claims, near the southeast corner of Eagle Lake about 2 miles by road north of the Eldorado camp. The property is commonly called the Eagle-Ace. The claims were staked by J. Nesbitt and transferred to Eagle-Ace Uranium Mines Limited. Late in 1950 the present company was formed to take over this group and the ABC group nearby. Prospecting in 1949 resulted in thirty-eight radioactive discoveries, and in 1950 forty-five more were found. In 1951 a small mining plant was installed and a three-compartment shaft was begun in November of the same year. Two levels were established in 1952 at depths of 150 and 275 feet. In 1954 two additional levels were placed at 425 and 575 feet. A contract with Eldorado was negotiated for the treatment of Nesbitt-Labine ore at the Ace-Fay plant, and 19,885 tons of ore were reported to have been shipped late in 1955, when the contract expired.

The claims are underlain mainly by mafic rocks, granite and granitic gneiss of the Tazin group. The principal deposits are near the eastern part of a wide band of sedimentary rocks altered in part to chlorite and epidote near granitic gneisses. The trend of the rocks is northeast. Dips are mostly steep but they vary because the rocks in the mine area are intricately folded. They are cut by three parallel strike faults: the Contact fault on the east, which separated the chlorite-epidote rock from the granitic gneiss; the Eagle fault, about 550 feet to the west, underlain by a narrow band of slate, which is the most favourable host rock; and the Riley fault or shear zone about 200 feet west of the Eagle. The Riley fault dips 70°E whereas the others dip about 50°W, so far as can be determined from a few minor slips at the contact of different rock types. Pitchblende occurred in cross-fractures, commonly one half inch to 2 inches wide, within the faulted and folded area. Some fractures were radioactive for lengths of as much as 150 feet. Many of these cross-fractures were found at or near the crest of the anticlinal part of a large drag-fold, between the Eagle and Contact faults. Faulting, apparently right-handed, took place along many of the cross-fractures, places along right-handed bends commonly containing more pitchblende than elsewhere. Ore-bearing faults offset the Eagle fault which is considered a pre-mineral fault. The favourability of the slate is attributed to the relative ease with which it fractured.

Pitchblende occurs mainly in pods and stringers associated with calcite, hematite and a little pyrite. Other metallic minerals reported by Robinson, are: chalcopyrite, bornite, magnetite, and traces of galena, covellite and tin. Non-metallic, introduced minerals, besides calcite, are: chlorite and, locally, quartz. Red alteration usually did not extend into the wall-rocks more than a few inches. The few veins that continued to the bottom level were observed to flatten.

Mining was done on four levels. The ore was found to bottom at depth, operations being stopped in 1955.

The 15,600 tons of ore shipped in 1954 and 1955 graded between 0.146 and 0.244 per cent U_3O_8. The rate of shipment was from 75 to 110 tons a day.

Lake Cinch Mine

The Jam group of Lake Cinch Mines Limited consists of eight claims at the southwest end of Cinch Lake. It is about 2 miles southwest of Uranium City and is reached by a branch road. The claims were staked in 1948 by James Robb for Charles Swenson and were acquired in 1950 by Cinch Lake Uranium Mines, Limited. Surface work was done and sixty-five diamond-drill holes totalling 13,752 feet were bored. In 1954, control of the property passed to the present company, which is controlled by Violamac Mines Limited. An additional 22,500 feet of diamond drilling in sixty-five holes was then done on the two most promising zones. Shaft sinking was begun in September 1955, two levels being established. Work was resumed in 1957 after completion of the Lorado plant, shipping of ore beginning in May 1957. The company reported that to the end of August 1958 shipments totalled 33,319 tons, averaging 0.287 per cent U_3O_8.

The property is underlain by northeasterly striking gneisses of the Tazin group, and sedimentary and volcanic rocks of the Athabasca series. The Black Bay fault strikes northeast through the centre of the property, separating the Tazin rocks to the north from the Athabasca rocks to the south. The Tazin strata strike northeast and dip steeply to the north or south. In places they are intruded by basaltic dykes.

The orebodies occur in Tazin gneisses, in a wedge between two faults called the Crackingstone River fault and the Main Ore fault. The main deposit lies in a drift-covered valley which was probed by diamond drilling. The following account is condensed from a recent publication (Anon., 1957) because it contains information more recent than that obtained by the writers. The Crackingstone River fault strikes easterly, dips steeply south, and is inferred to meet the Black Bay fault near the east boundary of the property. The Main Ore fault strikes northeast parallel with the Black Bay, dips 45° to 75°S, and converges westward with the Crackingstone River fault. The intervening host rock is quartz-feldspar paragneiss and chlorite-feldspar augen gneiss, much mylonitized and coloured by red alteration. Two types of structures contain ore. That of highest grade is in a band of dark red mylonite 2 to 10 feet wide, within the Main Ore fault. The ore is not coextensive with the fault, but is limited to a shoot on the second level extending from 45 to 365 feet northeast of the junction with the Crackingstone River fault. It extends upward for about 135 feet, and downward an undetermined distance. Pitchblende is the main ore mineral but small amounts of green and greyish yellow radioactive material are also present. The pitchblende is disseminated irregularly through the mylonite in fine feathery fragments and rims. Calcite and chlorite are intimately associated, and reddish brown, earthy hematite, disseminated throughout most of the mylonite, is densely concentrated near pitchblende. Pyrite, chalcopyrite, specular hematite and rutile occur locally.

The other type of ore shoot is controlled by steeply dipping tension fractures striking east to southeast between the two faults. Movement on these fractures was slight but sufficient to form breccia and fracture zones that have been filled by specular hematite, calcite and pitchblende. Pitchblende veinlets and breccia fillings are up to half an inch wide. Intensified red hematitic alteration accompanies the ore. Ore shoots are 1 foot to 7 feet wide and 50 to 250 feet long; five such shoots were followed on each level.

Drilling at the west side of the property indicated an ore shoot in paragneiss, in the hanging-wall of the Crackingstone River fault. This shoot is believed to lie in a tension fracture similar to those in the hanging-wall of the Main Ore fault.

Martin Lake Mine

The R.A. group of Eldorado Mining and Refining Limited, which contains the Martin Lake mine, covers a strip of land about half a mile wide and 2 miles long that separates the north ends of Martin and Beaverlodge Lakes. The group also contains water claims extending eastward for about a mile to the boundary of the Ura group. Two small groups called the Bar and Cab, within this area, are, however, held by other owners.

The ridge between Martin and Beaverlodge Lakes rises to about 400 feet above the level of the lakes, and is formed by rocks of the Athabasca group consisting of a succession of flows or sills of amygdaloidal basalt alternating with beds of arkose, sandstone and minor conglomerate (*see* Fig. 12). These strata dip 45° to 80°W and are on the east limb of a broad syncline. The rocks are displaced slightly by several steeply dipping faults and shear zones. The most prominent ones strike N60°E to N70°E, less-prominent ones strike N30°W, and minor faults, shear zones and fractures strike in several other directions, as described below. The faults may be branches from the St. Louis fault.

Many of the faults and shear zones contain carbonate, and both the wall-rocks and the carbonate are much stained by hematite. The carbonate vein-filling contains stringers and disseminations of pitchblende (*see* Fig. 13). Small amounts of copper selenides, native copper, bornite, chalcocite, covellite, chalcopyrite, clausthalite and gold have been reported.

Evidence of significant mineralization has been found only in basalt, which, near the showings, forms sills or flows from about 50 to 300 feet thick. Pitchblende-bearing stringers have been found only rarely in the intervening arkose or sandstone, which seems to have been physically less favourable for fracturing, as well as chemically less favourable as a host rock.

The deposits were studied in detail by R. B. Allen (1950) who found that the main mineralized faults and shear zones have an average strike of N68°E and that shorter ones strike about N85°E. He stated that the latter commonly occur as branching spurs along non-radioactive shear zones striking N30°E to N40°E, thus forming *en échelon* zones.

After stripping and trenching had revealed evidence of possibly significant mineralization, an adit was begun in 1948 from a point near the shore of Martin

Lake. About 3,000 feet of crosscutting and drifting and 200 feet of raising were done, as well as about 12,000 feet of diamond drilling from underground stations. One main mineralized block and several minor ones were partly outlined, but it is difficult to estimate sizes and average grades because of the irregularity of the stringers and the differences in grade that would be effected by mining selectively or by taking larger amounts of lower grade material. An unfavourable feature is the large amount of carbonate gangue. In 1952 and 1953 an adit was driven from the shore of Beaverlodge Lake to join the above-described workings and so form a convenient haulageway. This adit was connected by a short road to the one extending to the Eldorado treatment plant. In 1954 trial stoping was done and ore was trucked to the plant, but this work confirmed earlier opinions that only a small-tonnage operation would be possible.

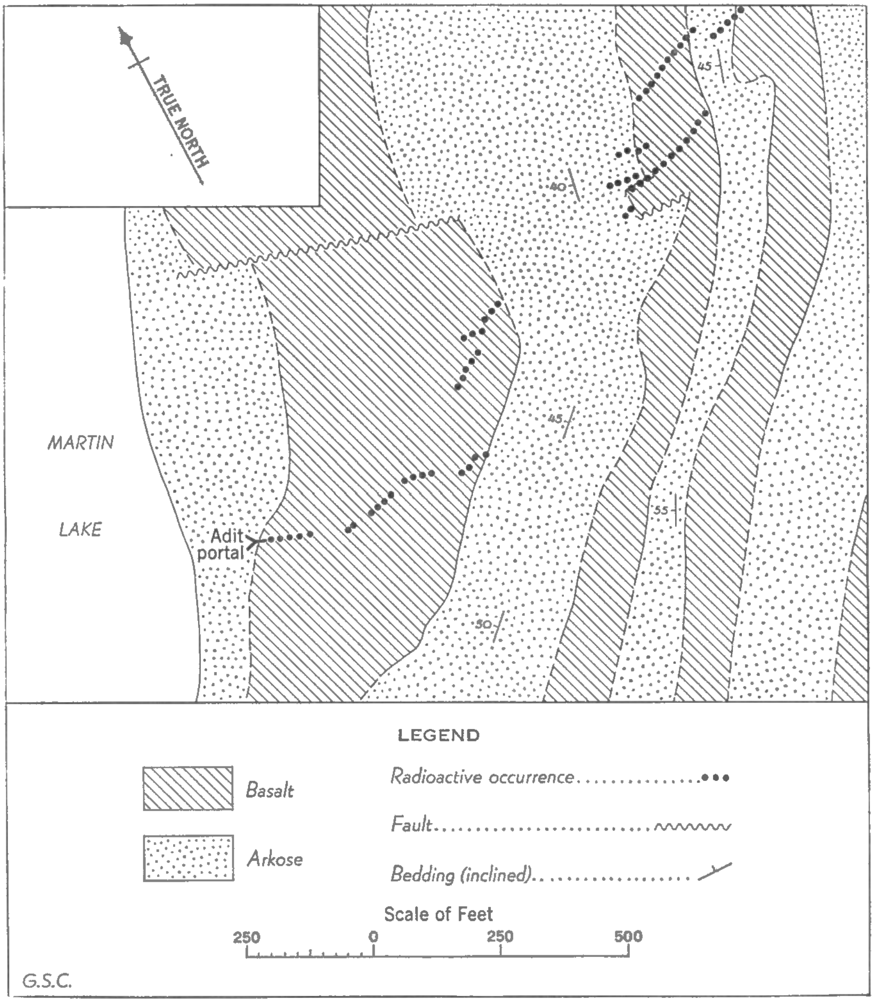


Figure 12. *Geological plan of part of R.A. group, Lake Athabasca, showing positions of Martin Lake deposits and portal of adit.* From plan by Eldorado Mining and Refining Limited.

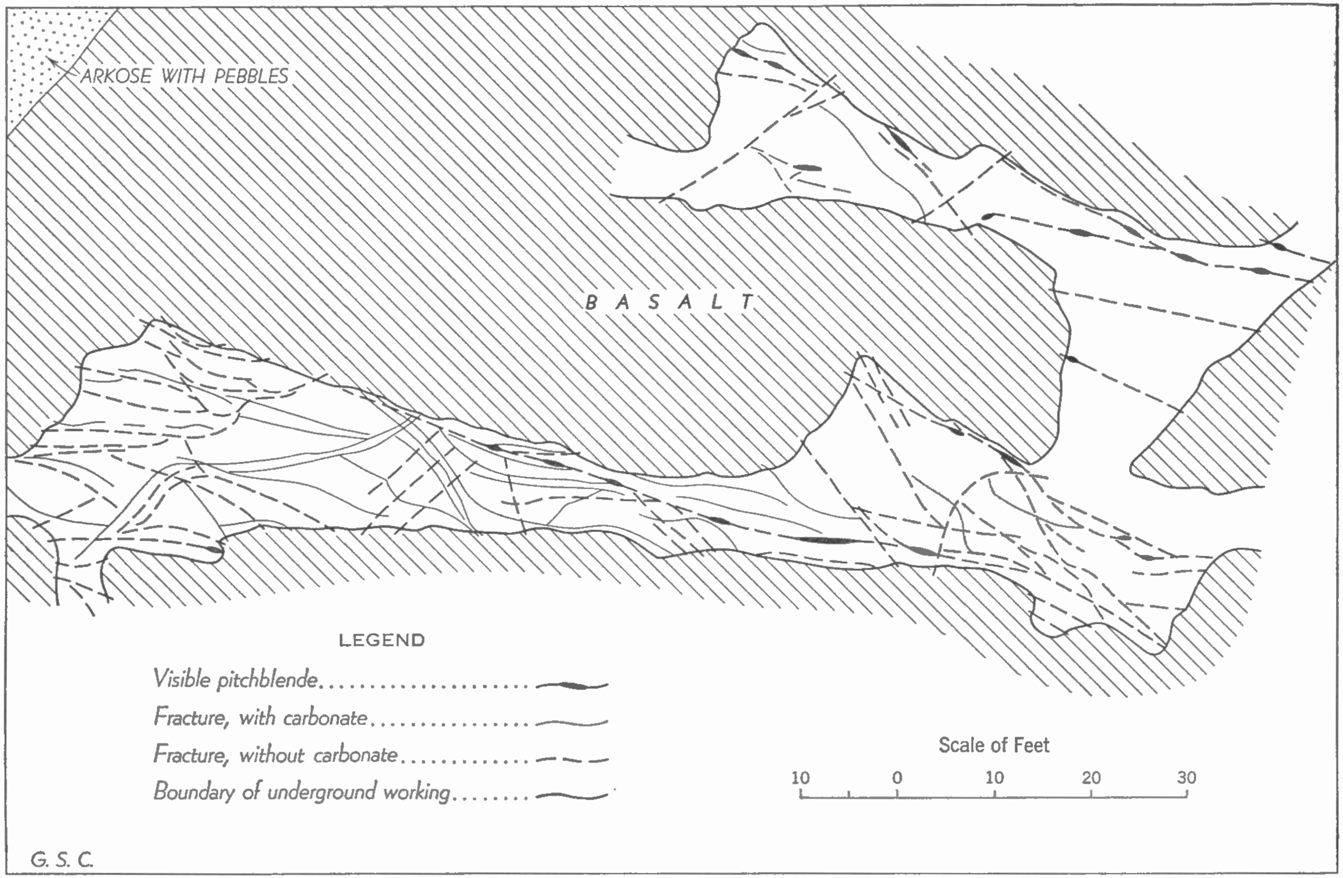


Figure 13. Plan of part of underground workings, Martin Lake mine. Many fractures are omitted, and occurrences of visible pitchblende are generalized. From plan by Eldorado Mining and Refining Limited.

National Explorations Mine

The Pat group of nine claims, owned by National Explorations Limited, is 12 miles northeast of Uranium City and 3 miles northeast of the Eldorado camp. A road 4½ miles long connects the mine with the road from Uranium City to the Eldorado camp.

The claims were staked by P. Riley, who found five radioactive occurrences there. They were acquired by the company in 1951. Surface prospecting by Geiger counter, and a radiometric survey made on the ground, resulted in the discovery of about thirty occurrences. Most of these were investigated by trenching, and many high assays were obtained from surface samples. Several of the showings were explored by diamond drilling. In 1952 an inclined shaft was sunk to a vertical depth of 40 feet on the "C" showing. In 1954 a vertical three-compartment shaft was sunk to a depth of 360 feet, and three levels were established at depths of 100, 200 and 300 feet below surface. Shipments to the Eldorado plant were begun under contract in 1955, and were reported to average 0.22 per cent U_3O_8. Shipments were intermittent during parts of 1956 and 1957, and in 1957 the mining rate was reported to be 50 tons a day. A contract to ship ore to the Lorado plant was reported in 1957.

The property is underlain by granitized sedimentary rocks of the Tazin group. Most of the deposits occur in grey to white granitic gneiss or foliated granite containing lenses of paragneiss, amphibolite and quartzite. The strike of the gneissosity is N55°E and dips are about 70°SE. The rocks are cut by two subparallel, flat-dipping shear zones separated by a zone of steeply dipping fractures, some of which have also been traced for short distances above and below the two flat-dipping shear zones. The more northerly shear zone strikes northwest and dips 30°SW; the other strikes northwest to a point near the shaft, where the strike becomes westward. This shear zone dips from 15° to 45°SW. The axis of the 'bend' in this shear zone plunges 15°SW. Both the shear zones and the steeply dipping fractures contain pitchblende, hematite, pyrite and a little chalcopyrite, in a gangue of calcite, quartz, chlorite and graphite. Fluorite was noted in one vein, and thucholite was reported from one sample.

The wall-rocks of the shear zones and fractures show various degrees of red alteration, the more intense type being a useful guide in the search for ore. The best ore was found where the bend of the shear zone mentioned above lies close to and is parallel with the more northerly shear zone. Hogarth (personal communication) noted that radioactivity is strongest where sheared fractures intersect granite-gneiss or a diopside rock, and that where they intersect bands of quartzite they are 'tighter' and presumably leaner. Orebodies were reported to vary from 1 foot to 4 feet in width and to be up to 125 feet in length.

Nicholson Mine

The property of Consolidated Nicholson Mines Limited is at the north side of Lake Athabasca, 2 miles east of the site of Goldfields. It contains veins carrying several metals, which were explored first for their copper content in 1930 and for their gold content in 1935. In 1935 prospectors or engineers recognized pitchblende at two of the showings, probably being familiar with the mineral because of the interest being taken at that time in the Eldorado discovery at Great Bear Lake. Alcock (personal communication) stated that the men working on the property at the time of his visit in 1935 indicated the mineral to him. This led to the publication that, as already mentioned, played an important part in focusing attention on the area in 1944. Two short adits were driven about 1936, apparently because of interest in gold. No work was done for several years thereafter, but the claims were retained by predecessors of the present company. When private work for uranium was resumed in 1948 trenching and diamond drilling were done, two shafts were sunk in 1949 on the No. 2 and No. 4 zones, and underground exploration was done later. This showed the presence of rich shoots in the No. 4 zone, but insufficient for an independent treatment plant. Arrangements were made to ship ore to the Eldorado plant. Shipments having a gross value of $551,817 were reported to have been transported by haulage on ice during parts of 1955 and 1956. The annual report of the company intimated that the deposit was not exhausted, but that the contract with Eldorado expired and that an offer to extend it was at a lower price which was unacceptable.

The claims are underlain by dolomite, dolomitic quartzite and ferruginous quartzite breccia, of the Tazin group. These strata have been intruded by a basic sill that is altered to amphibolite. The rocks are folded steeply. A pronounced northwesterly striking depression in the northwestern part of the property may mark a fault or shear zone, but overburden prevents study of this feature.

Four deposits were found during early work on the property; these are numbered 1 to 4 (*see* Fig. 14). An additional radioactive deposit, called the No. 1 extension, was found in 1949. The No. 4 appears to be the most important, and has received most attention.

The No. 1 zone is on the Jim claim, at the east side of the property. It is a vein up to 10 inches wide, in quartzite; it strikes N64°W and dips 45°NE. It is a carbonate vein containing pitchblende, sulphide minerals and cobalt bloom. The length of the vein is not apparent from the surface showing. Another showing that is grouped with the No. 1 lies about 800 feet north of it, but is not on strike. The two showings were explored by seven short diamond-drill holes, but results were inconclusive.

The showing called the No. 1 extension was detected through overburden, about 1,500 feet northwest of the No. 1 and the same distance east of the No. 2. Stripping revealed a radioactive zone at a contact between quartzite and ferruginous quartzite. It is exposed for a length of about 25 feet and may extend farther. The most radioactive part seems to be about 8 feet wide, but this is uncertain because cracks may contain secondary uranium minerals over a greater width than that of the primary deposit. Surface sampling showed significant amounts of uranium across widths as much as 6 feet, the highest assay being 1.84 per cent U_3O_8 for a width of 1½ inches. This sampling also showed up to 0.20 ounce in gold, and 14.34 ounces in silver, a ton. No primary minerals have been identified.

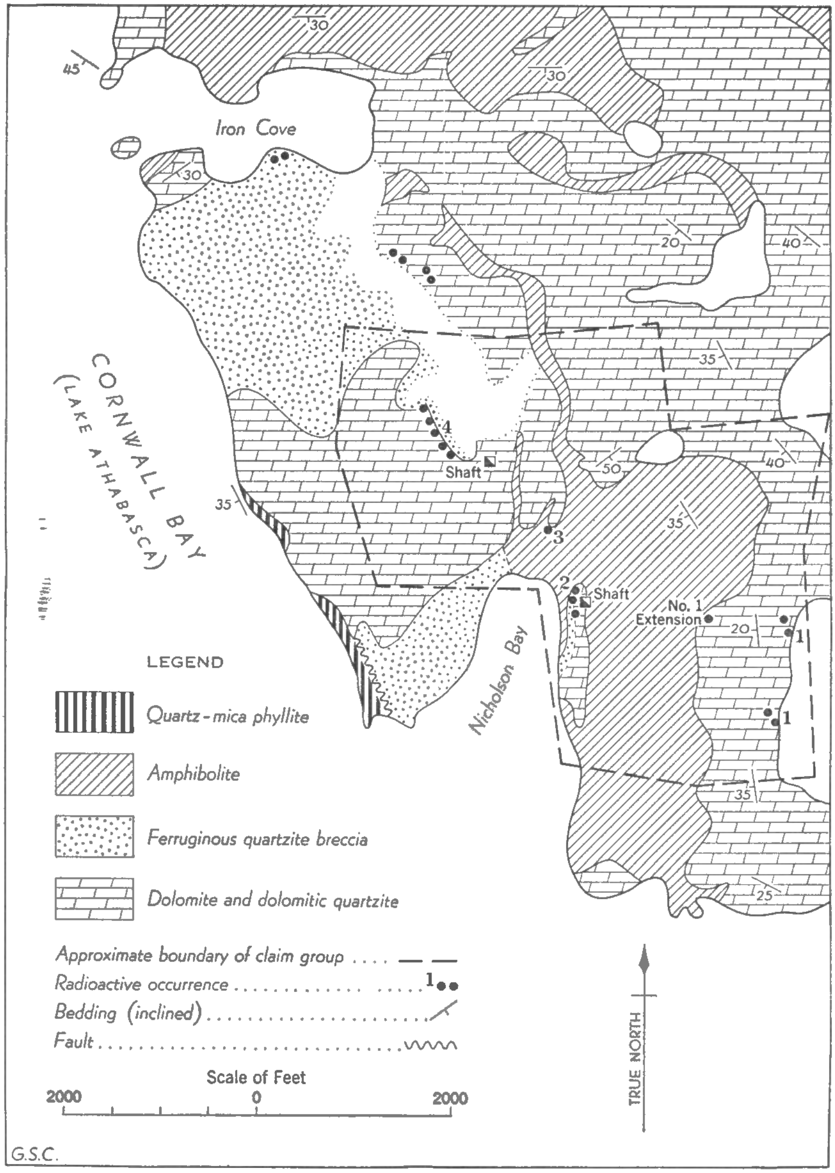


Figure 14. **Sketch map showing geology and locations of radioactive zones on property of Nicholson Mines Limited, Saskatchewan. Geology after A. W. Jolliffe. Boundary of claim group shown approximately.**

The No. 2 zone is at a contact between quartzite and ferruginous quartzite breccia, about 200 feet east of the head of a small bay called Nicholson Bay. The zone strikes north, dips vertically, and was traced on surface for 180 feet. It is to 1½ feet wide and consists of several *en échelon* fractures. It contains carbonate, pitchblende, specular hematite and small amounts of sulphide and arsenide minerals; sampling indicated the presence of gold and platinum. Tiemannite (HgSe) and dyscrasite (Ag_3Sb) were identified by Kaiman in samples from this zone. A shaft was sunk to explore the zone in 1949, and 565 feet of lateral work was done on the 100-foot level. Short sections contained considerable pitchblende, but in general the results were disappointing.

The No. 3 zone is a copper showing, 600 feet north of the head of Nicholson Bay, at a contact between amphibolite and dolomitic quartzite. Uranium stain was seen in places; pitchblende has been reported but was not seen by the writers.

The No. 4 vein strikes N30°W, dipping almost vertically. It lies at a contact between dolomitic quartzite and ferruginous quartzite breccia, and is exposed along a steep hillside that forms the southwest side of the depression mentioned above as possibly marking a fault. A shaft was sunk near the vein and work was done on three levels 100, 200 and 325 feet below surface, but only the two upper ones were accessible when the deposit was examined. The upper level encountered a shoot reported to have an average width of 3.8 feet, and an average grade of 0.38 per cent U_3O_8 and 0.23 ounce in gold a ton. Under this shoot, on the 200-foot level was a body with an average width of 6 feet, reported to average 0.47 per cent U_3O_8. A drift along a branch fracture nearby encountered a short mineralized body 5 feet wide, reported to average 3.75 per cent U_3O_8. The vein consisted chiefly of carbonate, with quartz as a second gangue mineral. Hematite, pitchblende, rammelsbergite and other cobalt-nickel arsenides are the principal metallic minerals; minerals occurring in small amounts are thucholite, chalcopyrite, arsenopyrite, galena, pyrite and sphalerite (Robinson, 1955, p. 18). At the surface and on the upper level, the vein was banded, and has the appearance of having been deposited in open, brecciated zones. On the second level, however, the vein was massive, showing suggestion of having been formed at least partly by replacement. The shoots encountered were of good width and grade and fairly long, but where mineralization was lacking, there was little evidence of an unmineralized 'break'.

Rix Mine

The property of Rix-Athabasca Uranium Mines Limited is about 6 miles by road from Uranium City and about 7 miles north of Bushell. In 1949 the company acquired a concession of 6 square miles, called DD-1, part of which was afterwards retained as mining claims. Radiometric surveys on the ground in 1950 and 1951 resulted in discovery of one hundred and sixty-seven radioactive occurrences, of which fifty were considered to warrant further exploration in the form of trenching, sampling or shallow diamond drilling. Later, the more promising areas, called the Smitty, Leonard, "201", and Chance Lake, were explored intensively by diamond drilling. The first underground work was undertaken in 1951, when a 381-foot adit was driven on the largest of the Leonard series of fractures. In 1952 interest shifted to the Smitty showing where drilling had indicated a high-grade zone about 400 feet long and 25 feet wide. A vertical shaft was begun in the autumn of 1952 and during the winter two levels were established at 125 and 250 feet below surface. The shaft was deepened in 1956 and again in 1957, when a total of seven levels had been established. Arrangements were made with Eldorado to ship ore to the Ace-Fay plant, the Rix mine becoming the first privately owned producer in Canada when shipments were begun at about 100 tons a day in April 1954. By the end of 1957, ore containing 600,000 pounds of uranium had been shipped. The company reported that a second contract had been negotiated with Eldorado for the shipment of ore containing 77,000 pounds of uranium. Early in 1958 negotiations were being made with Lorado Uranium Mines Limited for shipment of additional Rix ore to the Lorado plant. Facilities at the Rix mine were reported to be sufficient to permit production at an increased rate of 200 to 300 tons of ore a day.

In 1955 a small but reportedly rich ore shoot was mined above the Leonard adit. Early in 1956 the adit was widened and an internal vertical shaft was sunk to permit levels 125 feet and 250 feet below the adit level. The company reported that up to the end of 1957 only development ore had been shipped from the Leonard workings.

The following account of the geology is based partly on a description by company geologists prepared at the time of the Commonwealth Mining Congress, which is more up to date than some of the writers' observations.

The country rock on this property is chiefly paragneiss of the Tazin group, with granitic phases grading into granitic banded gneisses. These rocks strike about N30°E and most dip steeply to the east. Locally, the paragneisses are crenulated and drag-folded.

Post-Tazin faulting resulted in a complex pattern of faults, fractures and zones of brecciation. Pitchblende occurs chiefly along shear zones and fractures and related breccia zones which cross the regional strike of the paragneisses at angles of 45 to 90 degrees. Faults parallel with the paragneisses or cutting them at small angles are the most prominent structural features and locally are known to be significant in controlling ore deposition.

The Smitty orebodies are in a narrow zone of mylonite and much brecciated paragneiss associated with the immediate foot-wall and hanging-wall of the Smitty fault, which strikes about N40°W and dips 32° to 40°SW. This fault has been exposed underground for a total length of about 1,300 feet. In the eastern part of the Smitty workings the fault pattern is very irregular, fingering out in a series of discontinuous shear zones and fractures. The distribution of pitchblende is progressively more erratic eastward from the shaft, where ore is confined to narrow discontinuous zones of brecciation associated with the individual shear zones and fractures, beyond which the pitchblende is so scattered that dilution would prohibit economic mining.

Northeast of the shaft the Smitty fault appears to have been offset some 450 feet to the north by the Boom Lake fault zone, a northeasterly striking zone that crosses the property and which possibly continues farther north for about 8 miles. No evidence of the Smitty fault was found within the Boom Lake zone, but exploration below the second level was reported to indicate that the latter structure exerts significant control on ore distribution.

The ore consists of fine-grained to coarse-grained, red-altered fragments of country rock in a very fine grained matrix that contains silica, carbonate and chlorite in various proportions. Pitchblende is disseminated in the rock and also forms networks of veinlets in the breccia. There is much finely disseminated hematite. Calcite is usually found in abundance in the higher-grade ore zones. Minor constituents are pyrite, chalcopyrite, sphalerite and galena, the last generally accompanying rich concentrations of pitchblende.

Reserves at the Smitty mine were reported at the end of 1957 to be 37,638 tons, with an estimated grade of 0.24 per cent U_3O_8. In the Leonard area reserves of probable ore were estimated by company officials at 18,000 tons with an additional 50,000 tons of possible ore.

Bancroft Area

The Bancroft region is the only part of Canada where uranium is produced from deposits of the general pegmatitic class, and is one of the few such places in the world. It is in southeastern Ontario about 100 miles northeast of Toronto and 200 miles west of Montreal. The region is in the Haliburton highlands in the southern part of the Grenville geological province of the Canadian Shield. It is an established summer resort and farming area, fairly well provided with roads and served by a branch of the Canadian National Railways. The climate is temperate, with hot summer days and below zero temperatures in winter. Ordinarily the prospecting season is from the beginning of April to the beginning of December.

Apart from the recent interest in uranium, the region has long been of interest to geologists and mineralogists because there Adams and Barlow (1910) performed classical work that did much to point the way to later investigations in the Grenville, and because it and the surrounding territory abound in mineral occurrences of various kinds, including the type localities of some minerals. Ellsworth (1932) and several other mineralogists described many of these occurrences. In recent years J. Satterly (1943), J. E. Thomson (1943), and D. F. Hewitt (1957) revised the regional geology for the Ontario Department of Mines, Satterly described many of the radioactive deposits (1957), and S. C. Robinson made a special study of their mineralogy (1958).

History

Feldspar, mica and other minerals have been mined intermittently in a small way in the general Bancroft region for many years. Interest in radioactive occurrences dates at least from about 1922 when uraninite was found at the Richardson deposit (*see* Fig. 15), on what is now the Fission property, and when Ellsworth (1922, 1924) began the study of radioactive deposits in the territory between Georgian Bay and Ottawa River. An attempt was made to develop this as a source of radium from 1929 to 1931. Several radioactive occurrences were found in various parts of the Grenville region during the next few years. When uranium became of interest after 1943 many of these occurrences were re-examined by government geologists, but despite their accessibility they were considered too small, of too low average content, or otherwise unsuitable.

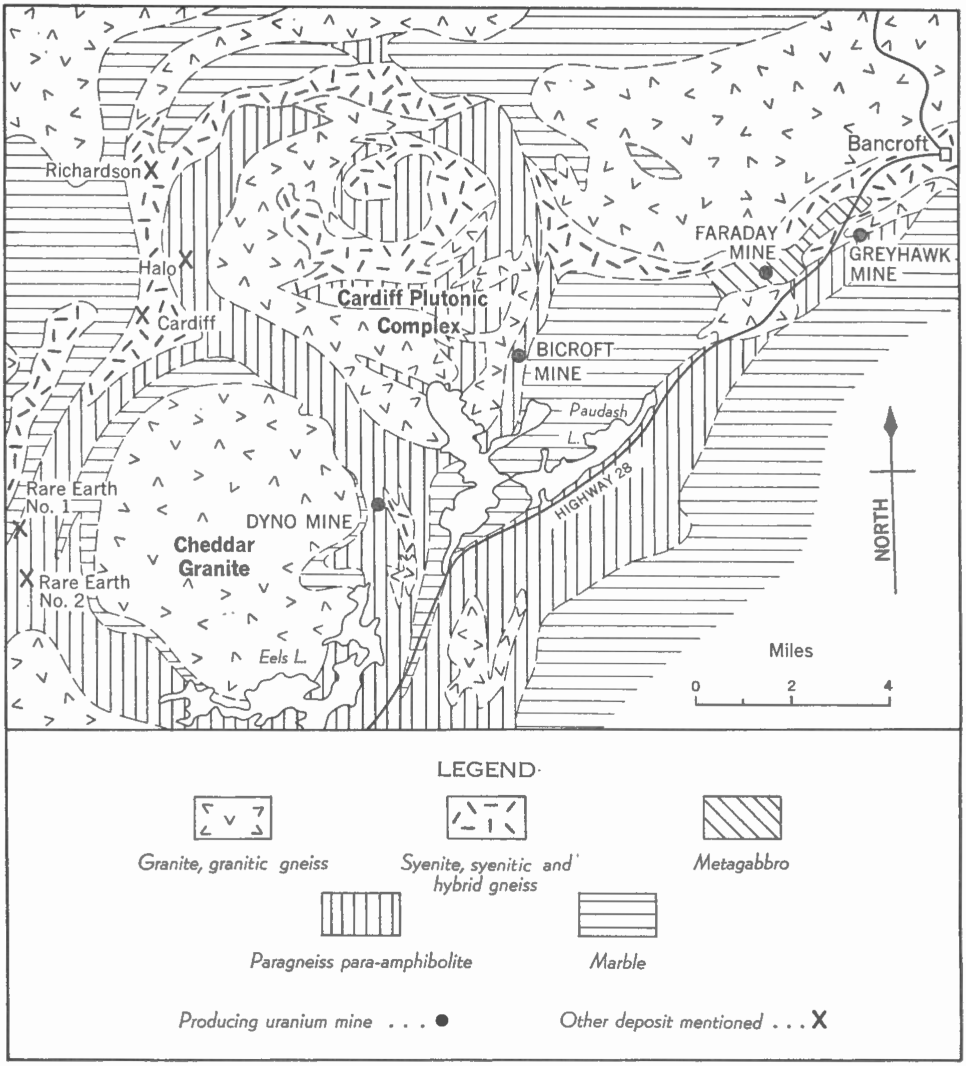


Figure 15. **Geological diagram of part of Bancroft area, Ontario, showing producing uranium mines and other deposits mentioned in text. Many additional radioactive occurrences are not shown. From map by D. F. Hewitt, Ontario Department of Mines.**

The resumption of private staking for radioactive minerals in 1948 caused much prospecting in this region because of its earlier discoveries, its settlements and its accessibility. Many additional occurrences were found, and were examined by government and company geologists and engineers, but little work other than preliminary exploration was recommended. It must be borne in mind that at that time there was no interest in deposits averaging about 0.1 per cent U_3O_8, that the radioactive minerals in many of the deposits were refractory, that the methods that made treatment of such ores economically practicable had not been perfected, that agreements for purchase of precipitates at special prices were not being made, and that even after these conditions changed few of the earlier discoveries were attractive. The critical year was 1953, when the Centre Lake showings, found in the previous year, were exposed sufficiently to permit examination, and when important results were obtained by diamond drilling at the Faraday property, where the first discoveries had been found a few years earlier. Great credit is due to G. W. Burns and R. J. Steele, discoverers of the Centre Lake deposits, part of which are now the Bicroft mine, and to the late Arthur Shore, discoverer of the Faraday mine, for their intelligent prospecting and excellent preliminary exploration. As a result of these discoveries much staking, prospecting and exploration of old and new discoveries took place in 1954, 1955 and 1956. Seventeen deposits were explored from shafts or adits. Agreements for sale of precipitates at special prices were negotiated by the Bicroft, Canadian Dyno, Cavendish, Faraday and Greyhawk companies. Plants with capacities of about 1,000 tons of ore a day were built at the Bicroft, Faraday and Canadian Dyno mines, and these came into production in 1956, 1957 and 1958 respectively. The Greyhawk company began shipping ore to the Faraday plant in 1957. Cavendish Uranium Mines Limited, whose property is southwest of the area covered by Figure 15, was merged with Rare Earth Mining Company Limited to form Amalgamated Rare Earth Mines Limited, which also acquired the property and deposits of Halo Uranium Mines Limited; plant construction and production have not been begun.[1]

Geology

The Grenville province is characterized by highly metamorphosed sedimentary rocks that are now largely paragneiss, amphibolite and marble, and by numerous bodies of plutonic rocks of several kinds. Hewitt (1957) stated that in the Bancroft region the older intrusions are gabbro, diorite and ultrabasic rocks, and that after these were locally altered to metagabbro, metadiorite, amphibolite and hornblende schist, the intrusion of nepheline syenite, syenite and granite took place, accompanied by *lit-par-lit* injection, granitization and syenitization. This was followed by emplacement of bodies of granite and syenite pegmatite and diabase. Many age determinations on radioactive minerals from pegmatitic rocks in the general Grenville province range from 1,100 to 800 million years, suggestive of mid-Proterozoic age. The Grenville sedimentary rocks were at first considered Archæan, and later as younger than Archæan. Despite the age determinations, it is not clear whether the Grenville sedimentary strata were all part of a cycle of sediments, plutonic rocks and pegmatites all of about the age the determinations suggest, or whether some were much older.

The main geological features of the part of the Bancroft region that contains producing uranium mines are three granitic complexes, more or less circular and each roughly 6 miles in diameter (*see* Fig. 15). Hewitt named the more westerly

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[1] At the end of 1960 only the Bicroft and Faraday mines were in operation.

of these the Cheddar granite, the central one the Cardiff plutonic complex, and the eastern the Faraday granite. The Cheddar body is "a circular double dome of granitic rock, six miles (10 km) in diameter, mantled by limy paragneiss, para-amphibolite, and pyroxene granulite all of which are intruded and partly replaced by syenitic and granitic rocks. The Cardiff plutonic complex, lying immediately to the north, has the shape of a cylinder plunging to the southeast and consists of three main intrusive sheets: the Centre Lake granite, the Monck Lake granite, and the Deer Lake syenite. It also is flanked by metasediments intruded and replaced by syenitic and granitic rocks; much sedimentary material occurs in wide bands within the plutonic complex. The Faraday granite lying to the east is a south-dipping granite sheet forming the south margin of the Hastings Highland gneiss complex. It is overlain by a zone of mixed hybrid gneisses including metasediments, granitic and syenite rocks and metagabbro." The three intrusive complexes and their flanking metasediments show more or less concentric trend-lines.

Radioactive deposits. The main types of radioactive deposits in the region are (1) dykes and lenses of pegmatitic granite and syenite, commonly called pegmatites but most sufficiently fine grained to be classed as granite or syenite; (2) granite pegmatites showing internal zoning; (3) metasomatic bodies in marble, pyroxenite and granite-gneiss; and (4) calcite-fluorite-apatite veins. The producing deposits (Bicroft, Canadian Dyno, Faraday and Greyhawk) are of the pegmatitic granite and syenite class. They, as well as several others, are in the 'halos' of metamorphic rocks surrounding the three granitic complexes mentioned above (*see* Fig. 15).

Satterly (1957, p. 8) has further classified the producing deposits, and several other radioactive occurrences in the general district, as follows:

I. Deposits in granitic and syenitic bodies.
  A. Simple bodies of intrusive origin (fissure-fillings).
    1. Unzoned (no known radioactive occurrences).
    2. Zoned—granite-pegmatite (MacDonald feldspar mine).
  B. Complex bodies of both intrusive and replacement origin plus assimilation of country rock. Typical ore-shoot units are:
    1. Pyroxene granite (or syenite) -pegmatite (Bicroft, in part) (Faraday, in part) (Halo, in part) (Greyhawk, in part) (Canadian Dyno, C zone).
    2. Leucogranite, leucogranite-pegmatite with or without magnetite (Faraday, in part) (Greyhawk, in part) (Canadian Dyno, B Zone) (Cavendish) (Rare Earth).
    3. Cataclastic quartz-rich granite-pegmatite (Bicroft, in part) (Greyhawk, in part) (Halo, in part).

II. Metasomatic deposits in limy rocks.
  A. Metasomatic deposits in marble.
  B. Metasomatic deposits in metamorphic pyroxenite.

III. Hydrothermal deposits.
    A. Calcite-fluorite-apatite veins (Fission) (Nu-Age) (Halo).
    B. Calcite-fluorite-apatite-biotite-pyroxene (Cardiff Uranium).
    C. Calcite-biotite-apatite (Silver Crater, Basin property).

Robinson described the principal deposits as consisting mainly of microcline-microperthite, and antiperthite, sodic plagioclase (in part peristerite), and quartz, with pyroxene, hornblende, and minor biotite and muscovite. The mafic minerals and magnetite are commonly locally concentrated. Fluorite and calcite are usual minor constituents. The main radioactive minerals are uraninite and uranothorite, and minor ones are allanite, betafite, zircon and fergusonite. The principal supergene minerals are uranophane and beta-uranophane, with some kasolite.

The producing deposits are commonly complex bodies, cutting the wallrocks in places and replacing them elsewhere. Locally, some parts of deposits that are essentially granitic are of the metasomatic class. They are radioactive throughout, but ore shoots are distributed irregularly in them, commonly occurring near the walls, at constrictions and terminations of dykes, and at zones of shattering in them. Mineralogically, ore shoots are commonly associated with concentrations of mafic minerals and magnetite. Satterly (1957, p. 9) concluded that the rocks most favourable for the occurrence of ore shoots are pyroxene granite (or syenite)-pegmatite, leucogranite or leucogranite-pegmatite with or without magnetite, and cataclastic quartz-rich granite-pegmatite. Robinson and Hewitt stated that uranium-bearing dykes are mostly rich in soda and contain much peristerite and sodic antiperthite.

Bicroft Mine

Bicroft Uranium Mines Limited holds ninety claims and six licences in Cardiff, Faraday and Herschel townships. The mine is in lots 27 and 28, concession XI, Cardiff township. It is about 10 miles directly southwest of Bancroft, and is reached by a branch road about 5 miles long that leaves highway 28 near the east end of Paudash Lake.

History. The main Bicroft deposits were found in 1952 by G. W. Burns, an amateur prospector of Peterborough, Ontario, who studied the subject extensively and applied his knowledge in a most creditable manner. His discoveries were the most attractive surface showings of the general pegmatitic class found in Canada to that time, and they, together with high-grade intersections obtained on the property of Faraday in 1954, were the critical features in the history of the Bancroft camp, therefore the circumstances are worth relating in some detail. In a letter to the Geological Survey of Canada, dated December 18, 1955, Mr. Burns stated:

> I always was interested in rock and minerals but did not know very much about what I was looking at and purchased a piece of property in Cardiff Twp. on which was a nice large showing of what I was told was molybdenite but after purchasing property found out it was only large flake graphite (and by the way I still hold this so called

> molybdenite deposit). This was in 1948 so right there I decided to try and get a knowledge of what I was looking at to some extent, and studied all the books in our Peterboro Public Library including government mineral reports of all kinds but, one book I acquired and I think I got it from your department, was called 'Prospecting for Uranium and Thorium in Canada' which gave me the information which resulted in my finding the original showing at Bicroft.
>
> In an old report in the library here which was printed I think in 1912 on the mineral mica I read of a showing in Cardiff Twp. composed of very large plates of phlogopite and went to Mr. Howard Sarginson to see if he could tell me where this old pit was as he lived on adjoining lot, but he had never saw nor heard of it, but was willing to go with me to show me Centre Lake which I had never been to. As we were walking along an old wagon road I saw where a wheel of a steel rimmed wagon had slipped across the face of a rock exposure and it was covered with a purplish coloured dust and upon chipping it with my hammer found it to be very deep purple fluorspar and by the book (Prospecting for Uranium and Thorium) the colour was due to a radioactive mineral in the same vicinity, and at the next exposure about 75 yards north I found a crystal about ¼ inch diameter completely surrounded by radial fractures of 1-2 inches in length which the same book said was caused by the radioactivity of the crystal inside the fractures, I dug the crystal out and brought it home and the next day went back with my son and looked around some more and found several nice surface samples which due to colour of oxide on them I thought must be associated with uranium, but I did not own a geiger counter and only knew where there was one in Peterboro which was owned by Mr. Robert Steele so I took my samples to him to have them checked on his counter and he said they read very high and could we get together and get some ground staked in partnership before the news got out, which we started to do the next day but as neither of us had ever staked a claim before we did not get as much ground covered as we should have, due to being too painstaking in sighting lines, measuring claims, etc. and then the word got out and we were surrounded by staked claims so we rented a Warsop rock drill and blew out some trenches from which we sent samples to your department for mineral identification and among which were uraninite.

The prospectors did surface exploration an unusually good way. Late in 1952, C. C. Huston assumed direction of further work for a Toronto syndicate which acquired the claims and formed Centre Lake Uranium Mines Limited. Additional surface work was done, diamond drilling was begun, and an adit was driven. Principal drilling was at intervals of 100 feet, with some holes at 50 feet. These explorations led to the sinking of a shaft for further exploration in 1954. Meanwhile, occurrences had been found in the general northward continuation of the Burns and Steele zone, on claims acquired by Croft Uranium Mines Limited, a subsidiary of Macassa Mines Limited formed in 1953. The "Croft" zone was trenched, diamond drilled along a length of 4,000 feet, and explored by an adit. In 1955 these two properties were merged as Bicroft Uranium Mines Limited, work being concentrated on the Centre Lake part of the combined holdings. An agreement for sale of precipitates at special price was completed, a production shaft was sunk to a depth of 1,300 feet, and ten levels were established. A treatment plant rated at 1,000 tons of ore a day was built, and operation was begun late in 1956. Production in 1957 was reported to be 414,024 tons of ore with an average value of $18.92 a ton. In 1958 production was reported to exceed 1,300 tons a day, and exploration was being done on a zone to the south of those included in pre-estimates. Much credit is due to the management and geologists of the original syndicate and the later companies for exploring, interpreting and operating unusual and difficult deposits.

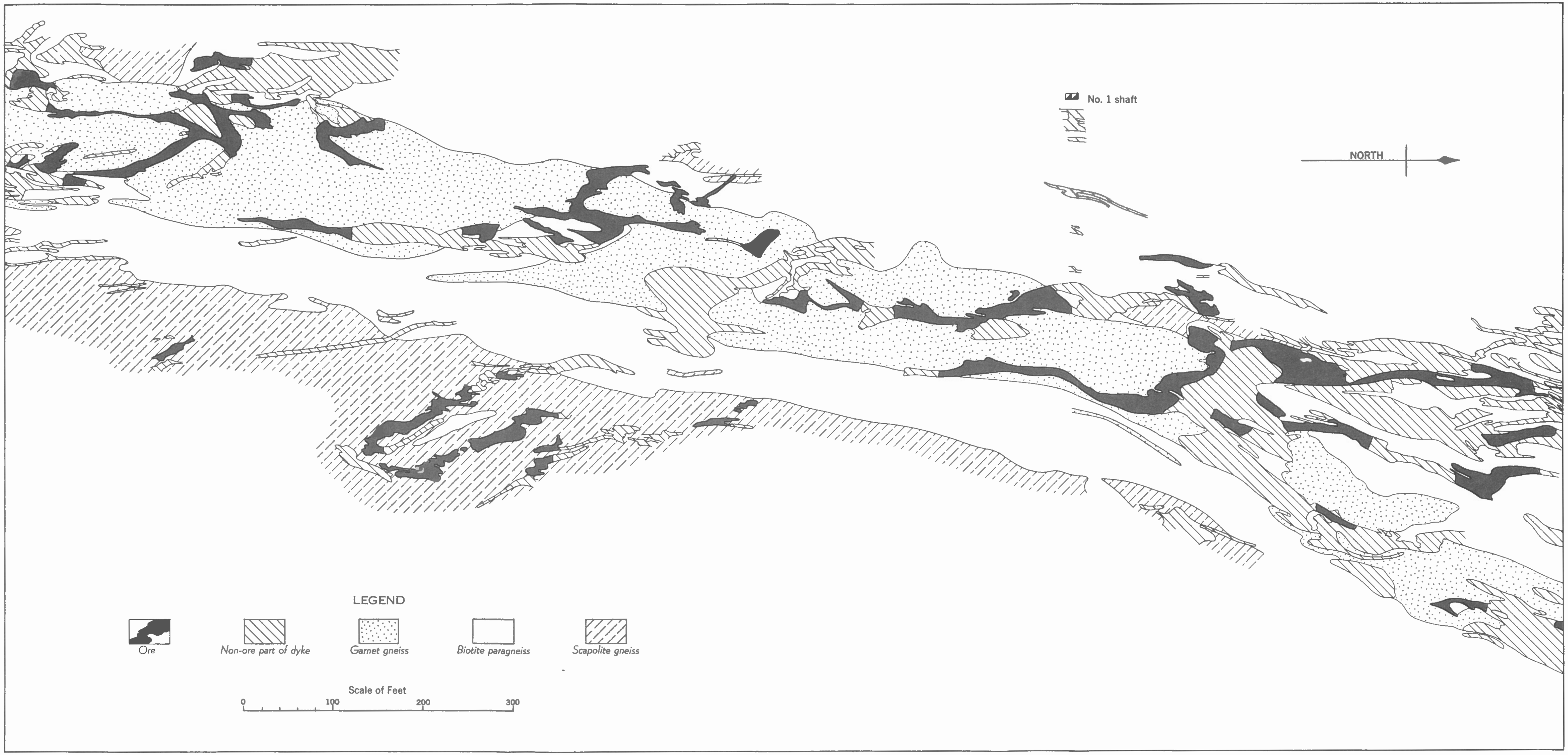

Figure 16. Geological diagram of part of first level, Bicroft mine. From plan by Bicroft Uranium Mines Limited.

Geology. The deposits are in a northerly trending belt of paragneiss and amphibolite forming the east flank of the Centre Lake granite sheet, which is part of the Cardiff plutonic complex (*see* Fig. 15). Satterly (1957, p. 31) described the rocks of the favourable zone as biotite paragneiss, amphibolite, scapolite-biotite gneiss, garnet-sillimanite-biotite paragneiss, and a narrow band of silicated marble. These are intruded and replaced by lenticular 'dykes' of both sodic and potassic syenite and granite and related rocks in a zone about half a mile wide extending for about 3½ miles. Satterly stated that it appears to be terminated to the north by a fault. The 'dykes' range from a few feet to 80 feet in width and from a few feet to 400 feet in length (*see* Fig. 16). They are arranged in an *en échelon* fashion, striking northerly and dipping from 40° to 70°E, commonly transgressing slightly the attitude of the host rocks.

The ore minerals are uranothorite and uraninite, accompanied locally by allanite, zircon, titanite, apatite, fluorite, pyrite, pyrrhotite and molybdenite. Satterly (1957, p. 34) listed pyrochlore, betafite anatase and umangite as rare accessory minerals. Mafic minerals are pyroxene and biotite, some bodies containing considerable pyroxene. In contrast to the mafic shoots at the Faraday mine, those at the Bicroft contain little magnetite (S. C. Robinson, personal communication). Red alteration occurs locally, particularly at contacts with sillimanite-garnet-biotite gneiss and where reddish feldspar is present in amphibolite. Uranium to thorium ratios vary in different bodies, thorium being more abundant in the pyroxene granite (Bryce, *et al.,* 1958).

The present mining operations are confined to a 3,000-foot zone at the south end of the property where structural and lithological controls have influenced the concentration of radioactive material. Ore shoots occur within the syenitic or granitic 'dykes' and range from 35 to 215 feet in length. A single dyke may contain two or three such shoots, separated by low-grade material, or an entire dyke may constitute ore. Forty-nine ore shoots were outlined on the first level, and reported to have a combined length of 4,143 feet and an average width of 5.9 feet. These indicated a tonnage potential of 2,808 tons a vertical foot. Diamond drilling has indicated ore to a depth of 1,000 feet. The vertical continuity of the shoots is remarkably persistent compared with their shorter and more irregular lateral extent. For example, one ore shoot is only about 60 feet long but extends at least 600 feet down dip. The shoots are generally lenticular with apophyses and minor swells. They dip eastward at an average of 50 degrees although rolls produce varying dips. Ore boundaries are irregular but most are well defined. The richest zones are often found at the foot-wall or hanging-wall contacts. Ore consists either of highly siliceous phases of the pegmatitic granite or pegmatitic pyroxene granite. Ore is commonly localized where the dykes cross a band of garnet-sillimanite-gneiss or scapolite gneiss, which enclose only barren pegmatitic granite.

Kelly (1956, p. 88) stated that the uranium content cannot be consistently correlated with any easily recognizable indicator. Most high-grade sections, however, are red altered, they contain megascopic uranothorite, and they exhibit a fine parallel shattering (Bryce, *et al.,* 1958, p. 83).

Sampling and geological control. Because of the rather unique conditions at this mine, the following information is quoted from a recent paper by the mine staff (Bryce, *et al.,* 1958, p. 84):

> The ore minerals are brittle and concentrated in shatter-zones, with the result that it is almost impossible to get representative muck or chip samples.
>
> Muck sampling is the responsibility of the mucking crew which takes a handful from each car to make up a 20-car sample. This handful of rock is known to contain too great a proportion of fines to be representative; it is weighted in favour of the friable, high-grade ore to such an extent that muck assays must be cut by an average 20% to agree with mill figures.
>
> Chip samples are taken on all pegmatite in development headings, on all take-down backs, and in troublesome stopes, whenever requested by the geologist in charge. The development chips are used to outline ore sections and calculate grade and tonnage potential. Each ore-section is separately averaged, and the high assays then cut to that average. This arbitrary and very severe cut produces in practice a figure some 35% less than the uncut average, but a figure which nevertheless checks the mill-grade very closely.
>
> Diamond-drilling sludge sampling was tried for a year, then abandoned after a thorough analysis had assessed it as costly, and unreliable to the point of being downright misleading.
>
> It is perhaps worth mentioning that the association of high radioactivity with shattering accounts for the fact that the surface expression of a high-grade pegmatite is usually a heavily overburdened depression unlikely to be touched by trenching or found by radiometric instruments.
>
> Many of the problems connected with both every-day work and long-term planning are fundamentally geological. The scope of geological control has gradually been extended during the past year at the request of the mining department, until the geological staff now comprises 7 geologists together with 6 samplers.
>
> An attempt is made to have each breast and face marked daily by a geologist; wherever possible he lays out sufficient work to keep night shift busy as well. His function is to bring his experience to bear on all relevant information from test holes, diamond-drill holes, sections, projections, assays and geigers, and to apply the result to each mark-up.

Faraday Mine

The property of Faraday Uranium Mines Limited comprises twenty-five lots and parts of four others in Faraday township. The mine is in lots 16 and 17 of concession XI, 5 miles southwest of Bancroft and within a mile of highway 28.

History. The original discovery on this property was made by the late A. H. Shore, an independent prospector, on lot 15, concession A. His first communications were in 1949 but it is possible that the discovery occurred in 1948. Faraday Uranium Mines Limited was incorporated in 1949 with Shore as president. Shore did much stripping and rock trenching on this and nearby discoveries. These were examined by several engineers and geologists, who were impressed with their accessibility and the size of some, but not with the results of sampling. Late in 1949 J. C. Rogers in a private report recommended further surface work and sampling. Extensive work was not done at that time because Shore was injured seriously. This accounts for the omission of a description of the property from the first edition of this report, for Shore was unable to reply to a request for permission to include the description. In 1952 financing and management of the company were assumed by interests related to Newkirk Mining Corporation, and diamond drilling was commenced in December of that year. Geological and both airborne

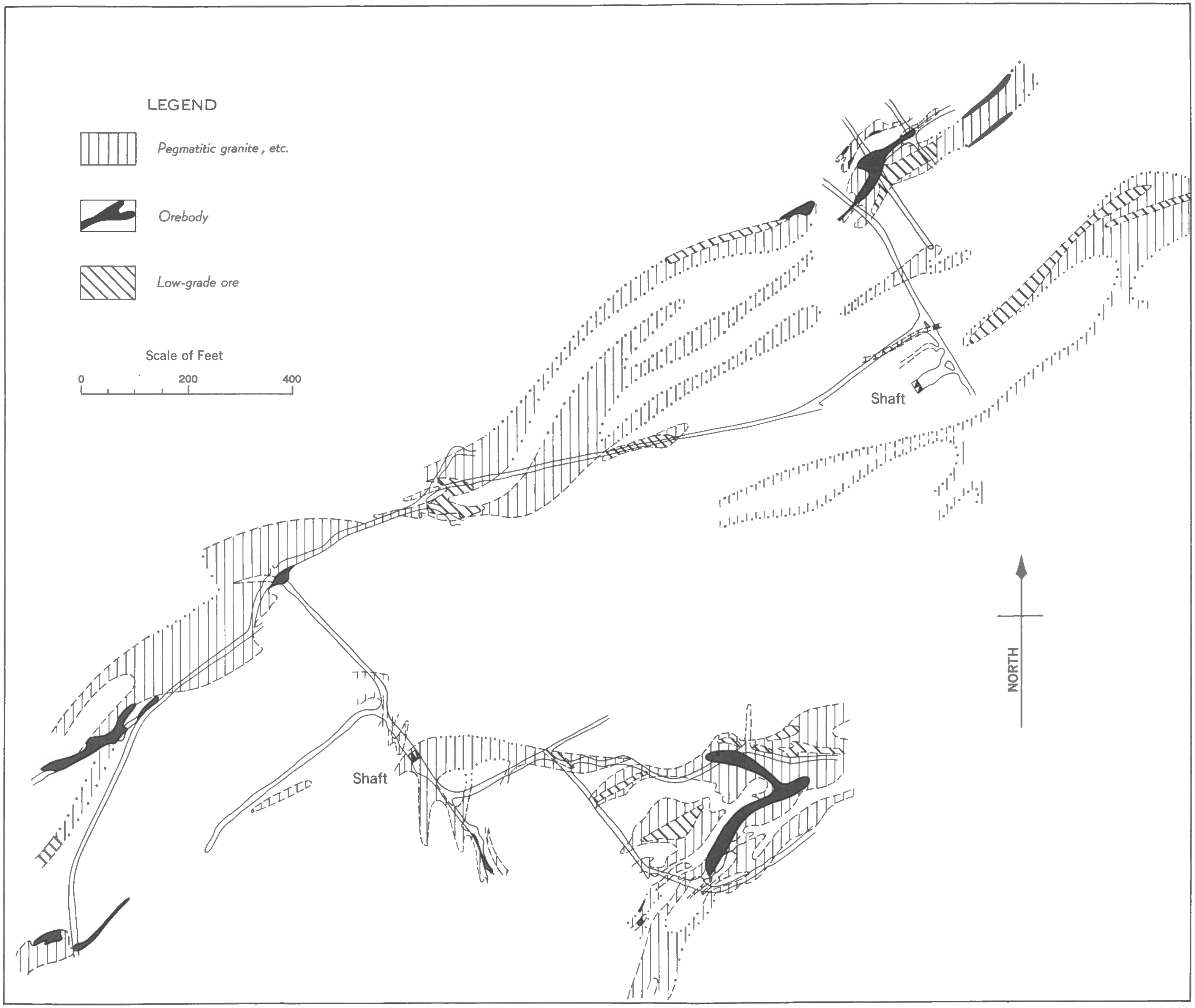

Figure 17. Geological diagram of part of first level, Faraday mine. From plan by Faraday Uranium Mines Limited.

and ground geophysical surveys provided a better understanding of the attitudes and relationships of the occurrences, which were recognized as being in seven main zones. In 1953 a second drilling program was begun to test the A and E zones, about a quarter of a mile west of the original showings. This outlined zones for a length of 2,500 feet and to a depth of 500 feet, in which certain intersections in the E zone provided more encouraging assays. In 1954 still better intersections were obtained in mafic rocks in these two zones, and adits were driven to explore each of them. A winze was sunk from one adit. It was reported that by late 1955 this work had confirmed the drill results closely and indicated 1,660,980 tons averaging 0.112 per cent U_3O_8. An agreement for sale of precipitates at special price was made in January 1956. A production shaft was sunk, also from an adit, to a depth of 863 feet, and five levels were established. A treatment plant with a capacity of 750 tons of ore a day was built, and operation was commenced in April 1957. The capacity was increased later, and in 1958 the plant was handling 1,350 tons a day, partly from the neighbouring Greyhawk mine. Mill feed for 1957 averaged 0.0859 per cent U_3O_8, and 405,271 pounds of U_3O_8 were produced from the Faraday mine in that year.

Geology. The deposits are in a belt of metagabbro and amphibolite on the south flank of the Faraday granite (*see* Fig. 15). These mafic rocks strike east and dip fairly steeply to the south.

The orebodies are parts of a system of pegmatitic granite dykes found at intervals over a distance of about 6,000 feet and a width of several hundred feet. Some of the material in the dykes appears to be of metasomatic origin. The predominant trend is N70°E, with fairly regular dips of 50° to 60°SE (staff of Faraday Uranium Mines, 1957). Dips are commonly flatter, however, in the lower levels. The dykes are irregular in shape, and the lenticular ore shoots within them are even more irregularly and erratically distributed. The average stoping width was stated to be 17 feet, and the maximum sustained stoping width 60 feet. Close study by mine geologists, use of portable counters underground, and unusually careful car sampling were used to control the grade of material mined.

An orebody may consist of a series of irregular lenses of better-grade material. Ore shoots commonly occur at the margins of a mass of pegmatitic granite. In some places the bodies conform with the attitude of the host rock, even following structures that appear to be minor folds, and in other places they transgress the host rock. The staff reported that no consistent control over pegmatite emplacement had been noted, that folding or faulting later than the pegmatitic granite had not been recognized, and that fractures are rare although lenses of recrystallized breccia had been found locally.

The principal ore minerals are uraninite and uranothorite. Other radioactive minerals are allanite, cyrtolite, uranophane and beta-uranophane, and rare earth minerals containing cerium and lanthanum. The uranium to thorium ratio is about 2 to 1. Satterly (1957, p. 111) stated that the rocks of the ore shoots are leucogranite, pyroxene granite (or syenite)-pegmatite, and magnetite or magnetite-pyroxene bodies in 'pegmatite'. The staff reported that criteria for the presence of orebodies include hematite staining; abundant ferromagnesian minerals, including augite and hornblende; the presence of large tabular inclusions of country rock; and frequently the presence of magnetite, particularly in the richer zones. One of the last-named mafic bodies, about 13 feet wide and 240 feet long and reported to average 0.40 per cent U_3O_8, occurred in the upper part of the mine (*see* Fig. 17, largest body) and was responsible for early high-grade intersections. It provided rich ore for blending with lower-grade material, some of which was reported to contain only 0.07 per cent U_3O_8.

Dyno Mine

Canadian Dyno Mines Limited (formerly Dyno Mines Limited) has three groups of claims in Cardiff township, called the South, North and West groups. The South group, in which the mine is situated, comprises fourteen claims and two lots in Cardiff township; the mine is in lot 12, concession VIII, 3 miles north of highway 28 and 18 miles from Bancroft.

History. In November 1953, Paul Mulliette discovered radioactive occurrences that were subsequently investigated and acquired for Dyno Mines Limited (Pancer, 1957). Adjoining claims were acquired at about the same time. Diamond drilling was begun in November 1953, on a showing near the northern end of the property. At the same time geological mapping and, presumably, some form of radiometric surveying, were commenced. This resulted in discovery of three promising zones, which were drilled, and during the course of this work two new zones were discovered. Diamond drilling from the surface continued throughout 1954 and part of 1955. A total of 55,725 feet were completed in one hundred and twenty-four drill-holes along a strike distance of about 6,500 feet. Spacing of drill-holes was at 200-foot intervals. Five potential ore zones were outlined. By the middle of 1955, a sufficient tonnage of ore had been outlined to warrant underground exploration. A shaft was sunk at the north end of what is called the "B" zone, to a depth of 1,000 feet, and work was eventually done on five levels. An agreement for sale of precipitates at a special price was obtained, and preparations for a treatment plant rated at 1,100 tons of ore a day were begun in 1956. Production began in May 1958.

Geology. The deposits are in a belt of paragneiss, para-amphibolite, and other rocks at the east flank of the Cheddar granite (*see* Fig. 15), striking about N25°W and dipping about 50°E. The host rock of the orebodies is commonly biotite-hornblende-feldspar gneiss.

The orebodies and potential ore zones consist of a series of northerly striking pegmatitic granite dykes, dipping about 50°E. They are nearly conformable with their metasedimentary host rocks but crosscutting relationships can be seen locally. The five zones are almost in line and may be connected at depth. Each zone contains numerous branching dykes of different widths, but all are lenticular.

All dykes are not of ore grade, and the widest rarely contain ore. Dykes that do contain ore may do so only in certain parts (*see* Fig. 18).

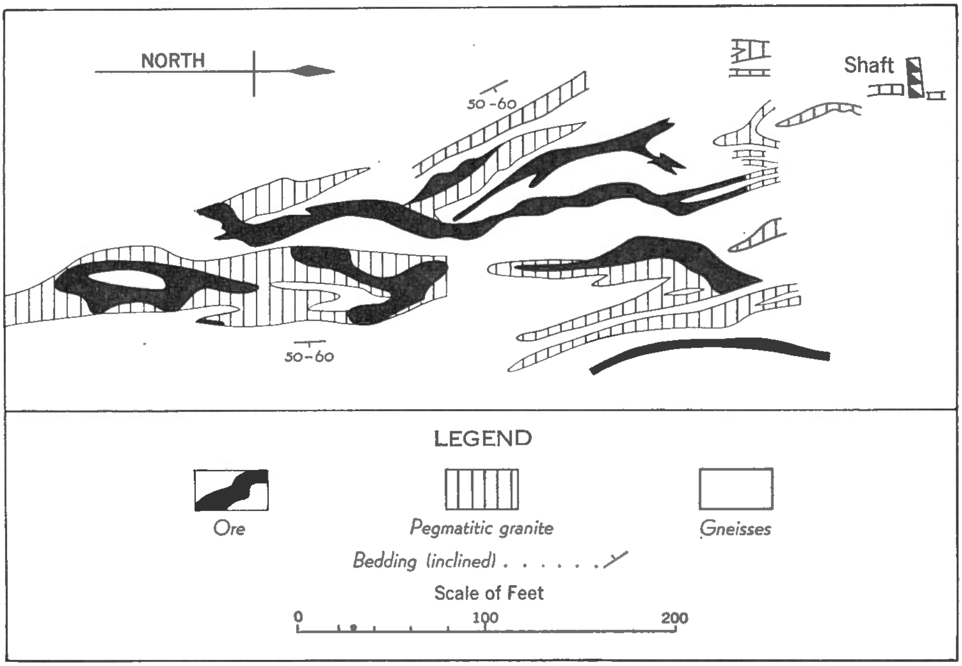

Figure 18. **Geological plan, part of 180-foot level, Dyno mine. From plan by Canadian Dyno Mines Limited.**

The dyke system on which the shaft was sunk was explored extensively for a length of 800 feet and to a depth of more than 1,000 feet, dykes being from 3 to 60 feet wide. Vallance and Skrecky (1957) reported that "where the dykes are narrow, in the order of 12 feet or less, mineable grade across the full dyke width exists. In the wider dykes, only a portion of the dyke may contain a sufficient concentration of uraniferous minerals to make ore grade. Such lenses are not confined to any single portion of the dyke and may occur in the centre or along either wall or cross from one wall to the other. Tenor of ore within the lenses varies from 0.05 per cent U_3O_8 to in excess of 1.00 per cent U_3O_8." Two sets of narrow fractures have been observed. One set strikes N20°W and the other strikes nearly north; the ore is nearly always associated with the latter.

The uranium-bearing minerals are uraninite and uranothorite. Other radioactive minerals are allanite and cyrtolite. Peristerite and magnetite are common in the ore. The ore of higher grade usually exhibits a dark red coloration and an increase in magnetite content. Underground exploration was said to have revealed better grades and tonnages than were indicated by drilling. Ore reserves were estimated by the company to average 0.093 per cent U_3O_8.

Greyhawk Mine

Greyhawk Uranium Mines Limited holds three groups of claims in Faraday township, obtained largely from Goldhawk Porcupine Mines Limited in 1955. These are called the North, East and South groups. Radiometric and geological surveying resulted in several discoveries and diamond drilling was done to explore occurrences on all groups. The deposit from which ore is mined is in the South group, in lot 10, concession XII. This was discovered in 1955 by two company employees, K. D. Thompson and M. Card, while performing a reconnaissance with Geiger counters. A rock exposure was found to be radioactive over an area 60 by 300 feet, and after only a little sampling and no trenching it was diamond drilled at intervals of 50 and 400 feet. A total of about 32,000 feet of drilling was done to test a zone 2,000 feet long to a vertical depth of 450 feet. The sinking of a shaft for further tests was begun in 1956, exploration being done on three levels.

The zone consists of easterly striking dykes of pegmatitic granite intruding metagabbro. The dykes, which pinch and swell, vary in width from 1 foot to 60 feet, dip 30° to 60°S, and generally follow the gneissosity of the country rock. Inclusions of wall-rocks lie here and there within the dykes. The ore minerals are uraninite and uranothorite. The ore shoots within the dykes have an average length of about 100 feet, an average width of 6 feet, and a slope depth of from 50 to 100 feet. Higher concentrations of radioactive minerals occur where the host rock is richer in mafic minerals and where it is much fractured; most dykes and ore zones within the dykes are narrower than those at Bicroft; variable amounts of chlorite occur with the ore; the ore is never found in the metagabbro but commonly in contact with it; no high grade deposits have been found to date, and the average grade of the ore is probably slightly lower than that at other orebodies being mined in the Bancroft camp. Fockler (personal communication) stated that the development grade was about 10 per cent below the grade indicated by surface diamond drilling, and that the tonnage outlined in underground development work, as of November 1, 1957, was about 30 per cent below the tonnage indicated by surface diamond drilling. The following information was obtained from company reports. The ore was reported in 1957 to average 0.095 per cent U_3O_8. Shipments to the Faraday mine began in August 1957 and were continued at about 200 tons a day. To the end of 1957 a total of 19,568 tons with a recoverable value of $11.40 per ton was shipped. In 1958 drilling from the third level confirmed the continuation of the ore to a depth of 450 feet, and work on two additional levels was planned. Shipments at an approximate rate of 150 tons a day averaged 0.082 per cent U_3O_8, from ten stoping areas in the mine. Plans to increase shipments to 300 tons a day by the end of the year were announced.

Northwest Territories

Eldorado Mine[1]

The Eldorado mine, at the east shore of Great Bear Lake, is the most northerly producing lode mine in Canada. It is owned and operated by Eldorado

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[1] This mine was closed in 1960, the last ore being hoisted in September.

Mining and Refining Limited. The history of the mine is outlined in the historical section of this report.

The only settlement in the region other than small camps is the Eldorado establishment at LaBine Point, officially known as Port Radium, about midway along the east shore of Great Bear Lake. The settlement of Cameron Bay, 4 miles away, has been abandoned.

Aircraft are the only practical means of passenger travel to the region. Port Radium is 270 air miles north of Yellowknife, and about 850 miles north of Edmonton. Aircraft equipped with floats or skis based at Yellowknife, fly to Port Radium on charter and also make occasional scheduled trips. Larger, wheel-equipped aircraft fly from Edmonton to a landing field on the south shore of Great Bear Lake, whence the trip to Port Radium is continued by boat. Most heavy freight is shipped from Edmonton to the railhead at Waterways, thence by barges of the Northern Transportation Company on the Mackenzie River system. The route from Waterways to Port Radium is 1,380 miles long, and freight must be trucked on long portages at Fort Smith and on Great Bear River. The average season for water transportation at Great Bear Lake is from July 15 to October 15.

The geology and mineralogy have been described by Kidd (1932, 1933, 1936), Kidd and Haycock (1935), Lord (1941), Murphy (1946), Jolliffe and Bateman (unpublished map, 1944), Campbell (1957), and others. Although recent work has added greatly to detailed knowledge, it has not changed the fundamental descriptions already published. The following short description is mainly a summary of the above-mentioned reports, with recent additions kindly supplied by D. D. Campbell, former Eldorado geologist.

The rocks exposed at and near the mine are members of the Echo Bay group, and intrusive rocks. Jolliffe and Bateman subdivided these rocks as follows, in descending order of age:

(9) Late quartz diabase
(8) Early diabase, locally amygdaloidal
(7) Granite
(6) Granodiorite

Echo Bay Group (1-5)

(5) Massive and stratified tuff, in part porphyritic; separates each of the andesitic flows (4).
(4a) Porphyritic breccia, andesite; some tuff; assemblage representing upper parts of the andesitic flows.
(4b) Amygdaloidal andesite, in part porphyritic; some tuff and breccia.
(4c) Porphyritic andesite, representing lower parts of the andesitic flows.
(3) Feldspar porphyry, hornblende-feldspar porphyry; locally fragmental, but probably largely intrusive.
(2) Stratified rocks: thinly banded cherty sediments; bedded tuff and coarser fragmental rocks; banded limestone (on Cobalt and Limestone Islands only).
(1) Massive crystalline tuff; age relationships to (2) indefinite.

Many of the rocks of the Echo Bay group are much altered, so that it is difficult or impossible to determine their exact original character. This fact, with the added complication that some contacts are gradational and some are faulted, makes the relationships of some of the units uncertain. This is particularly true of units 1 and 2, as listed above. The most abundant rocks at and near the mine are units of 1, 2 and 3. The porphyry forms bands and masses within the stratified rocks, and may represent either sills or flows; the evidence available suggests that in the mine area the porphyry is entirely intrusive. The total thickness of the stratified rocks is more than 2,000 feet, unless beds have been repeated as a result of structural conditions that are not apparent. The oldest plutonic rock has been classed as diorite by some workers and as granodiorite by others; the main body of this rock is about 2 miles northeast of the mine. Nearer to the mine, granite is exposed at several places along the shore of the lake and on nearby islands, leading to the conclusion that it underlies much of the lake in the vicinity of the mine, and that it may underlie more of the mainland at depth. Apophyses of granite have been found in the westerly mine workings. Aplite dykes intrude the granite, and they also cut some of the older rocks within 1,000 feet of the granite contacts. The youngest rocks near the mine are diabases, divided into two groups. Early diabase dykes are cut by structures containing pitchblende. The late diabase forms flat-lying bodies that may once have been continuous; apophyses of this rock cut some of the pitchblende-bearing veins.

In the mine area, rocks of the Echo Bay group as well as most of the tabular intrusive porphyry bodies strike northeast and dip 30° to 70°SE. (other porphyry bodies dip northwest). This general attitude of the older rocks is modified by broad warps in the vicinity of granite apophyses to the west. In addition the sedimentary rocks of the Echo Bay group have been complexly deformed adjacent to, and particularly above, the intrusive porphyry bodies. Numerous faults, some of which have displacements of several miles, have strikes ranging from slightly east of north to northeast and all appear to be later than the folding. Rocks of all ages have been faulted, but only slight displacement of the late diabase has been found. Many faults are branching. The stronger faults form wide zones of shearing and brecciation, a few being several hundred feet wide. The main mineralized faults and shear zones are shown on Figure 19.

The orebodies range from narrow, high-grade veins that are stoped by resuing to stock-works up to 40 feet wide that are only partly of ore grade. Individual veins range in width from less than an inch to about 10 feet. The orebodies are distributed at irregular intervals within eight roughly parallel shear and fracture zones, which coalesce in the northeastern and southwestern parts of the mine. The average strike is N65°E, and dips range from 60°N to vertical. Shoots of minimum stoping width range in length from 50 feet to 700 feet, and have been followed vertically for more than 1,100 feet. The orebodies locally widen to as much as 15 feet where multiple fracture zones are mineralized with pitchblende. The orebodies are almost entirely confined to the stratified rocks or to places where the fracture zones follow contacts between these rocks and

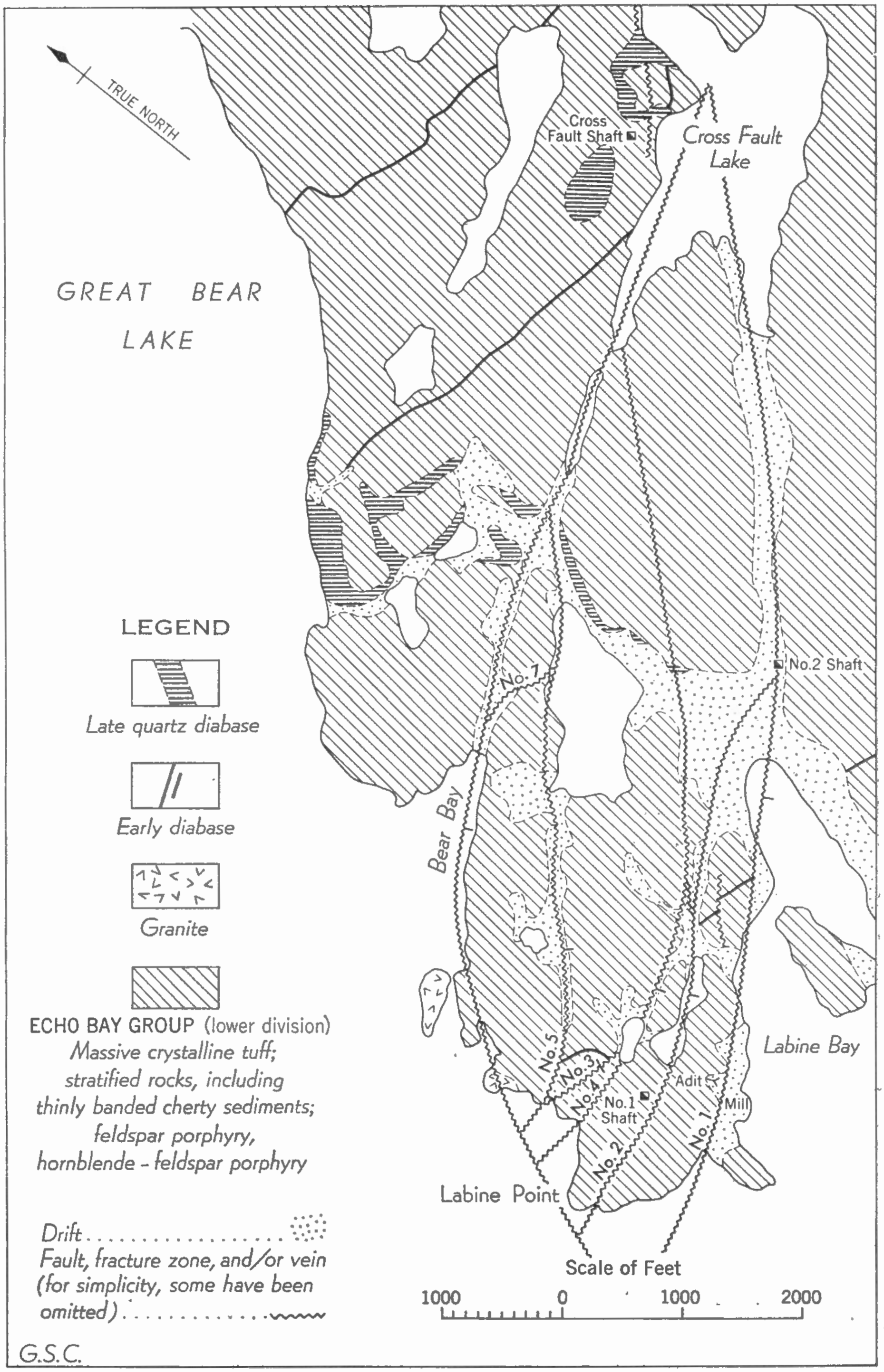

Figure 19. Eldorado mine and vicinity, Great Bear Lake, Northwest Territories. The orebodies are in Nos. 1, 2, 3, and 5 zones. After map by Jolliffe and Bateman, revised by D. D. Campbell, 1957.

early diabase; they extend only a short distance into parts of the zones that cross porphyry, granite, or massive tuff, and longitudinal sections show that the orebodies rake in conformity with the distribution of porphyry and massive tuff bodies. Recent work by Campbell has shown that there appears to be a marked distribution of ore shoots around 'noses' of porphyry. The influence of the porphyry has been predominantly due to the fact that it did not fracture as readily as the other rocks. Few changes in the character of mineralization with depth have been found, the main differences being that silver has only been found in important amounts to 600 feet below surface and botryoidal pitchblende decreases with depth.

In the lower levels to the west, the ore-bearing fracture zones penetrate the granite but are noticeably constricted within it. One orebody continues along No. 3 zone into the granite for about 200 feet before dying out.

The deposits consist chiefly of altered rock, quartz, carbonate minerals and hematite, with smaller amounts of pitchblende, chalcopyrite, sulpharsenides of cobalt and nickel, native silver and bismuth, pyrite, argentite, galena and chlorite. By microscopic study Haycock identified pitchblende, magnetite, hematite, "limonite", arsenopyrite, pyrite, smaltite-chloanthite, safflorite-rammelsbergite, skutterudite, nickel-skutterudite, cobaltite, gersdorffite, glaucodot, nickeliferous lollingite, niccolite, polydymite, molybdenite, native bismuth, bornite, chalcopyrite, chalmersite, tetrahedrite, freibergite, chalcocite, covellite, sphalerite, galena, stromeyerite, jalpaite, argentite, hessite, native silver, pyrolusite, psilomelane, polianite (?), and five other minerals that could not be determined, bringing the total number of metallic minerals recognized by him to forty.

Haycock found that the pitchblende occurs in several forms, which he called botryoidal, colloform, cellular, dendritic, spherulitic, brecciated, and vein forms, the last being minute seams. Some of these types are intimately associated with quartz, forming what is called 'siliceous pitchblende ore'. Haycock also found that the pitchblende is of two distinct compositions, with different ratios of UO_2 to UO_3.

Mineral deposition occurred in four main stages, resulting, in places, in banded orebodies; all stages are not represented in some orebodies. Pitchblende is believed to have been the earliest metallic mineral formed, and native silver the last. The pitchblende has been generally brecciated and commonly pulverized by movement along the fracture zones and the fragments have been locally redistributed by later solutions. Pitchblende, pyrite, magnetite, chalcopyrite and cobalt minerals are found in orebodies throughout the mine; but native silver and nickel minerals were only found to any extent in the upper workings. Despite its distribution, most of the native silver is believed to be primary. Secondary uranium minerals were common in surface workings and were found in minor amounts in the uppermost level. Gruner and Gardiner (1950) list becquerelite, curite and liebigite as secondary uranium minerals found at Great Bear Lake.

The ore-bearing zones, from south to north, are called the No. 1, No. 2, No. 3, No. 4, No. 5 or Dumpy, No. 6, No. 7, and No. 8. In order of importance, they are the No. 1, No. 3, No. 2 and No. 5. The Nos. 1, 2 and 5 are shear zones containing some gouge, the ore occurring in areas where tension fractures lie along the shear zone, especially in the vicinity of masses of porphyry. Nos. 4, 6 and 8 zones have been minor producers. The No. 1 zone is much banded and shows evidence of three main stages of deposition, the first represented by massive quartz with a little chlorite, and pyrite; the second, mainly by quartz and hematite followed by pitchblende, silver and cobalt-nickel minerals; and the last stage, by small veins of quartz, carbonate and chalcopyrite cutting the late diabase. The No. 2 zone consists partly of banded carbonate with seams of pitchblende, together with silver, chalcopyrite, hematite and cobalt-nickel minerals, and partly of pitchblende veins along narrow chloritic shear zones. The No. 5 zone resembles the No. 1, but on a smaller scale. The No. 3 (*see* Fig. 20) is a zone of discontinuous fractures, which form a breccia cemented by relatively little vein matter. Pitchblende and chalcopyrite are more disseminated than in the other zones, and sulphide and arsenide minerals are more abundant than in the other zones.

Kidd and Haycock (1935, p. 885) considered that the conditions under which the deposits were formed were "mesothermal almost to epithermal". Haycock made further studies of this problem in 1950, including studies of the decrepitation temperatures of quartz, higher temperatures being found in samples from the orebodies than elsewhere.

Evidence of reddish, hematitic alteration is widespread in the upper levels only, and the process has affected rocks of all ages except the late diabase. Where most intense, as in and near parts of the mineralized zones, the alteration resulted in a hard 'jasperoid' containing quartz, hematite, magnetite, sericite, chlorite and carbonate. Murphy (1946, p. 432) stated that the alteration is undoubtedly related to the quartz-hematite stage of mineralization. Argillic alteration is the most pervasive and ubiquitous type of wall-rock alteration along all exposed shear and fracture zones in the mine. It has affected all rock types and is post-pitchblende.

The mine is operated from a shaft placed between the No. 2 and No. 3 zones. The first level is connected with an adit to form a haulageway. The other levels are below the level of the lake, the deepest being 1,650 feet below the shaft-collar. The mine contains about 22 miles of underground workings. Long exploratory drifts were recently driven to the northeast on the No. 1 and No. 2 zones.

A prospect shaft was sunk on showings about three quarters of a mile northeast of the mine, and another shaft explored showings about 1½ miles northeast of the mine. These are on the general strike of zones at the mine. In addition, structures parallel with those that contain the orebodies of the mine remain to be explored completely. The annual report of Eldorado Mining and Refining Limited for 1957 stated "Ore reserves at the end of the year were 131,200 tons of .58% ore, some 14% lower in total U_3O_8 content than reserves at December 31, 1956, and a further decrease is anticipated by the end of 1958. On the basis of present estimates, the ore reserves of the mine will be approaching exhaustion towards the end of 1960". The treatment plant has a rated capacity of 300 tons of ore a day.

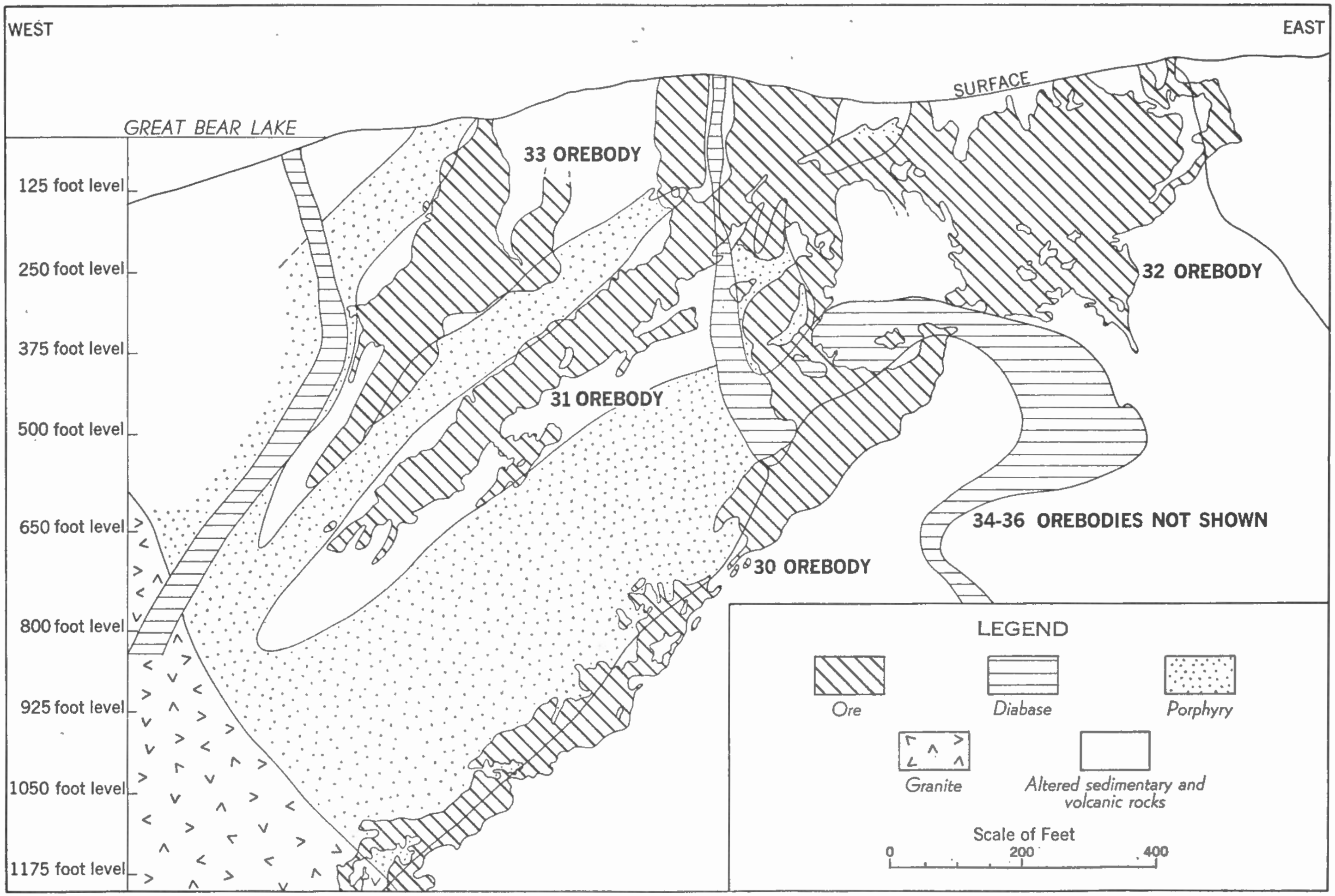

Figure 20. Longitudinal section of No. 3 vein, Eldorado mine, Great Bear Lake, Northwest Territories, showing distribution of orebodies. After D. D. Campbell, Eldorado Mining and Refining Limited.

In recent years a substantial part of the mill-feed has been tailings stockpiled after treatment several years ago in a plant that recovered only part of the pitchblende. Ore has also been obtained from the Uranium claim group which adjoins the Eldorado property and is owned by Ventures Limited and Dominion Explorers Limited. Eldorado leased these claims and pays a royalty on ore produced from the Eldorado No. 5 and No. 7 veins, which extend into them from the Eldorado mine.

Rayrock Mine[1]

The Rayrock mine, on the Beta group of claims, is owned by Rayrock Uranium Mines Limited. It is in the Marian River region, 100 miles northwest of Yellowknife. Access is by float-equipped aircraft from Yellowknife, and by a 35-mile gravel road connecting the mine with a dock and warehouse at the head of Marian Lake, a part of the Great Slave waterway. In February 1957 a truck convoy was loaded in Edmonton and driven directly to the mine, using frozen waterways where necessary. A highway around the west end of Great Slave Lake, joining Hay River to Yellowknife, is under construction and the Rayrock road could be connected to this.

History. Yellow radioactive stains were found in 1934 by officers of the Geological Survey of Canada about 2½ miles east of Marian River on ground eventually staked as the Ted group (Lang, 1952, p. 61). In 1948 pitchblende was found on claims held jointly by Thorium Exploration and Gold Limited and Camsell River Silver Mines Limited, for both of which A. V. Giauque was agent. This became known as the "Giauque" occurrence. It is a short distance southwest of the main Rayrock occurrences. The Beta group is apparently a restaking of all or parts of these claims and those included in the former MM group.

In 1952 prospecting became more intensive and pitchblende was discovered on claims optioned to Lodge Uranium Mines Limited. This company was reported to have done limited Geiger prospecting and some rock trenching in 1953. Subsequently, control of the Beta property was acquired by American Yellowknife Mines Limited, whose name was changed to Rayrock Mines Limited. A vigorous program of exploration and development was undertaken by the latter in 1953 and 1954. Following a program of surface diamond drilling an adit was begun in 1955. This underground exploration revealed a 300-foot high-grade zone, and an internal shaft was sunk. A contract was negotiated for sale of uranium precipitate, a treatment plant rated at 110 tons of ore a day was built, and milling began on May 31, 1957.

Geology. The deposit is near the west boundary of the Canadian Shield, about 10 miles east of the Palæozoic contact. Bedrock is well exposed on a series of hills, ridges and cliffs. The rocks include quartzite, dolomite, argillite, chert and mica schist of the Snare group, apparently of Proterozoic age and believed to be about equivalent to the Echo Bay group at Great Bear Lake. These are

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[1] This mine was closed in July 1959.

intruded by granitic rocks that include granodiorite and quartz monzonite, but which are not readily separable and are referred to below as 'granitic' (McGlynn, 1957). The prominent, right-handed, Marian River fault strikes northeast, dips steeply southeast, and has an apparent horizontal displacement of about 6 miles.

The granodiorite is traversed by quartz stock-works ('giant quartz veins') which strike parallel with the Marian River fault. Subsidiary tension fractures branching from the main fault appear as zones of intense fracturing within the quartz veins; the principal orebodies on the Beta group have been found in such zones. The fault and associated stock-works cross the property for a length of about 9,000 feet. Locally, they pass through a series of granitized rocks in which subsidiary faults and shears, some quartz-filled, have been developed. The 'zone of influence' of the Marian River fault is reported by N. W. Byrne (1957) to be best developed on the northwest, or foot-wall side, and to extend across an area up to 1,000 feet wide. Pitchblende-bearing veins and breccia zones occur within subsidiary structures. The No. 1 zone consists of a northwesterly dipping fault along which occur lenses and short ore shoots in much-brecciated granitic rock. The important No. 6 zone, 900 feet west of the Marian River fault, is an offshoot from the main stock-work and is from about 4 to 40 feet wide and up to 300 feet long (*see* Fig. 21). It consists of impure, grey and greenish quartz which has been fractured, brecciated and intruded by late white quartz. At least three main ages are indicated. Between the quartz and the granitic host rock there is an alteration zone approximately 5 to 30 feet wide, composed of fine-grained siliceous rock that varies from red through pale brown to apple green as the amount of hematite and epidote varies (op. cit.). Near radioactive zones the host rock shows typical red to chocolate-coloured alteration.

One of the final events of the formation of the stock-work was the introduction of pitchblende and intimately associated hematite in open fractures and crushed zones in the quartz and in altered granitic rock. The pitchblende is mostly fine grained rather than massive, and is finely crushed indicating slight movement during the period of deposition (op. cit.). A little specular hematite, pyrite and chalcopyrite have been found.

To summarize, the main features of this deposit, which might be useful guides to searching for additional ore of this kind, are:

1. Small, tight fractures near a major fault.
2. A quartz stock-work.
3. Red coloration of the host rocks, due to hematitization.
4. A wide zone of epidotized wall-rock surrounding the most radioactive sections of the quartz core; and epidotization of rocks outside the quartz core.
5. Other forms of wall-rock alteration, such as silicification and chloritization.
6. Remnants of altered sedimentary rocks within a zone of alteration.

The annual report of the company for 1957 stated that the ore occurrences are more irregular in outline than was expected and that, consequently, ore

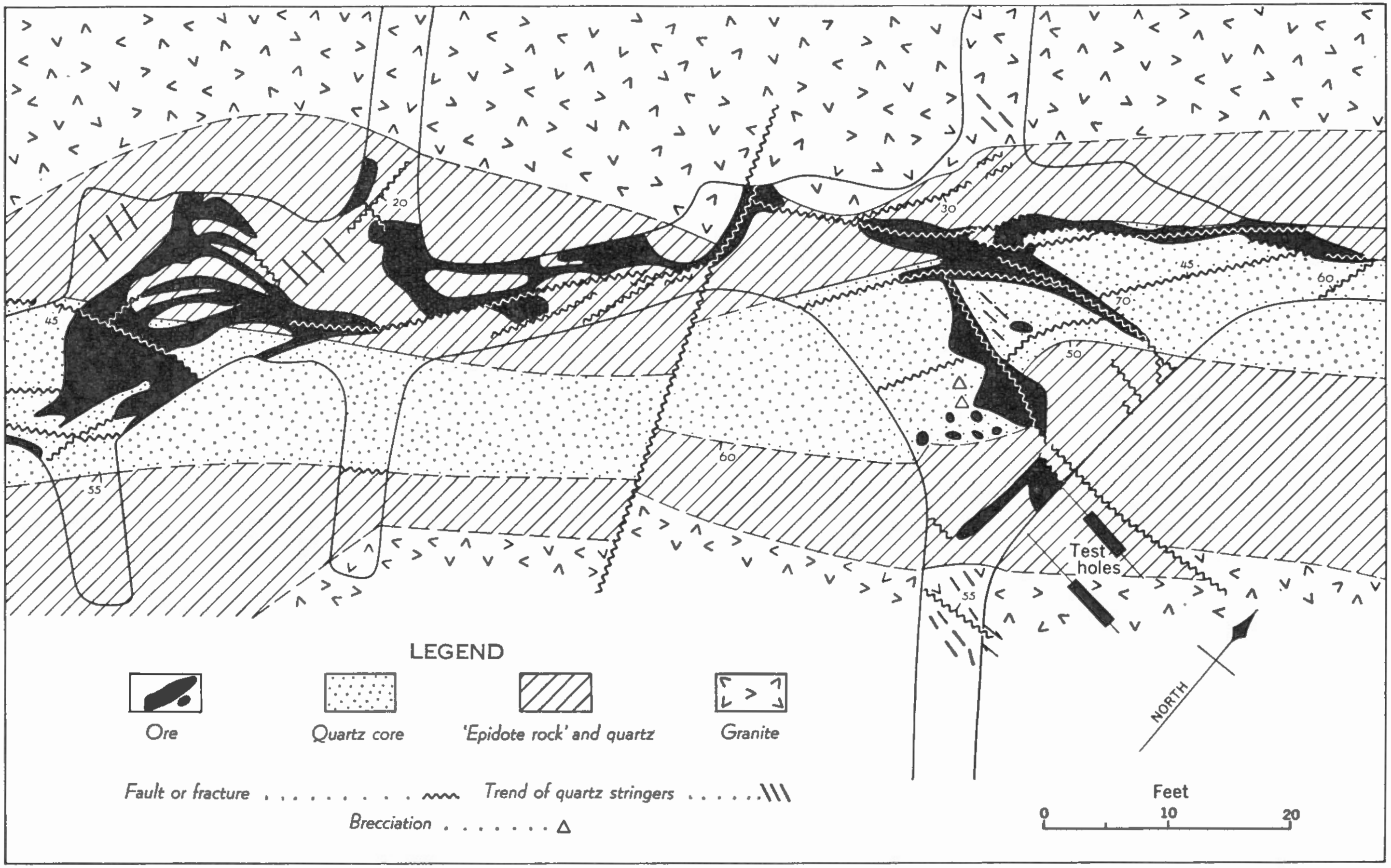


Figure 21. Plan of part of adit level, Rayrock mine, showing main orebodies in generalized manner. From plan by Rayrock Mines Limited.

reserves are difficult to estimate ahead of actual mine development. The grade of ore milled averaged $49.56 per ton during the first 5 months when the plant was being 'tuned', and $66.50 per ton during the next 3 months ending January 31, 1958. In 1958 the mine was developed on five levels, the deepest being 625 feet, and four additional levels were planned to a total depth of 1,125 feet.

Contact Lake Mine

The Contact Lake mine, 9 miles southeast of the Eldorado mine, was formerly a small producer of native silver and minor amounts of pitchblende. The claims were staked in 1931, and from 1936 to 1939 a 25-ton mill was operated intermittently by Bear Exploration and Radium, Limited. Lord (1941, p. 50) reported that the total production up to the end of 1939 was 6,933 pounds of U_3O_8 and 348,250 ounces of silver, from 10,079 tons of ore milled, plus some crude silver ore shipped in 1934. In 1942 the claims were bought by International Uranium Mining Company, Limited, which did additional exploration between 1944 and 1949, including radiometric and geological surveys, 15,300 feet of diamond drilling, and a little underground work. Late in 1949, the company was reorganized as Acadia Uranium Mines Limited. Diamond drilling was done to explore, below the bottom level, the ore shoot from which previous production was obtained. Work was stopped in 1950.

It was estimated in 1944 that 9,940 tons of mill tailings contained 27,000 ounces of silver and 4,000 pounds of U_3O_8. A recent estimate of ore in place above the second level states that 3,000 tons containing 100 ounces in silver a ton and 1 per cent U_3O_8 are available, and that a similar tonnage lies above the stoped area on the third level.

Three principal quartz-carbonate veins occur in fractured and sheared zones in granodiorite (*see* Fig. 22). Granite is in contact with the granodiorite about 1,000 feet southwest of the main or No. 1 zone. The granite appears to intrude the granodiorite, and the veins are believed to have been formed after the intrusion of the granite. As described by Lord (1941, pp. 53-55) and Parsons (1948, pp. 11-12) the No. 1 zone is up to 5 feet wide. It has been exposed on surface at the principal outcrop for a length of 350 feet and has been followed underground for 1,100 feet east of the shaft to its juncture with the No. 3 zone; the No. 1 zone is open to the west. In places, this zone contains veins of quartz and carbonate minerals, and these veins contain, or contained, shoots carrying native silver, some hematite, pyrite, chalcopyrite, magnetite, bornite and pitchblende, and a little arsenopyrite, chalcocite, tetrahedrite, algodonite, chalcostibite, famatinite, cobaltite, safflorite-lollingite, glaucodot, niccolite, gersdorffite, rammelsbergite, breithauptite, sphalerite, galena, native bismuth, bismuthinite, pearcite, stromeyerite, argentite, hessite, malachite, azurite, erythrite and secondary uranium minerals. Pitchblende was one of the earliest metallic minerals formed, and native silver was the latest. In places the wall-rock is altered to chloritic material, and in other places shows typical red alteration.

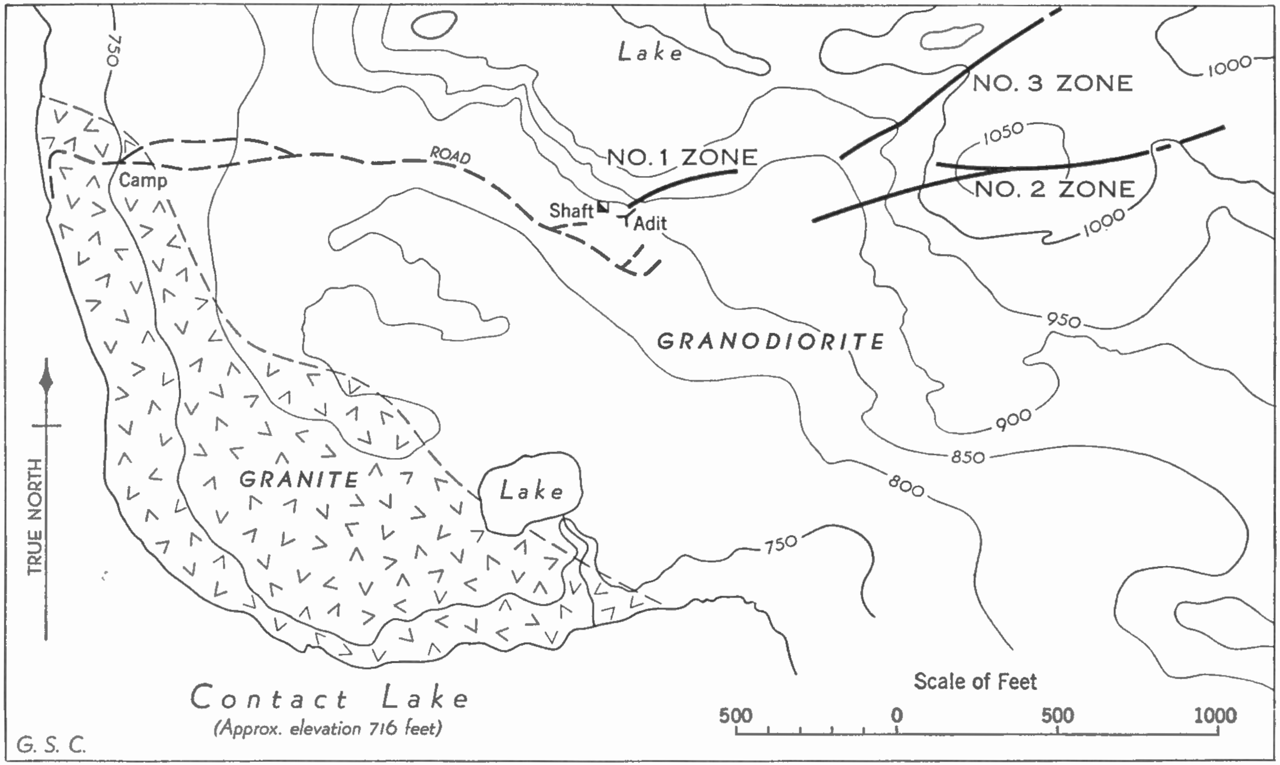


Figure 22. Geological diagram showing vein zones, Contact Lake mine, Northwest Territories. From plan by Bear Exploration and Radium, Limited.

Underground work was done on all three zones. The No. 1 was explored and mined from an adit and a shaft, two levels from the shaft being 90 and 190 feet below the adit. About 2,400 feet of drifting was done on No. 1 zone. The No. 2 zone consists of quartz-carbonate stringers in a sheared zone 2½ feet wide; it has been traced for 1,340 feet on surface, and was explored by drifting for 711 feet on the second level. Metallic minerals include hematite, chalcopyrite and native silver; no pitchblende is known to occur, but radioactivity is reported to have been detected. The No. 3 zone consists of similar stringers in a sheared zone 4 feet wide, traced for 2,000 feet on surface. A total of 932 feet of drifting was done on No. 3 zone, on two levels. It contains hematite, chalcopyrite and pyrite. Several other zones were explored by diamond drilling, and silver was found in some of them.

Non-Producing Examples

The following non-producing deposits are described briefly because they illustrate types or variations that are not included among the producers. They were selected mainly because information was available from underground workings or diamond drilling, or because one of the writers happened to be familiar with the deposit. The inclusion of descriptions of these deposits and exclusion of others in no way implies economic preferences.

Bolger Deposit

An unusual example of supergene mineralization occurs on one of the Bolger claims, held by Eldorado Mining and Refining Limited northeast of the Ace-Verna mine. A pitchblende occurrence outcrops near the bottom of a slope. Gravel beyond this is cemented by secondary material classed as gummite, for an area of 6,500 square feet. This material, which the company estimated to average 1.42 per cent U_3O_8, was apparently leached from the pitchblende in the outcrops by surface waters that moved a short distance into the adjacent gravel before depositing their contained uranium.

Bugaboo Creek Placers

Placer deposits at and near Bugaboo Creek, British Columbia, are the most extensively tested examples of Recent radioactive placers. Twelve placer leases held by Quebec Metallurgical Industries Limited are reported to include eight deposits in the upper valleys of Bugaboo, Vowell and Forster Creeks about 45 miles south of Golden (Rowe, 1958). These creeks flow easterly on the slopes of Purcell Mountains and are tributaries of Columbia River (*see* Fig. 23).

A sample of sand from the head of Bugaboo Creek collected by G. O. Reid was assayed in 1949 and found to contain 0.21 per cent U_3O_8 (Lang, 1952, p. 44). In 1953, F. T. Russel and A. Archer, believed to have been in the employ of Quebec Metallurgical Industries, made further discoveries by means of fluorescent tests (Rowe, 1958). The company did extensive churn drilling and erected a small mill for extraction tests mainly with a view to recovering niobium, but also uranium and thorium. At Bugaboo Creek the placer is 17 feet deep, 550 feet wide and 3,850 feet long (Holland, 1956). The minimum amount available for dredging on the various leases was estimated by the company at 65 million cubic yards; grade was not announced (Rowe, 1958).

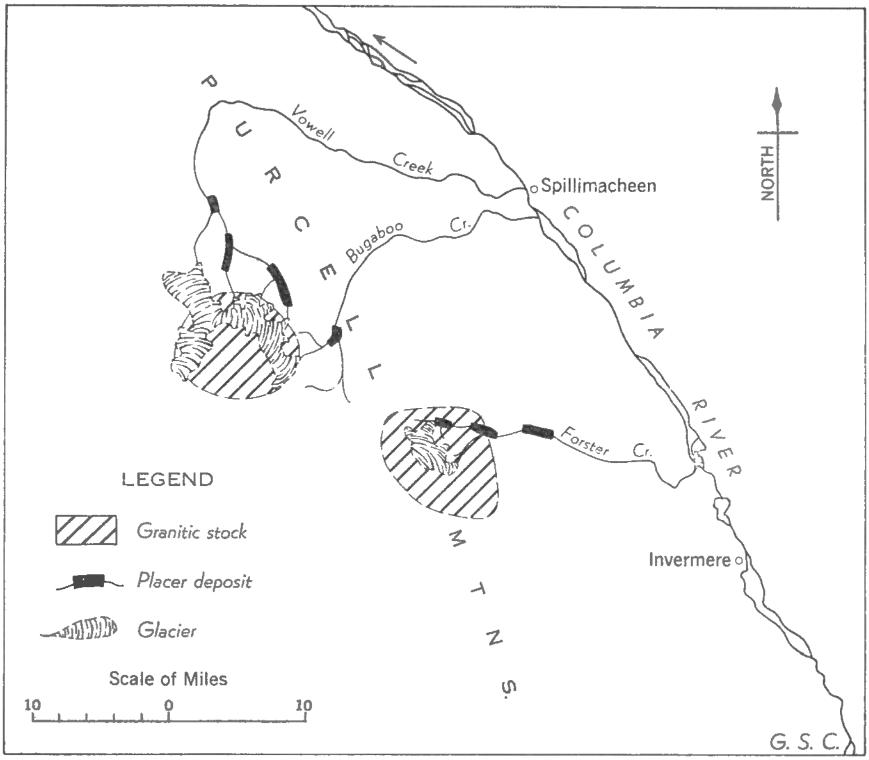


Figure 23. ***Sketch map showing the Bugaboo Creek placer deposits, southeastern British Columbia, and their relationship to granitic stocks, glaciers and glacial streams.*** **From map by H. D. Hughes, Quebec Metallurgical Industries Limited, 1955, after Rowe, 1958.**

Recent alluvium is concentrated in the upper waters of the streams from outwash of active glaciers (Reesor, 1957). Sand concentrates containing magnetite studied by the Geological Survey were found to contain a member of the pyrochlore-microlite series, a member of the euxenite-polycrase series, allanite and uraninite, as well as several non-radioactive minerals. Uranothorite is listed as a constituent by Merrett (1957). These minerals are evidently eroded from the Bugaboo and Horsethief granitic stocks near the headwaters of the creeks, and possibly also from contact metasomatic deposits associated with them.

Uraninite and a member of the euxenite-polycrase series were identified in a crushed and concentrated sample of the Horsethief granite collected by Reesor.

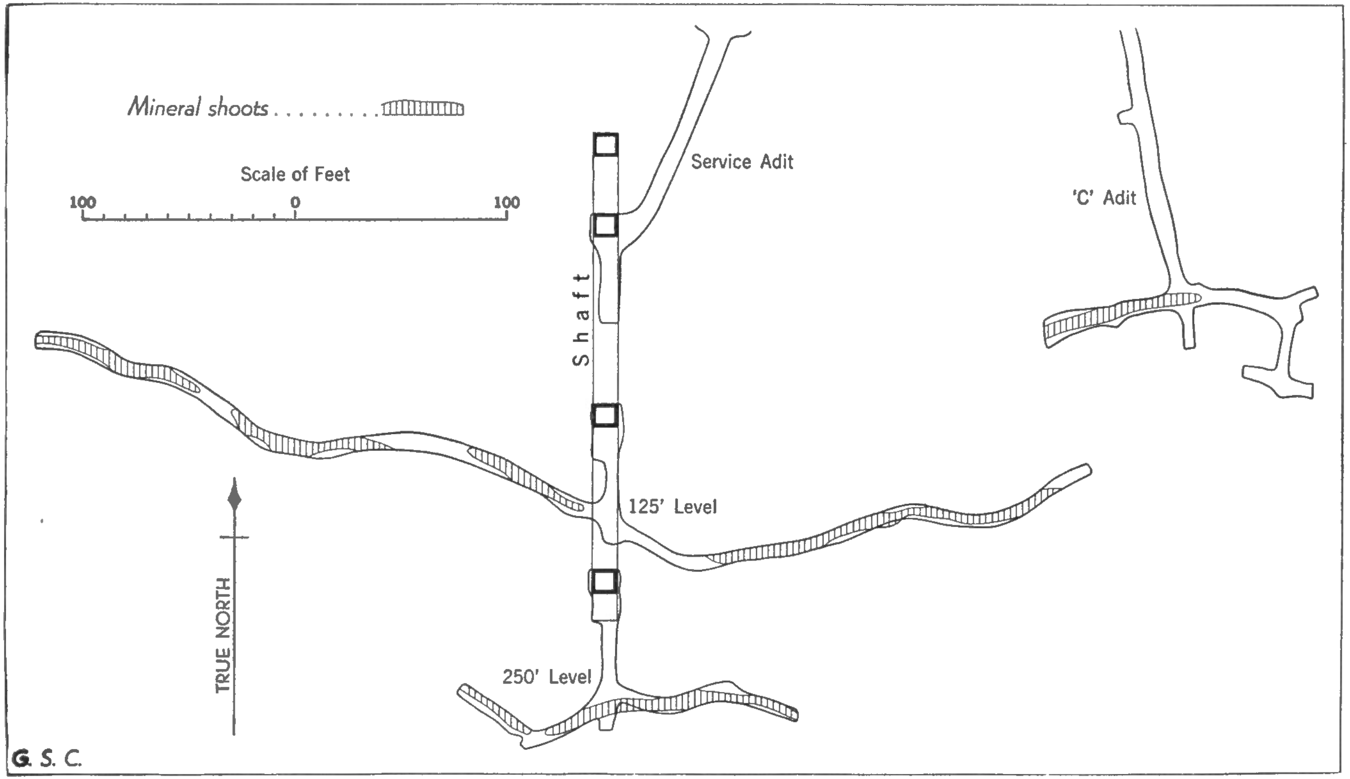


Figure 24. **Composite plan of main workings, Cardiff property, Ontario. From plan by Cardiff Fluorite Mines Limited.**

Cardiff Property

This property is an example of the calcite-fluorite deposits that appear to be replacements of single beds (Satterly, 1956), and its underground workings provide considerable information. The property, in Cardiff township about 17 miles west of Bancroft, Ontario, was formerly held and explored by Cardiff Fluorite Mines, Limited, which was reorganized as Cardiff Uranium Mines Limited in 1953. At the times of the writers' visits to the district, the property was closed.

The deposits are in a zone of metamorphic rocks surrounding a granitic complex (*see* Fig. 15) and, according to Satterly (1957) are in a "band of limy paragneiss near its contact with crystalline limestone".

The earlier work on the property was done mainly to test its fluorite possibilities. Five zones, designated A to F, were followed intermittently over a distance of 2 miles, and during later exploration the A, E and F were grouped as the 'North zone' and the B and C as the 'South zone'. Adits were driven to test the C and E zones, and in 1950 an inclined shaft was sunk on the C and drifting was done on two levels at 125 and 250 feet below the surface (*see* Fig. 24). The deposits are vein-like bodies of calcite and purple fluorite. Additional minerals listed by Satterly are uraninite in crystals up to half an inch in size, biotite, apatite, scapolite and pyroxene.

The principal work was done on the South zone, where the company reported six shoots from 33 to 60 inches wide and from 60 to 175 feet long, and that channel sampling showed averages of 0.095 per cent U_3O_8 (radiometric) and 18.10 per cent CaF_2. It reported that bulk samples weighing 4½ tons and 500 pounds, from the South and North drifts on the 125-foot level assayed 0.08 and 0.12 per cent U_3O_8 respectively; tests on the larger sample indicated that uraninite could be readily concentrated by conventional gravity methods with treatment costs low, owing to the elimination of fine crushing as no secondary crushing is required; the tests produced a concentrate containing 32.99 per cent U_3O_8, with a recovery of 81.47 per cent.

McLean Bay Occurrence

A fairly large, low-grade thorium-uranium deposit at McLean Bay of Stark Lake, 16 miles east of Snowdrift trading post (*see* Fig. 25), Northwest Territories, was found by prospectors for Eldorado Mining and Refining Limited. This company examined it with considerable interest during the early days of intensive search for uranium deposits, before better ones were found in other districts.

The deposit occurs in dolomite mapped as part of the Kahochella formation, which is one of the formations of the lower part of the Great Slave group of late Precambrian age. The dolomite is interbedded with quartzite, and the beds dip 45°SE. Most radioactivity was found in a bed that has an average width of 43 feet and that contains concentric structures believed to be algal. Within this bed, two zones 10 and 6 feet wide contain more radioactive minerals than the rest of the bed. These zones are brownish red at many places, because of the presence of hematite. Radioactive minerals cannot be seen in the field, but laboratory work by S. Kaiman of the Mines Branch showed fine-grained monazite and uraninite (or pitchblende), and the presence of monazite was confirmed by Steacy.

After surface trenching was done, the deposit was explored for a length of 1,400 feet and to a vertical depth of 200 feet, by 2,535 feet of diamond drilling. Many surface and core samples were tested. Only one out of 246 samples showed more than 0.05 per cent U_3O_8 equivalent, 81 samples showed 0.01 to 0.05 per cent U_3O_8 equivalent, and 164 showed less than 0.01 per cent U_3O_8 equivalent. The average was estimated at 0.033 per cent U_3O_8 equivalent, but tests showed about five times as much thorium as uranium. The average content of U_3O_8 was estimated to be about 0.005 per cent.

Other radioactive occurrences associated with sedimentary rocks were found by Eldorado prospectors near Stark Lake, and on Preble Island.

Quebec Columbium Property

This property, which is near Oka, Quebec, some 20 miles west of Montreal, is an example of the pyrochlore-bearing fenite deposits. It is essentially a niobium rather than a uranium property, and is described more fully in a recent report on Canadian niobium deposits (Rowe, 1958). The following is mainly a condensation of Rowe's report. Further information on the geology can be found in a paper by O. D. Maurice of the Quebec Department of Mines (1956).

Near Oka, gneisses and other rocks of the southern part of the Grenville province of the Canadian Shield are intruded by a complex of carbonate and alkaline rocks which are probably of post-Precambrian age and part of the Monteregian petrographic province. Structurally, the Oka Hills are regarded as part of the Beauharnois Axis, a partly buried ridge of Precambrian rocks extending from the Shield southward to the Adirondacks. The Oka complex is about 1½ by 4 miles in size and is incompletely known because outcrops are few. It comprises carbonate rocks composed mainly of calcite; calc-silicate rocks, including okaite (a coarse, massive rock consisting essentially of melilite) and monticellite; alkaline silicate rocks consisting mainly of members of the ijolite, microijolite and jacupirangite series; and lamprophyric rocks. Gneiss, granulite, anorthosite and gabbro are altered to what are classed as 'fenites' along contacts with various rocks of the Oka complex and as inclusions in microijolite. The alteration is caused chiefly by replacement of original minerals by calcite and, or, veinlets and small patches of soda pyroxene, soda amphibole or chlorite.

Radioactive rocks apparently were first discovered near Oka by F. Manny, a prospector. Samples sent by him to the Geological Survey contained a mineral of the pyrochlore-microlite series, and he was so advised. His claims were examined by S. B. Bond of the Molybdenum Corporation of America, which purchased them and adjoining claims. Bond (personal communication) found additional radioactive occurrences by driving slowly along roads in an automobile and noting the readings of an ordinary scintillation counter. Several other companies acquired claims and explored radioactive discoveries, but the largest amount of work is understood to have been done on what is called the Bond zone, on claims now held by Quebec Columbium Limited, a company formed in 1956 as a joint subsidiary of Molybdenum Corporation of America and Kennecott Copper Corporation.

The Bond zone is described by Rowe as composed mainly of calcite rock, microijolite, and biotitized microijolite with lesser amounts of ijolitic rocks, altered ijolitic rocks, okaite, altered okaite and soda pyroxene-biotite-calcite-pyrochlore rock. Pyrochlore, apparently the most abundant niobium mineral, occurs mainly in the last-named rock. Other niobium minerals are betafite, niocalite and niobian perovskite. Several shoots have been outlined in the zone, some transgressing various rocks. The zone was explored by diamond drilling at intervals of 100 and 200 feet, and from a shaft. This work was reported in 1957 to have indicated 30 million tons carrying from 0.10 to 2.0 per cent Nb_2O_5. The company is understood to be satisfied that a process for extracting the niobium has been developed, and to be awaiting clarification of the demands. The uranium content of the deposit was not published, but the company is believed to have investigated the possibility of recovering as a by-product the uranium that apparently occurs as a minor constituent of some of the niobium minerals.

Rex Property

A short account of this occurrence is included as an example of what are considered to be pegmatites of 'intermediate' or 'basic' composition.

The Rex group of twenty-four claims is on a peninsula at the south shore of Stark Lake, 130 miles east of Yellowknife and 14 miles east of Snowdrift. Messrs. A. Krys and H. R. Wilson found a radioactive occurrence there in 1949 and staked the group, which was acquired by Ridley Mines Holding Company.

The claims are underlain partly by sedimentary rocks of the lower part of the Great Slave group, and partly by quartz diorite, which outcrops on the northwestern claims. Six main radioactive deposits, called the A, B, C, D, E, and Stevens, have been found within an area of about 700 feet by 5,000 feet in the southeastern part of the diorite stock (*see* Fig. 25). The combined length of the deposits is about 1,900 feet, and the average width about 3 feet. The deposits occupy steeply dipping fractures, some striking northwest and some north; two subsidiary mineralized fractures strike northeast. The fractures are filled with pegmatitic material of an unusual type, apparently related to the quartz diorite. The dominant mineral is actinolite. Minerals occurring in smaller amounts are apatite, magnetite, calcite, fluorite, and uraninite in crystals up to a quarter of an inch in size.

Eleven pits showed width ranging from 1 foot to 6 feet. Because the rocks are well exposed, the zones can be traced fairly well on the surface. In places, instead of continuous fractures, a series of *en échelon* cracks is mineralized. The longest zone traced is the "C", which has been found intermittently for a length of about 650 feet. Lang took one chip sample across 6 feet in a pit on the B zone; this showed 0.095 per cent U_3O_8 equivalent. Another, chipped across

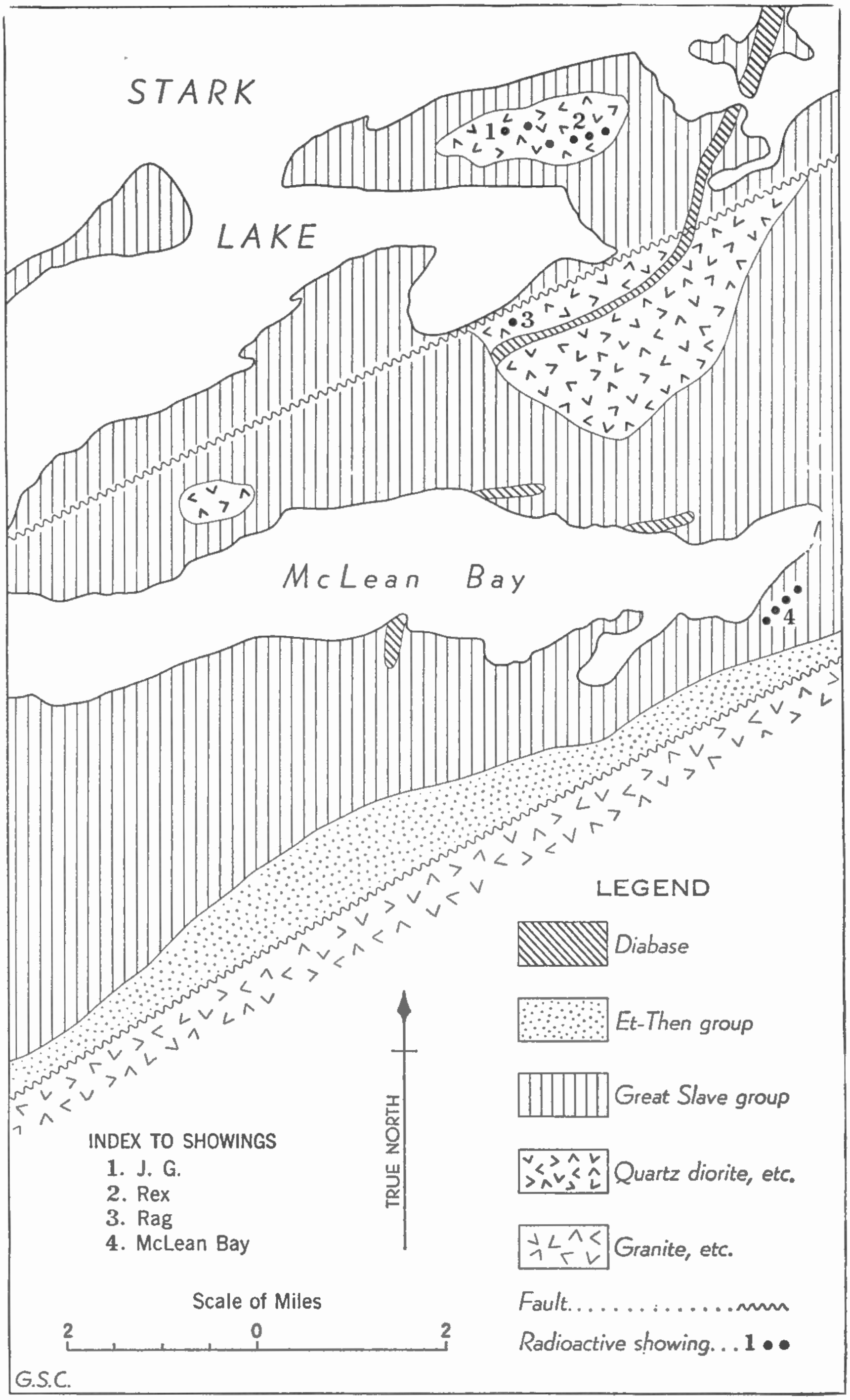


Figure 25. Sketch map showing generalized geology and radioactive occurrences, Stark Lake region, Northwest Territories. Geology after I. C. Brown, 1949, and F. Q. Barnes, 1951.

3 feet in a pit on the C zone, showed 0.99 per cent U_3O_8 equivalent. The Stevens zone, which was exposed after the writers' visit, was reported to be 10 feet wide for a length of 100 feet, with a possibility of further extension beneath overburden; chip samples showed 2.02 per cent U_3O_8 for a width of 5 feet. Fifteen diamond-drill holes, totalling 3,300 feet, were reported to have been drilled along the C zone, with intersections of 3 to 45 inches and assays ranging from 0.01 to 2.99 per cent U_3O_8; the deepest intersection was 170 feet below surface. In 1952 an adit was driven to explore the C zone at shallow depths, and a little additional diamond drilling was done in 1954.

Rexspar Property

The Rexspar property in central British Columbia is 3 miles south of Birch Island station, on the main line of the Canadian National Railways about 80 miles north of Kamloops. It is owned by Rexspar Uranium and Metals Mining Company. An agreement for sale of uranium precipitates was negotiated but difficulties in arranging for financing have so far prevented construction of a treatment plant. Although the property is not producing, it is described briefly because it is the only one in the Cordilleran region for which contract negotiations were made, and because the deposits are fairly distinctive.

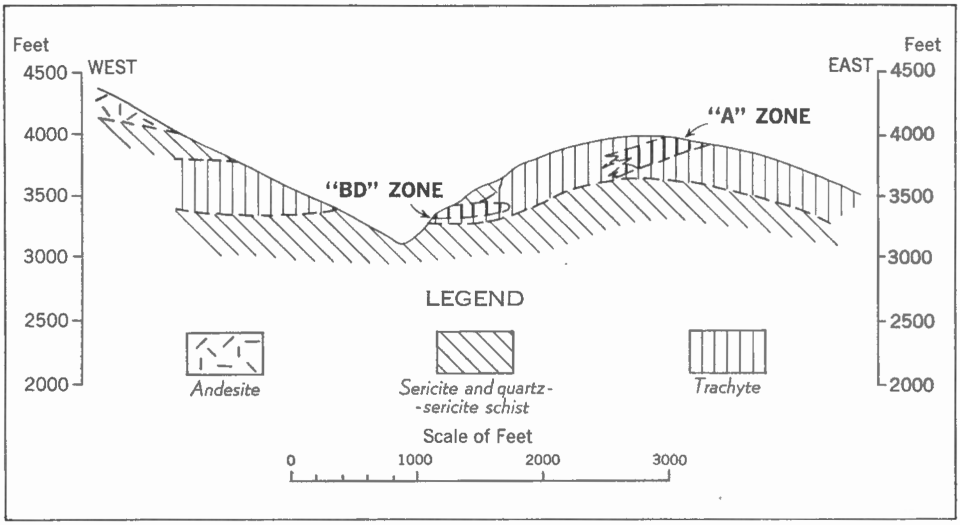


Figure 26. **Section through "A" and "BD" zones, Rexspar property, looking north. From plan by Rexspar Uranium and Metals Mining Company.**

History. The property includes the former Smuggler claim, on which quartz veins containing silver-bearing galena and a little gold were explored by open-cuts and three short adits about 30 years ago. Bog manganese (wad) was discovered on the north slope of the property but an investigation of this deposit proved that it was below commercial grade. In 1942 a separate deposit of fluorite-celestite was diamond drilled and bulk sampled. More than one million tons of material reported to contain 20 per cent fluorite and 15 per cent celestite were outlined in what is known as the 'fluorite zone'. A routine test of diamond-drill core by an officer of the Geological Survey indicated that rock near the fluorite zone was radioactive, and in 1949 an examination by another officer assisted the owners in locating a radioactive zone; other zones were found soon afterwards (Joubin, 1955).

The property was acquired by the present owners in 1950. Under the direction of Technical Mine Consultants Limited, a program of prospecting, geological mapping, trenching, stripping, sampling and diamond drilling was begun. Underground exploration was done on two main radioactive deposits, the "A" zone and the "BD" or "Black Diamond" zone, in hope of establishing a combined operation for fluorite, uranium and, possibly, rare earth metals.

Geology. The rocks at and near the property are described by Walker (1931) as metamorphosed sediments of Precambrian (?) age intruded by bodies of granodiorite and lamprophyre dykes. The ridge on which the deposits were found consists mostly of trachyte, underlain by sericite schist, quartz-sericite schist and argillaceous rocks (*see* Fig. 26). To the west of the workings sericite schist occurs above and below the trachytic member, and these in turn are overlain by andesite. All the rocks have been folded, the sedimentary rocks in particular have become schistose, and the more competent rocks are fractured and faulted. The radioactive zones appear to have been displaced by faults. The general strike of the schistosity near the main deposits is northeast, with dips about 30°NW.

Economic geology. Joubin and James reported (1956) that radioactivity had been found only in the trachytic member, which is composed of a layered complex of light coloured porphyritic feldspathic tuffs, breccias and flows. These rocks show various degrees of sericitization, albitization and carbonatization. The principal radioactive zones are dark layers in the trachytic member. The principal radioactive minerals uraninite and uranothorite are finely disseminated in parts of the trachytic member in which biotite, sericite, pyrite and fluorite are abundant. Other radioactive minerals that have been reported are uranothorianite, pitchblende, bastnaesite, torbernite and metatorbernite. Samples studied in the Mines Branch, Department of Mines and Technical Surveys, contained uraninite rather than pitchblende (M. R. Hughson, personal communication). Bastnaesite was identified first in a sample sent to the United States Geological Survey (Leaming, 1953). The most radioactive material contains fine-grained biotite and pyrite, the latter forming from 5 to 20 per cent of the rock, and is more schistose and banded than lower-grade material which contains coarser-grained biotite and pyrite.

Structural geology. According to Joubin and James (1956) both primary and secondary structural controls have influenced the deposition of the ore minerals. They consider that depositional structures in the trachytic series exercised a primary control because "only the darker-coloured tuff beds usually found in the upper section of the trachytic series have been selectively replaced to form ore. These tuff beds are irregular in detail and to some extent lenticular, probably owing to depositional conditions. Other minor irregularities may be caused by contemporary sills or flows interrupting or lifting the unconsolidated tuffs". Secondary structural control in the form of "shearing parallel to the bedding appears to have exerted some control on mineral deposition, as evidenced by: presence of brecciated fluorite cemented by later fluorite, presence of mineralization only where the characteristic mica has been deformed and recrystallized, marked elongation of pyroclastic fragments parallel to the mineralized layers, layered distribution of pyrite and brecciation of the outer edges of barren trachyte in the tuff layers. The evidence suggests that shearing in the trachytic rocks was concentrated in the weaker tuff beds and that this movement combined with favourable chemical conditions to localize the ore".

The precise classification of the radioactive deposits on this property is indefinite. They appear to be of high-temperature replacement or metasomatic origin.

Deposits. The 'A' zone is a flat-dipping lens that outcrops near the crest of a high ridge between Foghorn and Holt Creeks (*see* Fig. 26). It averages 20 feet in thickness and has been traced along strike for about 600 feet. It appears to pinch out at a slope depth of about 300 feet. An adit at elevation 3,840 feet was driven on the east side of the mountain to explore this zone. Up to the end of 1956 a total of 2,170 feet of crosscutting, drifting and raising had been done. Mineralogical work done on a bulk sample at the Mines Branch showed that the principal radioactive mineral in this zone is uraninite, closely associated with rutile (M. R. Hughson, unpublished report).

The 'BD' or 'Black Diamond' zone outcrops just above Foghorn Creek on the steep western slope of the above-mentioned ridge. It is about 1,600 feet west of the 'A' zone and 500 feet below it. Surface diamond drilling and about 1,000 feet of adit tunnel outlined a flat-dipping lens with a strike length of about 450 feet, dip-slope length of about 300 feet, and an average thickness of 50 feet. In this zone the radioactivity appears to be mainly associated with uranothorite, associated with rutile (M. R. Hughson, unpublished report).

Press releases by the company in 1955 stated that 600,000 tons averaging 1.75 pounds of U_3O_8 per ton were outlined at the 'A' zone, and more than 500,000 tons averaging 1.53 pounds at the 'BD'. The annual report of the company for 1957 stated that about 30,000 additional tons of ore was outlined at the BD zone, and that about 263,500 tons of ore grading 1.53 to 1.56 pounds of U_3O_8 per ton was outlined in another zone called the 'B'. Preparatory work was done for construction of a plant rated at 650 tons of ore a day.

Richardson Deposit

The Richardson, one of the earliest Canadian deposits to be explored for radioactive minerals, is described briefly because it is an example of a zoned

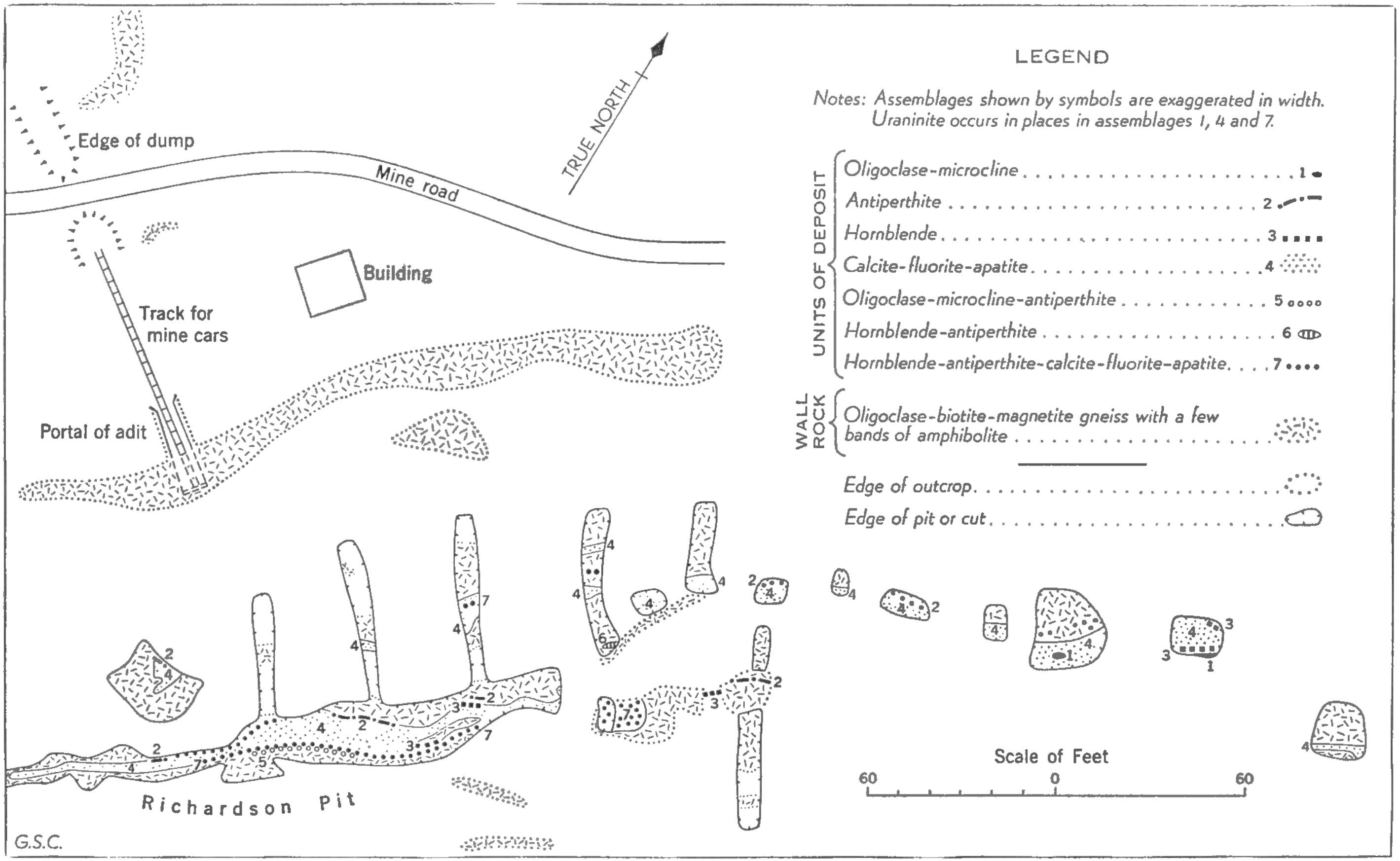


Figure 27. Geological plan of part of Richardson deposit, Fission Mines Limited, Wilberforce, Ontario. From plan by R. B. Rowe, 1952.

calcite-fluorite deposit that has some of the characteristics of pegmatites. It is on claims near Wilberforce, some 16 miles west of Bancroft, Ontario, now owned by Fission Mines Limited. Uraninite was found there about 1922 by the late W. M. Richardson. Trenching and underground exploration were done from 1929 to 1931 when attempts were made to operate the property as a source of radium. Fission Mines Limited acquired the claims in 1946 and did about 12,000 feet of diamond drilling to test the uranium possibilities.

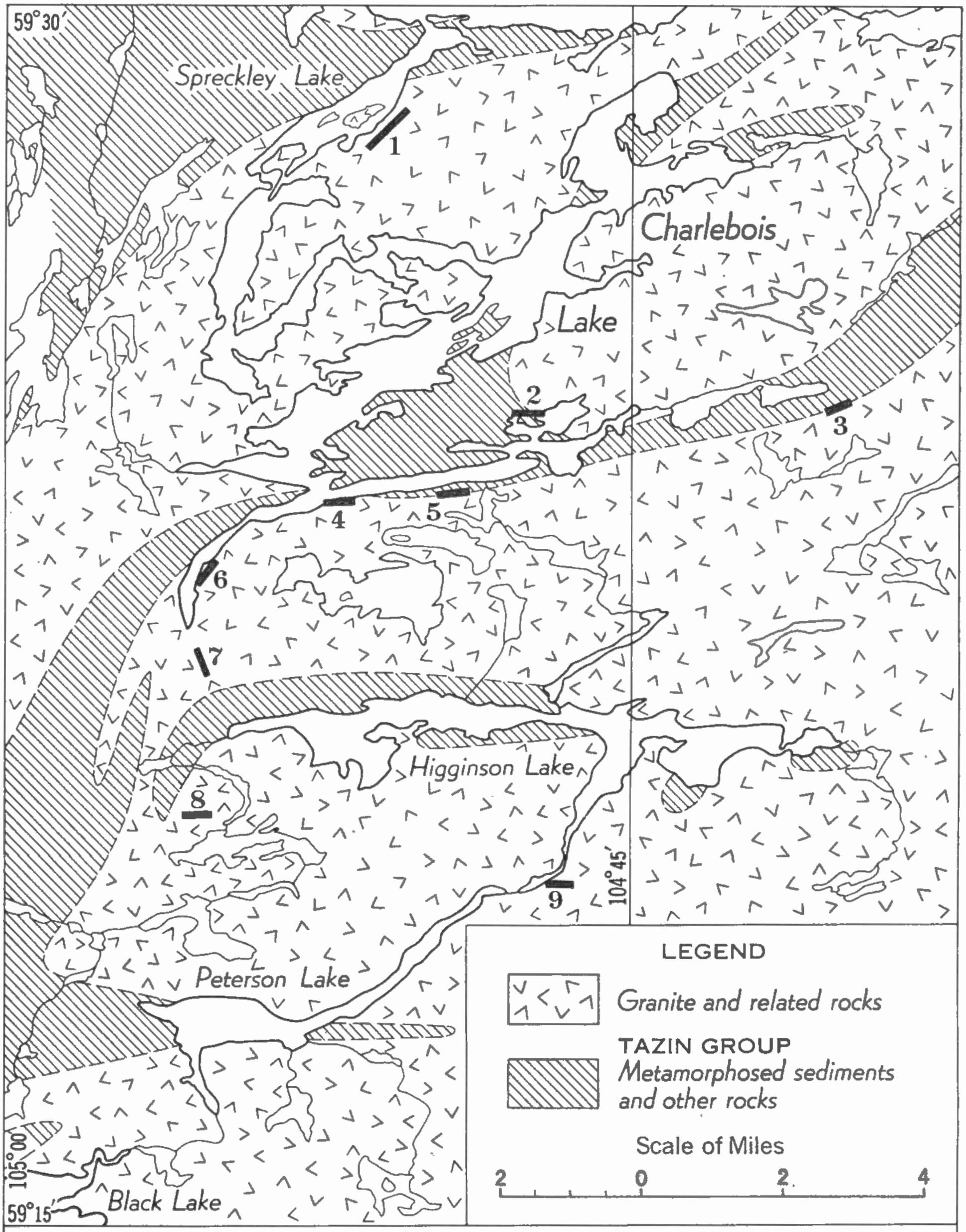
The deposit is in the same general zone of metamorphic rocks as the Cardiff property (*see* Fig. 15), the rocks there being granite, syenite and scapolite gneisses. The Richardson and other deposits on the property are vein-like bodies composed mainly of various proportions of interbanded and contorted calcite, purple fluorite and feldspars. Other minerals reported are pyroxene, apatite, hornblende, black mica, magnetite, and occasional occurrences of uraninite, allanite, uranothorite, zircon, titanite, molybdenite, pyrite and pyrrhotite (Ellsworth, 1932; Satterly, 1957). Some of the uraninite is coarse-grained, a 5-pound crystal being described by Meen (1950).

Rowe (1952) studied the Richardson deposit in detail for the Geological Survey of Canada to test the applicability of the methods of mapping internal structures to deposits of this kind (*see* Fig. 27). He stated:

> The veins of the deposit are zoned and exhibit internal structural and textural features remarkably similar to those of granitic pegmatites (Cameron, Jahns, McNair, and Page, 1948), although they are lithologically different. From the walls inward, the zones are as follows: oligoclase-microcline, oligoclase-microcline antiperthite, hornblende, and calcite-fluorite-apatite core. Zones may be missing or telescoped so that the full sequence is present only in a few places.
>
> Radioactivity at the eastern end of the deposit seems to be associated with the oligoclase-microcline zone, whereas at the western end, it is associated chiefly with the calcite-fluorite-apatite core.
>
> Post calcite-fluorite deformation has caused granulation and flowage of the calcite and fluorite of the core.

Rowe summarized his theory for the origin of the deposit as follows: "The feldspathization of the amphibolite and the production of the zoned Richardson deposit were the result of one process that was motivated by the introduction of high-temperature hydrothermal solutions carrying SiO_2, CO_2, F and B. These solutions penetrated slightly deformed amphibolite and were available when larger fractures, the loci of the zoned bodies, developed. The zonation and mineralogy of the deposit can be explained by the rearrangement of pre-existing material plus the addition of material from the solutions". He believed that the uranium may have been introduced hydrothermally, or that it occurred formerly as an accessory constituent of the wall-rocks and was redistributed by hydrothermal solutions.

At the Richardson pit the main 'vein' is described by Rowe as being 190 feet long and up to about 12 feet wide. The work done by the present owners was mainly to try to establish a fluorite operation with a uranium by-product. They announced that, as a result of drilling, it was estimated that 80,000 tons of fluorite might be recovered from 300,000 tons of rock. The presence of apatite was possibly



INDEX TO DEPOSITS

1. **Spreckley Lake group,** Dee Explorations Limited; 2. **M.C. group;** 3. **Mike group;** 4. **Row group;** and 5. **Sun group,** Charlebois Lake Uranium Mines Limited; 6. **Art group,** The Consolidated Mining and Smelting Company of Canada Limited; 7. **Bell group,** Charlebois Lake Uranium Mines Limited; 8. **Corrigan group,** Dee Explorations Limited; 9. **Rapids group,** The Consolidated Mining and Smelting Company of Canada Limited.

G.S.C.

Figure 28. *Sketch map showing generalized geology, Charlebois Lake region, Saskatchewan. After G. M. Furnival, 1939. Also shows locations of deposits diamond drilled in 1951.*

objectionable. Ten samples from the main 'vein' were reported to have assayed 0.065, 0.114, 0.114, 0.12, 0.07, 0.096, 0.01, 0.01, 0.006 and 0.10 per cent U_3O_8.

Row Property

Several banded, tabular, uraninite-bearing bodies were found in the Charlebois Lake area of northern Saskatchewan, about 150 miles east of Beaverlodge. The deposits lie along contact zones between Precambrian gneisses, schists and other metamorphic rocks of the Tazin group and granitic intrusions (*see* Fig. 28). They have been classed by different workers as pegmatites, migmatites and contact metasomatic deposits. Because of this problem in terminology, and for the sake of brevity, these occurrences are called 'Charlebois type' in the tables at the end of this report. One of the deposits, on the Row group of claims, is described briefly below as an example of this type. This property was selected because it is one of those on which considerable testing was carried out, and is better known to the writers than the others.

Closely related to the granite, but apparently later than it, are zones having the general characteristics of migmatites, containing alternating bands and lenses of medium- to coarse-grained granitic material and schist that is commonly biotitic. Mawdsley (1952, 1958), who studied the deposits in detail, stated that the bands range in thickness from paper-thin to 30 feet. Fine-grained uraninite averaging 0.2 mm is the main radioactive mineral mostly occurring in biotite. Thorianite was found locally, as well as a little molybdenite and pyrrhotite.

The deposits are considered to be related to late differentiation of the granitic intrusions, and to be of the general contact metasomatic class; although commonly referred to as pegmatitic, most lack the coarse texture of typical pegmatites as well as their dyke-like character. Mawdsley found that the most common feldspar is oligoclase. He concluded that the deposits formed where the metamorphosed sedimentary rocks were rich in soda, and that after the typical granitic (or fine-grained pegmatitic) material had consolidated, parts of it were replaced by an end product relatively rich in potash and, still later richer in silica, sulphides of molybdenum and iron, and uranium oxide. He considered that this took place where the almost-consolidated earlier rock was "shattered as a consequence of the great and changing stresses to which it was subjected."

From 1949 to 1952 the Row deposit was explored extensively, first by Arctic Yellowknife Mines Limited and later by Charlebois Lake Uranium Mines Limited. The zone was traced for a length of about 1,700 feet, and intermittent trenching showed its width at surface to be from 7 to 10 feet, and its probable dip to be about 60°S. Diamond drilling at 25-foot intervals along seven sections of the zone was reported to have indicated 432,000 tons averaging 0.06 per cent U_3O_8 equivalent, to a drilled depth of 250 feet. This was not considered economic.

Yamba Lake Occurrence

A low-grade thorium placer occurrence was found at the southwest shore of Yamba Lake in the Northwest Territories, 200 miles northeast of Yellowknife.

A large esker evidently contains small amounts of radioactive mineral. Where the esker follows the shore of the lake, wave action has concentrated the material to make a small beach placer estimated to contain about 70 tons of sand. A sample was separated into a magnetic fraction, which showed 0.001 per cent U_3O_8 equivalent, and a non-magnetic fraction which showed 0.037 per cent U_3O_8 equivalent. All radioactivity was attributed to thorium, but the mineral was not identified definitely. It is probably monazite, derived from the weathering of gneisses injected by granite or pegmatite containing monazite.

Yates Property

The Yates property contains examples of the class of deposits that seem to be of contact metasomatic origin, one being fairly well exposed by an adit. The property comprises lots 18 to 21 of range IV and lots 17 to 20 of range V in Huddersfield township in Quebec about 60 miles northwest of Ottawa. There mica was mined from a pegmatite dyke many years ago. During the recent interest in uranium J. M. Yates detected radioactivity at one of the old pits. This led to the formation of Yates Uranium Mines Limited and, from 1953 to 1956, to extensive prospecting and diamond drilling and some underground exploration, which resulted in discovery of six zones of the contact metasomatic type, called the Matte, Camp, Lake, Belanger, Cliff, and Belisle.

The deposits are in the Grenville province of the Canadian Shield, which there includes bands of crystalline limestone and bodies of pyroxenite (meta-pyroxenite) that appear to be of contact metasomatic origin.

The Matte zone on surface consists of a lens of crystalline limestone and meta-pyroxenite in contact with granitic pegmatite on the northeast or foot-wall side and with mixed gneisses of Grenville type on the hanging-wall. The zone has been stripped and trenched along its northerly strike for about 600 feet showing the average width of the limestone lens to be about 20 feet. Uranothorite, thorite and allanite are distributed sparsely throughout the crystalline limestone. The deposit is generally most radioactive where its main constituent, calcite, is salmon pink in colour. Probably the most conspicuous feature of this deposit is the great abundance of fluorite, mostly of the purple variety, and large crystals of apatite; biotite, diopside and pyroxene crystals are also present in the crystalline limestone.

A 500-lb bulk sample from the Matte zone was sent to the Mines Branch by the company. An analysis of a head sample of this material showed 0.089 per cent U_3O_8 and 0.32 per cent ThO_2. Radioactivity was found to be due entirely to uranothorite.

About 10,000 feet of diamond drilling was done to explore the Matte zone to a depth of 600 feet and for a length of 600 feet along strike. A 300-foot adit driven to crosscut the Matte zone intersected the limestone about 130 feet vertically below the surface showing. About 200 feet of drifting was done along the limestone bed, which there was estimated to be 30 to 50 feet wide. The part of the zone exposed underground consists of brecciated crystalline limestone and metapyroxenite with pegmatitic intrusions. Most of the fluorite, apatite and spotty occurrences of radioactive minerals are in the hanging-wall part of the limestone bed.

The Lake zone, 3,200 feet distant along the strike of the Matte zone, is similar geologically to it. Samples from this zone were reported by the company to average 0.193 per cent U_3O_8 and 1.29 per cent ThO_2.

The Camp zone consists of a band of crystalline limestone and pyroxenite traceable for 500 feet with widths ranging from 10 to about 45 feet, and is probably succeeded on strike by a series of similar bodies. Beta-uranotile, a yellow secondary product of uraninite, was the only radioactive mineral recognized.

The Belanger showing is in a lens of limestone and pyroxenite more than 95 feet long and 10 to 15 feet wide, but extending less than 25 feet down the dip. Uranoan thorianite, the chief radioactive mineral, is accompanied by smaller amounts of thorite, allanite and beta-uranotile and occurs chiefly in the limestone in association with green diopside and coarse pink calcite. The distribution is not uniform; and pod-like masses of 'high grade' material, probably of the order of 0.10 to 0.15 per cent U_3O_8 over 20 to 25 square feet, are separated by areas of much lower grade.

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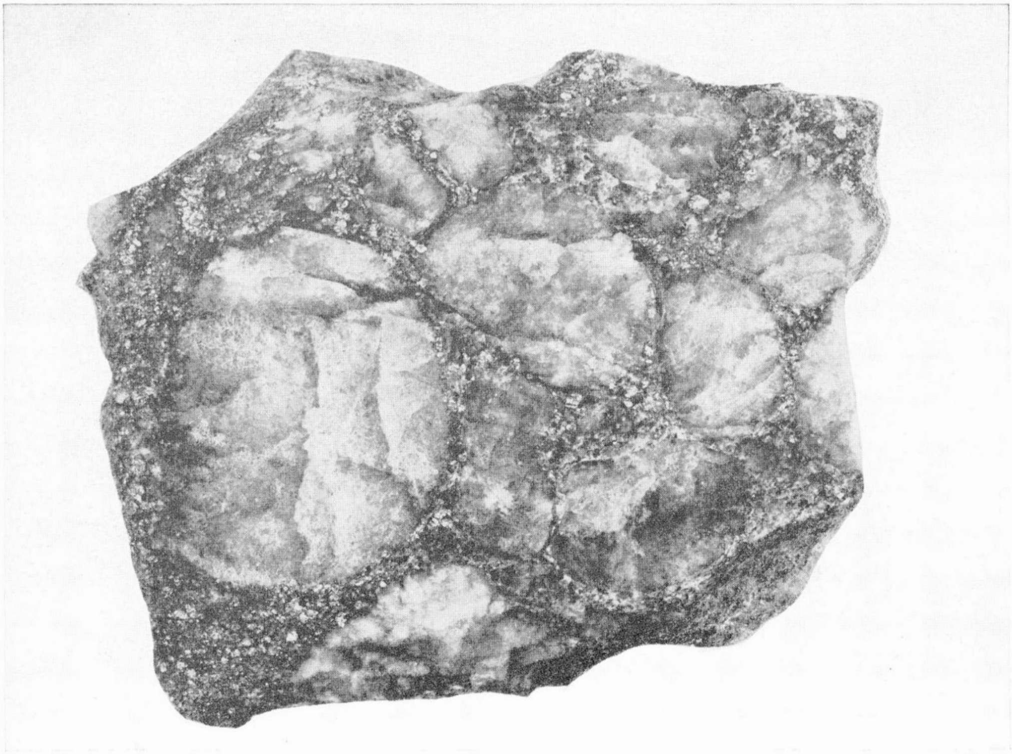
7-1-57 J.W.G.

A. Typical conglomerate ore underground, Blind River area.

Plate II

B. Sharp basal contact of conglomerate ore, Pronto mine.

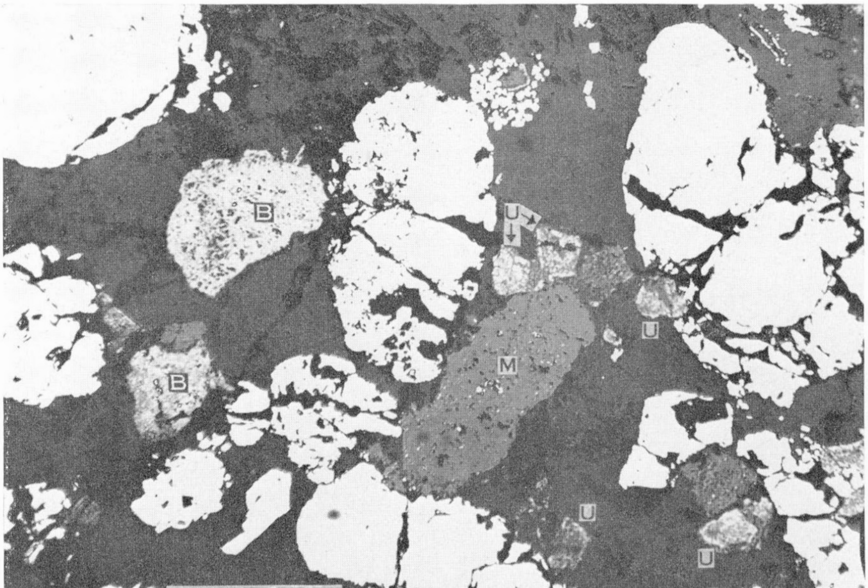
4-4-57 J.W.G.



111530

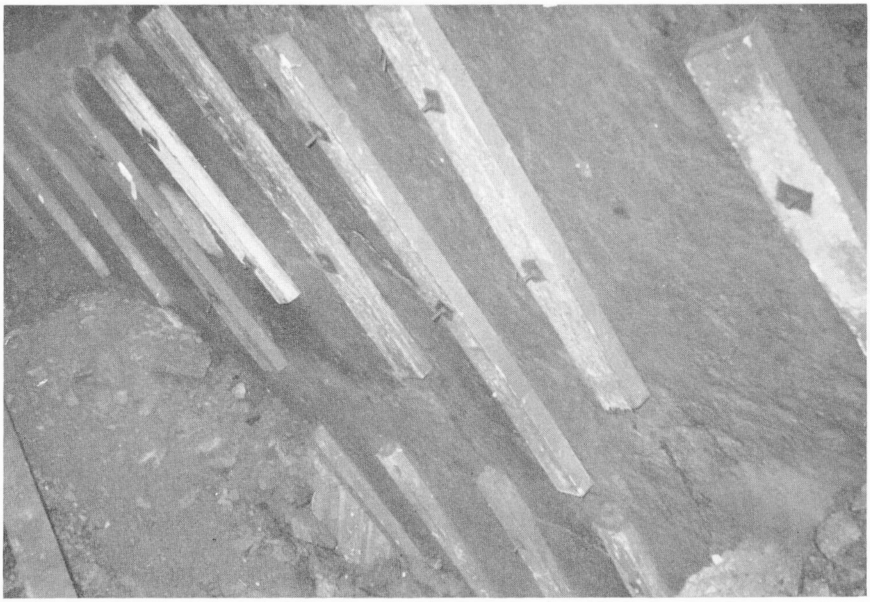
A. *Specimen of typical ore, Blind River area. Natural size.*

Plate III



111534

B. *Photomicrograph of a polished section of the conglomeratic matrix of a specimen of Blind River ore, showing the three principal radioactive minerals, brannerite (B), uraninite (U), and monazite (M). The light coloured grains are pyrite; the dark greyish background is chiefly quartz and white mica; and the black spots are pits produced during the polishing process.*



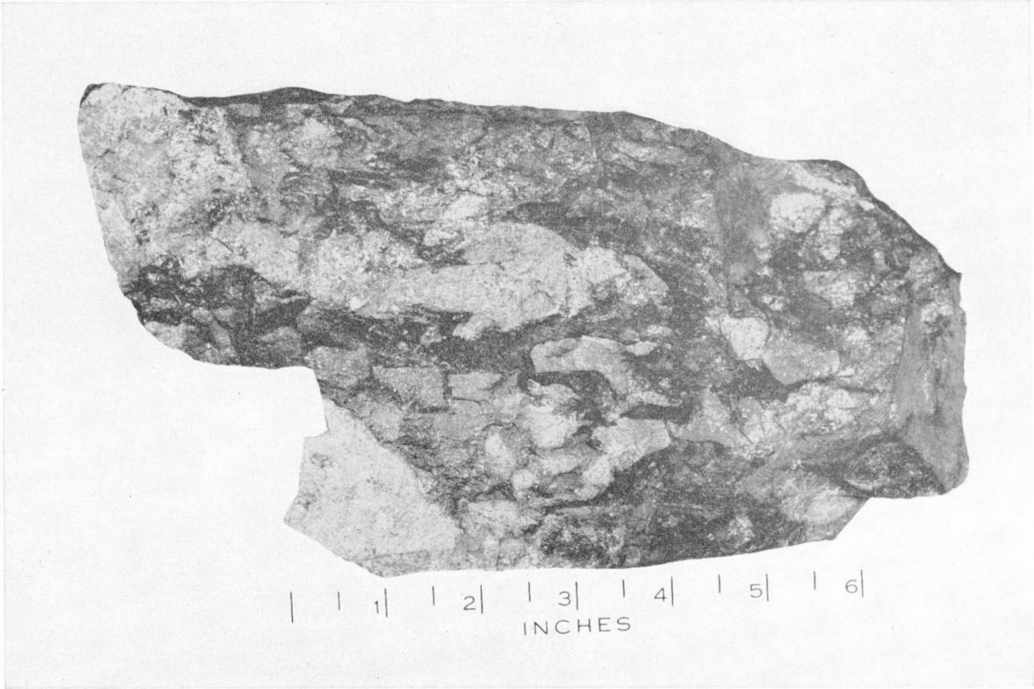
1-6-56 J.W.G.

A. *Hanging-wall of St. Louis fault, Ace mine.*

Plate IV

10-6-56 J.W.G.

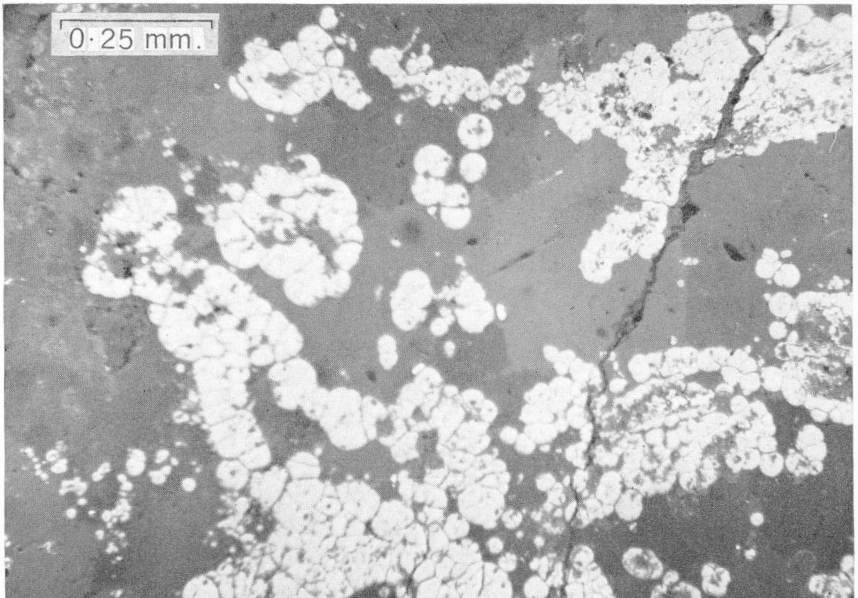
B. *Open-pit, Gunnar mine.*



111528

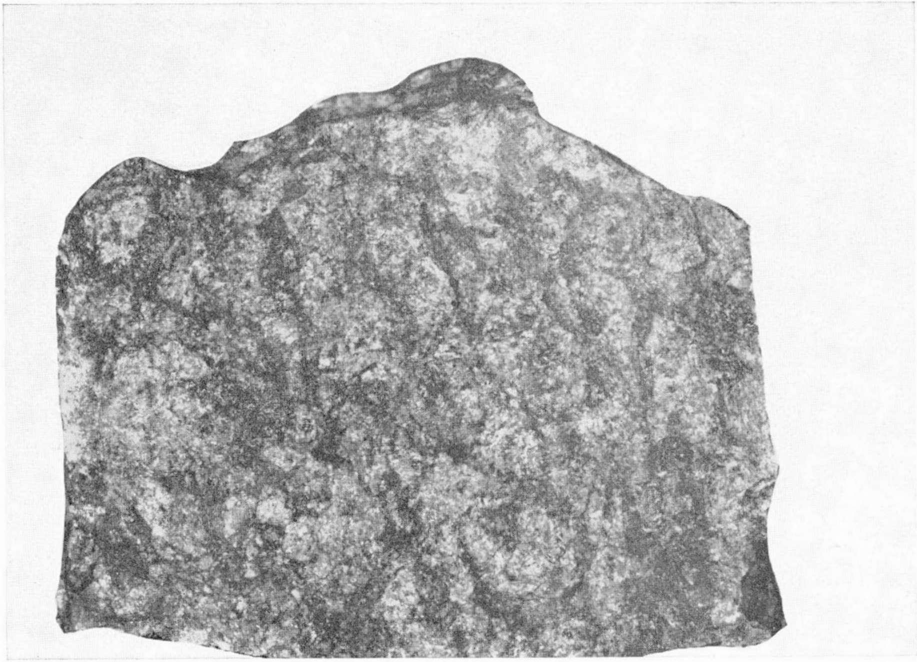
A. *Specimen of high-grade ore, Ace Mine. Black areas are chiefly pitchblende.*

Plate V



111535

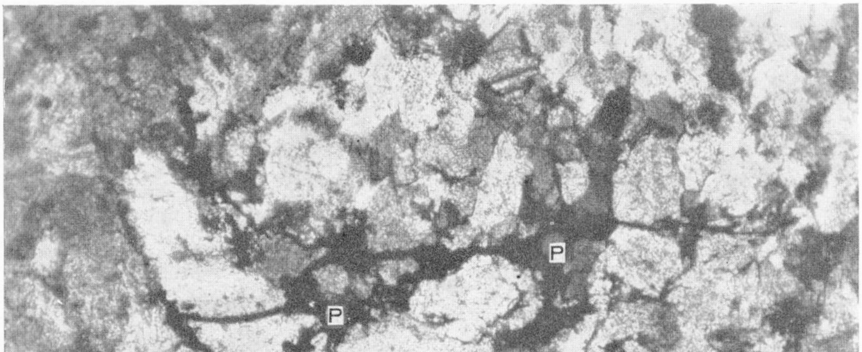
B. *Photomicrograph of a polished section of ore from the Beaverlodge region, showing coalescing spheroids of pitchblende (light grey) in calcite (dark grey).*



111531

A. *Specimen of ore, Gunnar mine. Natural size.*

Plate VI



111532

B. *Photomicrograph of a thin section of ore from the Gunnar mine, Beaverlodge area, Saskatchewan, showing pitchblende (P) rimming and replacing grains of quartz.*

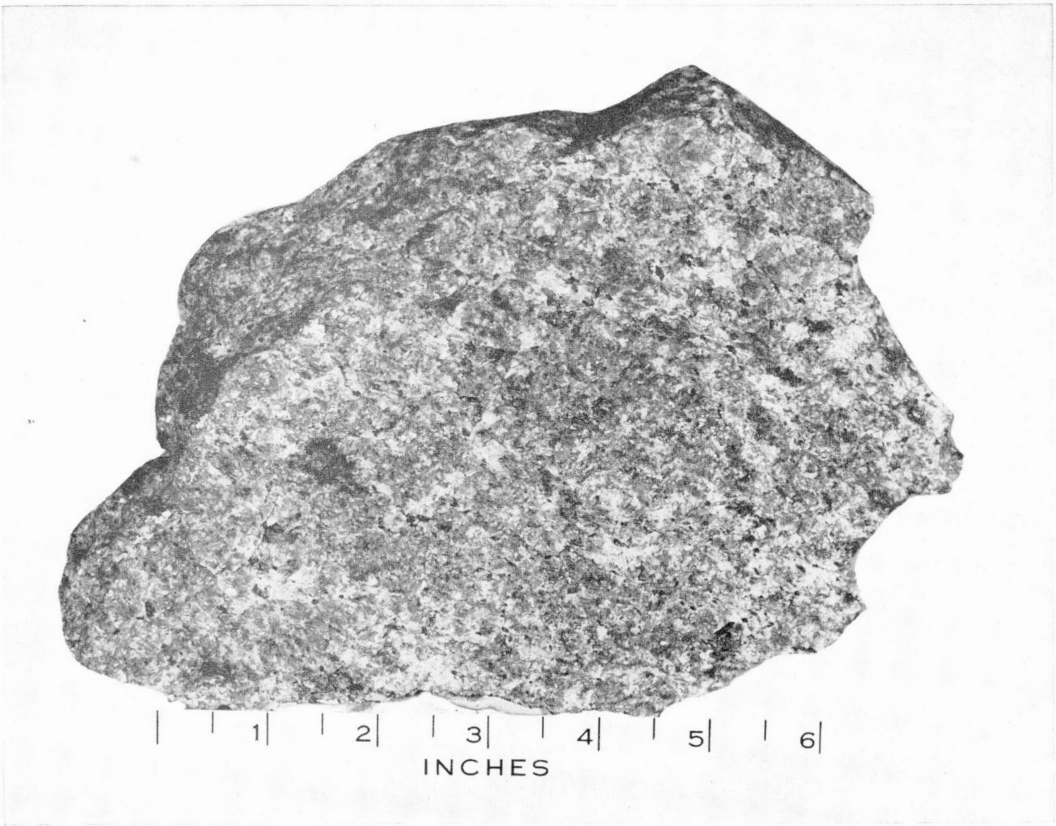
2-5-57 J.W.G.

A. Contact between paragneiss (left) and pegmatite, Bicroft mine.

Plate VII

B. Pegmatitic ore, Faraday mine.

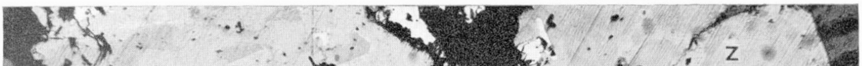
13-3-57 J.W.G.



A. Specimen of pegmatitic granite ore, Bancroft area.

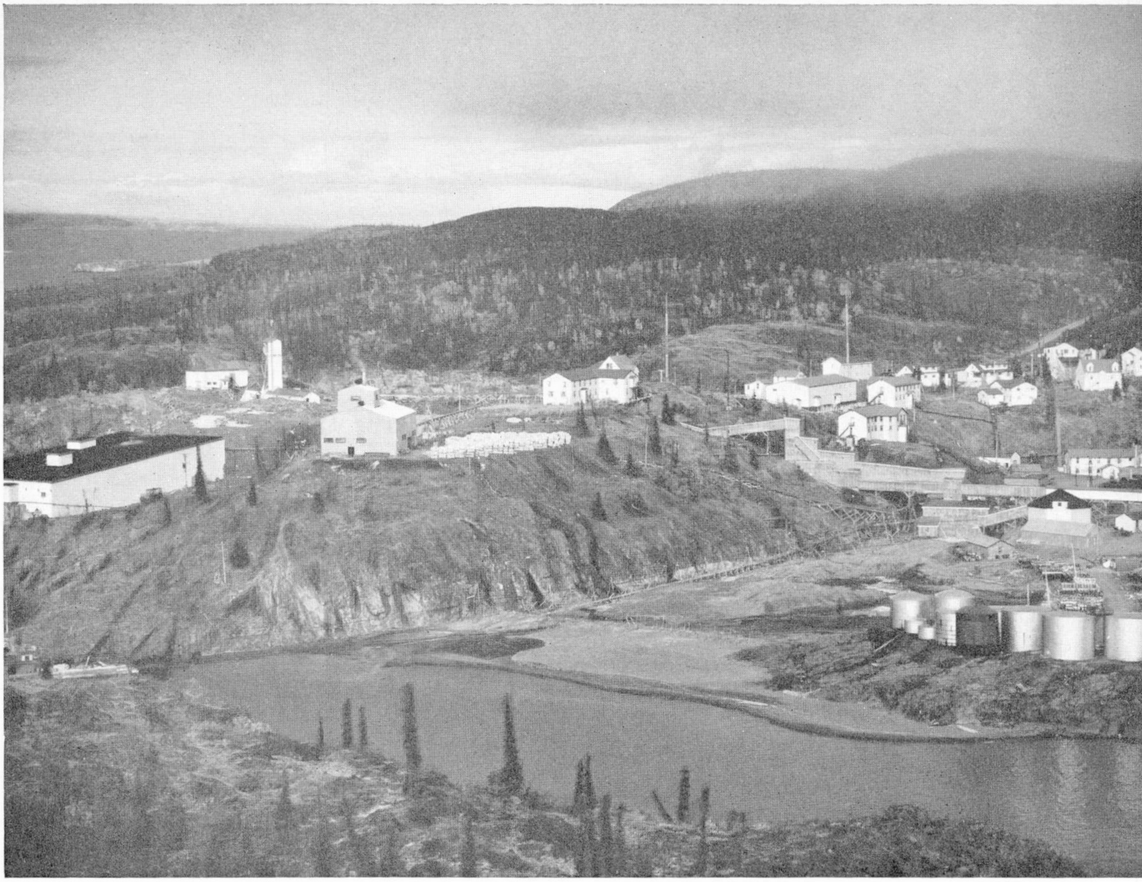
111529

Plate VIII



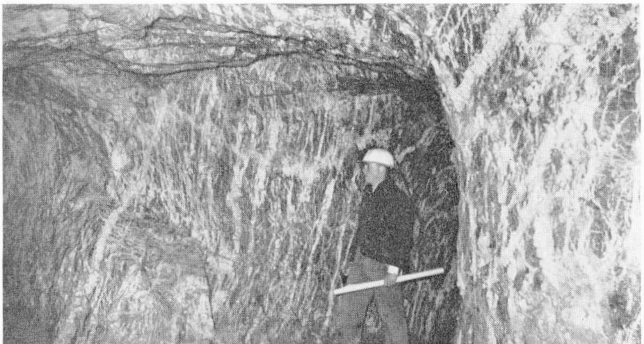
111533

B. Photomicrograph of a polished section of pegmatitic granite ore, Bancroft area, Ontario, showing uraninite (U), titanite (T), magnetite (M), and zircon (Z). The dark grey part is quartz. Note the reaction rim where the uraninite is in contact with the titanite. The black areas and irregular lines are pits and fractures, and illustrate the shattering produced by radioactive minerals in pegmatitic rocks.



A. Eldorado mine, Great Bear Lake. Note dredge in left foreground, for recovering old tailings. Photo by George Hunter, by courtesy of Eldorado Mining and Refining Ltd.

Plate IX



8-8-56 J.W.G.

B. Quartz stock-work in which Rayrock orebodies occur (orebodies not so suitable for photography).

TABULAR DATA FOR RADIOACTIVE PROPERTIES

Explanatory Notes

Scope. The following tables list brief information on most mining properties from which uranium or thorium in amounts of 0.05 per cent or more, or uranium or thorium minerals, were reported up to the end of 1957. Because of the decline in prospecting for uranium thereafter, too few additional discoveries were reported to warrant changing the tables, which were nearing completion by the end of 1957. A few discoveries that were known earlier are omitted because permission to publish information was not obtained, but the number is insignificant. All reasonable efforts were made to allow for changes in ownership and claim groupings, but a few omissions or duplications on this account are almost inevitable because of the enormous amount of data handled and the failure of some claim holders to report fully. In a few instances concessions that are known to have expired are included because of uncertainty as to subsequent re-staking. In a few other instances occurrences that were reported but perhaps never staked are included. The tables are arranged by provinces, and the Yukon and Northwest Territories, because it is believed that for certain uses this will prove convenient. Consideration was given to segregation according to mining divisions or camps but it was decided that the complications would outweigh the usefulness. The information given in the tables has been considered and checked as carefully as circumstances permitted but is not guaranteed.

Name. An attempt has been made to select the most appropriate short name for a property or unstaked occurrence, taking into consideration the fact that geographical or claim names are more likely to be permanent than the names of claim holders. For Ontario and Quebec, township designations have generally been adopted. In Western Canada, where few of the mining areas are subdivided into townships, the names of claims or claim groups have generally been used. Where the foregoing designations are lacking or incomplete, names of lakes or other features, or names of discoverers or property holders have been used. In some instances supplementary names are included in parentheses.

Location. Additional brief information on the location is included in a separate column. Where possible the concession and lot numbers are listed, but in unsurveyed territory the nearest well-known lake, river, or town is usually cited. In the Saskatchewan tables the expression 'Beaverlodge Lake area' is used for an area within a 20-mile radius of the centre of Beaverlodge Lake.

Owner, etc. The names of individuals or companies given in the tables are not necessarily the present owners but the last on the records. The addresses of companies are not included because they can be found in directories.

Type. The conventions used for types of deposits follow those outlined in the section on types in Part II of this report so far as practicable. In some instances deposits had to be classed arbitrarily as granitic or pegmatitic, because of incomplete information. Metasomatic types have not been differentiated in all cases between the general type and the fenites. The term vein is used as a short, convenient word to include small and large tabular bodies, whether fracture-fillings, replacements, disseminations, or breccia fillings. Where more than two are listed for one property, separate occurrences of different types have been distinguished.

Radioactive minerals. The names used are in accordance with the section on mineralogy in this report, except for recent revisions in that section after the tables were completed. Where possible, the mineral most likely to be of economic significance, if any, is listed first, and others are listed in decreasing order of abundance if this is known. In many instances the presence of radioactive material is based on results of radiometric or other forms of assaying, without supplementary mineral identifications.

Stage of exploration. Most properties have been prospected with a Geiger counter in some manner. Unless owners of properties specifically reported work done as "detailed Geiger counter survey" or "radioactivity grid survey", such work as preliminary "prospecting" and "Geiger counter reconnaissance" was omitted. For the purpose of these tables stages of exploration have been standardized as follows:

Scintillometer grid survey
Airborne radioactivity survey
Trenched, stripped or open pitted
Bulk sampled[1]
Diamond drilled[2]
Underground
Underground (producing)

References. Where available, at least one reference to more detailed publications exclusive of newspapers is included. Where several are available an attempt was made to list the most recent references, or what is considered the most detailed account, or both. Only enough information is included in the tables to permit relation to the list at the end of this report. Page numbers are omitted in the interests of brevity, because most lengthy publications contain indexes. References to producing deposits are included in the descriptions in Part III. Persons desiring unpublished information on properties should write the owner rather than the Geological Survey of Canada, because the latter does not have sufficient staff to permit correspondence on these matters even in those instances where the owners would permit it to do so.

A few anonymous articles are indicated "Anon" and will be found near the beginning of the list of references on page 214.

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[1] This is rarely used because most occurrences have been sampled in some form.

[2] Includes all forms of diamond drilling, i.e. pack-sack type, X-ray, standard heavy rig, and both large and small footages.

Abbreviations Used in Tables

Anon—anonymous
Assoc—Associates
Br—Branch
Co—Company
Cons—Consolidated
Con(s)—Concession(s)
Corp—Corporation
Cty—County
Dd or dd—diamond drill(ed)(ing)
Develop—Development
Divs—Divisions
E—East
Eldorado—Eldorado Mining and Refining Limited
Explor—Exploration(s)
ft—foot or feet
GML—Gold Mines Ltd.
gp or Gp—group
GSC—Geological Survey of Canada
hwy—highway
in or ins—inch or inches
L—Lake
lb—pound or pounds
Ltd—Limited
mag—magnetometer
mi—mile(s)
Mich—Michigan
Min—Minister
min(s)—mineral(s)
N—North
No—number
NW—Northwest
occ(s)—occurrence(s)
p—page
Pen—Peninsula
PO—Post Office
pp—pages
Pres—president
prop—property
Pros—prospecting
Pt—Point
pub—publication
R—River
rge—range
rges—ranges
RR—Railroad
S—South
scint—scintillometer
ser—series
S½—south half
St—Street
Sta—Station
Ste—Saint
Synd—Syndicate
tp(s)—township(s)
UML—Uranium Mines Ltd
uran—uranium
W—West
*—described in text

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
				ALBERTA			
All-Rabo	Leggo Lake area, NE corner of Alta	Dog River Mining Co	Vein	Pitchblende and its alteration products	Trenched		
Aye 1-15	Near Fort Chipewyan	American Yellowknife Mines Ltd	Pegmatitic	Yellow secondary mins			
Biggs occ	Tp 115, rge 7, N of Flett L, W 4th mer	J. Biggs, McMurray, Alta	Pegmatitic				
Chip-Chico-Kazan-Lassie gps	10 to 6 mi N of Fort Chipewyan	New Delhi Mines Ltd	Pegmatitic	Yellow secondary mins, monazite, uraninite	Diamond drilled	Collins and Swan, 1953	
Fort Chipewyan occ	Tp 113, rge 6, W end of L Athabasca	New Delhi Mines Ltd	Pegmatitic	Secondary mins, monazite, uraninite	Diamond drilled		Also known as Giauque discovery
Holman occ	Tp 115, rge 7, Flett L area	H. L. Holman, 628-16th St NW, Calgary, Alta	Vein	Monazite			
Jo 1-15	Near Fort Chipewyan	Radiore UML	Pegmatitic	Yellow secondary mins			
Joe-Bep-Bip	Fort Chipewyan area	Beta Gamma Mines Ltd	Pegmatitic				
JS-DR	55 mi SE of Fort Smith	Dog River Mining Co	Pegmatitic				

Lassie-Per	N of Fort Chipewyan	New Delhi Mines Ltd	Pegmatitic	Cyrtolite, monazite	Trenched		"B" zone of Chip-Chico-Kazan-Lassie gps
TBY and BYT gps	5 mi N of L Athabasca at Fidler Point	Goldfields UML	Vein	Pitchblende	Diamond drilled	Ferguson, 1953	
YEI-KNI-AV-DD	Fort Chipewyan area	New Delhi Mines Ltd	Pegmatitic	Secondary mins			
			BRITISH COLUMBIA				
Abe	6 mi S of Fraser Lake village	J. Pataji, C.S. Powney, A. Almond and others, Vanderhoof, BC		Autunite ?, sabugalite, torbernite	Trenched		
Adams Lake occ	Kamloops area	M.D. McKechnie, B C Dept of Mines				Ann Rept, Min of Mines, BC, 1955	
Am	Skagit R tributary near mi 30 on Hope-Princeton hwy	Canam Mining Corp Ltd		Uraninite, monazite		Ann Rept, Min of Mines, BC, 1949	
Arctic Trout	Between Parsnip R and Tudyah L	N. Nicholls, 4444 SE Marine Dr, Burnaby, BC					
Armstrong	5 mi E of Armstrong	L.J. Bird, Armstrong, BC	Pegmatitic	Uraninite ?		Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Arrow Lake	9 mi W of Arrow Park	J. Drummond, Carroll's Landing, Nakusp, BC	Granitic ?				
Atlin (Boulder gp)	Headwaters of Boulder Ck, NE of Atlin	Magnet Cove Barium Corp	Contact metasomatic	Zeunerite, uraninite, metazeunerite	Trenched		
Atlin (Husselbee occ)	10 mi NW of Atlin, between Atlin L and Tagish L	W.J. Husselbee and associates, Atlin, BC	Contact metasomatic	Uraninite, thorite	Diamond drilled ?	Ann Rept, Min of Mines, BC, 1953	
Bell	2 1/2 mi S of Harrison Hot Springs on Harrison L	L.G. Woodman, Box 426, Whiterock, BC	Vein				
Black Diamond	Chu Chua	R. Johnston, Chu Chua, BC				Lang, 1952	This may be same Black Diamond deposit now owned by Rexspar
Bugaboo Creek* occ	Head of Bugaboo Ck, W of Brisco, BC	G.O. Reid, Box 327, High River, Alta	Placer	Pyrochlore		Lang, 1952, Ann Rept, Min of Mines, BC, 1953	
Bugaboo placers	Bugaboo Creek, Selkirk Mtns	Quebec Metallurgical Industries Ltd	Placer	Uranothorite, zircon, euxenite, pyrochlore, uraninite, allanite	Drilled	Ann Repts, Min of Mines, BC, 1927, 1928	Principally a niobium (columbium) deposit

Bullock mine	Lardeau area, near Poplar Creek P O	Nelson Lardeau Mines Ltd, KWC Block, Nelson, BC	Vein ?	Autunite ?, torbernite ?	Old underground workings	Ann Rept, Min of Mines, BC, 1952	Former gold workings
Churchill	Zeballos area, at head of Lime and Fault creeks	S.N. Ray, 4717 Pender St, Vancouver, BC					
Clark-Lute Creek-Yule-etc	Cedar Creek, 3 mi E of Birch Island	Deer Horn Mines Ltd	Hydrothermal (replacement ?)		Diamond drilled		Under lease to Rexspar. Formerly known as Lynn-Stan-Clark-Yule
Clinton occ	Near Clinton	R.A.A. Johnston, GSC, reported	Pegmatitic			Lang, 1952	
Cobalt	4 mi N of Pyramid near Chappel Ck	B. Wiebe, Likely, BC					
Cranbrook area occ	Western slopes of Rocky Mtns, 20 mi W of Cranbrook	E. Frost, Cranbrook, BC	Vein				
Dall Lake occ	Lat 58°40' N, long 127°30' W	R. Anson-Cartwright, 30 Wineva Ave, Toronto, Ont.	Float in a creek			Lang, 1952	
Delta and Highland Boy	Hazelton area	A. M. Whiteside, M.S. Logan, 615 W Pender St, Vancouver, BC	Vein ?		Underground	Lang, 1952	
Demon and Colti groups	Near head of Moose Ck, just SE of Yoho National Park	W.H. Patmore et al, 2826 Alamein Ave, Vancouver, BC	Metasomatic ?	Niobium and thorium mins		Ann Rept, Min of Mines, BC, 1954	Also known as Moose Creek occ

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
François Lake occ	3 mi E of E end of François L	B. Almond and associates, Vanderhoof, BC					
Gem	25 mi NW of Bridge R camp	J.M. Taylor, 1949 Beach Ave, Vancouver, BC	Pegmatitic	Allanite, uraninite	Underground	Lang, 1952; Ann Rept, Min of Mines, BC, 1948, 1956	Also known as Little Gem
Genelle area occ	7 mi N of Trail near No 3 hwy	R.G. Tjader, Trail, BC	Pegmatitic	Uraninite, monazite			
Giant and Coxey mines	Rossland	Giant: CM&S Coxey: A.J. Arland, 3692 Osler St, Vancouver, BC	Vein ?		Underground	Lang, 1952	Formerly worked for gold and copper
Gibson Creek occ	N of Castlegar	J. Sawchenko and associates, 207 Gore Ave, Vancouver, BC	Granitic	Uraninite	Pit work		
Gold-Thorium claim	Foot of Grand Canyon on Fraser R near Sinclair Mills	E.P. Short, Sinclair Mills	Placer			Lang, 1952	
Golden Wonder claim	Juniper Ck, Rocher Déboulé Mt, Hazelton camp	G.L. Oates, 4350 Capilano Rd, North Vancouver, BC	Vein	Uraninite	Underground	Lang, 1952	
Grandview claim	5 mi N of Houston, BC	C.S. Powney, Fort St James, BC					

Granite Creek occ	5 mi S of Manson Creek village	Northwestern Explor Ltd	Metasomatic ?	Columbite, uranoan pyrochlore	Stripped	Ann Rept, Min of Mines, 1954	
Henday-Andromeda leases	Bugaboo Creek	D.H. Simpson, Spillimacheen, BC	Placer				
Homestake	Near Hazelton	Western Uranium Cobalt Mines Ltd		Allanite		Lang, 1952	
Hope occ		E. Howard, Minto Mines P O, BC	Placer			Lang, 1952	
Horsefly River occ	Below junction of Horsefly and Mackay Rivers	R.B. Earle, 2254 Bowker Ave, Victoria, BC	Placer				
Index prop	Texas Creek near Lillooet	W.R. Bacon, Ann Rept, Min of Mines, BC, 1949	Vein	Uraninite	Underground	Lang, 1952; Ann Rept, Min of Mines, BC, 1949	Index molybdenite prop
International claim	Lot 932, Yale division at International Boundary near Hope	Rihia Mining Co, 640 W Hastings St, Vancouver, BC		Carnotite ?		Ann Rept, Min of Mines, BC, 1938	Old lead prospect
Kelowna occ	15 mi E of Kelowna	O. Hill, 819 Clement Ave, Kelowna, BC	Pegmatitic	Fergusonite		Lang, 1952	
Lemon Creek occ	S of Slocan	D. Bain, Trail, optioned to Jackson Basin Mining Co Ltd	Pegmatitic ?	Allanite, fergusonite ?	Underground	Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Liard Hot Springs	Near Mile 497, Alaska hwy	Provincial reserve					Radioactivity detected in springs and tuffa
Lucky-Bill-Tag	On Kootenay R near CPR bridge at Sproule Creek	A. and W. Jorgensen and F. Mawer, Nelson, BC	Pegmatitic	Uraninite			
Lucky Boy 1-5	1 mi S of Slocan R and 1/2 mi W of Crescent Valley radio station	F. Esovoloff, Thrums, BC	Pegmatitic	Fergusonite, thorite, samarskite, monazite		Ann Rept, Min of Mines, BC, 1956	
Lucky Day claim	Jerome Creek, Slocan Mining Div	D. Bain, 2233 2nd Ave, Trail, BC					
Lucky Mining claims	Junction of Arrow Ck and Goat R	J. Wolfe, N. Biccum, R. Hawke, Creston, BC		Thorite			
Lytton Bar occ	Lytton, on Fraser R	Reported by S.S. Holland, BC Dept Mines	Placer	Uraninite		Lang, 1952; Ann Rept, Min of Mines, BC, 1948	
Lytton (Botanie occ)	Lytton Ck, Thompson R, Botanie Valley. Adit is 2 mi E of Lytton	Rose Mining Corp			Underground		
Lytton (Paquet occ)	7 mi N of Lytton on Lillooet hwy	F. Paquet	Sedimentary ?	Metazeunerite	Trenched		

Lytton (Ryan occ)	1 mi E of Lytton	C.P. Ryan, Lytton, BC					
Marmurph claims	Not given	M. Whyte, 1900 Belmont St, Victoria, BC	Granitic ?				
McBride occ	Near McBride	T.R. Goodell, McBride, BC	Placer	Radioactivity probably due mainly to thorium			
Molly mine	Lost Creek S of Salmo	CM & S	Granitic ?	Uraninite	Underground	Laug, 1952	Molybdenite prop
Nation River	Omineca Mining District	S.W. Wood, Box 2844, Boise, Idaho	Placer	Monazite, uraninite			
Nicola occ (Guichon mine)			Pegmatitic	Allanite		Ann Rept, Min of Mines, BC, 1949; Lang, 1952	
Pacific Gold UML prop	25 mi NW of Bridge R gold camp	Pacific Gold & UML	Vein	Uraninite ?	Trenched	Lang, 1952	
Paradise	4 mi S of Lempriere Sta	St. Eugene Mining Corp	Metasomatic	Pyrochlore		Ann Rept, Min of Mines, BC, 1952	
Quadra Island occ	Gowland Harbour Quadra Is		Vein ?	Carnotite reported but subsequent examinations failed to find it		Lang, 1952	Primarily a vanadium deposit
Quesnel River occ	8 mi above Fraser R junction	Not given Johnston, GSC, reported	Placer	Monazite		Lang, 1952; Johnston, 1915	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Red Rose mine	Hazelton camp	Western Uranium Cobalt Mines Ltd	Vein		Underground	Lang, 1952	
Rexspar*	Birch Island	Rexspar Uranium & Metals Mining Co	Hydrothermal (replacement ?)	Uraninite, uranothorite, pitchblende and others	Underground		Also known as Smuggler prop
Rocher Déboulé mine	Hazelton camp	Western Uranium Cobalt Mines Ltd	Vein	Uraninite	Underground	Lang, 1952	Former copper, gold, silver producer
Silver Spur 1-12	6 mi E of Kitchener	R.T. Drury, L. Simpson, Kitchener, BC	Vein ?				
Sooke region occ	S end of Vancouver Island	H.H. Heustis, 815-402 W Pender St, Vancouver, BC		Radioactivity mostly due to thorium			
Taseko-Mohawk	Taseko R area, NW of Bridge R camp	L.J. Russell, Lillooet, BC	Vein			Lang, 1952	Also known as Mother Lode-Mohawk
Thistle claim		R.B. Hartt, R.R. 1, Campbell R, BC	Vein	Thucholite ?		B C Dept of Mines, 1898-1905	
Verity	About 23 mi E of Blue R	St. Eugene Mining Corp Ltd optioned from O.E. French	Metasomatic ?	columbite, pyrochlore, zircon, uraninite	Stripped	McCammon, 1952	
Victoria	Hazelton camp	Farwest Tungsten Copper Mines Ltd	Vein and/or pegmatitic	Uraninite, allanite	Underground	Lang, 1952; Ann Rept, Min of Mines, BC, 1948, 1949, 1950	Also known as Hazelton View

MANITOBA

East Found	1 mi W of Star Lake	Whiteshell Uranium Syndicate	Pegmatitic	Cyrtolite, thorite, uraninite, allanite, uranothorite	Pit work	Lang, 1952	
Fox claims	Tooth Lake	J. Ziyone and associates, 112 Machray Ave, Winnipeg, Man			Pit work		
Gem Lake occ		Tooth Lake Mining Synd	Pegmatitic ?				
Huron claim	Pointe du Bois area	Winnipeg River Tin Co	Pegmatitic	Uraninite, monazite, columbite-tantalite		Lang, 1952	Beryl prospect
Remniak	Herb Lake area ?	M. Remniak, Herb Lake, Man	Pegmatitic			Lang, 1952	
Schaller occ	Bird River area	R.J.R. Schaller, Fort Garry, Man				Lang, 1952	
Tooth Lake occ	Tps 20, 21, rge 16, E of 1st meridian	Tooth Lake Syndicate	Pegmatitic				
Triangle	Mileage 101, Trans-Canada hwy	D.S. McLeod optioned to Graham-Bousquet GML	Pegmatitic	Uraninite	Trenched	Lang, 1952	
West Found	Mileage 101, Trans-Canada hwy		Pegmatitic	Uraninite		Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
			NEW BRUNSWICK				
Coxs Brook occ	20 mi SW of Campbellton	C. T. Ritchie, 22 Albertus Ave, Toronto, Ont	Vein ?	Pitchblende or uraninite	Diamond drilled	Gross, 1957	
Hampton occ	3 1/2 mi NE of Hampton Sta	Kingston UML	Vein ?		Diamond drilled	Gross, 1957	
Harvey occ	8 mi SW of Harvey Sta	Rio Canadian Explor Ltd	Vein (replacement)	Uranospinite, saleeite ?	Diamond drilled	Gross, 1957	
Shippigan Island occ	Chaisson Beach	C. McAllister, J.W. McCarthy, Bathurst, NB	Sedimentary (nodules in sandstone)	Uraninite or pitchblende		Gross, 1957	
			NEWFOUNDLAND				
Indian Head occ	St. George's Bay, Nfld		Granitic	Uraninite, gummite		Heyl & Ronan, 1954	
Kitt's showing	Kaipokok Bay, Makkovik area, coast of Labrador	British Newfoundland Explor Ltd	Vein	Pitchblende	Underground		
Monkey Hill occs	Makkovik area, coast of Labrador	British Newfoundland Explor Ltd	Vein and pegmatitic	Pitchblende	Diamond drilled		About 22 occs in area
Ocean View occ	Mouth of Flat Bay River, Nfld	J.J. Dodd, Ocean View, Nfld					
Seal Lake occs	96 mi NW of Goose Bay, Labrador; Ten Mile L area	Frobisher Ltd and Kennco Explor Ltd	Vein and metasomatic	Pitchblende, kasolite, monazite, pyrochlore-microlite ser	Diamond drilled		

Searston occ	Mouth of Grand Codroy River, Nfld	J.J. Dodd, Ocean View, Nfld				
Torbay occ		J.J. Dodd, Ocean View, Nfld				

NORTHWEST TERRITORIES

Abitau R	50 mi NE of Tazin L	New Santiago Mines Ltd			Trenched	
Ace	Hottah L	Hottah Lake Uraniums Ltd			Trenched	Anon: Western Miner, vol 26, No 11, p 142
Achook Island	Gt Bear L	M. Feniak, GSC, reported	Vein	Pitchblende, secondary mins		Feniak, 1949; Lang, 1952
AG	Near Murky Channel, Gt Slave L	C.E. Ridley, Maida, North Dakota			Diamond drilled	Lang, 1952
Balachey occ	SE corner Gt Bear L, Balachey L outlet	Fairmount Explor Co	Vein		Trenched	Lang, 1952
Beaulieu occ	46 mi E of Yellowknife	Beaulieu-Yellowknife Mines Ltd	Vein	Monazite ?		Lord, 1951
Bell claim	Snowdrift area, Gt Slave L	Ridley Mines Holding Co	Vein ?		Diamond drilled	Lang, 1952
Bell gp	10 mi SE of Eldorado, Gt Bear L	Port Radium Mines Ltd	Vein		Underground	Lang, 1952

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Beta* (Rayrock mine)	Near Maryleer L, Marian R area	Rayrock Mines Ltd	Vein	Pitchblende, uranophane, thucholite	Underground (producing)		
Bingo	SE corner of Hottah L	Radiore UML	Vein	Pitchblende	Diamond drilled	Lang, 1952	
Blende	Zebulon L	Bateman, Freakes, Muir, Anderson, Parker; Yellowknife, NWT		Pitchblende		Lang, 1952	
BM	Marian R area	Altomac UML	Vein	Pitchblende	Diamond drilled		
CA 1-7	Marian R area	New Alger Mines Ltd		Pitchblende	Diamond drilled		
Contact L*	9 mi SE of Eldorado	Acadia UML	Vein	Pitchblende	Underground	Lang, 1952; Lord, 1941, 1951	Former silver and pitchblende producer
Copmor-MM	Simpson Island near Harnie Bay, Gt Slave L	J.A. Harquail and associates, Yellowknife, NWT	Pegmatitic ?			Lang, 1952	
Cormac	Hottah L area, E arm of Beaverlodge L	Cons Beta Gamma Mines Ltd	Vein	Pitchblende, uranophane	Underground	Lang, 1952	
DeStaffany prop	N shore Gt Slave L, 60 mi SE of Yellowknife	DeStaffany Tantalum Beryllium Mines Ltd	Pegmatitic	Tantalite	Diamond drilled	Lang, 1952	
Echo Bay	E coast Gt Bear L, E of Labine Pt	Cons Mining & Smelting Co under option to Eldorado	Vein	Pitchblende	Underground	Kidd, 1936; Lang, 1952	

Edgell Island	Resolution gp off SE coast of Baffin Island	C.C. Chappell, Sydney, NS	Pegmatitic	Monazite		Lang, 1952
El Bonanza	E shore Gt Bear L, 6 mi S of Port Radium	El Bonanza Mining Corp Ltd	Vein	Pitchblende	Underground	Lang, 1952
Eldorado mine*	Port Radium, Gt Bear L	Eldorado	Vein	Pitchblende, curite, becquerelite, liebigite	Underground (producing)	
Gamma	Marian R area	Tarbell Mines Ltd	Vein	Pitchblende	Trenched	
Gee	N shore of E arm of Gt Slave L, E of Burpee R outlet	J. McAvoy, 10043 Jasper Ave, Edmonton, Alta	Pegmatitic	Uraninite		Lang, 1952
Glacier L occ	3 mi NE of Port Radium					Lang, 1952
Glen L occ	SW end of lake, 1 1/2 mi E of El Bonanza		Vein	Pitchblende		Lang, 1952
GM	1 1/2 mi NE of entrance to Murky Channel, E arm Gt Slave L	American Yellowknife Mines Ltd	Vein	Pitchblende	Trenched	Lang, 1952
Gossan Island occ	Echo Bay, Gt Bear L					Lang, 1952
Hab 1-14*	McLean Bay near Snowdrift, E arm Gt Slave L	Eldorado	Sedimentary	Monazite, uraninite	Diamond drilled	Lang, 1952

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Hepburn L	Lat 66°22'N, long 115°30'W	A. M. Berry, 10009-101A Ave, Edmonton, Alta					
Hunter Bay occ	E shore of Gt Bear L	Eldorado ?	Vein	Pitchblende	Trenched	Lang, 1952	
JB	20 mi SW of Eldorado mine, Gt Bear L	Fairmont Explor Ltd			Diamond drilled	Lang, 1952	
JG	S shore of Stark L	G. Oystrek and associates, Yellowknife, NWT	Vein?	Pitchblende		Lang, 1952	
JUF	Barnston R area	J. Woolgar, Yellowknife, NWT	Granitic			Lang, 1952	
Key (Eldorado)	Nonacho region, lat 60°54' N, long 109°42' W	Rossland Mining Co	Vein	Pitchblende	Trenched	Lang, 1952	
KR	Treasure L, Marian River area	B. Raymond, Yellowknife, NWT				Lang, 1952	
Lady Grey Lake occ	200 mi SE of Yellowknife; lat 60°54' N, long 100°30' W	T. Payne, Yellowknife, NWT		Allanite		Lang, 1952	
LL	Near Zebulon L, E of Hottah L	I. Bennet, Yellowknife, NWT	Vein	Pitchblende ?		Lang, 1952	

Lode-Sonny Boy	NE end Dowdell Peninsula, Gt Bear L	J.R. Stirrett, 350 Bay St, Toronto, Ont		Pitchblende ?	Trenched	Lang, 1952
Mar	W side of Marian L	Kix Uranium Ltd	Vein	Secondary min	Trenched	
Marian	N of Marian L	Duback Yellowknife Mines Ltd or W. Rossing, Yellowknife	Vein	Pitchblende	Diamond drilled	Lang, 1952
Mystery Island occ	Gt Bear L	Radium Corp of Canada	Vein	Pitchblende	Underground	Lang, 1952
Nicholson L occ	NW end of Nicholson L, SW of Dubawnt L	A. Stinson, Stony Rapids, Sask				Lang, 1952
Nonacho L occ		Eldorado				Lang, 1952
Nori	Culbert L, 50 mi N of Marian R	Radiore UML	Granitic			
Pitch 8-10	Beverley Bay area, Hottah L	United Uranium Corp Ltd	Vein	Pitchblende, torbernite	Undergound	Lang, 1952
Pitch 27, 28	3/4 mi E of NE corner of Hottah L	United Uranium Corp Ltd	Vein	Pitchblende, secondary uran mins	Diamond drilled	Lang, 1952
Pitch-Ind	N shore of E arm, Beaverlodge L	United Uranium Corp Ltd	Vein	Pitchblende, torbernite	Diamond drilled	Lang, 1952
Rag	S shore of Stark L	Radiore UML	Vein ?	Pitchblende	Diamond drilled	Lang, 1952
Rex*	Stark L, E arm of Gt Slave L	Ridley UML	Vein	Uraninite	Underground	Lang, 1952

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Sloan R occ	30 mi NW of Port Radium	Feniak, GSC, reported	Vein	Pitchblende		Lang, 1952	May be same as Hunter Bay occ
Stevens Island occs	12 mi NE of Port Radium					Lang, 1952	
Sun	Marian R area	Cons Northland Mines Ltd	Vein	Pitchblende	Underground		
Ted	Treasure L, Marian R area	Yellowknife Volcanic GML	Vein	Pitchblende, secondary uran mins, thucholite ?	Diamond drilled	Lang, 1952	
Ted 1-13	Marian R area, 3 mi W of Rayrock mine	New Athona Mines Ltd	Vein		Diamond drilled	Lang, 1952	
Tee L occ	56 mi N of Fort Smith	Eldorado	Pegmatitic			Lang, 1952	
Thekulthili L occ	S of E arm of Gt Slave L	L. Kaip and A. Ritz, Likely, BC		Allanite		Lang, 1952	
Thompson	Bow L, E coast Gt Bear L, Echo Bay area	Indore GML	Vein	Pitchblende, secondary uran mins	Diamond drilled	Lang, 1952	Now Pitch 1-4 gp
Troga and Sarga	Gt Slave L, between Taltson and Snowdrift rivers	H. Kloss, Hay River, NWT					

UO	N shore Belleau L, 50 mi NE of Port Radium	Ridley Mines Holding Co	Vein			Lang, 1952
U_3O_8 and Fred	Marian R area	F. Lypka and L. Page, Yellowknife, NWT	Vein	Radioactivity probably mainly due to thorium	Diamond drilled	Lang, 1952
UR	Hidden Bay, W side of Hardisty L	Gold Uranium Explor Ltd	Vein	Pitchblende	Diamond drilled	Lang, 1952
UR 1-14	7 mi W of Snowdrift	Ridley Mines Holding Co	Vein		Trenched	
Uranium	La Bine Point, Gt Bear L	Eldorado	Vein	Pitchblende	Diamond drilled	Lang, 1952
Vance Peninsula occs	N shore of penin, 12 mi NE of Port Radium					Lang, 1952
White Eagle mine	SE corner Gt Bear L near outlet of Camsell R	Camsell River Silver Mines Ltd	Vein		Underground	Lang, 1952
Whitney Lake occ	Whitney Inlet, 35 mi NE of Chesterfield Inlet	N. Scutt, Churchill, Man	Vein	Radioactivity probably mainly due to thorium		
Workman Island occ	E coast of Gt Bear L	International Uranium Mining Co	Vein	Pitchblende	Underground	Lang, 1952
XAM	Barnston R area	J. McAvoy, Yellowknife, NWT	Granitic	Uraninite, secondary uran mins		Lang, 1952
Yamba Lake occ*	Lac de Gras area	Not staked	Placer	Monazite ?		Lang, 1952

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
			NOVA SCOTIA				
Black Brook area	1 1/2 mi up Black Brook from Waugh River	Dawmac Mining & Oils Ltd, King Copper Mining Corp	Sedimentary		Diamond drilled	Gross, 1957	
Georgeville occ	3/4 mi NW of Georgeville	Eastern-Northern Exploration Ltd	Pegmatitic	Cyrtolite, uranothorite		Gross, 1957	
New Ross occ	3 mi N of New Ross, Lunenburg cty	Eastern-Northern Exploration Ltd	Vein	Torbernite ?	Diamond drilled	Johnston, 1915; Lang, 1952; Gross, 1957	
			ONTARIO				
Admaston tp	Con 11, lot 7	J. Mask, Renfrew, Ont	Radioactive float				
Agawa Bay area	N of Agawa Bay, L Superior	J. Franz, Jr, Sault Ste Marie, Ont	Vein	Pitchblende		Lang, 1952	Also known as Franz gp
Agawa River occ	About 1 mi NW of mouth of Agawa R	J.G. McCombe, 651 Queen St E, Sault Ste Marie, Ont	Vein		Trenched	Lang, 1952	Also known as Ottawa Associates prop
Alice tp	Con 15, lot 13	R. McCoshen, Sudbury, Ont		Euxenite-polycrase ser		Lang, 1952	
Anstruther tp	Con 1, lots 17, 18	Zenmac Metal Mines Ltd	Granitic	Uranothorite	Diamond drilled	Satterly, 1957	
Anstruther tp	Cons 1, 2, lots 19-28	Aubelle Mines Ltd	Granitic		Diamond drilled	Satterly, 1957	

Anstruther tp	Con 3, lots 22-28; con 4, S1/2 lots 23-27	Farcroft Mines Ltd	Granitic	Uraninite, allanite, uranothorite	Diamond drilled	Satterly, 1957	
Anstruther tp	Cons 4, 5, lots 16-22	Avillabona Mines Ltd	Granitic		Diamond drilled	Satterly, 1957	
Anstruther tp	Cons 4, 5, lots 23-27	Brunsman Mines Ltd	Granitic	Uranothorite	Diamond drilled	Satterly, 1957	
Anstruther tp	Con 9, N1/2 lot 2 and N1/2 lot 3	Gray Wolfe Exploration Co Ltd	Granitic	Uranothorite, allanite, zircon	Diamond drilled	Satterly, 1957	Also known as Stony Creek property
Anstruther tp	Cons 9, 10, 11, lots 29-35	El Sol Gold Mines Ltd	Granitic	Uranothorite, zircon	Diamond drilled	Satterly, 1957	
Anstruther tp	Con 10, N1/2 lot 2; con 12, S1/2 lot 3	Higgins Uranium Mines Ltd	Granitic	Uranothorite, zircon	Diamond drilled	Satterly, 1957	
Anstruther tp	Con 11, lot 36	R. Halliday, Apsley, Ont					
Anstruther tp	Con 17, S1/2 lot 4	K. Webster, Gooderham, Ont	Granitic				
Anstruther tp	Con 17, lots 5 & 6; con 18, lots 4-9	Garland Mining & Development Co Ltd	Granitic	Uraninite, allanite, uranothorite, cyrtolite	Diamond drilled	Satterly, 1957	
Anstruther tp	Con 18, lots 21-24	Anstruther Rare Metals Ltd	Granitic		Diamond drilled	Satterly, 1957	
Anstruther & Burleigh tps	Anstr: con 1, lots 26, 27; Bur: cons 11 & 12, lots 23-25	Newkirk Mining Corp Ltd	Granitic	Uraninite, allanite, uranothorite, zircon, melanocerite	Diamond drilled	Satterly, 1957	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Aubinadong gp	Tp 4G, E end Ranger (Aubakagama) Lake	H. Evans, Gros Point, Mich	Granitic	Uraninite ?	Stripped	Lang, 1952	
Awrey and Street tps	14 mi E of Sudbury on hwy 17	L. L. Peer, Wahnapitai P O, Ont	Granitic	Allanite	Trenched and airborne geophysical		
Bagot tp	Con 4, lot 23	Goldyke Mines Ltd		Uraninite			
Bagot tp	Con 4, lots 27, 28	Zenith Molybdenite Corp				Lang, 1952	
Baldhead River occ	Mouth of river on shore of Lake Superior	Soo-Tomic UML	Vein	Pitchblende	Diamond drilled	Lang, 1952	
Baldwin tp	Agnew Lake	Jellicoe Mines Ltd	Conglomeratic		Diamond drilled		
Baldwin & Hyman tps	42 mi SW of Sudbury	New Thurbois Mines Ltd	Conglomeratic ?		Diamond drilled		
Bamaji Lake	90 mi N of Sioux Lookout	McCombe Mining & Explor Ltd	Pegmatitic ?				
Bathurst tp	Con 9, lot 22	C. Innes, Balderson, Ont	Pegmatitic	Euxenite, fergusonite, cyrtolite		Lang, 1952	Old feldspar workings
Bessner mine	Henvey tp, con B, lot 5		Pegmatitic	Thucholite, uraninite, allanite, cyrtolite		Ellsworth, 1932; Lang, 1952	Old feldspar mine

Bethune tp	5 mi E of Kearney, Ont	N.B. Tiffany, Buffalo, NY				Lang, 1952	Staked in 1938 for vanadium, tantalum, titanium and gold. Also known as Tiffany property
Bicroft mine*	Cardiff tp,con 11, N1/2 lots 27 and 28, etc	Bicroft UML	Granitic	Uraninite, uranothorite, zircon, allanite	Underground (producer)		
Bigwood tp	Con 8, lot 3	J.F. Howard, Box 353, North Bay, Ont			Trenched		
Blue Rock Cerium property	Monmouth tp, con 6, S1/2 lots 18 and 19	Amalgamated Rare Earth Mining Corp	Granitic	Uranothorite, gummite ?, uraninite, allanite, zircon, fergusonite, uranophane	Underground	Satterly, 1957	
Botsford Lake occ	Near Rosnel	W.A. Pierce					
Bridges tp	About 35 mi E of Kenora	A.L. Wilson	Granitic	Uranophane	Diamond drilled		
Brougham tp	Con 9, lot 18	A. Legris, Dacre, Ont	Granitic				
Brougham tp	Con 18, lot 31	H.A. Legris, Dacre, Ont	Granitic				
Bruton tp	Con 7, lot 26	A.J. Tomlinson					
Buckles mine*	Tp 149	Northspan UML	Conglomeratic	Brannerite, uraninite, monazite	Underground (producer)		Ore treated at Lake Nordic plant

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Burgess Mine	Carlow tp		Pegmatitic	Uraninite		Lang, 1952	Once worked for corundum
Burleigh tp	Cons 4, 5, 6, lots 21-23	Bibis Yukon Mines Ltd	Granitic		Diamond drilled	Satterly, 1957	
Burton tp	Con 14, N1/2 lot 37	N.A. Taylor, 790 Eastern Ave, Toronto, Ont				Lang, 1952	Also known as Taylor occ
Butt tp	Con 7, S1/2 lot 13		Pegmatitic	Uraninite, allanite ?		Ellsworth, 1932; Lang, 1952	Also known as Elliot claim. Once worked for muscovite
Butt tp		Algonkian Uranium Corp Ltd	Granitic				
Butt & Proudfoot tps		D'Eldona GML	Granitic	Priorite, monazite, pyrochlore, cyrtolite	Diamond drilled ?		
Butt & Proudfoot tps	Butt tp, con 5, lot 3	McRae Uranium Prospecting Synd	Pegmatitic			Lang, 1952	
Calder-Bousquet prop	Blind River camp	Calder-Bousquet GML					
Calvin tp		La Salle Yellowknife GML		Mins of columbium and uranium		Lang, 1952	
Calvin tp	Con 4, lot 22		Granitic	Euxenite		Mines Br pub No 731, 1932, p 51	

Calvin tp	Con 9, lot 19 or 20		Granitic	Polycrase	Underground		
Calvin tp	Along hwy 17, near Eau Claire	Molybdenum Corp of America	Pegmatitic	Euxenite, allanite, samarskite ?		Lang, 1952	Formerly worked or explored for feldspar
Cameron prop	About 2 mi E of S end of Vermilion Lake	M. Y. Cameron, Kenora, and C. Alcock	Granitic	Uraninite, monazite	Trenched	Chisholm, 1950; Lang, 1952	
Camray prop	On L Superior, 50 mi N of Sault Ste Marie	Camray Mines Ltd	Vein	Pitchblende	Underground	Lang, 1952	
Canagau prop	Near Montreal River, north of Sault Ste Marie	Canagau Mines Ltd	Vein	Pitchblende	Stripped	Lang, 1952	
Cane tp	Con 2, lot 2	Caneonti Mines Ltd	Vein	Pitchblende	Diamond drilled, trenched	Lang, 1952	Old silver workings of Cane Silver Mines Ltd
Can-Met mine*	Tp 144, Quirke Lake	Can-Met Explor Ltd	Conglomeratic	Uraninite, monazite, brannerite	Underground (producing)		
Cardiff tp	Zone 1: con 2, N1/2 lot 8	Triton UML	Metasomatic	Uraninite	Diamond drilled	Satterly, 1957	
	Zone 2: con 2, S1/2 lot 9		Granitic	Uranothorite	" "	" "	
	Zone 3: con 1, N1/2 lot 9 and con 2, S1/2 lot 9		Granitic	Allanite, uranothorite	" "	" "	
Cardiff tp	Con 2, N1/2 lot 10	R. W. Doubt, no address given	Granitic	Allanite, uranothorite	Stripped	Satterly, 1957	
Cardiff tp	Con 5, lots 10, 11	Milhol Explor & Develop Ltd	Granitic	Allanite, uranothorite	Diamond drilled	Satterly, 1957	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Cardiff tp	Eels Lake; con 6, S1/2 lot 6	Cons Thor Mines Ltd	Granitic	Uranothorite, allanite	Diamond drilled	Satterly, 1957	Also known as Thor group
Cardiff tp	Con 6, lot 12	J.C. Cottrill, Apsley, Ont	Granitic	Monazite ?	Diamond drilled	Satterly, 1957	
Cardiff tp	Con 6, lot 13	L. Reid, Picton, Ont	Granitic				
Cardiff tp	Con 7, N1/2 lot 9	J. Gilbert, no address given	Granitic	Uranothorite, cyrtolite	Diamond drilled	Satterly, 1957	
Cardiff tp	Con 9, lot 22	Aumacho River Mines Ltd	Granitic	Allanite, uraninite, uranothorite ?	Diamond drilled	Satterly, 1957	
Cardiff tp	Con 10, N1/2 lot 10; con 11, lot 10 and N1/2 lot 11	Molybdenum Corp of America	Granitic	Uranothorite, allanite	Diamond drilled	Satterly, 1957	
Cardiff tp	Con 10, lots 11-13	Pickering Metal Mines Ltd	Granitic	Uranothorite, allanite, zircon	Diamond drilled	Satterly, 1957	Also known as Tomlinson and Mulliette prop
Cardiff tp	Con 11, S1/2 lot 11	Climax Molybdenum Co	Granitic	Uranothorite, allanite, zircon	Diamond drilled	Satterly, 1957	Also known as Halet prop
Cardiff tp	Con 12, lots 7-11; con 13, lots 7, 8	Canada Radium Corp Ltd	Granitic	Ellsworthite, uraninite, uranothorite	Underground	Lang, 1952; Satterly, 1957	Also known as Canada Radium mine
Cardiff tp	Con 13, S1/2 lot 9	West Lake Mining Co Ltd	Granitic	Uranothorite	Trenched	Satterly, 1957	
Cardiff tp	Con 13, S1/2 lot 31	Cons Tungsten Mining Corp of Canada	Pegmatitic	Uraninite, uranothorite	Diamond drilled	Satterly, 1957	

Cardiff tp	Con 14, N1/2 lot 5	Kemp UML	Contact metasomatic	Uranothorite, thorite	Diamond drilled	Satterly, 1957	
Cardiff tp	Con 14, lots 6, 7	Kenmac Chibougamau Mines Ltd	Granitic	Uranothorite, allanite	Underground	Satterly, 1957	
Cardiff tp	Con 14, S1/2 lot 11	Mindus Corp Ltd	Granitic	Uranothorite, allanite, uraninite, ellsworthite	Diamond drilled	Satterly, 1957	
Cardiff tp	Con 15, S1/2 lots 2 and 3; con 16, lots 1-3, N1/2 lot 4	Stratmat Ltd	Granitic	Uraninite, allanite	Diamond drilled	Satterly, 1957	Also known as Reasor prop
Cardiff tp	Con 15, S1/2 lot 20	D.E. Foster, no address given	Granitic	Uranothorite, zircon, allanite	Diamond drilled	Satterly, 1957	
Cardiff tp*	"C" zone: con 17, N1/2 lot A	Cardiff UML	Metasomatic	Uraninite, uranothorite	Underground	Wolfe & Hogg, 1948; Satterly, 1957	Principally a fluorite deposit
Cardiff tp	Con 18, lots A, and 1	Essential Minerals Prospecting Synd	Vein ?			Lang, 1952; Wolfe & Hogg, 1948	Calcite-fluorite deposit
Cardiff tp	Con 18, lot 12	Formerly Ranrouyn prop	Granitic			Wolfe & Hogg, 1948; Lang, 1952	Claims abandoned
Cardiff tp	Con 19, lots 8-10	Anuwon UML	Granitic	Uraninite	Diamond drilled	Satterly, 1957	Also known as McLean-Hogan prop
Cardiff tp	Con 20, S1/2 lot 7	Burma Shore UML	Granitic	Uraninite, uranothorite	Diamond drilled	Satterly, 1957	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Cardiff tp	Con 20, lots 7, 8	G. Pickens, Wilberforce, Ont	Vein ?	Uraninite, allanite		Wolfe & Hogg, 1948; Lang, 1952	Calcite-fluorite deposit
Cardiff tp* (Richardson deposit)	Con 21, lots 4-6, N1/2 lot 7	Fission Mines Ltd	Vein	Uraninite, allanite, uranothorite, zircon	Underground	Wolfe & Hogg, 1948; Lang, 1952; Rowe, 1952; Satterly, 1957; Ellsworth, 1932	Principally a fluorite deposit
Cardiff tp	Con 21, lot 8	Nu-Age UML	Granitic and vein	Uraninite, uranothorite	Underground	Satterly, 1957	Old fluorspar occ. Also known as Tripp prop. 50-ton concentrator plant installed
Cardiff tp	Con 21, lot 9	Nu-Age UML	Vein and pegmatitic	Uraninite	Underground	Satterly, 1957; Lang, 1952	Also known as Montgomery prop
Cardiff tp	Con 22, W1/2 lot 5	Bancroft UML	Granitic	Allanite, uranothorite	Stripped	Satterly, 1957	
Cardiff and Monmouth tps	Card: con 15, N1/2 lots 1 and 2 Mon: con 11, lot 35	Empire Oils and Minerals Inc	Granitic	Uranothorite	Diamond drilled	Satterly, 1957	
Carlow tp	Con 5, lot 1	Mentor Explor & Develop Co Ltd	Pegmatitic	Uranothorite	Trenched	Satterly, 1957	Also known as Carr zone

Carlow tp	Con 5, lots 2, 3; also con 4, lot 2; con 5, lot 4; con 3, lot 1	Mentor Explor & Develop Co Ltd	Granitic	Allanite, uranothorite	Trenched	Satterly, 1957	Also known as Wash Tub zone
Cavendish tp	Con 3, lot 3	Silanco Mining & Refining Co Ltd	Granitic	Zircon, uranothorite, fergusonite	Diamond drilled	Satterly, 1957	Also known as Windover prop
Cavendish tp	Con 3, N1/2 lot 16 and N1/2 lot 21; con 9, lot 16; con 11, S1/2 lot 14	Drude UML	Granitic	Allanite, zircon, uranothorite	Diamond drilled	Satterly, 1957	Four main groups
Cavendish tp	Con 4, lot 8 and S1/2 lots 5 and 7	Macfie Explorations Ltd	Granitic	Allanite, uranothorite	Diamond drilled	Satterly, 1957	
Cavendish tp	Con 5, N1/2 lot 14; con 6, lot 13	Cromwell Uranium & Development Co Inc	Granitic	Allanite, zircon, uranothorite, uranophane, betafite	Diamond drilled	Satterly, 1957	
Cavendish tp	Con 6, lot 11	Ganymede UML	Granitic	Uranothorite	Diamond drilled	Satterly, 1957	
Cavendish mine	Cavendish tp, con 7, S1/2 lot 14 (shaft site)	Amalgamated Rare Earth Mining Co	Granitic	Uranothorite, thorite, uraninite, allanite, cyrtolite, anatase	Underground	Satterly, 1957	Awarded gov't contract
Cavendish tp	Con 9, lot 3	M. Cziraky, Nogies Creek, Ont	Granitic				
Cavendish tp	Con 9, lot 15	D.J. Smith, Box 145, Beaverton, Ont	Granitic	Uranothorite		Lang, 1952	
Cavendish tp	Con 10, lot 4	K.S. Read, Bobcaygeon, Ont	Granitic				

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Cavendish tp	Con 11, N1/2 lot 21	Silanco Mining & Refining Co Ltd	Granitic	Allanite, zircon, uraninite, uranothorite	Trenched	Satterly, 1957	Also known as Pencil Creek prop
Cavendish tp	Con 14, S1/2 lot 24 and N1/2 lot 25	Kelbee Rare Metals Corp Ltd	Granitic	Uraninite, uranophane, uranothorite, allanite, zircon	Diamond drilled	Satterly, 1957	
Chandos tp	Con 16, S1/2 lot 9	Consolidated Uranium Corp	Granitic	Uranothorite, allanite	Underground	Satterly, 1957	
Chapman tp	Con 8, lot 3	W. Raney, Sr, RR 2, Sundridge, Ont	Granitic	Columbite-tantalite, pyrochlore-microlite ser			
Charon Lake occ	N of Charon L and 6 mi NE of Caramat (Geraldton area)	P. M. Bortz, Stoneboro, Pa	Granitic				
Chisholm tp	Con 17, lots 20, 21	A. Sanseville, RR 1, Alderdale, Ont					
Clarendon tp	Con 11, lot 33	Mr. Lewke, Plevna, Ont	Placer				
Conger tp	Con 9, lots 4, 7, 9, 10	Ellsworth, GSC, reported	Pegmatitic	Uraninite, calcio-samarskite, thucholite, cyrtolite, allanite		Ellsworth, 1932; Lang, 1952	Formerly a muscovite prospect in lots 9 and 10

Conger tp	Con 10, lot 7	G. Colautti and Opeongo Mining Co	Pegmatitic	Euxenite, columbite, monazite ?		Lang, 1952	Formerly worked for feldspar
Cons Denison mine *	Tp 150, on W shore of Quirke L	Consolidated Denison Mines Ltd	Conglomeratic	Brannerite, uraninite, monazite	Underground (producer)		Largest single producer in Canada. Probably has largest reserves of any mine in world
Cramette occ	About 7 mi N of Angler, Ont	C. Cramette, Ft William, Ont				Lang, 1952	
Creelman tp	Con 3, lots 10, 11	L. Leslie, Anstice, Ont	Conglomeratic	Uraninite	Diamond drilled		
Croft prop	Cardiff tp about 2 mi N of Bicroft mine	Bicroft UML	Granitic	Uranothorite, uraninite, allanite, cyrtolite, monazite	Underground	Satterly, 1957	
Curtin tp	Howry Creek, east-central part of tp, 12 mi SE of Espanola; claim S-69245	J.R. Bridger, 1310-55 York St, Toronto, Ont	Vein ?			Collins, 1925	Former gold prospect
Daley tp	One mi E of Long Lac in quarry on S side hwy	A. Brisebois, Geraldton, Ont	Pegmatitic ?	Radioactivity due mainly to thorium		Lang, 1952	Also known as Long Lac occ
Dalton tp	Con 12, lot 25	Johnston, GSC, reported	Pegmatitic	Allanite		Lang, 1952	
Damascus prop	2 1/2 mi E of mouth of Montreal River, N of Sault Ste Marie	Damascus Mines Ltd	Vein		Detailed radioactivity survey	Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Danaray prop	Pt aux Mines, 2 mi S of Camray prop	Danaray UML	Vein	Pitchblende ?	Bulk sampled	Lang, 1952	
Dickens tp	Con 1, lot 19	G. Colautti		Monazite		Lang, 1952	Feldspar deposit worked by Opeongo Mining Co
Dickens tp	Con 5, lot 27	Hewitt and Satterly, ODM, reported		Ellsworthite, euxenite, monazite		Lang, 1952	Worked for feldspar and mica in 1943
Dickens tp	Con 13, lot 9	Not given	Pegmatitic	Monazite		Lang, 1952	
Dickenson claims	Near mouth of Montreal River	P.J. Roche and associates	Vein			Lang, 1952	
Dill tp	Con 1, N1/2 lot 1	D. Mackay, 12 Ford St, Capreol, Ont	Pegmatitic				
Dill tp	Con 2, N1/2 lot 2, etc	Cubar UML	Pegmatitic	Betafite, allanite, ellsworthite, pyrochlore-microlite ser, euxenite	Diamond drilled	Lang, 1952 (see Bennett prop)	Old feldspar pits
Dill tp	Con 3, lot 4		Pegmatitic	Toddite	Underground	Lang, 1952; Ellsworth, 1932	Once worked for feldspar
Dill tp	Con 3, lot 6	Messrs Steel, Cushing and Larson; c/o F. Steel, 3 Lonsdale St, Minnow Lake, Ont	Pegmatitic				

Docker (?) tp	45 mi E of Kenora, N side Trans-Canada hwy	L. Parth, Kenora, Ont	Pegmatitic			Lang, 1952	Also known as Parth prop
Dolan gp	N side of MacGregor Cove, Lake Superior	J.P. Dolan, Toronto, Ont	Vein ?	Pitchblende		Lang, 1952	Also known as Beaver Rock gp Claims abandoned
Dryden tp	Con 2, lot 9	Tuc Metal Mines Ltd	Pegmatitic ?	"Rare-earth" minerals	Diamond drilled		Old mica-feldspar deposit
Dudley tp	Con 2, lots 1, 2	H.A. Fabis, Larder Lake, Ont	Pegmatitic				
Dungannon tp	Con 11, lots 17-26; con 12, lots 16-19; cons 13, 14, lots 16-20	C.W. Rockwell, 6515 N Clark St, Chicago, Ill	Pegmatitic				
Dungannon tp	Con 16, lot 14	Normingo Mines Ltd	Contact metasomatic	Uranoan thorianite	Stripped	Satterly, 1957	
Dyno mine*	Cardiff tp, con 8, lot 12, etc	Canadian Dyno Mines Ltd	Granitic	Uraninite, uranothorite, allanite, cyrtolite, hatchettolite, uranophane	Underground (producer)		Began producing in 1958
Eric Nelson occ	45 mi W of Port Arthur; rock cut along Trans-Canada hwy	E. Nelson, Port Arthur, Ont	Granitic	Uraninite		Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Faraday mine*	Faraday tp, con 11, lots 16-18, etc	Faraday UML	Granitic	Uraninite, uranothorite, allanite, cyrtolite, uranophane, "rare-earth" minerals	Underground (producer)		
Faraday tp		Bancroft Mica & Stone Products Ltd	Pegmatitic	Ellsworthite		Lang, 1952	Probably same prop as Silver Crater's Basin prop con 15, lot 31
Faraday tp	Con A, lots 21-24; con B, S1/2 lot 23	Bonville GML	Granitic	Uranothorite, beta-uranophane, ellsworthite	Diamond drilled	Satterly, 1957	
Faraday tp (Basin prop)	Con 15, lot 31	Silver Crater Mines Ltd	Hydro-thermal (vein ?)	Betafite, ellsworthite	Underground	Satterly, 1957	
Faraday tp (Baumhour prop)	Con 15, S1/2 lots 27, 28 and E1/2 lot 29	Silver Crater Mines Ltd	Granitic	Uranothorite, allanite, uranophane	Diamond drilled	Satterly, 1957	
Faraday tp (Kerr prop)	Con B, lot 28	Silver Crater Mines Ltd	Granitic	Allanite, uranothorite	Diamond drilled	Satterly, 1957	
Faraday tp (Lockwood prop)	Con A, lot 29	Silver Crater Mines Ltd	Metaso-matic	Uraninite, uranothorite	Diamond drilled	Satterly, 1957	
Fraser tp	Con 16, lot 24	E.R. Woermke, Pembroke, Ont	Pegmatitic	Allanite ?			Old feldspar quarry

Freeman tp	Con 3, N1/2 lot 5	H. Barnes, Torrence, Ont	Granitic				
Galway tp	Con 1, lot 18	M. Cziraky, Nogies Creek, Ont	Granitic				
Galway tp	Con 9, S1/2 lot 30; con 8, lot 27	Newkirk Mining Corp and associates	Granitic	Uraninite	Diamond drilled	Satterly, 1957	Also known as McWilliams prop
Galway tp	Con 10, lots 23 and 25	Silver Crater Mines Ltd	Granitic	Allanite, zircon, thorite, uranothorite, uranophane	Diamond drilled	Satterly, 1957	Also known as Crystal Lake prop
Galway tp	Con 11, lots 23, 24; and con 12, S1/2 lot 24	Kenmac Chibougamau Mines Ltd	Granitic	Zircon, uraninite, uranothorite	Diamond drilled	Satterly, 1957	Also known as Blott occ
Galway tp	Con 11, lots 23, 24; con 12, S1/2 lot 24 N shore of Crystal Lake	W. Blott, RR 3, St Catharines, Ont	Granitic	Uraninite, uranothorite	Diamond drilled	Satterly, 1957	
Galway tp	Cons 11 to 16, lots 7 to 14	Aubelle Mines Ltd		Uraninite	Scintillometer and geological surveys		
Galway tp	Con A, lot 40	F. Payce, c/o YMCA, Kingston, Ont	Granitic				
Gaudette tp		Alur Mines Ltd				Lang, 1952	Also known as Rivers-Creighton gp
Gibson tp	Hollow Lake			Allanite		Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Glamorgan tp	Con 1, lots 18-20, 22-24; con 2, lots 17-20, 22-24; con 3, lots 15-17; con 5, lot 32	Webster UML	Granitic	Uraninite, allanite, uranothorite			
Glamorgan tp	Con 2, S1/2 lot 19	Nu-World UML	Granitic	Uraninite, allanite, uranothorite, cyrtolite	Diamond drilled	Satterly, 1957	
Glamorgan tp	Con 2, lots 26-28	Nu-Cycle UML	Granitic	Uranothorite, allanite, zircon	Diamond drilled	Satterly, 1957	
Gratton tp	South rge, lot 67	O. Percy, Douglas, Ont					
Greenwich Lake occ	W side of Greenwich L, 30 mi NE of Port Arthur	Pan-Canadian Develop Co Ltd	Vein	Pitchblende, uranophane	Diamond drilled	Lang, 1952	Also known as Christianson prop
Greyhawk East gp	Faraday tp, con A, lot 13	Greyhawk UML	Granitic	Uranothorite	Diamond drilled	Satterly, 1957	
Greyhawk mine*	Faraday tp, con 12, lots 9, 10, 11, etc	Greyhawk UML	Granitic	Uraninite, uranothorite, pyrochlore, zircon, allanite	Underground (producer)		Ore treated at Faraday UML plant
Griffith tp	Con 2, lots 22, 23	O. Percy, Douglas, Ont					
Hagarty tp	Con A, lot 13			Allanite		Johnston, 1915; Lang, 1952	

Hallam tp	Con 6, N1/2 lot 8	Del-Can Minerals	Conglomeratic ?				
Halo Mine	Cardiff tp, (a) con 18, N1/2 lot 4;	Amalgamated Rare Earth Mining Co	Granitic	Uraninite	Underground	Satterly, 1957	Known as Northwest zone
	(b) Con 18, S1/2 lots 4 and 5		Granitic	Uranothorite, thorite	Underground	" "	Known as Lake zone
	(c) Con 18, N1/2 lot 6		Granitic	Uraninite	Diamond drilled	" "	Known as Pyroxenite zone
	(d) Con 15, lots 6, 7		Granitic	Uranothorite, uraninite, betafite	Diamond drilled	" "	Known as South zone
Hardy tp	Con 9, S1/2 lot 28	G. Tough, Bracebridge, Ont				Lang, 1952	Also known as Tough prop
Harvey tp	Con 12, lot 18	Cavendish Uranium & Mining Co Ltd	Granitic	Thorite, uranothorite, zircon	Diamond drilled	Satterly, 1957	Also known as R. Kennedy prop
Harvey tp	Con 16, lot 26	Big Nell Mines Ltd	Granitic	Uranothorite, zircon	Trenched	Satterly, 1957	Partly owned by L. Cadesky
Harvey tp	Con 16, lots 29-31 and con 17, E1/2 lots 29 and 30	Gray Wolf Explor Co (C.P. Cziraky, pres)	Granitic		Trenched	Satterly, 1957	Also known as Nogies Creek prop
Harvey tp	Con 17, lot 26	R.M. Clark, Lindsay, Ont				Lang, 1952	
Harvey tp	Mississagua Lake	Silanco Mining & Refining Co Ltd	Granitic	Allanite			
Hele tp	Con 3, lot 10	J.B. Tessier, 448 Dawson St, Port Arthur, Ont	Granitic ?				
Hemlo occ	Kenora-Port Arthur region	Lake Superior Mining Corp	Vein ?			Lang, 1952	Old gold prospect

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Henvey tp			Pegmatitic	Euxenite-polycrase ser		Ellsworth, 1932; Lang, 1952	Formerly worked for feldspar. Also known as Ambeau occ
Henvey tp	Con A, lot 4	H.S. Spence, Mines Br, Ottawa	Pegmatitic	Euxenite		Lang, 1952	
Henvey tp	Con B, lot 5	R.W. Clarke,	Pegmatitic	Thucholite, uraninite, allanite, cyrtolite		Spence, 1930; Ellsworth, 1931	Also known as Besner mine. Once worked for feldspar
Heron Bay occ		D.E. Smith, Marathon, Ont	Granitic			Lang, 1952	
Herschel tp	Con 5, N1/2 lot 26	Standard Oil & Alloys Corp	Granitic	Uranothorite	Diamond drilled	Satterly, 1957	Also known as Baptiste Lake prop
Herschel tp	Con 8, lot 39, etc	Peter Rock Mining Co	Pegmatitic	Pyrochlore, euxenite, uranothorite, allanite	Diamond drilled	Satterly, 1957	
Herschel tp	Con 16, lots 17, 18	F. Patterson	Granitic	Eschynite, euxenite-polycrase ser	Stripped	Satterly, 1957	
Horton tp	Con 3, lot 1	J.S. Dempsey and N. Harvey, Gen Deliv, Renfrew, Ont	Pegmatitic	Uranothorite, allanite		Quinn, 1952	
Hudson tp	Con 6, N1/2 lot 12	W.A. Spencer, RR1, New Liskeard, Ont	Vein		Diamond drilled	Lang, 1952	Also known as Spencer prop

Hyman tp	Agnew Lake area	Yellowknife Bear Mines Ltd			Diamond drilled		
Hyman tp	North shore of Agnew L	Noranda Mines Ltd	Hydro-thermal (vein ?)	Pitchblende ?	Trenched		
Jalore prop	Mileage 105, Algoma Central Railway	Jalore Mining Co Ltd	Vein	Pitchblende	Diamond drilled	Lang, 1952	
Jarvis tp	Reserve Lake	M.C. Gardiner, Haileybury, Ont				Lang, 1952	
Kennebeck tp	Con 3, lot 18	A.G.B. Campbell, Orangeville, Ont	Pegmatitic	Beta-uranophane			
Lackner & McNaught tps (Nemegos prop)	Near Chapleau	Multi-Minerals Ltd	Metaso-matic	Pyrochlore	Diamond drilled	Lang, 1952; Hodder, 1958; Parsons, 1957	Principally a niobium (columbium) deposit with iron and phosphate
Lake of the Woods occ	On island 10 mi S of Kenora	G.A. McLean, 506 First St S, Kenora, Ont	Vein			Chisholm, 1950; Lang, 1952	
Lacnor mine*	Tp 149	Northspan UML	Conglomer-atic	Brannerite, uraninite, monazite, thucholite	Underground (producing)		
Langton tp	Con 4, lot 9	M. Jensen, Kenora, Ont	Granitic		Diamond drilled	Lang, 1952	
Latchford tp	Con 9, lot 11	E.H. Cline, Monetville, Ont	Granitic				

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Livingstone tp	Cons 5 and 6, lots 17 and 18	W.H. Robillard, Gravenhurst, Ont	Pegmatitic	Allanite			
Long tp	Algoma Mills near shore of L Huron	Muskoka Construction Co	Vein ?	Pitchblende, thorite		Lang, 1952	Also called "Location X" but not same as Breton prop (now Pronto mine)
Loudon tp	Con 5, lot D	H.D. Tomlinson, 289 Midland Ave, Toronto 13, Ont	Pegmatitic	Thorite		Lang, 1952	
Loughborough tp	Con 9, lot 11	M.J. O'Brien Ltd	Pegmatitic	Euxenite, gadolinite		Ellsworth, 1932; Lang, 1952	
Loughrin tp	20 mi E of Capreol	J. Plexman, 95 King St E, Toronto, Ont	Pegmatitic ?			Lang, 1952	Near old feldspar pit
Lutterworth tp	Con 8, lot 11	E.T. Hogan, Wilberforce, Ont	Pegmatitic	Allanite, thorite, uranothorite		Johnston, 1915; Lang, 1952	
Lyndoch tp	Con 7, S1/2 lot 30, 31	W.A. Davies, Golden Lake, Ont	Pegmatitic ?				Old workings
Lyndoch tp	Con 15, lots 23, 30	E.C. Price, 325 Hunter St, Pembroke, Ont	Pegmatitic				
Lyndoch tp	Con 15, lot 25	Universal Light Metals Co	Pegmatitic	Allanite, lyndochite, monazite, "rare-earth" minerals		Lang, 1952	Once explored for beryl and other minerals

Lyndoch tp	Con 23, lot 23	T.B. Caldwell, Perth, Ont	Pegmatitic	Lyndochite, monazite, cyrtolite		Lang, 1952	Former beryl deposit
MacDougal occ	Mileage 92 on Algoma Central Railway	M. MacDougal		Meta-allanite		Lang, 1952	
MacGregor Cove	E of MacGregor Cove, Lake Superior	R.R. Hennessy, Sault Ste Marie, Ont	Vein		Trenched	Lang, 1952	Also known as Hennessy gp
MacGregor Cove occ	S of MacGregor Cove, shore of L Superior	J.G. McCombe, Sault Ste Marie, Ont	Vein or granitic or both	Ellsworthite, allanite		Lang, 1952	
MacGregor Cove occ	1 mi SE of MacGregor Cove, Lake Superior	Soo-Tomic UML	Vein		Diamond drilled	Lang, 1952	
Machar tp		C. Palangio, 845 McLaren St, North Bay, Ont		Allanite		Lang, 1952	
Mack tp	Camp Seven Bay E, Matinenda Lake	Talvey Metal Mines Ltd			Diamond drilled		
Maclennan tp	Con 3, SE corner of S1/2 lot 6 and con 2, lot 5	E. Chevrette, Skead, Ont	Granitic			Lang, 1952	
MacNicol tp	About 32 mi E of Kenora near hwy, Richard Lake	Campbell Island Mines & Explor Ltd	Granitic	Uraninite, uranothorite, beta-uranotile, allanite	Underground	Satterly, 1955	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
MacNicol and Jackman tps	N of Hawk L, 30 mi E of Kenora	Great Lakes Uranium Corp	Granitic	Uraninite, thorite		Chisholm, 1950; Lang, 1952; Satterly, 1955	Also known as Byberg prop and Hawk L occ
Madoc tp	Con 5, lot 11		Magnetite deposit	Secondary uran min		Lang, 1952; Logan, 1863, p 504, 675	Once worked for iron
Manitou Islands	Lake Nipissing	Beaucage Mines Ltd	Metasomatic	Uranoan pyrochlore	Underground	Rowe, 1954; Gill and Owens, 1957	Columbium deposit. Inactive in 1957. Also known as Newman deposit
Marathon occ	Angler siding, 5 mi W of Marathon	Port Monroe Uranium Prosp Synd	Vein			Lang, 1952	Also known as Potvine prop
Marathon occs	2 mi W of Marathon, Ont	Pic Bamoos Prosp Synd	Pegmatitic	Thorite		Lang, 1952	
March tp	Con 2, lot 6	M.J. O'Brien Ltd	Pegmatitic	Uraninite		Lang, 1952	Old feldspar workings
Mattagami River occ	3 mi N of Smoky Falls	Moneta Porcupine Mines Ltd	Pegmatitic			Lang, 1952	
Mattawan tp	Con 2, lots 6, 7	Purdy Mica Mines Ltd	Pegmatitic	Uraninite		Lang, 1952	Formerly worked for muscovite
Mattawan tp	Con 2, lot 29	C. Palangio, 845 McLaren St, North Bay, Ont	Pegmatitic	Euxenite-polycrase ser		Lang, 1952	

Mattawan tp	Con 3, lot 29	Molybdenum Corp of America	Pegmatitic	Euxenite-polycrase ser		Lang, 1952	Formerly worked for feldspar. Also known as O'Brien-Fowler prop
McDougall tp	Con 9, lot 27	J.A. Fenn, Parry Sound, Ont	Pegmatitic	Uraninite, thucholite ?			
McDougall tp	Con A, lots 12 to 17; con 5 to 7, lots 25 to 29	Ascot Metals Corp Ltd	Pegmatitic				
McDougall tp	Con A, lots 13 to 15	L. Chamberlain	Pegmatitic		Trenched		
McTiegue occ	2 1/2 mi NE of Frater on Algoma Central Railway	McCombe Synd, Sault Ste Marie, Ont				Lang, 1952	
Medicinestone Lake occ	S end of lake, Red Lake area	I.O. Persson, Red Lake, Ont	Granitic			Lang, 1952	
Migneron prop	Mileage 71, Montreal River hwy	A. Breton, Central Hotel, Sault Ste Marie, Ont, and others	Vein	Pitchblende	Trenched	Lang, 1952	
Milliken Lake mine*	Tp 149	Milliken Lake UML	Conglomeratic	Brannerite, monazite, uraninite, thucholite	Underground producing		
Monmouth tp	Claim EO 4239	G. Keller, 1232 Avenue Rd, Toronto, Ont	Granitic			Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Monmouth tp	2 1/2 mi W of Tory Hill	Charles Earle Uranium Prospecting Synd	Vein ?	Uranothorite		Lang, 1952	Samples submitted were pegmatite. Also known as Earle property
Monmouth tp	Con 3, lots 3 to 5; con 4, S1/2 lots 2 to 4 and lot 5	Cassiar Rainbow GML	Granitic	Uranothorite, euxenite, uranophane, allanite, cyrtolite ?, uraninite ?	Diamond drilled	Satterly, 1957	Property extends into Glamorgan tp
Monmouth tp	Con 4, lot 14	Jesko UML	Granitic	Uranothorite, allanite	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 4, N1/2 lot 19	Urotomic ML	Metasomatic	Uraninite	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 6, N1/2 lot 5	Wadasa GML	Granitic and contact metasomatic	Uraninite	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 6, S1/2 lot 32	Silanco Mining & Refining Co Ltd	Granitic	Uranothorite	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 9, lots 5 to 8	Canadian All Metals Explor Ltd	Metasomatic	Thorian uraninite, pyrochlore	Underground	Satterly, 1957	Inactive
Monmouth tp	Con 10, lots 7, 8; con 11, lots 9 to 12	Nu-Age UML	Vein	Uranothorite	Diamond drilled	Satterly, 1957	Also known as Old Smokey prop

Monmouth tp	Con 10, S1/2 lot 24 (zircon occ)	Saranac UML	Granitic and metasomatic	Zircon, thorite, allanite, uranothorite, uranophane	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 11, lots 5, 6	Red Bark ML	Granitic and metasomatic	Uraninite	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 12, lot 13	Long Ridge UML	Metasomatic	Uraninite	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 13, N1/2 lot 13	Roford ML	Granitic and metasomatic	Uranothorite, thorite	Diamond drilled	Satterly, 1957	At least 5 occurrences
Monmouth tp	Con 14, N1/2 lot 33	Acmac Mining Corp Ltd	Granitic	Uranothorite, thorite	Adit and surface cuts	Satterly, 1957	
Monmouth tp	Con 16, S1/2 lot 27	Cordell GML	Metasomatic	Uraninite	Diamond drilled	Satterly, 1957	
Monmouth tp	Con 16, lots 29, 30	T. Cudney, no address given	Metasomatic ? and syenite pegmatite	Uranothorite, kasolite, zircon	Stripped	Satterly, 1957	
Monmouth tp	Con 17, lots 30, 31	Desmont Mining Corp Ltd	Contact metasomatic	Uranothorite, allanite, uraninite	Stripped	Satterly, 1957	
Monmouth tp (Blue Rock Cerium prop)	Con 6, lot 19	Amalgamated Rare Earth Mining Corp	Granitic	Uranothorite, fergusonite, uraninite, uranophane, zircon, allanite	Underground	Satterly, 1957	Inactive 1957

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Monmouth tp (Rare Earth prop)	Con 8, lot 20	Amalgamated Rare Earth Mining Corp	Granitic	Uranothorite, gummite, fergusonite, cyrtolite, uraninite, allanite	Underground	Satterly, 1957	Inactive 1957
Monteagle tp	Con 1, S1/2 lot 5 (main showing)	Messrs Carr, Quirk and Mellish	Granitic	Allanite, uranothorite	Diamond drilled	Satterly, 1957	
Monteagle tp	Con 2, lots 17, 18	South State UML	Contact metasomatic	Uraninite	Stripped	Satterly, 1957	Also known as Musclow prop
Monteagle tp	Con 3, N1/2 lot 3	B.C. Robson	Granitic	Uraninite, zircon		Satterly, 1957	
Monteagle tp	Con 3, lots 27, 28, on property of owner	J.F. Ferril	Pegmatitic	Allanite		Lang, 1952	
Monteagle tp	Con 3, lot 1; con 4, lot 12; con 5, lots 1 to 4	Mentor Explor & Develop Co Ltd	Granitic	Allanite, uranothorite	Trenched	Satterly, 1957	Also known as Carr-Quirk-Robson prop
Monteagle tp	Con 4, lots 11, 12	J. Quirk, Birds Creek, Ont	Contact metasomatic and granitic	Uranothorite, thorite, ellsworthite	Trenched	Lang, 1952; Satterly, 1957	
Monteagle tp	Con 4, lot 5; con 7, lots 4, 5	W.M. Thompson	Granitic	Uranothorite	Stripped	Satterly, 1957	
Monteagle tp	Con 6, lots 20-24, 29; con 7, lots 22-24	J.R. Campbell, 136 Wheeler Ave, Toronto, Ont	Granitic			Lang, 1952	

Monteagle tp	Con 7, lot 14	Reported by D.F. Hewitt, ODM	Pegmatitic (granitic ?)	Euxenite		Lang, 1952	Also known as Genesee No 2 prop. Old feldspar mine
Monteagle tp	Con 7, N1/2 lots 18 and 19	Phillips-Doubt Grubstake Synd	Pegmatitic	Ellsworthite, uranothorite, cyrtolite, allanite, uraninite	Underground	Lang, 1952 Satterly, 1957	Also known as MacDonald feldspar mine
Monteagle tp	Con 7, lot 21	D.F. Hewitt, ODM, reported	Pegmatitic	Euxenite ?		Lang, 1952	Formerly worked for feldspar. Also known as Dwyer prop
Monteagle tp	Con 8, S1/2 lot 29	Peter-Rock Mining Co Ltd	Granitic	Allanite, uranothorite	Diamond drilled	Satterly, 1957	
Monteagle tp	Con 12, lot 6	Bancroft Feldspar Co (reported by D.F. Hewitt, ODM)	Pegmatitic	Allanite		Lang, 1952	Feldspar quarry
Monteagle tp (Thompson mine)	Con 7, lot 11	D.F. Hewitt, ODM, reported	Pegmatitic	Allanite		Lang, 1952	Mined for feldspar 1922-24
Monteagle tp (Woodcox mine)	Con 7, lot 17	Metro Minerals & Uranium Mines Ltd	Pegmatitic	Betafite, columbite, ellsworthite, allanite, hatchettolite, calciosamarskite, cyrtolite	Diamond drilled	Ellsworth, 1932; Lang, 1952; Satterly, 1957	Former feldspar mine
Monteith tp	Con B, lot 21	Ellsworth, 1932, pp 191-192 (see reference)		Allanite		Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Montreal River	4 mi from mouth of Montreal R, N of Sault Ste Marie	Hennessy Uranium Explor Inc	Pegmatitic		Trenched	Lang, 1952	Also known as Hennessy gp
Montreal River area		Roche Long Lac GML	Vein			Lang, 1952	
Montreal River area	N of Sault Ste Marie	W. M. Mackie, North Bay, Ont.				Lang, 1952	
Mowat tp	Con 13, lot 32	W. W. Currie					
Munro tp		International Ranwick UML	Placer	Monazite	Drilled		Also known as Reoplata prop
Murchison tp	Con 3, lot 8	R. A. Quinn, 55 Ephgrave Blvd, Peterborough, Ont	Pegmatitic				Formerly worked for feldspar
Murchison tp	Con 4, lot 14	Madawaska Feldspar Co	Pegmatitic	Fergusonite		Lang, 1952	Former feldspar mine
Murchison tp	Con 4, lot 15	Madawaska Feldspar Co	Pegmatitic	Allanite, fergusonite			Formerly worked for feldspar
Murchison tp	Con 6, lot 17	L. Aleck, Madawaska, Ont				Lang, 1952	
Murchison tp	Con 7, N1/2 lot 22	R. Van Meter	Pegmatitic				Formerly worked for feldspar

Murchison tp	Con 8, lot 22	Hewitt, ODM, reported	Pegmatitic	Allanite, euxenite		Lang, 1952	Also known as Cameron prop. Formerly worked for feldspar
Murmac prop	2 mi S of Montreal River	Murmac Lake Athabaska Mines Ltd	Vein	Uranophane and, probably, pitchblende	Diamond drilled	Lang, 1952	
Muskoka tp	Con 3, lots 12, 13; con 4, lots 11, 12; con 5, lot 12	D. Halden, 329 St Paul St, St Catharines, Ont					
Napray properties	Near mileage 107, Algoma Central Railway	Napray Mining Co Ltd	Vein			Lang, 1952	
Nordic mine*	Tp 149	Algom UML	Conglomer-atic	Brannerite, uraninite, monazite	Underground (producer)		
North Burleigh tp	Con 12, lot 21	J. W. McFadden, no address given	Pegmatitic				
Oak Lake occ	Near boundary of Kenora and Red Lake Mining Divs	M. Mahoney and F. and K. Kozur, Red Lake, Ont	Pegmatitic	Monazite, uraninite	Diamond drilled		
Olden tp	Con 2, E1/2 lot 17 and W1/2 lot 18	S. Hughes					
Olden tp	Con 11, lots 3, 30	W. G. Harvey, Clarendon Sta, Ont					
Palmerston tp	Con 3, lot 9; con 5, lots 2, 3	J. Eastman, Clarendon, Ont	Pegmatitic	Uraninite	Diamond drilled		

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Panel mine*	Tp 144, Quirke Lake	Panel Cons UML	Conglomeratic	Brannerite, uraninite	Underground		
Pardo tp	Tee Lake	Pickle Crow GML	Conglomeratic				
Pitt tp	Otter Rapids, E shore of Abitibi R, 90 mi N of Cochrane	Moneta Porcupine Mines Ltd	Vein and/or pegmatitic	Monazite		Lang, 1952	Also known as Mosher discovery
Port Arthur occs	In and near city of Port Arthur		Vein	Uranium-bearing anthraxolite		Ellsworth, 1934; Lang, 1952	
Port Monroe occ	N shore L Superior	D.E. Johnson, Port Coldwell, Ont				Lang, 1952	Also known as Johnson prop
Pronto mine*	Long tp	Pronto UML	Conglomeratic	Brannerite, uraninite, thorogummite, thucholite, monazite	Underground (producing)		
Quibell occ	1 mi W of Quibell, Ont	J.P. Meehan, Quibell, Ont	Granitic			Lang, 1952	
Quirke mine*	Tp 150, Quirke Lake	Algom UML	Conglomeratic	Brannerite, uraninite, monazite, uranothorite, thucholite	Underground (producing)		

Raglan tp	Con 9, lot 27	J.H. Webster, 20 Caithness St, Toronto, Ont	Pegmatitic			Lang, 1952	
Raglan tp (Craig mine)	Con 18, lots 3 and 4, near Craigmont	Wartime Metals Corp	Granitic	Allanite, uraninite, euxenite		Ellsworth, 1927; Hewitt, 1954	Also known as Craig Corundum mine - formerly worked for corundum
Ranson occ	Lower dam on Montreal River	R.R. Ranson, Sault Ste Marie, Mich	Vein	Pitchblende		Lang, 1952	
Roche gp	N of Ranwick prop	F. Roche, 802, 85 Richmond St, W, Toronto, Ont	Vein	Pitchblende		Lang, 1952	
Ross tp	Con 7, lots 2, 3; con 9, lots 6, 7	D. Waite					
Sabine tp	Con 1, lot 28	H. Bolton	Pegmatitic	Euxenite		Ellsworth, 1932; Lang, 1952	Formerly worked for feldspar
Servos tp	Con 6, lot 6	Graham Lake Mining Synd	Granitic	Eschynite-priorite ser		Lang, 1952	
Shackleton tp	Con 10, lot 2	M.A. Provencher	Pegmatitic				
Sheddon tp (Peach occ)	16 mi E of Blind River	Panel Cons UML	Conglomer-atic		Diamond drilled		
Sherborne tp	6 mi SE of Dorset	B. Anderson, 417 Prince Edward Dr, Toronto, Ont	Pegmatitic			Lang, 1952	Also known as Dorset occ
Sherbrooke tp		R.M. Clarke, 120 Angeline St, Lindsay, Ont	Pegmatitic	Euxenite ?		Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Shields tp		N. MacLean, Box 231, Sault Ste Marie, Ont				Lang, 1952	Strong radioactivity reported
Shields tp	15 mi N of Sault Ste Marie	J.E. Gimby					
Snowdon tp	Con 1, lot 20			Uraconite		Lang, 1952	
Snowdon tp	Con 2, lot 11	C. Giles, 26 Barclay St, Hamilton, Ont	Granitic	Uraninite, thorite			
Snowdon tp	Cons 6 to 11, lots 10, 17, 19-24, 26, 28	L.S. Winch	Granitic				
Snowdon tp	Con 6, lots 16, 17	A. Di Renzo	Pegmatitic				
South Sherbrooke tp	Con 3, N1/2 lot 18	Christie Lake Mines Ltd	Granitic	Brannerite, uraninite, thorite	Diamond drilled	Moddle, 1957	
South Sherbrooke tp	Con 5, lot 13	Orser-Kraft Feldspar Ltd	Pegmatitic	Euxenite		Lang, 1952	Former feldspar prop
South Sherbrooke tp	Con 6, lot 15, near S boundary	A. Garrett, Smiths Falls, Ont				Lang, 1952	
Spanish-American mine*	Tp 150	Northspan UML	Conglomeratic	Brannerite, uraninite, monazite, thucholite	Underground (producing)		

Stanleigh mine*	Tps 149, 155	Stanleigh Uranium Mining Corp Ltd	Conglomeratic	Brannerite, uraninite, monazite	Underground (producing)		
Stanrock mine*	Tps 144, 150	Stanrock UML	Conglomeratic	Brannerite, uraninite, monazite, thucholite	Underground		
Storrington tp	Con 10, lot 28	E.H. Ubdegrove, Reddendale P.O., Ont					
Summerville tp	Con 12, lot 9	J.H. Webster, 20 Caithness Ave, Toronto, Ont				Lang, 1952	
Tarbutt tp	Con 3, lot 1	Tarbutt Mines Ltd	Vein	Pitchblende	Underground		Explored for copper also
Timagami Lake occs	E end of Timagami L	J.P. Neil, Palo Alto, Calif				Lang, 1952	
Tooker occ	Claim SSM 169442, 1 mi E of L Superior	E.O. Tooker, RR 2, Wayland, Mich				Lang, 1952	
Tp 25	Rge 16, SW corner	J.E. Gimby, Sault Ste Marie, Ont	Pegmatitic			Lang, 1952	
Tp 27	Rge 16	Algoma Ore Properties Ltd				Lang, 1952	
Tp 28	N of Labine-McCarthy prop	Patrick UML	Vein	Pitchblende	Trenched	Lang, 1952	
Tp 28	Rge 14	Labine-McCarthy UML	Vein	Pitchblende	Underground	Lang, 1952	Inactive

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Tp 28	Rge 14, E of Labine-McCarthy prop	Ranrouyn Mines Ltd	Pegmatitic			Lang, 1952	
Tp 28	Rge 16	F. Joubin, 68 Yonge St, Toronto, Ont	Vein	Pitchblende		Lang, 1952	Also known as Barnes-Prior prop
Tp 28	Rge 16, claim SSM 16808	F. Joubin, 68 Yonge St, Toronto, Ont	Granitic			Lang, 1952	May be same as Barnes-Prior prop
Tps 28 and 29	Rge 14	Fausten Explor Ltd	Vein			Lang, 1952	
Tps 28 and 29	Rges 14 and 15, 1 1/2 mi SE of mouth of Montreal River	Ranwick UML	Vein	Pitchblende	Underground	Lang, 1952	
Tp 28	Rge 17, near mileage 100, Algoma Central Railway	R. B. Phillips, Elkhart, Indiana	Pegmatitic			Lang, 1952	
Tp 29	Rge 14	Batchawana UML	Vein	Pitchblende		Lang, 1952	Also known as Batchawana prop
Tp 29	Rge 14, adjoins Camray prop	Bobcam Mines Ltd	Vein	Pitchblende	Prospected	Lang, 1952	Also known as Bobcam prop
Tp 29	Rge 14; 100 ft from Montreal River hwy at mileage 70.5	A.C. Mosher and G. Byles	Vein	Pitchblende		Lang, 1952	

Tp 29	Rge 15; N of Ranwick prop	Van Lake Prosp Synd	Vein		Trenched	Lang, 1952	Also known as Nolan gp
Tp 29	Rge 23, 2 1/2 mi SE of Wawa	T. Surluga, Wawa, Ont	Pegmatitic			Lang, 1952	
Tp 31	Rge 20, near Red Rock River	G.H. Mangun, 15713 Heyden Ave, Detroit, Mich				Lang, 1952	
Tps 41, 42	30 mi E of Kenora	F.J. McFarlane, and C.A. Campbell, Kenora, Ont	Granitic	Kasolite, uranophane, beta-uranotile, allanite	Diamond drilled	Lang, 1952	Also known as East Hawk Lake occ and possibly as Byberg prop
Tp 143		McIntyre Porcupine Mines Ltd	Conglomeratic		Diamond drilled		
Tp 143	22 mi NE of Algoma Mills	Nasco Cobalt Silver Mines Ltd	Conglomeratic		Diamond drilled		
Tp 143 (Aquarius prop)		Pardee Amalgamated Mines Ltd	Conglomeratic	Thucholite	Underground		
Tp 143 (Stancan Z-5 gp)		Stancan Uranium Corp	Conglomeratic		Diamond drilled		
Tps 143, 149		Abeta Mining Corp Ltd	Conglomeratic		Diamond drilled		
Tps 143, 149, 155		St Mary's UML	Conglomeratic		Diamond drilled		
Tp 144		Conecho Mines Ltd	Conglomeratic		Diamond drilled		

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Tp 144 (Z-7 gp)		Stancan Uranium Corp	Conglomeratic		Diamond drilled		
Tp 149		Geneva Lake Mines Ltd (Genex)	Conglomeratic		Diamond drilled		
Tp 149		Norsynco Mining & Explor Co Ltd	Conglomeratic		Diamond drilled		
Tp 149	N side of Elliot Lake	Kamis UML	Conglomeratic		Diamond drilled		
Tps 155, 161	Moon Lake	Moon Lake UML	Conglomeratic		Diamond drilled		
Tp 161	Matinenda Lake	Anabar Mining & Develop Co Ltd	Conglomeratic		Diamond drilled		
Tp 161	Matinenda-Moon lakes area	Dominion Uranium Corp	Conglomeratic		Diamond drilled		
Tp 161 (Moneta prop)	16 mi N of Blind River	Sapphire Petroleums Ltd	Conglomeratic		Diamond drilled		
Tp 176	N shore of West Twin Lake	C.E. Kemp, Sault Ste Marie, Mich		Secondary mins		Lang, 1952	
Tp 3H	SW corner of Ranger (Aubakagama) Lake	M.C. Gardiner, Haileybury, Ont	Vein			Lang, 1952	

Tps 4D and 4E	Aubrey Falls, Mississagi R	Preston East Dome ML	Vein			Lang, 1952	
Tp 4E		E.B. James, Sault Ste Marie, Ont				Lang, 1952	Also known as James occ
Tp 10D		J. Glowacki				Lang, 1952	
Tp U	S side of Rawhide Lake	C. Mattaini, Algoma Mills, Ont	Vein				
Turner tp		Harrison Minerals Ltd			Diamond drilled		Also known as Sevillis-Friday gp
Tustin tp	Near Game Lake	H.W. Hawes	Granitic	Uranophane, uraninite			
Vermilion Lake occ	Near Vermilion Lake	P. Ratuski, Kenora, Ont				Lang, 1952	
Vermilion Lake prop	1 1/2 mi E of Vermilion Lake	S. Stevenson, Kenora, Ont	Pegmatitic	Monazite, uraninite		Lang, 1952	
Victoria tp	22 mi E of Blind River	Victoria Algoma	Conglomeratic	Uranothorite	Diamond drilled		Also known as Truss-Nausau
Vogt tp	S arm of Lake Timagami	Aubay UML	Conglomeratic		Diamond drilled		Uranium-gold-iron prospect
Vogt tp	S arm of Lake Timagami	D'Eldona GML			Diamond drilled		
White Lake area	E of Regan Sta, S of CPR line	A. Punkari, CPR, Regan, Ont					

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Whitman tp	S side of Paquette Lake	Northland Mines Ltd & American Yellowknife GML			Trenched	Lang, 1952	Also known as Byrne group
Wilberforce tp	Con 3, lot 6	T.J. James, RR 1, Hyndford, Ont	Vein ?				
Wilks mine	Near Verona, Ont	J.C. Dunlop, Hoyle Mining Co Ltd		Allanite		Lang, 1952	
			QUEBEC				
Argenteuil cty	S of St Andrews East	P. Labreche, St Andrews East, Que	Pegmatitic ?				
Atwater tp	1 mi SE of Hunter's Point L Kipawa area	Belleterre Quebec Mines Ltd	Vein ? or sedimentary ?	Uraninite, uranophane, allanite	Diamond drilled		
Baskatong tp	Rge 2, W1/2 lots 22-24; lots 25-31	Gatineau UML	Contact metasomatic	Uranothorite, thorite, pyrochlore, ellsworthite, uraninite ?	Diamond drilled	Que Dept Mines PR 330	
Beraud tp		R. Bourcier, et al, Box 871, Val d'Or, Que	Pegmatitic				
Beraud tp, Gelinas and Martel occ		Reported by R. Bourcier, Val d'Or, Que	Pegmatitic				

Beraud tp	Near mileage 27, Rapid Seven Road	S. Skrypek and Syndicat de Prospection, Malartic, Que	Pegmatitic			
Bressani tp	Yvonne L, 112 mi NE of Senneterre	Barnat Mines Ltd	Granitic	Uraninite, allanite, uranophane ?, gummite ?	Aerial scint and mag surveys, diamond drilled	
Callieres tp		Cons St Simeon Mines Ltd	Pegmatitic	Uraninite, allanite, fergusonite	Trenched and diamond drilled	Lang, 1952
Callieres tp	Rge SW 1, SW1/4 lots 4-7; NW1/2 lot 8; rge SW 2, lots 1-9, SE1/2 lot 10; rge NE 2 lots 1-3; rge SW 3, lots 1-10	St Simeon Synd, St Simeon, Que	Pegmatitic	Allanite, fergusonite, uraninite	Bulk sampled	
Callieres tp	Rge SW 1, lots 20-24	C.A. Brouillard, St Simeon, Que	Pegmatitic	Uraninite	Trenched	
Clapham tp	Rge 2, lots 38, 39, 42-49; rge 3, lot 46	M. Adams, Portage du Fort, Que	Pegmatitic	Allanite, cyrtolite, uranothorite, uraninite	Stripped and trenched; 102 ft of diamond drilling	
Clapham tp	Rge 3, lot 28	M. Adams, Portage du Fort, Que	Pegmatitic	Allanite, uranothorite, uraninite ?	Trenched	
Clapham tp	Rge 5, lot 49	Leys Mining Corp Ltd	Pegmatitic			
Clarendon tp	Lot 12	H.F. Klock, 535 Somerset St W, Ottawa, Ont	Pegmatitic			

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Dorion tp	Rge 9, lots 39, 40	Copper-Uranium Ltd	Pegmatitic	Uranothorite, allanite, thorite, uraninite ?	Trenched	Que Dept Mines PR 330	
Egan tp	Rge B, W1/2 lots 66-71	J. Lavoie, Val d'Or, Que	Pegmatitic				
Egan tp	Rge 1, lot 1	E. McSheffrey, Maniwaki, Que	Granitic	Uraninite, zircon, uranothorite	Diamond drilled		
Egan tp	Rge 1, lots 2-6, road cut near Eagle R	A.S. Watson, Box 88, Maniwaki, Que	Pegmatitic	Allanite, uranothorite		Que Dept Mines PR 330	
Egan tp	Rge 3, lots 6-13	Cobalt Cons Mining Corp and Silanco Mining	Pegmatitic and contact metasomatic	Uraninite	Trenched	Que Dept Mines PR 330	
Egan tp	Rge 3, W1/2 lot 27	O'Leary Malartic Mines Ltd	Granitic				
Egan tp	Rge 8, lots 33-35	R. Kelly, Box 764, Maniwaki, Que	Pegmatitic				
Grand Calumet tp		Calumet Explor Ltd	Contact metasomatic ?		Stripped	Lang, 1952	
Grand Calumet tp	Rge 1, lot 23	J.T. Derouin, Calumet Island, Que	Pegmatitic				

Grand Calumet tp	Rge 5, SW parts of lots 30-33; rge 6, lots 27-34; rge 7, lots 27-34	Calumet UML	Contact metasomatic and pegmatitic	Uranothorite, monazite, thorite, uraninite-thorianite ser	Diamond drilled	Lang, 1952	
Grand Calumet tp	Rge 6, lot 23; rge 7, lots 24-26; rge 8, lots 22-34	Calumet Contact UML	Contact metasomatic ?	Uranothorite	Diamond drilled		
Grand Calumet tp	Rge 8, lots 11, 12; rge 9, lots 9-12	Struan UML	Pegmatitic	Uraniferous thorite, uraninite, allanite ?	Diamond drilled	Gittins, 1956	
Grand Calumet tp	S rge, lots A, B, C; rge 4, lots 1, 2	L. Meilleur, RR 1, Calumet Island, Que	Pegmatitic				
Grenville tp	Rge 5, lot 12	J. Brown, Calumet, Que					
Harvey tp	Rge 5, S1/2 lots 6, 7; rge 6, N1/2 lots 6, 7	J.R. Dalliare, 466 Rue de Sales, Chicoutimi, Que	Contact metasomatic				
Huddersfield tp	Rge 1, lots 27-32; rge 2, lots 26-31	Cons Halliwell Ltd	Granitic ?	Thorianite, uraniferous thorite	Diamond drilled	Kretz, 1957	
Huddersfield tp	Rge 3, lots 12-28	Empire Oil & Minerals Inc	Pegmatitic			Kretz, 1957	
Huddersfield tp*	Rge 4, lots 19-21; rge 5, lots 19-20	Yates UML	Contact metasomatic	Uranothorite, thorite, allanite, beta-uranotile	Underground	Kretz, 1957	Inactive

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Huddersfield tp	Rge 4, lots 25-38	Soma Duvernay GML	Contact metasomatic ?	Uranoan thorianite, monazite, thorite	Diamond drilled	Kretz, 1957	
Huddersfield tp	Rge 5, lots 21-24; rge 6, S1/2 lots 21-24 and lots 25-28	Huddersfield Uranium & Minerals Ltd	Contact metasomatic ?	Thorianite	Stripped	Kretz, 1957	
Huddersfield tp	Rge 8, lots 23, 24, 27	H. F. Klock, 535 Somerset St W, Ottawa, Ont				Kretz, 1957	
Hull tp	Rges 14, 15, lots 15, 16	O'Leary Malartic Mines Ltd	Pegmatitic		Diamond drilled		
Jolliette tp	McLaren lumber lease, Menjo Depot	Gill Mining Corp					
Kensington tp	Rge 7, lot 48	J. Gagnon, RR 1, Maniwaki, Que		Uranothorite, allanite, thorite	Stripped and trenched	Que Dept Mines PR 330	
Leslie tp		T. Hayes, Woodroffe P O, Ont					
Leslie tp	Rge A, lot 13	H. F. Klock, 535 Somerset St W, Ottawa, Ont					
Letellier tp	10 mi NE of Seven Islands	Seven Islands Mining & Explor Co Ltd	Pegmatitic	Uraninite, gummite ?, monazite ?	Trenched and diamond drilled	Que Dept Mines PR 330	

Levy tp	Abitibi cty, Chibougamau area	Opemiska Copper Mines Ltd	Vein	Uraninite or pitchblende	Underground (copper producer)		
Low tp	Rge 8, N1/2 lot 22; rge 9, lots 19-24, N1/2 lot 25	D'Eldona GML	Pegmatitic	Uraninite, allanite, thorogummite	Trenched		
Low tp	Rge 11, lots 30, 31	R. and F. Wilkie, Venosta, Que	Pegmatitic	Uranothorite, allanite, uraninite, zircon	Stripped		
Lynch Lake occ		H. Frost, Fort Coulonge, Que	Pegmatitic				
Lytton tp	Rge 1, lot 26	Alta Mines Ltd and/or L.K. Smith, Val d'Or, Que	Pegmatitic				
Lytton tp	Rge 1, lots 25-40; rge 2, lots 18-47; rge 3, lots 23-46; rge 4, lots 35-45	Baskatong Uran Mining Synd and and Lytton Uran Mining Synd					
Lytton tp	Rge 3, lots 37, 38	J. Lavoie, Box 397, Val d'Or, Que	Pegmatitic	Allanite, zircon, thorite			
Maisonneuve tp		E.W. Smith, 2615 Wellington St, Montreal, Que	Pegmatitic				
Maisonneuve tp	Rge 2, lots 1, 2	South State UML	Pegmatitic	Euxenite, uraninite, samarskite, fergusonite	Diamond drilled; underground workings re-opened	Ellsworth, 1932; Lang, 1952	Also known as Maisonneuve mine

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Mann tp	Rge 1, lots 1-3, Cross Point	W.B. Busteed, Cross Point, Que	Vein	Pitchblende	Diamond drilled	Lang, 1952; Gross, 1957	
Masham tp	Rge 10, lot 55	L.B. Rochester, 72 Queen St, Ottawa, Ont					Also known as Indian molybdenite or Bain mine
Mekinac tp	Rge 1, lots 30-33	G. Naud, St Joseph de Mekinac, Que	Pegmatitic	Monazite		Que Dept Mines PR 330	
Miniac tp	Rge 2, lot 31	A. Berube, St Dominique du Rosaire, Abitibi, Que	Float				
Mitchell tp	Extreme SW corner of tp	Duvex Oils & Mines Ltd	Pegmatitic	Allanite, uranothorite	Diamond drilled	Que Dept Mines PR 330	Also known as Dumulon occ
Mont Laurier	Near Lievre R	Reported by P. Arbic, Mont Laurier, Que	Pegmatitic	Ellsworthite, allanite, uraninite, uranothorite		Lang, 1952	
Mousseau tp	Rge 2, lot 13, rge 3, lot 14	P. Begin, St Veronique, Que	Pegmatitic ?				
Normand tp	Lac a Baude	J.M. Yates, 545 St Aubin St, Ville St Laurent, Montreal, Que		Allanite			
Oka (Bouscadillac GML)	Deux Montagnes cty	Bouscadillac GML	Metasomatic	Pyrochlore, monazite	Diamond drilled	Maurice, 1957	

Oka (Coulee-Headway prop)	Deux Montagnes cty, near Oka	Coulee-Headway group	Metasomatic ?		Diamond drilled	Maurice, 1957	
Oka (Oka Rare Metals Mining Co Ltd)	Deux Montagnes cty, near St Joseph du Lac	Oka Rare Metals	Metasomatic	Niobium and thorium mins	Underground	Maurice, 1956, 1957	Inactive
Oka* (Quebec Columbium Ltd)	Deux Montagnes cty	Quebec Columbium Ltd	Metasomatic	Monazite, uraninite, betafite, pyrochlore-microlite ser	Diamond drilled	Rowe, 1954; Maurice, 1956, 1957	Large deposit of niobium (columbium)
Onslow tp	Rge 11, lot 5 and N1/2 lot 6	E. Marion, Onslow Corners, Que					
Pope Lake occ	N of Pope L, near Pope, Labelle cty	A. Duquette, Mont Laurier, Que	Pegmatitic	Allanite, ellsworthite			
Portland tp	Rge 2, lot 28	O'Leary Malartic Mines Ltd	Pegmatitic		Diamond drilled		
Portneuf cty	Deschambault and Portneuf parishes	Portneuf Molybdenum Corp	Pegmatitic	Uraninite, uranothorite ?	Trenched, 40-foot shaft	Lang, 1952	
Portneuf cty	Deschambault and Portneuf parishes, rge 3, lots 331, 333, 334, etc	L. A. Gaudry, Quebec city	Pegmatitic	Autunite ?, uranophane ?, uraninite, uranothorite ?, gummite	Trenched	Lang, 1952	Also known as Gaudry-Caron prop
Preissac tp	Rge 7, lots 53, 54	E. Grondin, Val d'Or, Que	Pegmatitic			Lang, 1952	
Provost tp	Rge A, SW1/2 lot 18	South State UML	Pegmatitic		Stripped		

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Sicotte tp	Rge 1, lots 22-30; rge 2, lots 26-29	Alta Mines Ltd and Nemrod Mining Co Ltd	Pegmatitic	Uraninite, uranophane, uranothorite, allanite, zircon	Trenched and bulk sampled		
Rouville cty	St Hilaire Parish	Chess Uranium Corp			Diamond drilled		Niobium, "rare earths", thorium, uranium prospect
Remigny tp	Rge 9, N1/2 lots 27-34	V. Taylor, Dobie, Ont, or Cons Northland Mines Ltd					
St Mathieu tp	3 mi from Shawinigan Falls, lots 38, 39	A. Perrault, Shawinigan Falls, Que	Pegmatitic ?			Lang, 1952	
St Thuribe occ	Portneuf cty, St Joseph con, lots 8-14	A. Bolduc, St Thuribe, Portneuf cty	Pegmatitic				
Templeton tp	Rge 12, S1/2 lot 20	A. Wallingford, Gatineau Point, Que	Pegmatitic	Euxenite		Lang, 1952	
Thorne tp	Rge 1, lot 18	M.W. Sharpe, Coldwell, Que					
Thorne tp	Rge 2, lot 19	C.H. Cone, H.G. Wills and others, Shawville, Que	Pegmatitic	Monazite, allanite			

Tp P-68	About 5 mi NW of Lepine Depot	Copper-Uranium Ltd	Pegmatitic	Monazite, allanite, thorite, uraninite, uranothorite, euxenite	Trenched	Lang, 1952	
Villedeau tp	Lac Sairs, SE side	A.J. Cunningham and others, 1127 Gorman St, North Bay, Ont	Pegmatitic				
Villeneuve tp: and Portland tp:	Rge 1, lots 30-35; S1/2 lots 37, 38; rge 2, S1/2 lots 30-35 Rge 10, lots 29-32	C.D. Salkeld and others, 6420 Sherbrooke St W, Montreal, Que	Pegmatitic	Uraninite, gummite, fourmarierite			Formerly U.G. Mica prop
Wakefield tp	Rge 3, lots 24, 25	O'Leary Malartic Mines Ltd	Pegmatitic	Uraninite, euxenite-polycrase ser	Trenched		
Waltham occ	Black River area	C.D. Sauriol, 1027 Dease St, Fort William, Ont				Lang, 1952	
West Templeton tp	Lot 25A	R.A. Mutter, 1067 Stormont St, Ottawa, Ont					
SASKATCHEWAN							
ABC	Beaverlodge L	Nesbitt-LaBine UML	Vein	Pitchblende, zippeite	Underground	Lang, 1952; Christie, 1953; Robinson, 1955	Inactive
Ace*	Beaverlodge L	Eldorado	Vein	Pitchblende	Underground (producing)		

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
AD	Crackingstone Pt, L Athabasca	Crackingstone Mines Ltd	Vein				May be part of GC-Dick gp and/or Vix 1-10 gp
A & D concessions	Black L	Black Lake UML	Vein			Lang, 1952	
AL .	L Athabasca	Norancon Explor Ltd	Vein	Pitchblende	Pit work	Blake, 1951; Lang, 1952	
Al 1-12	Wapus L	Columbia Minerals Explor Ltd	Granitic				
Alan-Gail-Dix	Yahyah L, Beaverlodge L area	Lorado UML	Vein ?	Secondary mins	Diamond drilled		
Alco 1-7*	Beaverlodge L	Lorado UML	Vein	Pitchblende, uranophane	Underground (producing)		
Alda 1-12	Dumont L	J. Albrecht, Prince Albert, Sask	Pegmatitic	Uraninite			
Al-Liz	Nisikkatch L, lat 59°54' N, long 107°54' W	A. Slaby, Uranium City, optioned to Orchan UML	Pegmatitic	Allanite, cyrtolite, monazite	Trenched	Hogarth, 1957	Apatite deposit with cerium and yttrium earths
Alpha	Charlebois L	E. F. Partridge, Prince Albert, Sask	Charlebois			Lang, 1952	
Amax 1-59	Beaverlodge L	Pardee Amalgamated Mines Ltd	Vein	Pitchblende, uranophane	Diamond drilled	Lang, 1952; Christie, 1953; Robinson, 1955	

Andy 1-9	Laird Island, Tazin L	Iso UML	Granitic	Pitchblende	Diamond drilled		
Arch 11-19	Crackingstone Pen, Beaverlodge L area	Gunnar Mines Ltd	Vein	Secondary uran mins	Diamond drilled		
Arko-Gulch, etc	Black Bay, L Athabasca	Gulch Mines Ltd	Vein	Pitchblende	Underground	Lang, 1952	Inactive
Art	Charlebois L	Cons Mining & Smelting Co	Charlebois	Uraninite ?	Trenched	Lang, 1952	
Ath	Beaverlodge L area	Athona Mines Ltd			Diamond drilled	Lang. 1952	
Axe	Beaverlodge L	Polamet Mines Ltd	Vein	Pitchblende	15-foot adit	Lang, 1952; Christie, 1953	
Azor*	Beaverlodge L area	Cayzor Athabaska Mines Ltd	Vein	Pitchblende, uranophane, zippeite	Underground (producing)		
B 1-18	Dewdney Island, Tazin L	Caba Uranium Ltd	Vein	Pitchblende	Pit work ?		
Bailey Lake	Lac la Ronge area	Discovered by Sask Gov't survey party	Pegmatitic	Secondary uran mins			
Bar 1-4	Beaverlodge L	Beaver Lodge UML	Vein ?	Pitchblende	Diamond drilled		
Bar 5-9	Mickey L, Beaverlodge L	Beaver Lodge UML	Vein	Pitchblende	Underground	Christie, 1953; Robinson, 1955	Inactive
Baska 1-63	Foster Lakes area	Baska UML	Pegmatitic	Uraninite, davidite			

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Baska 1-18	Beaverlodge L area (Fish L)	Baska UML	Vein	Pitchblende	Diamond drilled		
Baska 19-40	Beaverlodge L area (Raggs L)	Baska UML	Vein	Pitchblende	Diamond drilled		
Bat	Beaverlodge L area (Prince L)	Goldfields UML	Vein	Pitchblende	Diamond drilled		
Bay	Beaverlodge L area (Black Bay, L Athabasca)	Gui-Por Uranium Mines & Metals Ltd	Vein	Pitchblende	Diamond drilled	Lang, 1952	
Beaver River occ	L Athabasca, lat 59°24' N, long 107°45' W	Unstaked - reported by E. Partridge, Prince Albert, Sask	Vein	Pitchblende		Blake, 1952	
Bela-Rowthorne-Bird	Lac la Ronge	Westpol Explorations Ltd	Pegmatitic		Diamond drilled		
Bell	Charlebois L	E.F. Partridge, Prince Albert, Sask	Charlebois	Uraninite, thucholite ?	Trenched	Lang, 1952	
Bert 1-21	Neely L, Beaverlodge L area	Gwillim Lake GML			Diamond drilled		
Bev	Beaverlodge L area (Crackingstone Pen)	Larum Mines Ltd	Vein	Pitchblende	Diamond drilled		
Bird 1-7	Grease R, about 16 mi E of Fond-du-Lac	J.J. Power and R.B. Stanley	Vein		Trenched		Reported by McPherson, Sask Dept Nat Res

Black Bear Island Lake	Lac la Ronge area	E. F. Partridge, Prince Albert, Sask	Pegmatitic			Lang, 1952	
Blende 1-8	Beaverlodge L	ViolaMac Mines Ltd			Diamond drilled		
Bob	Tazin L	Baska UML	Vein and pegmatitic	Pitchblende	Diamond drilled		
Bob 1-9	Cameron Island, L Athabasca	Twin Bay Mining & Explor Co Ltd	Vein	Pitchblende, secondary mins	Diamond drilled		
Bolger*	Beaverlodge L area	Eldorado	Vein	Pitchblende, secondary mins	Diamond drilled	Lang, 1952; Christie, 1953	
Boom 1-17	Beaverlodge L area	Goldfields UML	Vein	Pitchblende	Underground (shipped ore)	Christie, 1953; Robinson, 1955	Inactive
Box mine	Beaverlodge L area	Cons Mining & Smelting Co Ltd	Vein	Pitchblende, thucholite ?	Diamond drilled	Lang, 1952; Christie, 1953	
Brown 1-27	Matthews L	C. Salling, D. Brown	Vein				
Bruce-Elaine	Nevins L area	E. Otto, Uranium City, Sask	Pegmatitic				
Bug-Pine-Ore	Beaverlodge L	Basalt UML	Vein and granitic	Pitchblende, secondary mins, uraninite ?	Diamond drilled		
Bulyea R occ	Grease Bay area, L Athabasca	Hogarth, GSC, reported		Monazite			Probably unstaked
Bur-Hub-Rub	Foster Lakes area	Ad Astra Minerals Ltd	Granitic	Uraninite, pitchblende	Diamond drilled	Lilge, 1955	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Butch	4 mi E of Stony Rapids	F. MacAskill, Stony Rapids, Sask	Vein	Pitchblende		Lang, 1952	
Cab 1-3	Beaverlodge L	Noranium Minerals	Vein		Diamond drilled		
Cab-Paul-Mike-Tom-Jim	Beaverlodge L	Athabasca UML	Vein	Pitchblende, secondary uran mins	Diamond drilled	Lang, 1952; Christie, 1953; Robinson, 1955	
Cal 1-24	Beaverlodge L	Edoran Oil Corp Ltd	Vein	Pitchblende	Diamond drilled		
Car 1-15	Black Bay, L Athabasca	Jesko UML	Vein	Pitchblende, secondary uran mins	Underground		Inactive
Cat-Dog-Eunice	Bearcat L, Beaverlodge L area	Scintilore Mines Ltd					
CC	L Athabasca	Langley Bay Uranium Ltd	Vein	Pitchblende, secondary mins	Diamond drilled		
Cec-Mel	Sucker Bay, L Athabasca	Goldfields UML	Vein and pegmatitic		Diamond drilled	Lang, 1952	
Chev-Rollie	Le Blanc L, Beaverlodge L area	Empire Explor Ltd	Granitic				
Chris-June	Charlot L, Beaverlodge L area	Minifee UML	Pegmatitic	Allanite, monazite, cyrtolite, yellow secondary min	Trenched		

Chuck	Beaverlodge L	Baska UML	Vein	Pitchblende	Diamond drilled		
Chum-Top-Alone	N of Jean L, Beaverlodge L area	Beta Gamma UML	Vein	Pitchblende	Underground	Lang, 1952; Christie, 1953; Robinson, 1955	Inactive
Clix 1-41	Beaverlodge L	Clix Athabasca UML	Vein	Pitchblende, secondary mins	Diamond drilled		
Con-Tape-Baldy	Beaverlodge L area	Goldfields UML	Vein	Pitchblende, secondary mins	Diamond drilled		
Corrigan L occ		Dee Explor Ltd					
Corrigan-Stinson	Charlebois L area	A. Stinson	Charlebois	Uraninite		Lang, 1952	
Dawn	Beaverlodge L	Para Uranium Ltd	Vein	Pitchblende	Diamond drilled	Lang, 1952; Christie, 1953	Formerly Radiore's Con group on former YY concession
Dette	Fredette L, Beaverlodge L area	Pardee Amalgamated Mines Ltd	Vein	Pitchblende	Diamond drilled	Christie, 1953; Robinson, 1955	
Di	Crackingstone Pen, Beaverlodge L area	Baska UML	Vein	Pitchblende	Diamond drilled		
Dick 1-18	Crackingstone Pt, Beaverlodge L area	Big Jackpot Mines Ltd	Vein	Pitchblende, fourmarierite, uranophane	Diamond drilled		
Dick 3, 4, 9, 14, 15	Crackingstone Pt, Beaverlodge L area	Crackingstone Mines Ltd	Vein		Diamond drilled		

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Dill	Fredette L, Beaverlodge L area	Detta Minerals Ltd	Vein	Pitchblende	Diamond drilled	Lang, 1952	Part of former FF-1 concession
Don	Beaverlodge L area	Eldorado	Vein	Pitchblende	Diamond drilled	Lang, 1952; Christie, 1953; Robinson, 1955	
Don	Mitchell Island, L Athabasca	Anuwon UML	Vein	Pitchblende ?	Scintillometer survey and geological mapping		
Dot 1-30	Virgin L, Beaverlodge L area	Baska UML	Vein	Pitchblende	Underground		Inactive
Dot 2-22	Forget L, Beaverlodge L area	Lorado UML			Diamond drilled		
Duf 1-21	Beaverlodge L area	Anuwon UML	Pegmatitic	Allanite ?, pitchblende, uraninite, uranothorite	Diamond drilled		
Eagle	Beaverlodge L	Eldorado	Vein	Pitchblende	Underground	Lang, 1952; Christie, 1953; Robinson, 1955	Inactive
East Manawan L occ	Churchill R area	Reported by Sask Gov't geologist	Pegmatitic			Kirkland, 1957	
Ed	Murmac Bay, Beaverlodge L	Lake Lingman Gold Mining Co			Diamond drilled		

Ed-Bon* (Gunnar mine)	St Mary's Channel, L Athabasca	Gunnar Mines Ltd	Replacement and supergene enrichment (vein type)	Pitchblende, uranophane	Open pit and underground mining (producing)		
Ed-Tom	Beaverlodge L	Basalt Bay Mines Ltd	Vein	Pitchblende	Diamond drilled	Lang, 1952	
Ede-Boo	Laird Island, Tazin L	Northwest UML	Pegmatitic				
Ella-Helen	Beaverlodge L area	Keymor GML	Pegmatitic ?	Secondary mins			
Emar	Beaverlodge L	Eldorado	Vein	Pitchblende	Diamond drilled	Lang, 1952; Christie, 1953	
Erickson occ	Stony Rapids area	F. Erickson, Stony Rapids, Sask		Monazite	Pit work	Lang, 1952	Formerly McCoy gp
Fat	Beaverlodge L	Commercial UML					
Ferris L occ	Beaverlodge L area; 3 mi NE of Le Blanc L	Gui-Por GML	Pegmatitic or granitic	Uraninite ?	Diamond drilled		
Fish-hook Bay gp	L Athabasca, Beaverlodge L area	Consolidated Nicholson Mines Ltd	Vein	Pitchblende, uraninite	Diamond drilled	Lang, 1952; Christie, 1953; Robinson, 1955	May be property acquired by Black Bay UML
Fisher-Haydukevich	Black L	Fisher Uranium Co Ltd	Pegmatitic			Lang, 1952	
FKR	Sucker Bay, L Athabasca	Varmac Mines Ltd	Vein and pegmatitic	Pitchblende, secondary uran mins	Diamond drilled	Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Fold 1-71	Fold L, Beaverlodge L area	New Hosco Mines Ltd	Vein	Pitchblende	Diamond drilled	Christie, 1953	
Foster Lake claims	Foster Lakes area	Eldorado		Pitchblende			
Fox	Crackingstone Pen, Beaverlodge L area	St Michael UML	Vein	Pitchblende	Diamond drilled		
G con	Black L	E. F. Partridge, Prince Albert, Sask	Pegmatitic			Lang, 1952	
Gal	Mickey L, Beaverlodge L area	Camdeck Mines Ltd	Vein	Pitchblende	Diamond drilled		
Gamp	Beaverlodge L	Cons Red Poplar Minerals Ltd	Vein	Pitchblende, gummite	Diamond drilled		
GB 1-17, 24	Crackingstone Pt, L Athabasca	Gwillim Lake GML	Vein				
GC	Crackingstone Pt, L Athabasca	Crackingstone Mines Ltd	Vein	Pitchblende	Diamond drilled		
Gil	Lodge Bay, L Athabasca	Eldorado	Vein	Pitchblende	Diamond drilled	Robinson, 1955	
Grace and Ladd	Langley Bay, L Athabasca	Macfie Explor Ltd	Vein		Diamond drilled		
Grease Bay occ	L Athabasca	Hogarth, GSC, submitted sample		Monazite			Unstaked

Gretta*	Beaverlodge L	Black Bay UML	Vein	Pitchblende, secondary uran mins	Underground		Inactive 1957. Planned to ship ore.
Griff and Hall	Prince L, Beaverlodge L area	Goldfields UML			Diamond drilled		
Hab	Donaldson L, Beaverlodge L area	Eldorado	Vein	Pitchblende, thucholite ?	Diamond drilled	Christie, 1953	
Ham	Crackingstone Pt, L Athabasca	Iso UML	Vein	Pitchblende	Diamond drilled		
Hap 1-9	Milliken L, Beaverlodge L area	Gwillim Lake GML	Vein	Pitchblende	Diamond drilled		
Har	Camsell R, L Athabasca	Father Brown, Uranium City, Sask					
Hazel 1-6	Beaverlodge L	Bluegrass UML	Vein	Pitchblende, secondary mins	Diamond drilled		
Hearst	Beaver R - Oldman R area, L Athabasca	M. Kramer, Uranium City, Sask	Vein ?	Secondary uran mins			
HED-JR	Foster R	J.A. Syme, Flin Flon, Man	Pegmatitic				
Holm	Alces L, Beaverlodge L area	Goldfields UML	Vein and pegmatitic	Pitchblende	Diamond drilled		
Hub	Lac la Ronge	Northern Uranium Ltd	Granitic	Uraninite, monazite, allanite		Lang, 1952	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
HU-HP	Oldman R, L Athabasca	Oldman River UML	Granitic	Uraninite, soddyite	Diamond drilled		
HW and Diane	Melville L, Beaverlodge L area	Baska UML	Vein	Pitchblende	Diamond drilled	Lang, 1952	
Hy	Beaverlodge L area	Pacemaker Mines & Oils Ltd	Vein ?		Diamond drilled		
Hyd 1-10	Beaverlodge L	Imperial Mines & Metals Ltd	Vein	Gummite	Diamond drilled		
Ike 10-18	Beaverlodge L	Ameranium Mines Ltd			Diamond drilled		
Ike 19-27	Beaverlodge L	Consolidated Astoria Mines Ltd	Vein		Diamond drilled		
IO	Stewart Island, L Athabasca	Frobisher Ltd and Canada Pipelines & Petroleums Ltd (in litigation)	Vein	Pitchblende, thucholite, liebigite ?			
Iskwatan L occ	Churchill R area	Reported by Sask Gov't geologists		Allanite			
Isle	St Mary's Channel, L Athabasca	Glencair Mining Co Ltd	Vein		Diamond drilled		
Jag	St Mary's Channel, L Athabasca	Parbec Mines Ltd	Vein	Pitchblende	Diamond drilled		

Jam 1-8*	Cinch L, Beaverlodge L area	Lake Cinch Mines Ltd	Vein	Pitchblende	Underground (producing)	
Jam-Maj*	Beaverlodge L area	Nesbitt-LaBine UML	Vein	Pitchblende	Underground (former producer)	
Jean 1-30	Beaverlodge L area	Pardee Amalg Mines Ltd	Vein	Pitchblende	Diamond drilled	Christie, 1953; Robinson, 1955
Jet 1-9	Beaverlodge L	Ebor UML	Vein		Diamond drilled	
Jim 1-15	Crackingstone Pt, L Athabasca	Tazin Mines Ltd	Vein		Diamond drilled	
Jim-Gal	Mickey L, Beaverlodge L area	Camdeck Mines Ltd	Vein	Pitchblende, secondary uran mins	Diamond drilled	
JN	Grease Bay, L Athabasca	Fond-du-Lac, Exploration Co Ltd	Vein	Pitchblende, secondary uran mins	Diamond drilled	
JO	Milliken L, Beaverlodge L area	Pitchvein, Magnet Cons, & Gold Eagle Mines Ltd	Vein	Pitchblende		
Job	Beaver R area, L Athabasca	Gaitwin Explor Ltd		Pitchblende	Diamond drilled	
Jos 1-16	Laird Island, Tazin L	Durocher Uranium Co Ltd	Vein and pegmatitic	Pitchblende, uraninite, gummite, monazite	Diamond drilled	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Jos 17-26	Laird Island, Tazin L	Messrs Durocher, Demers and Heron, Uranium City, Sask	Vein	Pitchblende	Trenched		
JR	Foster Lakes	Quintor Mining Partnership	Pegmatitic ?				
Kara 1-25	Blackstone L	Nova UML	Pegmatitic	Secondary uran mins	Diamond drilled		May be same as Kara-Nada-Nova
Kara-Nada-Nova	Blackstone L area	E. Partridge and associates, Prince Albert, Sask	Pegmatitic	Uraninite			
Kay	Cypress R area, L Athabasca	Father Brown, Uranium City, Sask					
Ken	Crackingstone Pt, L Athabasca	Bonville GML	Vein	Pitchblende ?	Diamond drilled		
Key 1-15	St Joseph Pt, L Athabasca	Judella UML					
Kisseynew L occ	Flin Flon area	Reported by Sask Gov't survey party		Secondary uran mins			
Kix 1-10	Lodge Bay, L Athabasca	Kix Uraniums Ltd	Vein	Pitchblende	Trenched	Lang, 1952	
Kix 1-12, etc	Coe L, Beaverlodge L area	Hacker Atompower UML	Vein	Pitchblende			

Laird-Dew	Laird Island, Tazin L	Great West UML	Vein and pegmatitic	Pitchblende, allanite, cyrtolite	Diamond drilled		
La Ronge occ	Lac la Ronge area	La Ronge UML	Pegmatitic	Becquerelite, liebigite	Diamond drilled	Lang, 1952	
Last Chance 1-12	Laird Island, Tazin L	New Thurbois Mines Ltd	Vein				
LB	Virgin L, Beaverlodge L area	Beaver Lodge UML	Vein	Pitchblende, secondary uran mins	Diamond drilled		
L & B	MacIntosh Bay, L Athabasca		Vein	Pitchblende		Blake, 1951	
Len 1-9	St Joseph Pt, L Athabasca	Judella UML	Granitic ?	Secondary uran mins	Diamond drilled		
Leo 1-10	Crackingstone Pt, L Athabasca	Orchan UML	Vein	Secondary uran mins	Diamond drilled		
Loc-Moc-Doc	Murmac Bay, Beaverlodge L	Toff UML	Pegmatitic and vein	Pitchblende	Diamond drilled		
Lor	Viking L, Beaverlodge L area	Lorado UML	Pegmatitic and vein	Uraninite, monazite, pitchblende, uranothorite, pyrochlore-microlite, cyrtolite, meta-allanite	Diamond drilled	Robinson, 1955	Also known as Viking L deposit
Love	Raggs L, Beaverlodge L area	Eldorado					

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Lucky	Anne L, Beaverlodge L area	Winora GML	Vein	Pitchblende ?	Airborne radioactivity survey		
Lucy	Crackingstone Pen, L Athabasca	Uranium City Mining & Develop Co Ltd	Vein		Trenched		
Lux 1-9	Laird Island, Tazin L	Tara Explor Ltd	Vein	Pitchblende	Diamond drilled		
M concession	Black L area	Byrne interests			Trenched	Lang, 1952	Abandoned
Mad-Lad-Dad-Sad	Peak L, Haultain R area	Ad Astra Minerals Ltd	Pegmatitic				
Mar	St Mary's Channel, L Athabasca	Nesbitt-LaBine UML	Vein	Pitchblende, zircon	Diamond drilled		
Maree-Try-Dot	Milliken L, Crackingstone Pt	Maree Uranium Ltd	Vein		Diamond drilled		
Marg	Beaverlodge L area	Pluton UML	Vein	Pitchblende	Diamond drilled		
Martin L occ	Beaverlodge L area	Eldorado	Vein	Pitchblende	Underground	Lang, 1952; Christie, 1953; Robinson, 1955	
MH 1-12	Laird Island, Tazin L	Tara Explor Ltd	Vein and pegmatitic	Pitchblende, secondary uran mins, uraninite, allanite	Trenched		

Mic	Mic L	Eldorado	Vein	Pitchblende	Trenched	Christie, 1953
Mick 4	Oldman R, L Athabasca area	Nesbitt-LaBine UML	Granitic	Monazite, uraninite	Trenched	Robinson, 1955
Mick 5 & 6	Crackingstone Pt, L Athabasca	Nesbitt-LaBine UML	Vein	Pitchblende	Trenched	
Mick 7-9	St Mary's Channel, L Athabasca	Nesbitt-LaBine UML	Vein	Pitchblende, secondary uran mins	Trenched	
Middle L occ	Stony Rapids area	Dee Explor Ltd	Sedimentary	Autunite, phosphuranylite	Diamond drilled	Blake, 1956
Mike 1-17	Laird Island, Tazin L	Tara Explor Ltd	Vein	Pitchblende		
Mill	Beaverlodge L area	Pluton UML	Vein	Pitchblende	Diamond drilled	Lang, 1952
MLU	Charlebois L area	Dee Explor Ltd	Charlebois		Diamond drilled	Lang, 1952
Mor	Nero L, Beaverlodge L area	Gateway UML	Vein	Pitchblende, secondary uran mins	Diamond drilled	
Moy-Bup	Upper Foster L area	Ad Astra Minerals Ltd	Pegmatitic	Secondary uran mins	Diamond drilled	
Mur-Mac-JW	Near Goldfields, L Athabasca	Tazin Mines Ltd				Lang, 1952
Mus-Kaz	Otter L, La Ronge area	Loranda UML	Granitic	Autunite, uranophane	Trenched	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Muskwa 1-8	Porter L	E. Partridge and associates, Prince Albert, Sask	Granitic ?		Diamond drilled ?		
Nagus	Reed Bay, L Athabasca	S. and J Yanik, Uranium City, Sask	Vein	Pitchblende		Lang, 1952	Formerly called Dello group
Nap-Hy-Bunny	Laird Island, Tazin L	Commercial UML	Vein	Pitchblende	Diamond drilled		
NC-Par	Charlebois L area	Dee Explor Ltd	Charlebois		Diamond drilled		
Neiman L occ	25 mi NE of Goldfields, L Athabasca	Neiman Lake Uranium Prospecting Syndicate	Vein ?	Pitchblende		Lang, 1952	
Net-Ver-Vic-Wil	Fredette L, Beaverlodge L area	Goldfields UML	Vein and pegmatitic	Pitchblende	Diamond drilled	Lang, 1952	
Nicholson*	E of Goldfields, L Athabasca	Consolidated Nicholson Mines Ltd	Vein	Pitchblende, thucholite, gummite, liebigite, zippeite, cuprosklodowskite	Underground (former producer)		Inactive
Nisto-Tobey	Black L	Nisto Mines Ltd	Vein	Pitchblende	Underground	Lang, 1952	Inactive
Nistowiak	La Ronge area	La Ronge UML	Pegmatitic	Cyrtolite, pyrochlore-microlite ser, secondary uran mins	Pilot mill installed		Inactive

Norm 1-5	Beaverlodge L	Great West UML			Diamond drilled		
Nova	Blackstone L ?, La Ronge area	Nova UML	Pegmatitic	Uraninite			May be part of Kara-Nada-Nova gp
Nubar	N of Cornwall Bay, L Athabasca	Nubar Mines Ltd	Vein	Pitchblende ?, secondary uran mins	Trenched	Lang, 1952	
Nunn L occ	La Ronge area	Jahala Lake UML	Pegmatitic	Uraninite, monazite	Inclined prospect shaft	Lang, 1952	
NW-GC-LEE	Near Verna L, Beaverlodge L area	Radiore UML	Vein	Pitchblende, secondary uran mins	Underground (producer)	Lang, 1952; Christie, 1953	Under lease to Eldorado
OJ 1-25	Soulier L, Tazin L area	King Copper Mining Corp	Vein	Pitchblende, secondary uran mins	Trenched		
Orb Gp 1	Augier L, Beaverlodge L area	Pitch-Ore UML	Vein	Pitchblende	Diamond drilled	Lang, 1952; Robinson, 1955	
Orb Gp 2	Orbit Bay, L Athabasca	Orbit Uranium Developments Ltd	Pegmatitic and vein	Thorite, uraninite, pitchblende	Diamond drilled	Lang, 1952; Robinson, 1955	
Orb Gp 3	Near Orbit Bay, L Athabasca	Orbit Uranium Developments Ltd	Vein	Thucholite ?	Diamond drilled	Lang, 1952	
Orb-Ox	Orbit L, Beaverlodge L	Pitch-Ore UML	Vein	Pitchblende	Underground		Inactive
Otter Lake occ	Lac la Ronge area	Pioneer Contractors Ltd	Pegmatitic	Uraninite ?			
Pac	3 mi NW of Bushell, L Athabasca	Scintilore Mines Ltd	Vein	Pitchblende ?			

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Pac	NW of Uranium City, Beaverlodge L area	New Goldview Mines Ltd	Pegmatitic		Trenched		
P-D-Del	Miliken L, Crackingstone Pen	Norgold Mines Ltd and Cons Rochette Mines Ltd	Pegmatitic ?		Diamond drilled		
Pal	Mackintosh Bay, L Athabasca	J.C. Paulsen, Alberta Hotel, Edmonton, Alta	Vein	Pitchblende ?		Lang, 1952	
Pat 1-9*	Donaldson L, Beaverlodge L area	National Explorations Ltd	Vein	Pitchblende	Underground (producer)		
Peg-Herb	Beaverlodge L	Brunston Mining Co	Vein	Pitchblende	Diamond drilled		
Pip 1-9	Mathews L, L Athabasca area	G. Lonn, Ottawa, Ont					
Pitch 1-16	Max L, Beaverlodge L area	Canroc Oils Ltd	Vein	Pitchblende, secondary uran mins	Trenched		
Pitch-Blende-Hope	St Joseph Pt, L Athabasca	Byrne interests	Vein	Pitchblende		Lang, 1952	
Pitchco 1-24	Near Guest L, Beaverlodge L area	Independence Mining Co Ltd	Vein	Pitchblende	Diamond drilled		
Pitche 1-12	Beaverlodge L	Uranium Ridge UML	Vein	Pitchblende, tyuyamunite	Underground	Lang, 1952; Christie, 1953; Robinson, 1955	Inactive

Pitch-Ore gp	Beaverlodge L	Pitch-Ore UML	Vein	Pitchblende	Underground	Lang, 1952; Christie, 1953; Robinson, 1955	Inactive
Pix	Freda L, Lac la Ronge area	Studer GML	Pegmatitic ?	Allanite, uraninite		Lang, 1952	Also known as Corrigan, Studer or Struder, and RACU
Point 1-9	St Joseph Pt, L Athabasca	Commercial UML	Vein	Pitchblende, secondary uran mins	Diamond drilled		
Por	Le Blanc L, Beaverlodge L area	Pickering UML	Pegmatitic				
Pox 1-14	Black Bay, L Athabasca	New Marlon GML	Vein	Pitchblende ?	Diamond drilled		Drilling stopped because of difficulty in penetrating Black Bay fault
Pro	Foster Lakes area	Eldorado	Pegmatitic	Uraninite	Trenched. Airborne (helicopter) radioactivity survey		
RA*	Martin L-Beaverlodge L	Eldorado	Vein	Pitchblende	Underground	Lang, 1952; Christie, 1953	
Ram-AR	Beaver R area, L Athabasca	Nu-Age UML and Homer Yellowknife Mines Ltd	Granitic		Underground		
Ran	Martin L, Beaverlodge L area	Meta UML	Vein	Pitchblende	Diamond drilled		

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Rand	Beaverlodge L	Traverse Long Lac Mines Ltd	Vein ?		Diamond drilled		
Rapids	Charlebois L area	C M & S	Charlebois		Trenched	Lang, 1952	
Raz 1-7*	2 mi W of Uranium City	St Michael UML	Vein	Pitchblende, secondary uran mins	Underground		
Reno 1-6	Donaldson L, Beaverlodge L area	Ad Astra Minerals Ltd and Orchan	Vein	Pitchblende	Diamond drilled	Lilge, 1955	
Rex-Cat-Joe	Bearcat-Melma Lakes, Beaverlodge	American-Canadian UML	Vein			Lang, 1952	
Rio	Black L area	Dee Explor Ltd	Pegmatitic			Lang, 1952	
Rix (Leonard)*	Beaverlodge L area	Rix Athabasca UML	Vein	Pitchblende	Underground (producer)	Lang, 1952; Christie, 1953; Robinson, 1955	Inactive
Rix (Smitty)*	Beaverlodge L area	Rix Athabasca UML	Vein	Pitchblende, secondary uran mins	Underground (producing)	Lang, 1952; Robinson, 1955	
Rix 100	Beaverlodge L area	Pardee Amalgamated Mines Ltd	Vein	Pitchblende		Lang, 1952	
RL	Felix Bay, L Athabasca	Tazin Mines Ltd	Vein and pegmatitic	Pitchblende	Diamond drilled		

Ron 1-7	Gatzke (Nesbitt) L, Beaverlodge L area	Pardee Amalgamated Mines Ltd	Pegmatitic and vein	Uraninite, thorite, monazite	Diamond drilled	Lang, 1952; Christie, 1953; Robinson, 1955
Row-Mike*	Charlebois L area	Charlebois Lake UML	Charlebois	Uraninite, thorianite	Diamond drilled	Lang, 1952
Rusty	Fond du Lac, L Athabasca	Great British UML	Vein	Pitchblende, secondary uran mins	Diamond drilled	
SK	Black L area	S.K. Hansen, Yellowknife, NWT	Pegmatitic			Lang, 1952
SO	Beaverlodge L	Sudbury Contact Mines Ltd	Vein	Secondary uran mins	Diamond drilled	
Souter R occ	Charlebois L area	E.F. Partridge, Prince Albert, Sask	Charlebois		Trenched	Lang, 1952
Spreckly L occ	Charlebois L area	Dee Explor Ltd	Charlebois		Trenched	Lang, 1952
Stanley occ	Lac la Ronge area					Lang, 1952
Strike 6-9	N of Ace L, Beaverlodge L area	Rock Hill UML	Vein	Pitchblende	Underground	Lang, 1952; Christie, 1953
Sure	Gatzke L, Beaverlodge L area	Don Henry UML	Granitic	Uraninite	Deep pit	
Tena	Near Goldfields, L Athabasca	Beta Gamma Mines Ltd	Vein	Pitchblende	Diamond drilled	Lang, 1952
Tillie	Tazin L area	Great West UML	Pegmatitic	Pitchblende	Trenched	
Top	Lac la Ronge area	Ad Astra Minerals Ltd	Pegmatitic			

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
Tor 1-9	Beaverlodge L	Meta UML	Vein	Pitchblende	Underground	Lang, 1952; Christie, 1953	
Tot 1-17	Elder L, Beaverlodge L area	Goldfields UML	Vein	Pitchblende		Christie, 1953	
TOW	Lac la Ronge area	R. Anderson and L. McArthur, La Ronge, Sask				Lang, 1952	
TR 1-14	Near Bushell, L Athabasca	Jesko UML	Vein ?	Secondary uran mins	Diamond drilled		
Triveet L occ	Lac la Ronge area	Dee Explor Ltd				Lang, 1952	
Trojan	Fond du Lac area	E. Partridge and associates, Prince Albert, Sask	Vein	Monazite			
Tuck	Camsell Portage area	Great West UML				Lang, 1952	
Ura	Beaverlodge L	Eldorado	Vein	Pitchblende	Underground (producing)	Lang, 1952; Christie, 1953; Robinson, 1955	Also known as Fay zone
Urex 1-21	Camsell Portage area	Uranium Ridge Mines Ltd and others	Vein	Pitchblende	Diamond drilled		
Van	Cornwall Bay, L Athabasca	Rowan Consolidated Mines Ltd	Vein	Pitchblende	Diamond drilled		

Verna	Beaverlodge L area	Eldorado	Vein	Pitchblende	Underground (producing)		All part of Ace-Fay system of Eldorado mine
Vic-Bill	Forget L, Beaverlodge L area	Parker, Parker, Wordie and Hodgson, Uranium City, Sask	Pegmatitic			Blake, 1951	
Vix 1-10	St Mary's Channel, L Athabasca	Avillabona Mines Ltd	Vein ?	Pitchblende ?	Diamond drilled		May be part of AD gp
Voy 1-9	Laird Island, Tazin L	New Mylamaque Explor Ltd	Vein	Pitchblende	Underground		
Wapus L occ		P. Freisen reported, Sask Dept Nat Res	Pegmatitic				
War-Mac	Sheppard L, Tazin R area	Warmac Drilling Synd			Diamond drilled		
White Dog	L Athabasca, near Moose Is	Beta Gamma UML	Vein	Pitchblende, secondary uran mins	Trenched	Lang, 1952; Robinson, 1955	
Whiz-Rye	Near Bushell, L Athabasca	Gusto UML	Vein and pegmatitic	Secondary uran mins	Diamond drilled		
Wildnest L occ	Flin Flon area	Sask Dept Nat Res reported (Byers and Dahlstrom)	Pegmatitic	Secondary uran mins	Airborne scintillometer survey		
Wolf 1-3	Beaver R, 7 mi E of Goldfields	Athona Mines Ltd and associates	Vein	Pitchblende	Diamond drilled	Lang, 1952	
WS	Bleasdell L, Reindeer L area	Columbia Metals Explor Ltd	Pegmatitic	Uraninite, kasolite, uranophane	Diamond drilled	Cheeseman, 1957	

Name	Location	Owner, etc.	Type	Radioactive Minerals	Stage of Exploration	References	Remarks
YBY 1-5, 12-17	Crackingstone Pt, L Athabasca	Chimo GML	Vein	Pitchblende	Diamond drilled		
YBY 6-11, 18	Langley Bay, Crackingstone Pt	Graham Bousquet GML	Vein		Diamond drilled		
YK 1-13	N end of Milliken L, Crackingstone Pen	Pitchvein UML	Vein	Pitchblende, secondary uran mins	Diamond drilled		
			YUKON TERRITORY				
Dublin Gulch occs	Mayo District	Bostock, GSC reported	Granitic and placer	Allanite		Lang, 1952	
McQueston River occs	Mayo District	Bostock, GSC reported	Placer	Allanite, monazite		Lang, 1952	Thorium occs in gold placer workings
Star and Tip claims	10 mi NW of mile 816, Alaska hwy	B.A. Sage, 10824A, 82nd Ave, Edmonton, Alta			Trenched		

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