59-10

Wilkins

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 59-10

RARE EARTHS OF THE GRENVILLE SUB-PROVINCE, ONTARIO AND QUEBEC

(21, 31, 41)

E. R. ROSE

Price 25 cents

Feb 4
1960

CANADA

GEOLOGICAL SURVEY

OF CANADA

PAPER 59-10

RARE EARTHS OF THE GRENVILLE SUB-PROVINCE, ONTARIO AND QUEBEC

By

E. R. Rose

DEPARTMENT OF

MINES AND TECHNICAL SURVEYS

CANADA

CONTENTS

RARE EARTHS OF THE GRENVILLE SUB-PROVINCE, ONTARIO AND QUEBEC

INTRODUCTION

SUMMARY

Sixty-five reported occurrences of rare-earth minerals in the Grenville geological region of Quebec and Ontario were examined during the summer of 1957. Particular attention was paid to occurrences carrying the 'heavy' rare earths. Most of the occurrences are in more or less zoned granitic pegmatite dykes, and a few are in pegmatitic granite and granitic gneiss. Many are of relatively rare minerals found during the course of feldspar mining and are of a purely mineralogical interest. Few of the deposits hold promise of economic recovery of rare-earth elements except as by-product materials, but the fact that several of the occurrences do hold small quantities of the heavy rare earths, and of uranium, thorium, and niobium, lends some incentive to their investigation for possible future application.

The industrial market for the rare earths is limited by demand and price, but it is increasing with research. It concerns mainly the more readily available cerium metals. Until 1948, alluvial beach deposits of monazite sand in India and Brazil were the main sources of rare earths and thorium. These sources were largely supplanted after 1950 by production from a monazite-rich vein at Steenkampskraal in South Africa. North American supply is now chiefly from placer deposits of monazite in the Carolinas, Florida, and Idaho, and fault-fissure-vein and replacement deposits of bastnaesite in California and New Mexico. A plentiful supply of rare-earth concentrates is now available as a by-product of thorium extraction from monazite concentrates, and prices have dropped considerably in the past ten years. Monazite and bastnaesite are much richer in the light- or cerium-group earths, therefore better local sources of the heavy-group earths are desirable. Commercial adaptation of current research in these rare metals may create an increasing demand for them in the future.

The uranium deposits of the Blind River and Bancroft areas of Ontario, and the niobium (columbium) deposits of the Oka and Lake Nipissing areas of Quebec and Ontario respectively appear to be the most promising known sources of the rare earths in Canada. Minerals rich in the heavy rare earths are contained in some pegmatite dykes of the Grenville sub-province and elsewhere in the granitic terrains of Canada, but their distribution within the dykes is normally sparse and sporadic. These and other possible sources of rare-earth metals might be investigated if the demand warrants it.

Although rare-earth elements are not significantly radioactive, they are commonly associated with uranium and thorium. Therefore many of the minerals containing rare earths may be detected by delicate Geiger counters or scintillometers.

The rare earths have relatively large ionic radii and become enriched in late residual fractions of igneous rocks. Thus they are concentrated in pegmatites, granites, syenite and alkaline intrusions, and in hydrothermal or contact deposits associated with such intrusions. The rare-earth content of many igneous rocks is, however, exceeded by that of certain deposits of black shale, coal, petroleum, limestone, dolomite, and phosphorite. For this reason it would appear that metamorphic rocks developed at the contacts of such materials and igneous rocks, particularly alkaline intrusions, might be locally enriched in rare-earth minerals.

ACKNOWLEDGMENTS

Much of the information on the rare earths is extracted from previous descriptions, with a special acknowledgment due to the late H.V. Ellsworth's "Rare-Element Minerals of Canada" (1932) which is still a standard reference on the subject. Colleagues in Geological Survey laboratories provided many essential X-ray mineral determinations and spectrographic analyses. The study was facilitated by reference to extensive records on radioactive occurrences which are maintained by the Geological Survey; only those that have been released by the discoverers are mentioned in this report.

HISTORY AND DEFINITION

Rare earths have been found mainly as constituents of oxides, multiple oxides, silicates, and certain rare minerals. Mixtures of earthy oxides obtained from such minerals in the laboratory were at first thought to be chemical elements, hence the name earths. It was later found that these earths are actually mixtures of the oxides of rare metals that are difficult to separate and isolate. The rare-earth elements proper are now generally considered to constitute sixteen metals, the lanthanide series of elements (lanthanides) and yttrium. These sparingly distributed metals are commonly divided into a light group and a heavy group, often designated the cerium group and yttrium group respectively, as shown in Table I.

As indicated in Table I not all of these elements are to be considered as 'rare' in the earth's crust when compared to the average content of other trace elements. Nevertheless the rare earths have rarely been found in concentrations comparable to those of the other metals, probably because of the close affinities of one rare earth for another and the difficulty in separating them.

Table I

Rare-earth Elements

Group	Element	Symbol	Atomic No.	Atomic Wt.	Ionic Radius	Percentage in Argillaceous Sedimentary Rocks	
Cerium group (light)	Lanthanum	La	57	138.92	1.22	0.00183	Total light 0.01014
	Cerium	Ce	58	140.13	1.18	0.00461	
	Praseodymium	Pr	59	140.92	1.16	0.00055	
	Neodymium	Nd	60	144.27	1.15	0.00239	
	Promethium (illinium)	Pm(Il)	61	145?			
	Samarium	Sm	62	150.43	1.13	0.00065	
	Europium	Eu	63	152.0	1.13	0.00011	
Yttrium group (heavy)	Gadolinium	Gd	64	156.9	1.11	0.00064	Total heavy 0.00471
	Terbium	Tb	65	159.2	1.09	0.00009	
	Dysprosium	Dy	66	162.46	1.07	0.00045	
	Holmium	Ho	67	164.94	1.05	0.00011	
	Erbium	Er	68	167.2	1.04	0.00025	
	Thulium	Tm	69	169.4	1.04	0.00002	
	Ytterbium	Yb	70	173.04	1.00	0.00027	
	Lutecium (lutetium)	Lu	71	174.99	0.99	0.00007	
	Yttrium	Y, (Yt)	39	88.92	1.06	0.00281	

Yttrium and lanthanum are not true rare earths or lanthanons but are grouped with them because of their chemical similarities. Scandium (Sc) is also included by some authorities because of its close chemical relationship to yttrium. Thorium, uranium, hafnium (Hf), zirconium (Zr), niobium, and tantalum are other metallic elements that are commonly associated closely in nature with the rare earths proper.

PROPERTIES AND USES

The rare-earth metals have closely related chemical and physical properties because they have similar atomic structures; the main differences between them are in the arrangement of the three outer electrons. The heavy rare-earth atoms have smaller radii and hence are denser than the larger, lighter atoms. The differences between them however are slight and they are separable only with difficulty. Accordingly it has been suggested that they may still display the relative abundance they had in the primitive Earth, little disturbed by physical and chemical processes tending to cause selective separation. Investigation along this line may reveal information on the life history of the earth.

Cerium, the most abundant of the rare earths, is a soft, yellowish white metal that ignites at 160° C in air. Lanthanum is slightly harder, followed by neodymium, praseodymium, and samarium which is almost as hard as steel. The hardness generally increases with increasing atomic weight but varies considerably depending on manner of formation and tempering. The metals are fairly stable in dry air, but tarnish readily in moist air. They alloy readily with iron, zinc, magnesium, and aluminum. Cerium is pyrophoric, emitting hot sparks when filed or struck with steel. Misch metal, an alloy of the cerium group and about 8 to 10 per cent of other rare-earth metals, made from a combination of rare-earth chlorides, is used because of its pyrophoric property in igniters and lighter flints. It is also used as an additive in many grades of steel. Rare-earth chlorides are also used in the production of chrome, dentifrices, silk, aluminum, fertilizer, and catalysts.

Cerium oxide is used as a polishing agent for optical glass. Cerium hydrate is an ingredient of the special glass used to view highly radioactive operations.

The rare earths have drying properties that can be useful in the production of better paints. Neodymium and praseodymium may be used as colorants in ceramics.

Thulium, made radioactive, emits X-rays of proper length and strength for diagnostic use. A pea-sized bit of thulium is said to last a year as the source of rays in a small, portable X-ray unit.

The rare samarium isotope, Sm^{152}, is radioactive and, with the exception of the three heavy radioactive series (uranium, thorium, and actinium-Ac), is the only known alpha ray (helium) emitter found in nature. Another long-lived, naturally radioactive isotope is the rare lutecium Lu^{176}, whose radiation consists of penetrating gamma rays (similar to X-rays) and beta particles (negatively charged electrons).

The rare-earth metals are used in ferrous and non-ferrous alloys giving them good high-temperature strengths, and, in some cases, increased corrosion resistance, properties that may prove valuable in rocketry. They act as neutron absorbers, ranging from an extremely high neutron absorption cross-section in gadolinium to a low value in yttrium, and they may be adapted to control the rate of nuclear fission in atomic power plants. They are also used in flame-sprayed ceramic coatings and have many other miscellaneous uses. Research on industrial applications is continuing in the United States.

Only about 30 tons of cerium metals, alloys, and compounds are imported annually into Canada from the United States where about 1,500 tons of rare-earth materials are consumed each year. About 25 per cent each of this amount is used in carbon arc lighting, rare-earth metals, glassmaking, and in radio, radar, and television.

Many of the rare earths are now available in larger quantities than ever before. Prices of their purified oxides in small lots 99 per cent pure are reported to range from about $5 to $2,500 a pound; those of the light-group oxides range from $5 to $50, and those of the heavy-group oxides from $135 to $2,500 a pound. The prices of the oxides vary with purity, volume, and the individual element. It is expected that many rare-earth metals will also become available at prices less than $300 a pound and in larger amounts if the markets expand.

Table II

Some Physical Properties of Heavy Rare-earth Metals

Element	Melting Point (degrees C)	Estimated Boiling Point (degrees K)	Density (gm/cc)	Neutron Absorption Cross-Section (barns)
Lutecium	1,650-1,750	2,200	9.849	108+5
Thulium	1,550-1,650	2,400	9.318	118∓6
Yttrium	1,552	3,300	4.472	1.38∓.14
Erbium	1,500-1,550	2,900	9.058	166∓16
Terbium	1,400-1,500	2,800	8.253	44∓4
Holmium	1,500	2,600	8.799	64∓3
Dysprosium	1,400	2,600	8.565	1,100∓150
Gadolinium	1,350	3,000	7.868	46,000±2,000
	Metals above this are considered high-melting			
Samarium	1,052	1,900	7.540	5,500+200
Europium	900	1,700	5.166	4,600∓400
Ytterbium	824	1,800	6.959	36±4

SELECTED REFERENCES

Beard, W.J.
1955: Cerium; Mines Branch, M.R. 9.

Buck, Katharine L.
1957: Selected Annoted Bibliography of Thorium and Rare-Earth Deposits in the United States Including Alaska; U.S. Geol. Surv., Bull. 1019-F.

Butler, J.R.
1957a: Rare Earths and Thorium in Lyndochite; Am. Mineralogist, vol. 42, Sept.-Oct.
1957b: Rare Earths in Some Niobate-Tantalates; Min. Soc. (Gr. Br.), notice No. 99.

Ellsworth, H.V.
1932: Rare-Element Minerals of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 11.

Graham, A.R.
1955: Cerianite (CeO_2), a New Rare-Earth Oxide Mineral; Am. Mineralogist, vol. 40, pp. 555-705.

Hampel, C.A.
1944: Rare Metals Handbook; New York, Rainhold Publishing Corporation.

Heinrich, E.Wm.
1958: Economic Geology of the Rare-Earth Elements; Mining Mag., vol. XCVIII, No. 5, May 1958, pp. 265-273.

Himes, Richard C.
1958: Where Are the Rare Earths Today; Battelle Tech. Rev., vol. 7, No. 6, June 1958, pp. 3-8.

Janes, T.H.
1956: Rare, or Less Common, Metals in Canada; Mines Branch, M.R. 21.

Jones, R.J.
1957: Columbium (Niobium) and Tantalum; Mines Branch, Mem. Ser. 135.

Krauskopf, Konrad B.
1955: Sedimentary Deposits of Rare Metals; Econ. Geol., 50th anniv. vol. 1905-1955, pt. 1, pp. 411-463.

Lamb, Frank D.
1955: Rare-Earth Metals, from Mineral Facts and Problems; U.S. Bur. Mines, Bull. 556.

Lang, A.H.
1952: Canadian Deposits of Uranium and Thorium; Geol. Surv., Canada, Econ. Geol. Ser. No. 16.
1956: Prospecting in Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 7, (3rd ed.).

Maurice, O.D.
1957: Preliminary Report on Oka Area; Que. Dept. Mines, P.R. No. 351.

Nininger, R.D.
1954: Minerals for Atomic Energy; D. Van Nostrand Co. Inc., Toronto, New York, London.

Rankama, K., and Sahama, Th.G.
1950: Geochemistry; Univ. Chicago Press.

Robinson, S.C., and Abbey, Sydney.
1957: Uranothorite from Eastern Ontario; Can. Mineralogist, vol. 6, pt. 1, pp. 1-14.

Robinson, S.C., and Sabina, A.P.
1955: Uraninite and Thorianite from Ontario and Quebec; Am. Mineralogist, vol. 40, pp. 624-633.

Roscoe, S.M.
1957: Geology and Uranium Deposits, Quirke Lake-Elliot Lake, Blind River Area, Ontario; Geol. Surv., Canada, Prel. Rept. Paper 56-7.

Rowe, R.B.
1954: Notes on Geology and Mineralogy of the Newman Columbium-Uranium Deposit, Lake Nipissing, Ontario; Geol. Surv., Canada, Paper 54-5.
1955: Notes on Columbium Mineralization, Oka District, Two Mountains County, Quebec; Geol. Surv., Canada, Paper 54-22.

Sahama, Th.G., and Rankama, K.
1938: Preliminary Notes on the Geochemical Properties of the Maarianvaara Granite; compt. rend., Soc. Geol. Finland, 13.

Satterly, J.
1957: Radioactive Mineral Occurrences in the Bancroft Area; Ont. Dept. Mines 65th Ann. Rept., vol. LXV, pt. 6, 1956.

Spence, H.S.
1932: Feldspar; Mines Branch, Rept. No. 731.

Steacy, H.R.
1953: An Occurrence of Uraninite in a Black Sand; Am. Mineralogist, vol. 38, pp. 549-550.

Vickery, R.C.
1953: Chemistry of the Lanthanons; New York, Academic Press Inc., Butterworth Scientific Publications, London.

Vinogradov, A.P.
1956: The Regularity of Distribution of Chemical Elements in the Earth's Crust; Akad. Nauk Soyuza S.S.R., Geokhimiya, 1956, A.E.R.E. Lib/Trans. 795, 1957.

Walker, T.L., and Parsons, A.L.
1923: Univ. Toronto Studies, No. 16, contributions to Can. mineralogy.

OCCURRENCE AND DISTRIBUTION OF THE RARE EARTHS

GENERAL GEOLOGY

The Grenville geological sub-province, forming the southeastern part of the Precambrian Canadian Shield in Quebec and Ontario, consists mainly of gneiss, schist, amphibolite, metamorphic pyroxenite, crystalline carbonate rocks, other metasedimentary and metavolcanic rocks, and a host of igneous intrusions of various types and ages. Part of this complex assemblage of crystalline rocks, consisting chiefly of metasedimentary rocks such as quartzite, crystalline limestone and dolomite, granitic paragneiss, and possibly amphibolite, has been subdivided and named the Grenville series. In some localities other groups of metasedimentary and metavolcanic rocks, such as the Hastings and Bristol series and Keewatin-type rocks, may be present. These rocks are intruded and metasomatized in places by large and small bodies of gabbro, anorthosite, diorite, syenite, nepheline syenite, and granite. Granitic and syenitic pegmatite dykes, and fine-grained gabbro or trap-dykes are among the youngest intrusions of Precambrian age within the area. Near the margin of the Shield, however, the Precambrian rocks are overlapped by much younger sedimentary rocks of Palaeozoic age and in places contain infaulted blocks and outliers of these younger rocks.

On the southern border of the Grenville sub-province the Monteregian suite of alkaline intrusions cuts through both Precambrian and Palaeozoic rocks, and is thus of Palaeozoic or later age. These intrusions are considered by some to be as young as Tertiary, and it is possible that other similar intrusions may be present within the rocks of the Grenville sub-province proper. A complex intrusion of such rocks enriched in niobium-tantalum and in some of the rare earths has recently been discovered near Oka, in Quebec.

In this complex geological environment several kinds of rare-earth deposits might be expected to occur. Rare-earth minerals have been noted mainly in pegmatite dykes, granite, and gneiss, and more recently in the contact zones about alkaline intrusions. A summary list of probable modes of occurrence follows.

TYPES OF RARE-EARTH DEPOSITS IN THE GRENVILLE SUB-PROVINCE

1. Accessory minerals in igneous rocks
   - (a) granitic rocks
   - (b) alkalic rocks
   - (c) gabbroic rocks, anorthosite
2. Pegmatites
   - (a) segregated (zoned)
   - (b) non-segregated (complex)
3. Accessory minerals in metamorphic rocks
   - (a) contact metamorphic
   - (b) pyrometasomatic
4. Introduced minerals in replacement and fissure deposits
   - (a) veins
   - (b) irregular replacement deposits
5. Sedimentary deposits

In many cases, combinations of these modes of occurrence may be recognized as the result of an interplay of processes of igneous, sedimentary, metamorphic, and metasomatic origin.

RARE-EARTH MINERALS

Table III groups, according to composition, some of the rare-earth-bearing minerals that have been identified from the Grenville sub-province. It shows their chief modes of occurrence and attempts to indicate variations in content and relative proportions of light- and heavy-group earths as shown by chemical and spectrographic analyses of selected samples, taken from the literature.

Table III

Principal Rare-earth Minerals of the Grenville Sub-province

Mineral	Essential Composition	Provenance	Rare-earth Oxide Content % (analyzed)		
			Light	Heavy	Total (maximum)
Oxides					
Uraninite	Uranium (Th) oxide	Pegmatite, granite	0.14 - 2.71	1.02 - 4.04	5.58
Pitchblende(?)	Uranium oxide	Vein and hydrothermal	---	---	1.5
Thorianite	Thorium (U) oxide	Pyrometa-somatic	---	---	---
Cerianite(?)	Cerium (Th-U) oxide	Pyrometa-somatic	60 - 81.5	2.0 - 2.3	62 - 83.8
Multiple Oxides					
Brannerite(?)	Uranium (Ti) oxide	Placer deposits	---	---	---
Davidite(?)	Rare-earth (Fe-Ti) oxide	Albitized igneous rocks, granite, hydrothermal veins	---	---	---
Perovskite	Calcium (Ti) oxide	Alkalic intrusions, pyrometasomatic	---	---	---
(Euxenite-(polycrase	Titano-tantalo	Pegmatite	0.2 - 4.0	10.5 - 28.07	10.7 - 32.07
(Priorite-(eschynite (	Niobates of rare earths, uranium, etc.	Pegmatite	---	---	---
(Lyndochite (	High calcium, thorium	Pegmatite	4.34 - 12.11	7.9 - 18.22	20.01 - 22.56
(Samarskite ((	Tantalo niobate of rare earths, etc.	Pegmatite	4.78	14.34	19.12
(Calciosamar-(skite	With calcium	Pegmatite	1.68 - 4.04	10.71 - 11.38	12.39 - 15.42
(Pyrochlore-(microlite	Titano-niobate of calcium	Pegmatite	1.49 - 1.7	0.12 - 7.3	1.61 - 9.0
(Ellsworthite (	rare earths, uranium, etc.	Pegmatite	---	---	0.21 - 1.61
(Hachettolite	High in uranium	Pegmatite	0.12 - 0.5	0.62	0.12 - 1.12
(Betafite ((	Niobate of uranium, thorium, etc.	Pegmatite, veins, pyrometasomatic	0.1 - 2.9	0.28 - 19.8	0.38 - 22.7
Fergusonite-formanite	Niobate tantalate of rare earths, etc.	Pegmatite, mica schist	---	---	---
Columbite-tantalite	Niobate tantalate	Pegmatite, mica schist	---	---	0.82 - 2.0
Silicates					
Thorite and thorogummite	Thorium silicate	Pegmatite	---	---	0.25 - 1.5
Uranothorite	Thorium (U) silicate	Pegmatite	---	---	10.2 - 3.99
Allanite	Rare-earth (Th) silicate	Pegmatite, granite	13.44 - 21.15	0.76 - 1.64	14.2 - 22.79
Gadolinite	Rare-earth (Be, Fe) silicate	Pegmatite	2.85	46.47	49.32
Zircon (cyrtolite)	Zirconium silicate	Pegmatite, granite	0.34	6.76	7.1
Titanite (titanite-eucolite)	Calcium (Ti) silicate	Pegmatite, granite	---	---	more than 1
Garnet (andradite-almandine)	Ca, Fe, Al silicate	Pegmatite	---	---	more than 1

Table III (Cont'd)

Mineral	Essential Composition	Provenance	Rare-earth Oxide Content % (analyzed) Light	Heavy	Total (maximum)
Phosphates					
Monazite	Rare-earth (Th) phosphate	Pegmatite, placers	51.2 - 57.26	4.66 - 4.67	55.96 - 61.92
Xenotime	Yttrium phosphate	Pegmatite, gneiss	---	---	---
Apatite (brown)	Calcium phosphate	Pegmatite, veins	---	---	---
Britholite	Rare-earth silco-phosphate	Alkalic rocks, veins	---	---	---
Hydrocarbon					
Thucolite	Uranium hydro-carbon, etc.	Pegmatite	---	---	---
Fluo-carbonate					
Bastnaesite	Barium fluo-carbonate	Vein, hydrothermal	27.2 - 69.17	0.2 - 0.4	27.4 - 69.17
Silico-carbonate					
Cenosite	Hydrous rare earth with calcium silica	Pyrometa-somatic	3.22	35.46	38.68

(?) Indicates occurrence uncertain in Grenville sub-province

Rare earths occur as constituents of two hundred or more minerals, many of which have been found only in pegmatites. These minerals are generally complex in composition and almost invariably contain other elements such as uranium and thorium, and conversely uranium and thorium minerals commonly carry rare earths. They form combinations as titano-tantalo-niobates, titanates, silicates, phosphates, zirconates, carbonates, fluorides, etc. Silicates are probably the most abundant, phosphates and titano-tantalo-niobates less so. Allanite (orthite) is probably the commonest, most abundant and widely distributed rare-earth mineral. This silicate of rare earths, iron, alumina, and calcium, with minor amounts of thorium, uranium, and other elements, is commonly found in pegmatites, pegmatitic granite, and coarse-grained granitic gneiss; it also occurs less commonly in more basic rocks. Monazite, the phosphate of the rare earths and thorium, is not so widely distributed, but occurs as small crystals and grains in pegmatites and granites, and, as it resists weathering, it is commonly concentrated in alluvial deposits of heavy dark sands and their lithified equivalents. The rare earths of both monazite and allanite are predominantly of the cerium group, but both may carry yttrium-group oxides--in the case of monazite about 4.67 per cent, and of allanite, about 1.64 per cent, as shown by analyses.

The complex and refractory titano-tantalo-niobates or multiple oxides represented by such mineral series as euxenite-polycrase, fergusonite-formanite, columbite-tantalite, pyrochlore-microlite, etc. are among the most common rare minerals in pegmatites of the Grenville sub-province. Betafite, lyndochite, samarskite, calciosamarskite, ellsworthite, hachettolite, and toddite are less common, and may be varieties of these minerals. These minerals characteristically carry more of the yttrium-group oxides than of the cerium group, and in the case of euxenite may carry as much as 28 per cent of the yttrium-group oxides according to analyses. These multiple-oxide minerals are in places associated with the uranium-thorium oxides, uraninite and thorianite, and with the silicates uranothorite and thorite, each of which may carry appreciable amounts of the rare earths. The uranium-rich varieties of these minerals generally appear to hold slightly more of the heavy or yttrium-group earths than the thorian varieties.

Robinson and Sabina (1955) and Satterly (1957) have demonstrated that the uraninites of the granitic and syenitic bodies of the Bancroft area characteristically carry less than 10 per cent thorium oxide (ThO_2), that those of the calcite-fluorite-apatite veins and metamorphic pyroxenite contain between 10 and 18 per cent, and that those carrying more than 20 per cent ThO_2, and all thorianites, are found in metasomatized zones in marble, generally salmon-pink calcite. Uraninite is also more abundant than uranothorite in most of the occurrences, and is commonly more dispersed. Uraninite, thorianite, thorite, and uranothorite carry various amounts of rare-earth oxides, and certain uraninites have yielded as much as 5.58 per cent earths, most of which are of the heavy group. Certain uranothorites have yielded as much as 3.99 per cent, and certain thorites as much as 1.5 per cent rare-earth oxides. Cerianite, a new mineral oxide of cerium and other earths said to be isomorphous with uraninite and thorianite, has recently been described by Graham (1955) from near Nemegos, Ontario.

Gadolinite, a rare beryllium-iron silicate of the rare earths, may carry as much as 46.47 per cent of the heavy-group oxides according to analysis, but has been reported from only two localities in Canada, both in small amounts in pegmatites. Gadolinite and allanite may easily be confused and moreover do occur together. Zircon (cyrtolite), garnet (yttrian andradite-almandine), and titanite (titanite-eucolite) are more common rare-earth-bearing minerals in pegmatites and contact rocks of the Grenville sub-province. Cyrtolite from Conger township, Ontario was reported by Ellsworth to carry more than 7 per cent rare-earth oxides, 6.76 per cent being of the heavy group.

Fluorite (yttrofluorite), brown apatite (sammite), bastnaesite, xenotime, cenosite, lessingite, davidite, britholite, brannerite, cerite, melanocerite, uranophane, gummite, thorogummite, and pitchblende also carry rare earths, and many of these minerals have been noted in deposits in Canada. Yttrialite, thortveitite, mackintoshite, uranothorianite, and ancylite are among other rare-earth minerals that may be found.

DISTRIBUTION OF RARE-EARTH ELEMENTS

The distribution of the rare-earth elements in the rocks and rock-forming minerals of the earth's crust is rather imperfectly known. They have been found to total about 0.0026 per cent in silicate meteorites, about 0.0148 per cent in certain shales; and about 0.0079 per cent in igneous rocks of the Dutch East Indies. The best available estimates of the rare-earth content of various rocks are shown in Tables IV, V, and VI below. The tables indicate an overall rare-earth content of the lithosphere of 0.015 per cent, of which the light earths comprise about 77 per cent. As a group, the rare earths are more abundant than tin, tungsten, molybdenum, nickel, copper, cobalt, lead, zinc, niobium (columbium), thorium, or uranium, and are much more abundant than silver, gold, platinum, or mercury. Individually a few of the rare earths are as abundant as some of the base metals, and several are as rare as silver. Cerium is by far the most abundant of the rare-earth metals and together with yttrium forms about 60 per cent of the total. The light earths and yttrium together comprise about 87 per cent of the total.

In general, cerium-group earths are more abundant than those of the yttrium group in rocks of the earth's crust, and total rare earths are higher in felsic rocks than in mafic, as illustrated in Tables IV and V. That is the rare-earth content of nepheline syenites and granites is generally greater than that of gabbros. However the ratio of the cerium group to the yttrium group in granitic or acidic rocks is greater than the ratio in gabbroic or basic rocks. The total amounts and the differences involved however are small, and the abundance of the cerium and yttrium groups varies considerably. Thus in some granites and pegmatites, the yttrium earths predominate over cerium earths. Nepheline syenites and their pegmatites in general are relatively rich in cerium-group metals, and gabbros and diorites are relatively poor. Sahama and Rankama (1938) found that of the Archaean granites of Finland, those richer in the rare-earth metals mostly belong to the younger age groups.

Table IV

Rare-earth Content of Rocks
(parts per million)
(modified after Vinogradov 1956)

Element	Silicate phase of stone meteorites, chondrites	Ultrabasic rocks (dunites, peridotite, pyroxenite)	Basic rocks (basalt, gabbro, norite, diabase)	Neutral rocks (diorite, andesite)	Acidic rocks(granite, rhyolite, etc.)	Sedimentary rocks (clay, shale)	2 parts of acid rocks, 1 part of basic rocks
Yttrium	$7\cdot10^{-4}$	$4,5\cdot10^{-4}$	$1,8\cdot10^{-3}$	$3\cdot10^{-3}$	$2\cdot10^{-3}$	$3,3\cdot10^{-3}$	$2\cdot10^{-3}$
Light (cerium) group							
Lanthanum	$2\cdot10^{-4}$	---	$2,7\cdot10^{-3}$	$4\cdot10^{-3}$	$4,6\cdot10^{-3}$	$4\cdot10^{-3}$	$4\cdot10^{-3}$
Cerium	$2,3\cdot10^{-4}$	---	$\sim10^{-3}$	$3\cdot10^{-3}$	$6\cdot10^{-3}$	$3\cdot10^{-3}$	$(4\cdot10^{-3})$
Praseodymium	$1\cdot10^{-4}$	---	$1,3\cdot10^{-4}$	---	$1\cdot10^{-3}$	$5\cdot10^{-4}$	$7\cdot10^{-4}$
Neodymium	$3,5\cdot10^{-4}$	---	$(\sim1.10^{-3})$	$2\cdot10^{-3}$	$4\cdot10^{-3}$	$1,8\cdot10^{-3}$	$3\cdot10^{-3}$
Promethium	?	?	?	?	?	?	?
Samarium	$1\cdot10^{-4}$	---	$(1,5\cdot10^{-4})$	---	$6\cdot10^{-4}$	$5\cdot10^{-4}$	$(4\cdot10^{-4})$
Europium	$(3\cdot10^{-5})$	---	---	---	$(1,7\cdot10^{-4})$	$(1\cdot10^{-4})$	$(\ 10^{-4})$
Gadolinium	$(2\cdot10^{-4})$	---	$(2\cdot10^{-4})$	---	$(1\cdot10^{-3})$	$5\cdot10^{-4}$	$(7\cdot10^{-4})$
Terbium	$(6\cdot10^{-5})$	---	---	---	$(2,5\cdot10^{-4})$	$9\cdot10^{-5}$	$(\sim10^{-4})$
Dysprosium	$(2\cdot10^{-4})$	---	$(1,5\cdot10^{-4})$	---	(5.10^{-4})	$4\cdot10^{-4}$	$(4\cdot10^{-4})$
Holmium	$(7\cdot10^{-5})$	---	---	---	---	$(1\cdot10^{-4})$	?
Erbium	$(2\cdot10^{-4})$	---	$1\cdot10^{-4}$	---	$(2,5\cdot10^{-4})$	$2,5\cdot10^{-4}$	$(2\cdot10^{-4})$
Thulium	$(3,5\cdot10^{-4})$	---	---	---	$(2\cdot10^{-4})$	$(2\cdot10^{-5})$	$(1\cdot10^{-4})$
Ytterbium	$(2\cdot10^{-4})$	---	$1\cdot10^{-4}$	---	$(2\cdot10^{-4})$	$2,2\cdot10^{-4}$	$(2\cdot10^{-4})$
Lutecium	---	---	---	---	$(2\cdot10^{-4})$	$(2\cdot10^{-5})$	$(1\cdot10^{-4})$
Light (cerium) group	$10,1\cdot10^{-4}$	---	$49,8\cdot10^{-4}$	$90\cdot10^{-4}$	$199\cdot10^{-4}$	$99\cdot10^{-4}$	$122\cdot10^{-4}$
	0.00101%	---	0.00498%	0.009%	0.0199%	0.0099%	0.0122%
Heavy (yttrium) group	$19,8\cdot10^{-4}$	$4,5\cdot10^{-4}$	$23,5\cdot10^{-4}$	$30\cdot10^{-4}$	$46\cdot10^{-4}$	$48,8\cdot10^{-4}$	$38\cdot10^{-4}$
	0.00198%	0.00045%	0.00235%	0.003%	0.0046%	0.00488%	0.0038%
Total Rare Earths	$29,9\cdot10^{-4}$	---	$73,3\cdot10^{-4}$	$120\cdot10^{-4}$	$255\cdot10^{-4}$	$147,8\cdot10^{-4}$	$160\cdot10^{-4}$
	0.00299%		0.00733%	0.012%	0.0255%	0.01478%	0.0160%

Table V

Content of Certain Rare Earths in Igneous Rocks

(from Rankama and Sahama, 1950)

Rock	Per cent La, Ce, Nd	Per cent Y	Total
Dunite	0	less than 0.0008	less than 0.0008
Ultrabasics	0	0.00008	0.00008
Gabbro and dolerite	0	0.00079	0.00079
Syenite	0.0126	0.00079	0.01339
Granite	0.0185	0.00055	0.01905
Nepheline syenite	0.0430	--	--

Most of the rare earths in the earth's crust are thought to be held in minerals formed during the main stage of crystallization of igneous rocks. There is however a marked tendency for these elements to concentrate in the residual fluids of differentiating magmas as shown by their common occurrence as accessory minerals such as allanite, euxenite, pyrochlore, monazite, and fergusonite in granitic pegmatites. This is typical of the Grenville region. However, only a small part of the rare earths is enriched in pegmatites, as most of them are dispersed in the rock-forming minerals.

Because of the hard, heavy, refractory, and resistant nature of many of the primary rare-earth minerals, they become incorporated as rolled grains in clastic sediments or placer deposits, as monazite and zircon in beach sands. Some of the rare earths may be taken into solution during weathering and find their way into the chemical and transitional sediments such as limestone, shale, and phosphorite. In them, they may also be adsorbed on the surfaces of mineral particles, particularly clay, and may also be selectively enriched in certain organisms. The modern hickory tree for example is reported to incorporate selectively rare earths in its fibre. Coal ash is commonly slightly enriched in rare earths and may contain as much as 0.12 per cent, as shown in Table VI. In coal and lignite deposits, rare earths may be concentrated characteristically at the top of the seam, suggesting deposition from solutions moving along that plane.

Available information suggests the rare earths are more readily soluble than aluminum under tropical weathering conditions and may be carried farther in solution. They may replace calcium and become incorporated in limestones, and in secondary hydrous carbonate and phosphate minerals.

Table VI

Average Rare-earth Content of Sedimentary Rocks
(crustal abundance = 150 ppm or 0.015)

(after Krauskopf, 1955)

	Black Shale	Shale	Phosphorite		Limestone and Dolomite		Coal Ash		Asphalt and Petroleum Ash	
			Av.	Max.	Av.	Max.	Av.	Max.	Av.	Max.
ppm	25-100	200?	100-1,000	1,500	8-80		300-1,000	1,200?	2,000?	40,000?
%	.0025-.01	.02?	.01-.1	.15	.008-.08		.03-.1	.12?	.2?	4.0?

It is clear that source areas enriched in one or more of the rare earths could, under appropriate conditions, provide a sedimentary product of weathering, either chemical or mechanical, further enriched in that element. Advanced chemical weathering would of course reduce the amount of rare-earth minerals deposited in clastic sediments and increase the amount formed in chemical sediments. Predominantly physical weathering as associated with glaciation would favour preservation of some of the primary rare-earth minerals in the clastic sediments.

The reported concentration of rare earths in some asphalt is high enough to suggest possible by-product recovery. The few analyses indicating minor enrichment of rare earths in phosphorite, probably by isomorphous replacement of calcium and adsorption, and of scandium in iron-oxide sediments, suggest that these sediments should be further explored for these elements. Because of similarities in ionic radii between some of the rare earths and calcium, strontium, and barium, deposits of such minerals as calcite, celestite, and barite, etc., should also be tested for the presence of rare earths.

Little is known regarding the behaviour of the rare earths under metamorphism, and much of the Grenville terrane is in an advanced stage of metamorphism. It seems possible that rare earths adsorbed on clay particles and held in isomorphous replacement of calcium, might form different combinations and minerals under recrystallization stress, and that under severe or protracted metamorphism, migration and concentration of rare earth, uranium, thorium, and allied elements might be effected.

MAIN OCCURRENCES AND POTENTIAL SOURCES

Occurrences of rare-earth minerals commonly associated with uranium and thorium minerals are found mainly in mixed gneisses, metamorphic pyroxenite, and complex carbonate vein-dykes, as well as in pegmatite and pegmatitic granite in the Bancroft area of Ontario. Briefly, there is evidence supporting several methods of emplacement of these minerals, including igneous, metamorphic differentiation, metasomatic replacement, and fissure filling. Hydrothermal replacement and vein deposits of pitchblende are significantly absent in this region, perhaps indicating the predominance of igneous and metamorphic processes there and elsewhere throughout the Grenville sub-province.

In the Oka area of Quebec niobium (columbium), tantalum, rare-earth metals, thorium, and uranium are reported by Rowe (1955), Maurice (1957), and officers of the Molybdenum Corporation of America, to occur principally in the minerals pyrochlore, perovskite, betafite, niocalite, and britholite, all of which are said to be closely associated with Monteregian igneous and hydrothermal activity in an area of crystalline Grenville limestone, quartzite, gneiss, anorthosite, and gabbro. Many hydrous minerals are associated with the minerals mentioned above. Also, an intense alteration of the intrusive rocks and of the crystalline limestone, is visible in which calcite is replaced by biotite, magnetite, and apatite. So far, all the main zones of niobium and associated metals have been found in the contact zone between Grenville-type limestone and Monteregian intrusions, which consist mainly of alkaline rocks, okaite and ijolite, and lamprophyre. Similarly, on Newman, Calder, and Great Manitou Islands in Lake Nipissing, Ontario, niobium and uranium deposits, carrying small amounts of rare earths in uranian pyrochlore, monazite, and uraninite, are found in hydrothermally altered, alkalic, metamorphic rocks about a circular body of diorite that intrudes Grenville-type gneiss and crystalline limestone. These rocks are overlain by remnants of undeformed Ordovician limestone and conglomerate.

DESCRIPTION OF OCCURRENCES

In the time available it was not possible for the writer to visit all the numerous recorded occurrences of rare-earth minerals in the large area of the Grenville sub-province lying between Georgian Bay in Ontario and the Saguenay River in Quebec. However, 25 such occurrences were examined in Quebec and 35 in Ontario, and most of these were found to be in pegmatite dykes. None of the occurrences examined showed an abundance of rare-earth minerals or a sufficiently continuous distribution to warrant immediate development as rare-earth mines. In many cases the rare-earth minerals are so sparsely distributed that it is doubtful if they could be economically recovered even as a by-product of feldspar mining. However if the demand becomes great, by-product recovery from uranium or feldspar mining might be feasible. This might apply particularly to deposits relatively rich in the heavy rare earths. At present the market for rare earths is limited, and there is a plentiful supply of the light earths, mainly cerium, from American deposits of monazite and bastnaesite. Better sources of the heavy earths are desirable however and attention is drawn to some of the deposits in the Grenville sub-province in which they might be found.

Table VII lists alphabetically by townships most of the reported occurrences of rare-earth-bearing minerals in the Grenville sub-province of southeastern Ontario and southern Quebec. The nature of some of the known occurrences seen by the writer is described below. The occurrences are arranged alphabetically by townships and provinces. Other deposits are described in reports listed in the selected references.

The investigation was hampered by lack of quantitative analyses for samples collected for that purpose. It was found that chemical analyses for rare earths could not be made in the laboratories of the Geological Survey in time for this publication owing to the pressure of other work.

ONTARIO

Ambeau Mine (Henvey Tp., Parry Sound dist.)

Two small open-cuts on pegmatite dykes are located about 1/2 mile northeast of Britt station; they are about 100 yards apart. The main cut is 100 feet north of a trail leading from the Britt highway, and the westernmost pit is located a few feet south of the trail.

The main cut trends northeasterly and is about 200 feet long, 20 feet wide and 18 to 20 feet deep, being partly filled with water and debris. It follows a pegmatite dyke about 20 to 25 feet wide that cuts vertically through granitic and hornblendic gneiss. The dyke contains many inclusions and bands of gneiss and is composed mainly of impure feldspar and quartz, biotite, greenish muscovite, garnet, magnetite, martite, and a few dark crystals and clots of euxenite. Most of the euxenite seems to be concentrated on the south-central wall of the dyke about 3 feet from the east contact with the gneiss where one dark, strongly radioactive clot of minerals 6 inches in diameter and about 2 inches thick was found. The gneiss is sharply drag-folded along this eastern side of the cut, but generally the gneissosity strikes northeast and dips 80 - 85° SE. Banding in the dyke dips more gently to the southeast.

The pit to the southwest exposes a pegmatite dyke that strikes northerly and vertically through granitic gneiss, of which the gneissosity trends at about N 50° W and dips 35° NE. The dyke is about 20 feet wide and has a quartz core and microcline walls with admixed biotite and muscovite, ilmenite, magnetite, martite, and garnet. On the northwest side of the dyke the gneiss is invaded lit-par-lit by quartz veins and is concordant with the dykes, striking northerly and dipping steeply to the east.

Bessner Mine (Henvey Tp., Parry Sound dist.)

This abandoned feldspar quarry is located about 2 miles east of the Britt cut-off from provincial highway 69. It is reached by a farm lane passing easterly from the highway through fields on lot 5, con. B. A ridge about 1/3 of a mile south of Still River is formed mainly of hornblendic granitic gneiss, the gneissosity of which strikes generally at N 80° E to N 80° W and dips southerly. Heavy glacial grooves on whalebacks strike at N 30° E. A pegmatite dyke about 60 feet wide cuts through the gneiss at N 65° E with a steep southeasterly dip. Much of the dyke has been removed in a cut about 250 feet long by 30 feet wide, that is now completely water filled. Some pegmatite remains on the sides of the cut and at the southwestern end. It consists chiefly of microcline, perthite, quartz of various shades, salmon-coloured feldspar, biotite, chloritic biotite, altered hornblende crystals, brown garnet, magnetite, hematite stain, pyrite, and scattered crystals of cyrtolite, beryl, and clots of thucolite, uraninite, and allanite. Ellsworth reported the occurrence of an oily substance in two parallel fracture zones crossing the dyke at right angles. The zones are reported to be about a foot wide and 40 feet apart. Both zones are said to be saturated with a heavy yellow oil, in appearance resembling a thin vaseline. In addition numerous small, pea-like balls of hardened oil are said to be present in cavities and crevices of the shattered rock, but these were not seen by the writer.

Uraninite and thucolite are intimately associated and occur mainly along the walls of the pegmatite together with altered radiating crystals of chloritic, biotitic hornblende, but allanite and cyrtolite are also present in the centre of the dyke. According to Ellsworth most of the thucolite was found near the surface, only traces being noted in the lower part of the pit. A concentrate of uraninite from this occurrence analyzed by Ellsworth totalled about 3 per cent rare-earth oxides, equally divided between the light and heavy groups.

Britt Station (Henvey Tp., Parry Sound dist.)

A number of pegmatite dykes near Britt station on the Canadian Pacific railway have been worked in the past for feldspar and have been found to contain crystals of radioactive minerals. Among these are the Ambeau and Bessner mines. More recently, surface testing and diamond-drilling have been conducted on small pegmatite dykes, which also contain radioactive minerals, about 1/4 mile southwest of Britt station.

At a point about 200 yards south of the main Canadian Pacific railway line and its intersection with the Britt spur line, a pegmatite dyke in folded quartzitic paragneiss and hornblende gneiss has been exposed by stripping and in pits. A second dyke or an extension of the first is exposed in a small, narrow water-filled cut about 100 feet to the northeast. The dykes consist essentially of pink feldspar, quartz, and biotite, with accessory magnetite in part intergrown with biotite and altered to martite, and sporadic tiny black crystals of allanite, a few as much as 1/2 inch in diameter. The northern dyke contains considerable brown garnet and some euxenite as well as allanite, thorianite, thorite, and spinel in very small amounts, all of which were identified by X-ray diffraction photograph.

Bathurst Township (Lanark Co.)

A pegmatite dyke on lot 22, con. IX was opened for feldspar mining in a single pit and two test pits. The main pit is about 30 feet long, 20 feet wide, and 18 feet deep, in a field about 375 feet southwest of the gravel road from Balderson to Fallbrook, and northwest of Perth.

The dyke cuts through granite and granitic gneiss, the gneissosity of which strikes at N 60° W and dips 45° SW. The dyke strikes at about N 15° E and apparently dips almost vertically. It is exposed for a length of 150 feet and width of 30 feet, but test pits to the south along strike indicate that the dyke, or an extension of the dyke, outcrops for an additional 250 to 500 feet. Most of the material removed from the pits remains on the dumps.

The dyke is zoned, with a quartz-rich core flanked by zones of buff and pink feldspar that are intergrown with quartz. Tourmaline and euxenite occur sporadically in the outer zones of the dyke. Euxenite occurs in dark amber to black, vitreous crystals up to 5 inches long and 1/2 inch thick, and as clots in feldspar.

Some of the crystals are altered to dull black and dull green resembling allanite and gadolinite. Sunbursts of radial shattering and alteration are commonly found around grains of euxenite, one crystal 1/4 inch in diameter being surrounded by a red stained corona, 1 inch in diameter.

Qualitative X-ray fluorescent analysis of a sample of euxenite from this deposit indicated the presence of Cb, Y, Th, U, Ce, La, Er, Dy, Gd, Mn (manganese), Pb (lead), Ta (tantalum), Ti (titanium), and Fe (iron). In addition Lu, Yb, Pr, Nd, and Sm were detected in a chemical concentrate of this material.

Molybdenum Corporation of America Limited, (Bobjo and Bond) (Calvin Tp., Nipissing dist.)

Pegmatite dykes are reported to occur in lots 21 and 22, con. VIII, lots 19, 20, 21 and 22, con. IX, and lots 19, 20 and 21, con. X. These lots lie to the north and south of provincial highway 17. Three main dykes are reported, one on the north side of the highway and two on the south side.

At a point on highway 17, 1.2 miles west of the side road to Eau Claire a bush road for trucks leads northeasterly about 1/4 mile to a small lake, skirts the eastern end of the lake, and ends about 1/4 mile farther on near the northeast end of the lake(numerous bush roads branch from the main road en route). At this point in a clearing, parts of two pegmatite dykes are exposed by stripping and test pits. The dykes generally cut concordantly through granitic gneiss, striking at N 20° W and dipping 75° NE, but in places they are sharply discordant.

The main dyke strikes about N 5° E, dipping essentially vertically, and may be traced for a length of about 500 feet. It varies in width from 15 feet at the north to 30 feet in the centre and pinches sharply to 4 feet at the southern end, about 100 feet north of the small lake. At this point the dyke rolls and dips to the northeast. Several test pits have been made on the south-central part of the dyke, the largest of which is 23 feet by 7 feet by 10 to 14 feet deep.

The dyke consists mainly of a central core of white quartz, pink microcline in crystals rarely as much as 2 feet in diameter and biotite crystals as much as 4 inches in diameter, and walls of mottled pinkish feldspar, chloritic biotite, biotite, magnetite, martite, brown garnet, oligoclase, quartz, and hematite stain. In addition a few small grains of dark radioactive minerals including columbite and euxenite are present in places in the dyke.

A small dyke is exposed by stripping about 100 feet east of the first. At one point both gneiss and dyke strike at N 25° E and dip 40° SE, at another the dyke cuts discordantly across the gneiss. The dyke is about 12 feet wide and is exposed for a length of 100 feet. It consists chiefly of coarse-grained microcline and quartz with a quartz-rich centre containing biotite crystals as much as 4 inches thick and 6 inches in diameter. Martitized magnetite and garnets are concentrated in marginal zones.

Three bulk samples from a test pit are each reported to have shown 0.10 per cent U_3O_8, and 0.15, 0.10 and 0.12 per cent of niobium and tantalum oxides. Other analyses are reported at 0.14 and 0.3 per cent niobium and tantalum oxides. Five samples sent to the Ontario Department of Mines showed up to 0.49 per cent U_3O_8 equivalent and 0.42 per cent U_3O_8 chemical. A picked sample probably consisting of a single mineral showed 17.5 per cent U_3O_8 equivalent. A sample of euxenite-bearing material selected by the writer showed spectrographically a content of 0.04 per cent yttrium, 0.02 per cent niobium and less than 0.003 per cent scandium.

Conger Township (Parry Sound dist.)

A wide pegmatite dyke on lot 7, con. X, was formerly worked for feldspar. A deep cut about 75 feet long and 50 feet wide, with sheer walls 30 feet to water of undetermined depth, has been made on the dyke. The old road to the workings was negotiated by automobile in 1957, as far as the main line of the Canadian Pacific Railway. The remaining distance of about 1/2 mile westerly past the railroad tracks must be covered on foot.

A lenticular mass of pegmatite cuts through granitic and hornblende gneiss forming a ridge overlooking a southwesterly trending valley to the west. The northwest contact of the dyke is covered, but a width of 75 feet of the dyke is exposed to the east of the pit, and the dyke is probably at least 125 feet wide at this point. The hanging-wall (eastern) contact of the dyke strikes northerly but swings to about N 65° E at the south end and dips 70° SE. Banding in the dyke strikes to the north and dips 70 to 85° E. Gneissosity in the hanging-wall rocks also strikes northerly and dips easterly at about 40 degrees.

The dyke is composed essentially of quartz, microcline, plagioclase, muscovite and biotite. On the north end of the cut near the centre of the dyke, above a micaceous zone about 6 feet thick, black crystals of euxenite as much as 3 inches long and 1/2 inch wide, are disseminated in feldspar over a length of 8 feet and a width of about 2 inches, together with occasional brown crystals, 3/4 inch in diameter, of monazite and 1/8-to 1/4-inch crystals of reddish brown garnet. Near the south end of the cut, in pink feldspar, crystals of euxenite and columbite as much as 1 inch long occur with greenish muscovite and red garnet in a lenticular zone. This zone dips steeply to the east over a width of 11 inches and length of 7 feet. About 3 feet below this lens, black crystals and clots of columbite as much as 2 inches long occur in a zone about 3 inches wide and 3 feet long. A lens of dark, rusty, euxenite-bearing rock about 8 inches wide also is present on the southwest wall of the pit. A sample selected from this band contained 0.15 per cent yttrium. A chemical concentrate of this material was found to contain Ce, Y, La, Pr, Nd, Sm, Gd, Dy, Er, Yb, Lu, Th, U, Pb, Zr, Zn, Mn, and Fe.

Occurrences of allanite, calciosamarskite, uraninite, and thucolite have been found in pegmatite dykes in nearby lots in Conger township, but they appear to be of mineralogical interest only. Three of the occurrences however are in dykes east of a draw that extends northeasterly from a bay at the southeastern end of Blackstone Lake, and which may represent a favourable zone for prospecting.

Fry Lake (Seguin Falls) (Monteith Tp., Parry Sound dist.)

Two occurrences of allanite were located on the north and east shores of lower Fry Lake about 1/4 mile south of Seguin Falls, lot 21, con. B. A trail leads from the road south of the site of the old railroad station to the north shore of the lake. The mineral occurrences may be reached on foot by following the lake shore, but they are most conveniently reached by boat from the lake.

At the northeast tip of the lake east of the trail, a 30-foot-wide pegmatite dyke cuts discordantly through granitic and hornblendic gneiss at N 30° E and dips at 65° NW. The dyke is exposed for a length of about 80 feet and consists mainly of microcline, plagioclase, and quartz with minor amounts of biotite, magnetite, and an occasional crystal of allanite. A pit 6 feet in diameter and about 3 feet deep has been blasted in the red-coloured feldspar of the central part of the dyke, but radioactivity is low and few allanite crystals were seen. The gneiss at this end of the lake maintains a constant strike of about N 65 - 70° W and dips 75-80° N.

On the north shore of the lake the gneiss is corrugated, but generally maintains a regional westerly strike and steep northerly dip. At a point near the centre of the north shore, a shallow pit 5 feet in diameter has been made on a slope of pink pegmatite near the water's edge. The pegmatite dyke is irregular but is generally concordant with the enclosing gneiss, the gneissosity of which strikes at N 60° W and dips vertically. The dyke is about 25 feet wide and is exposed intermittently for a distance of about 50 feet along the shore, but it contains many inclusions and grades to pegmatitic granite and granite in part. The dyke consists predominantly of quartz, microcline, plagioclase, and biotite, but contains abundant crystals of allanite and magnetite in spots. In the pit, allanite in crystals as much as 1/2 inch long by 1/4 inch wide is disseminated through a zone of granite and pegmatitic granite about 5 to 6 feet wide. Individual allanite crystals are surrounded by a zone of radial fractures and reddish alteration. The weathered allanite grains are characteristically dark brown and may show light brown margins.

A chip sample taken over a width of 2 feet in the pit contained 0.3 per cent cerium and 0.1 per cent lanthanum determined spectrographically. Fluorescent X-ray spectrographic analysis of a chemical concentrate of this material showed the presence of Ce, La, Pr, Nd, Y, Th, Pb, Zr, Zn, Ba, Sr, Mn and Fe.

Long Lake (Foxton Mine) (Loughborough Tp., Frontenac Co.)

A small amount of feldspar has been removed from a pegmatite dyke on the west side of Long Lake about 1/4 mile from the southern end of the lake, on lot 11, con. IX. This is thought to be the locality of the old Foxton mine, and also the deposit from which feldspar was shipped via Perth Road station and in which part of a crystal of gadolinite was identified.

A wagon road negotiable by automobile branches westerly from the main gravel road to the abandoned Frontenac lead mine, and leads near the northern end of Long Lake where a wagon road branches westerly and leads to the northeastern side of the lake. From this point a row-boat may be used to reach the pit near the southwest end of the lake, a distance of about a mile. The small rock dump from the pit extends to the water's edge.

Fifty feet west of the lake shore a pegmatite dyke cuts between banded metamorphic pyroxenite on the east and gneissic hornblende granite on the west. The rocks are concealed by overburden and bush, and the pit, which is about 16 feet in diameter and 15 to 18 feet deep, is badly overgrown. The dyke appears to grade to hornblende granite on the west but it is at least 23 feet wide and 150 feet long, and may be as much as 30 feet in true thickness in places. It strikes at about N 30° E and dips about 35° NW. The foot-wall pyroxenite is badly decomposed near the dyke where a zone of soft, hematite-stained, apatite-bearing, chlorite schist parallels the dyke. On the hanging-wall the gneissosity in the granite strikes about N 70° E and dips steeply northwesterly.

The dyke is zoned, with masses of quartz and microcline, rarely as much as 10 inches in diameter, either separately or as intergrowths of the two in the centre. These are flanked by zones carrying, in addition, plagioclase, and small rusty zones in which small crystals of euxenite and possibly also allanite and gadolinite occur sparingly. Greenish flakes of mica and some pyrite, pyrrhotite, and chalcopyrite occur sporadically through the outer zones of the dyke especially on the foot-wall side.

A chemical analysis by H.V. Ellsworth, of part of the gadolinite crystal reported from this area, showed 10.29 per cent BeO, 0.14 per cent ThO_2, 2.85 per cent $(Ce, La, Di)_2O_3$, and 46.47 per cent $(Yt, Er)_2O_3$. A concentrate of such material would of course be an excellent source of the heavy earths. Euxenite also occurs sparingly in the dyke, but there is no indication of sizable concentrations of either of these minerals. However insufficient work has been done to expose and test the covered parts of the dyke. The presence of Y, Ce, Pr, Nd, Sm, Gd, Dy, Er, Yb, Lu, Th, Zr, Zn, Mn and Fe was detected in chemical concentrates of selected material from the dyke.

Lyndoch Township (Quadeville)

The type locality of lyndochite, a rare euxenite-like mineral, is situated in lot 23, con. XV, about 1 1/4 miles north-east of Quadeville on provincial highway 515. At a point 1.1 miles north of Quadeville the mine road leads easterly 0.2 mile to the mine where a pegmatite dyke in granitic gneiss strikes at N 56° E and dips about 15-20° NW. The dyke cuts sharply through a band of hornblende-biotite gneiss and gneissic granite. The foliation of the gneisses strikes easterly and dips about 35° S. The dyke is sinuous and irregular in width, and variable in composition and texture. At most it is about 45 feet wide on the floor of the cut, but as the dyke apparently dips rather gently to the north the true thickness of the dyke may be only about 20 feet; it varies greatly within short distances along strike. It is exposed in the cut for about 200 feet. Fragments or xenoliths of the country rock are included in the dyke in places. It is composed chiefly of pink feldspar, grey feldspar, and quartz, and small amounts of amazonstone, peristerite, tourmaline, blue-green beryl, magnetite, muscovite, lyndochite, euxenite, columbite, brown garnet, monazite, and strüverite (Nb-Ta bearing ilmenorutile).

A chip sample, taken across an 8-foot, central radioactive zone in the dyke, rich in lyndochite gave a spectrographic analysis of 0.1 per cent Ce, 0.05 per cent La, 0.1 per cent Th, and 0.04 per cent Y. This 8-foot width may, however, represent a zone only 2 to 3 feet in true thickness. A picked sample of lyndochite from this zone showed, on spectrographic analysis, a content of Nb and of Ti each greater than 10 per cent, and of Ca (calcium), Th, and Y each greater than 2 per cent with small amounts of Ce, La, Nd, U, Zr, Ta, Er, Dy, Gd, and Sm. A chemical analysis of lyndochite from this locality by H.V. Ellsworth gave a content of 4.34 per cent (Ce, La, Di)$_2$0$_3$, 18.22 per cent (Yt, Er)$_2$0$_3$, 41.43 per cent Nb$_2$0$_5$, 3.84 per cent Ta$_2$0$_5$, and 4.95 per cent Th0$_2$, etc. A spectrographic analysis by J. R. Butler of lyndochite from this locality showed a content of 12.11 per cent light-earth oxides, 7.9 per cent heavy-earth oxides and 10.76 per cent Th0$_2$, etc. In addition Pr, Eu, Tb, Tm, Yb, and Lu were also detected. The elements Ca, La, Pr, Nd, Sm, Gd, Y, Th, Pb, Zr, Zn, Mn, and Fe were detected in chemical concentrates of this material by X-ray fluorescence methods.

On lot 30, con. XV, of Lyndoch township, about 1.3 miles by mine road north of Eneas Lake on provincial highway 515 west of Quadeville, a second occurrence of beryl and radioactive minerals is known in a pegmatite dyke in this township. The dyke was once worked for feldspar but since abandoned. Pegmatite is exposed discontinuously by stripping for a length of about 300 feet and a width of 50 feet. Its dimensions may be larger in extensions to the south and west. The dyke appears to be composite and segregated. It contains at least three quartz-rich zones flanked by microcline, and it grades imperceptibly into pink granite on the north. Quartz- and microcline-rich zones in the pegmatite strike about N 50° W and dip steeply southwest.

The dyke is composed mainly of pink microcline, white quartz, and grey plagioclase (twinned), with abundant pale rose quartz, peristerite, myrmekite, green muscovite, and biotite, and sporadically distributed crystals of green beryl, columbite, euxenite, and fergusonite.

Maberly (Orser-Kraft) (South Sherbrooke Tp., Lanark Co.)

A pegmatite dyke was worked for feldspar intermittently for a number of years by Orser-Kraft Feldspar, Limited, Perth. The dyke is on lot 13, con. V. It is about 200 feet east of the Maberly-Westport gravel road, leading south from Maberly on provincial highway 7, at a point about 1.7 miles south of the first railway-crossing. It is about 1.2 miles north of Little Silver Lake. The workings are not visible from the road, but are hidden by rocky knolls and the roadside fence is not broken by a gate.

Behind a granite shoulder an opening has been made on a zoned pegmatite dyke that strikes at N 60° E and dips at 56° SE. The pit is about 100 feet long by 36 feet wide and is filled with deep water. The dyke is made of pegmatite and pegmatitic granite that cuts concordantly through granitic gneiss and granite. The dyke consists mainly of quartz, pink feldspar (microcline) in crystals as much as 6 inches in diameter, grey feldspar (plagioclase), red and rusty stained feldspar, muscovite, and tourmaline. Euxenite occurs sparingly, together with black tourmaline and reddish feldspar in a narrow zone near the western (foot-wall) side of the dyke. In one case euxenite was found as a tiny core in a tourmaline crystal. Other rare minerals such as xenotime may be present in small amounts according to Ellsworth.

In 1921 a shipment of 1,593 pounds of hand-picked euxenite-bearing material (feldspar) was concentrated, analyzed by H.V. Ellsworth, and products totalling 3.67 per cent of the ore material averaging 5.7 per cent U_3O_8, 2.3 per cent ThO_2, 0.48 per cent cerium-group earths, and 16.31 per cent yttrium-group earths were obtained.

A Pb/U age determination by H.V. Ellsworth on specimens of euxenite selected from this concentrate gave an age of 801 million years, an age considerably lower than that generally assigned to similar dykes in the Grenville sub-province. Ellsworth attributed the relatively low age to leaching or replacement of lead, possibly by silica.

MacDonald Feldspar Mine (Monteagle Tp., Hastings Co.)

The main workings of the MacDonald mine are located in lot 18, con. VII, about 2 miles by road east of Hybla station. Three smaller open-cuts are located on lot 19, con. VII, just west of the main workings.

A pegmatite dyke outcropping on an easterly facing hill was opened for feldspar in 1919, and produced a total of 35,048 tons between then and 1935, according to reports of the Ontario Department of Mines. The main dyke strikes westerly and dips about 60-70° N on the foot-wall side. The dip on the hanging-wall side varies as the dyke rolls flatly and pinches and swells there. Most of the readily available feldspar has been removed from this part of the dyke and present condition of the workings do not permit a thorough examination. From existing exposures, material on the mine dumps, and from prior descriptions the dyke seems to be a complex zoned pegmatite with a central core of massive white quartz, an intermediate zone of quartz, coarse-grained microcline and perthite, a wall zone of medium-grained plagioclase-microcline-quartz pegmatite, and a contact zone of fine-grained graphic granite. The quartz in places is glassy and transparent and in other places smoky or jet black. Hornblende, pyroxene, biotite, chlorite, and dark brown to black garnet occur in the outer zones. Scapolite is present near the contacts.

Magnetite, ilmenite, titanite, pyrite, and pyrrhotite are also to be found, and traces of molybdenite and galena have been reported. Many rare and radioactive minerals have also been identified, including allanite, pyrochlore (ellsworthite), cyrtolite (zircon), purple fluorite (antozonite), uranothorite, uraninite, thorianite, thorite, and hyblite.

Many of these rare minerals are intermixed with salmon-pink calcite that apparently was present in several pods in the dyke. A mass of white calcite visible at the eastern portal of the lower cut is associated with white quartz in the core of the dyke and is almost barren of radioactive grains. Elsewhere the rare minerals may be found sporadically distributed in feldspar and quartz, both of which are commonly radially shattered and stained around the radioactive grains. Pink and salmon-coloured calcite is commonly associated with both smoky black quartz and the radioactive minerals, particularly pyrochlore (ellsworthite) and zircon (cyrtolite). The pink colour of the calcite is commonly bleached around the margins of radioactive pyrochlore grains. The pyrochlore itself is present in two varieties, a black vitreous type and a softer, more shattered, amber-coloured resinous type which may be an alteration product of the hard black type as it occurs in borders around cores of the black type.

Pyrochlore (ellsworthite) also is present on the dump in association with mixtures of pyrite, pyrrhotite and black quartz. The yellow type of pyrochlore is said by Ellsworth to be more common in the calcite; the darker type more common in the quartz or with sulphide.

The mineral assemblages and association in the north dykes are similar, but there is no evidence of the occurrence of calcite lenses carrying pyrochlore. Some pink and white calcite-pyroxene skarn bands occur in the contact rocks, and, at the east end of the cut on the north dyke, a band of this pink calcite-pyroxene skarn is sharply cut through by the pegmatite dyke. At this point the top of the dyke is capped or covered by 4 feet of hornblendic gneiss that carries narrow bands of metamorphic pyroxenite and calcite-pyroxene skarn; the dyke occupies the axial part of a small anticlinal fold in the gneiss that plunges easterly. It is there apparent that pegmatite was emplaced after the formation of the calcite skarn and the metamorphic pyroxenite, and was structurally controlled in anticlinal folds that plunge gently easterly. However, the occurrences of pink and white calcite with quartz associated in places in the core zone of the main dyke apparently represent primary dyke minerals. The possibility is suggested that calcite was assimilated from pre-existing calcite skarn and crystalline limestone either in deeper levels of the dyke or in its parent magma.

Radioactive minerals are sparingly distributed through the dyke, but were apparently clustered most abundantly in pods of pink calcite, and in lenses of pyrrhotite and black quartz. The part of the white calcite core left at the portal of the lower adit on the dyke is singularly free of radioactive minerals. It seems reasonable to surmise that the salmon-pink colour of the calcite and the black colour of the quartz may be caused by minutely disseminated impurities including iron and manganese, as was concluded by Walker and Parsons (1923). Pink calcite is noticeably bleached in colour near radioactive grains, and radial shattering of the more brittle quartz and feldspar about radioactive grains is common. Ellsworth attributed this to fracturing during expansion caused by radioactive disintegration.

The age of ellsworthite in this dyke was determined by Todd at 175 to 105 million years, which if correct would place the formation of the mineral and probably also the emplacement of the dyke in the Mesozoic time. No other information substantiating this relatively young age of the dyke is available, and it is difficult to accept in the light of the generally accepted Precambrian age of these dykes as indicated by the general spatial and geological relations and supported in a few other cases by radioactive age-determinations. Post-Ordovician igneous intrusions that may be as young as the Tertiary are known however in the Monteregian intrusions, and also at Oka and northwest of Sept Iles in Quebec.

A selected sample of pyrochlore (ellsworthite) analyzed by X-ray fluorescent spectrography showed the presence of Nb, U, Th, Pb, Ta, Y, Dy, Yb, Fe, Mn, Ce, La, Nd and Ti. A chemical concentrate of this material showed in addition Pr, Sm, Gd, U, Pb, Zr, and Zn. Ce, Nd, Gd and Y were detected in chemical concentrate of garnet from this dyke. Ellsworth's analyses of similar material show only a small content of rare earths.

<u>Mattawan Feldspar</u> (Mattawan Tp., Nipissing dist.)

A pegmatite dyke on lot 29, con. III, was worked for feldspar in 1925-26. It is located about 5 miles west of the village of Mattawa on a hillside about 300 yards north of the Mattawa River. The old mine road branches to the northwest from the Moose Head Lodge road at a point 3 miles west of Mattawa. The mine road is not passable now by automobile, but with repairs to a bridge and other difficult spots, it could be made negotiable. The mine may be reached on foot a distance of about 1 3/4 miles west on the old road from the Moose Head Lodge road. At a point about 1 mile west of the Moose Head Lodge road where the old road divides, the southern branch leading westerly should be followed. The deposit could also be reached by boat from Lac Plein Chant, a widening of the Mattawa River.

Two side-hill open-cuts have been made on the dyke, one above the other. The lower or main cut is about 125 feet long, 23 to 33 feet wide, and 30 to 35 feet deep. The upper or second cut is about 60 feet north of the main cut and measures 120 feet long, 25 feet wide, and 18 to 20 feet deep. It is in part filled with shallow water. Some easily accessible feldspar remains in the dyke.

The dyke cuts sharply and discordantly through grey-black, hornblende-biotite-feldspar gneiss. The dyke strikes northeasterly and dips steeply to the northwest, and the gneissosity of the host rock strikes about N 60° W and dips steeply northeasterly. At the north end the dyke narrows to 10 feet and swings to the west as it cuts amphibolitic gneiss that strikes at N 50° W and dips steeply north. The dyke is segregated into a quartz-rich core with coarse-grained microcline on the sides, followed by zones of intermixed microcline, pink plagioclase, and books of biotite mica mainly on the hanging-wall side. Euxenite in shiny black crystals occurs sporadically through the dyke, but is most common in the marginal contact zones and in association with biotite. Single crystals of euxenite as much as 1/2 inch in diameter are common; one crystal as large as 3/4 inch by 1/2 inch was observed, and a clot of euxenite crystals measuring 3 inches long by 1 1/4 inches wide was seen on the hanging-wall side of the dyke. By X-ray spectrography a crystal fragment of euxenite from the dyke showed the following elements: Nb, U, Th, Pb, Ta, Er, Dy, Fe, Gd, Mn, Ce, Ti, Y. Thus a number of potentially valuable elements are present in small amounts, sporadically and erratically distributed.

Murchison Tp. (Thomas G. Hamilton Occurrence)

The writer was guided by Thomas G. Hamilton of Madawaska to two radioactive occurrences north of the Madawaska River in Murchison township.

At the first locality visited, a pegmatite dyke 17 to 20 feet wide with western contact covered, cuts sharply, vertically, and sinuously, for a distance of about 25 feet at about N 60° E, through hornblende gneiss. The gneiss dips gently east, and the dyke dips steeply west. The dyke pinches into paragneiss at the southern end and is covered on the north.

The dyke is composed essentially of rusty pink feldspar in grains 1/4 inch to 1 inch in diameter, quartz, biotite in poorly formed flakes up to 1 inch in diameter, and crystals and clots of allanite. Some of the clots of allanite are as much as 3 inches in diameter and individual crystals commonly measure 1/8 by 1/4 by 1/2 inch. Allanite is concentrated in a fracture zone in the central part of the dyke. The main allanite showing in a small cut on the dyke is about 6 feet long by 2 feet thick. This zone dips steeply west with the dyke.

A selected sample of high-grade material from this zone gave a spectrographic analysis of 2 per cent Ce, 2 per cent La, 0.3 per cent Th, and 0.05 per cent Y. Spectrographic analyses of chip samples taken vertically down 66 inches of face, and horizontally across 30 inches, gave: 1 per cent Ce, 1 per cent La, 0.15 per cent Th, and 0.02 per cent Y; and 0.5 per cent Ce, 0.2 per cent La, 0.1 per cent Th, and 0.02 per cent Y respectively. In chemical concentrates of each of these materials, Pr, Nd, Sm, Gd, Th, and Zr were also detected.

About 1/4 mile to the northwest across the valley, pegmatite is exposed on the side of a southwest-facing ridge of paragneiss. A pegmatite dyke coats the gneiss and forms a vertical northwest-trending cliff but also intrudes the paragneiss concordantly, and several narrow dykes follow the gneissosity. The dykes and the gneissosity strike northwesterly and dip about 10° E. The main dyke is about 12 feet thick and is traceable for about 75 feet along the cliff face. Several smaller dykes, less than 18 inches in thickness, parallel the main dyke in the paragneiss. The dykes carry allanite in small crystals and clots fairly uniformly disseminated in small amounts. The rock at the base of the cliff is not exposed but it is possible that the concordant dykes exposed on the cliff are offshoots from a larger, covered, discordant dyke below.

On the basis of incomplete information it is suggested that the two occurrences are on opposite limbs of a gentle anticlinal fold in the paragneiss, and that extensions of the occurrences might be found along the strike and down the dip of the bands involved.

QUEBEC

Back Mine (Canada Flint and Spar) (Derry Tp., Papineau Co.)

A large pegmatite dyke about 2 miles northeast of Glen Almond, has been worked for feldspar for many years, and is now operated by Canada Flint and Spar Company. It is reached by a private road branching northeasterly from highway 35 at a point about 8 miles north of Buckingham.

The dyke pinches and swells, varying in strike and dip, and forms a large mass that underlies an entire hill. The mine has been worked by tunnel and open-pit and has been sunk more than 100 feet down dip leaving a broad arch of rock above, supported by pillars, that forms a capping over most of the undermined hill. Trucks may be driven into the lower workings.

The dyke consists mainly of quartz, pale white microcline, soda spar, intergrowths of these minerals, and biotite. In addition considerable smoky quartz, brown garnet, black tourmaline, and muscovite are present, together with sporadic grains of pyrite, pyrrhotite, galena, allanite, thucolite, uraninite, and cyrtolite. Some of these radioactive minerals are to be found, in part replacing tourmaline, at the portal of the tunnel near the south contact of the dyke. Impure radioactive biotite is disseminated in narrow leaves throughout the dyke, in places forming about 2 per cent of the rock. Radioactivity of the biotite is attributed to microscopic inclusions of thorite, which has been identified by X-ray diffraction powder photograph.

Glen Almond (Canada Flint and Spar)(Derry Tp., Papineau Co.)

A pegmatite dyke located about 2 miles north of Glen Almond in lot 4, range II was opened for feldspar and later abandoned. The workings may be reached by automobile. The dyke is about 70 feet long, 30 feet wide, and 18 feet deep and is situated on the south side of the hill about 200 feet west of the road.

The dyke strikes at N 30° E and dips 65° NW. It is about 40 feet wide and cuts through amphibolitic gneiss. The dyke consists chiefly of coarse-grained red feldspar, quartz, intergrowths of quartz and feldspar, and much black tourmaline in crystals as much as 3 inches in diameter and 12 inches long. A few small grains of black euxenite, some as much as 1/2 inch in diameter and some with yellowish altered margins, are present in reddened feldspar associated with tourmaline.

Lac à Baude (Normand Tp., Laviolette Co.)

Allanite occurs abundantly in a dyke of pegmatitic granite east of Lac à Baude, about 44 miles northwest of Grand Mère. Lac à Baude is within the forest territory operated by the Consolidated Paper Corporation Limited, about 16 miles northeast of its Chienne Depot. It is accessible by a company-built sand and gravel road from provincial highway 19 at Mattawin, across the St. Maurice River on a company ferry, following the Chienne Depot road for 38 miles westerly parallel with the Mattawin River, then branching northerly a distance of 2.8 miles on the Strawhat Depot road, branching easterly a distance of about 0.5 mile to the forks of private roads the northerly of which leads about 0.5 mile to Sleigh Lake private lodge and the southerly about 9 miles to the west shore of Lac à Baude. Permission must be obtained from the owner of the lodge at Sleigh Lake to use the road to Lac à Baude, and to use the boat (chaloupe) to cross the rough, mile-wide lake. The 9-mile private road to Lac à Baude is barred by a locked gate. The road is very hilly and winding but is negotiable in summer by truck or jeep, and perhaps by automobile except possibly for a rough, very steep hill. There is no habitation or shelter on the lake. It might also be reached by float plane.

The deposit is situated about 465 feet east of a pine-wooded knoll on the eastern shore of Lac à Baude, on the face of a high rock cliff that is visible from the centre of the lake. The deposit may be recognized from the south-central part of the lake as a buff-weathered, slightly rusty spot on the crest of the northern extension of the main rock escarpment. This is on a bearing slightly north of a line drawn from the landing at the end of the road on the western side of the lake, through the northern tip of the point that juts from the south into the lake on the eastern side. The bearing from landing to deposit is N 65° E.

The deposit was found in 1893 by N. J. Giroux when assisting in surveying the Trois Rivières map-area . It was described by Robert Harvie of the Geological Survey of Canada in 1921, H.V. Ellsworth in 1933, and by K.M. Brown for Quebec Metallurgical Industries, Limited in 1951. Under Mr. Brown's direction part of the cliff face was blasted down and a 4-ton bulk sample was taken from the deposit. A double-wire aerial tramway which still remains was built to transfer samples to the lake shore.

The escarpment east of Lac à Baude is formed by a northerly trending, nearly vertical fault in banded grey and pink paragneiss, the gneissosity of which strikes at N 10° E and dips 15° E. A narrow dyke of pink pegmatitic granite and pegmatite cuts vertically (87° E) through the gneiss along the fault zone. The dyke is exposed along the cliff for a length of 137 feet, a face of 32 feet in height, and a width varying from 16 feet at the north end to 6 feet at the south end. At the northern end the dyke cuts sharply across gneissosity on the eastern contact, but at the southern end it dips concordantly with the gneissosity at least in part. Near the centre of the exposure the dyke dips 64° E. The western contact is obscured by talus on the side of the cliff. One small exposure suggests that the dyke grades to gneissic pink granite on part of the western contact.

The dyke consists mainly of pink microcline and quartz, some plagioclase, hornblende, biotite, magnetite and sporadic accessory crystals and clots of allanite; some of the latter are as much as 12 by 10 by 4 inches. Many of the allanite crystals are surrounded by a sunburst of reddish altered material. Some of the crystals measure 3 inches long by 1/2 inch wide. Microcline occurs in crystals up to 3 inches across, but is commonly less than 1/2 inch in diameter as is quartz. Hornblende and allanite occur commonly in crystals 1/2 inch in diameter, but crystals as much as 2 inches in diameter and 12 inches long are rare. Allanite also occurs in narrow seams or irregular veins in fractures in the dyke. A seam of allanite 2 inches wide displayed in the sample cut at the north end of the exposure, cuts vertically through the pegmatite and leads to a clot of the mineral 6 inches wide.

Allanite is the main black mineral in the dyke and forms about 2 per cent of the rocks. A chip sample taken across 5 feet of the central exposed part of the dyke was analyzed spectrographically and showed a content of about 1 per cent cerium, 1 per cent lanthanum, 0.5 per cent yttrium and 0.02 per cent niobium. Fluorescent X-ray spectrographic analysis indicated the presence, in small amounts, of thorium, uranium, gadolinium and neodymium as well. In addition, Pr and Sm were detected in chemical concentrates of these materials.

Maisonneuve Mine (Maisonneuve Tp., Berthier Co.)

This old mine is situated on a pegmatite dyke in lots 1 and 2, rge. II, about 100 feet south of the outlet of a small lake called Mica Lake. The dyke was discovered in 1880. It is accessible by automobile on a road leading northwesterly from the village of St. Michel-des-Saints, a distance of 10.1 miles. The road crosses the stripped outcrop of the dyke and continues on past the mine to a forestry tower. The main workings consist of a small surface pit, a water-filled shaft said to be 35 feet deep with ancient windlass, and underground drifts.

About 900 feet west of the old shaft, on top of the hill in thick bush, is another open-cut about 120 feet long, 12 to 20 feet wide, and 6 to 15 feet deep. This work, done before 1882, represents the first attempt in Canada to mine solely for rare-element minerals.

The main dyke is exposed by more recent stripping over a length of 600 feet and width of 45 to 100 feet. This represents a true thickness of 40 to 85 feet and the extension is covered at both ends. It strikes at about N 75° E and dips about 60° N, cutting for the most part concordantly through hornblendic paragneiss but displaying irregular, fretted contacts and containing numerous large inclusions of the wall-rock. The dyke on the hill to the west of the shaft is about 12 feet wide. It strikes at N 60° E and dips very steeply southeast. It cuts through rusty, black-weathered garnetiferous hornblende gneiss and is itself much altered and iron-stained. The dyke consists mainly of fine-grained, pyritic, micaceous pegmatite that displays on its walls some ruby muscovite in crystals up to 3 inches in diameter. A few tiny grains of a black radioactive mineral resembling euxenite or samarskite were found along the eastern wall of this dyke.

The main dyke is coarsely crystalline and crudely zoned. It consists chiefly of quartz, microcline, plagioclase, muscovite, biotite, and tourmaline, with accessory garnet, beryl, pyrite, and radioactive grains. The feldspars occur in fresh crystals, as much as 2 feet in diameter, in the interior of the dyke. Small black radioactive grains occur sparingly mainly in clusters in the wall zone and in the biotite-feldspar gneiss along the southern contact of the dyke. Samarskite, euxenite, and fergusonite have been reported from these, but it is difficult to recognize these minerals in the metamict state.

A composite sample of the dark minerals (mainly tourmaline) that are scattered abundantly through the dyke showed no traces of rare earths, but a chip sample taken across a width of 18 inches on the southern contact showed spectrographically a content of 0.02 per cent yttrium, some cerium and lanthanum, and 0.03 per cent niobium. Samarskite from the deposit is reported to contain 10 per cent U_3O_8 and 27 per cent Ta_2O_3. A sample of the samarskite was found by Prof. H.E. Barnes of McGill University to contain "0.04 to 0.05 gramme radium a ton". A sample of samarskite from the mine, analyzed by Milton Hersey, yielded 5.60 per cent tantalum oxide and 3.24 per cent thorium in oxide. In addition fluorescent X-ray spectrographic analysis of chemical concentrates of material from the dyke showed Ce, Pr, Nd, Gd, Y, Th, and Zr.

CONCLUSIONS

It is apparent from the foregoing that rare-earth minerals are difficult to identify and are seldom found in mineable amounts. They are commonly associated with uranium and thorium, and their main primary occurrences are in pegmatite, granite, and alkaline intrusions, in all of which they occur principally in accessory minerals. They may be found also in contact metamorphic, replacement, and vein deposits around such intrusions.

Bituminous, carbonaceous, calcareous and phosphatic sedimentary rocks and minerals may carry rare earths derived by chemical weathering. Physical weathering in glacial or sub-glacial climates favours preservation of primary, heavy, rare-earth mineral grains in clastic sedimentary rocks. Reconcentration of these minerals might be expected, particularly in areas where such rocks are invaded by later intrusions which may themselves contribute additional rare-earth elements.

Although pegmatites from gabbroic rocks are rare, they and the titaniferous deposits associated with alkaline rocks should not be ignored as possible sources of rare earths, witness the discovery of the dark mineral-like mixture of rare earth, iron, and titanium oxide, now known as 'davidite', in uraniferous deposits in albitized rocks in Australia. Davidite has not yet been reported in similar deposits in the Grenville province in Canada.

Only the heavy rare earths appear to be in sufficiently short supply to be of much concern to prospectors at present, and prospecting for these presents many difficulties. Not the least is the difficulty of obtaining accurate chemical analyses as these are generally made only for total rare earths and for cerium; the amount of heavy rare earths is thus uncertain. Some analytical firms may, however, be able to provide suitable analyses by spectrographic or other methods.

Table VII

Rare-earth Occurrences in Southern Ontario and Quebec

A. ONTARIO - Southeastern Part

Township and Name	Location	Type	Ratio $\frac{\text{Heavy}}{\text{Light}}$ Earth	Remarks
Anstruther Tp. Farcroft Mines	Peterboro Co., lots 22-28, con. III, S1/2 lots 23, 24, 26, 27, con. IV	Allanite, uranothorite, and uraninite in granitic pegmatite	probably low	not seen
Garland M & D	lots 4-9, con. XVIII	(same as above)	" "	" "
Gray Wolf Exp. (Stony Creek property)	lots 2, 3, con. IX	Allanite and uranothorite etc., in granite or pegmatite	" "	" "
Higgins Uranium	lots 1-4, con. X, XI, XII	Uranothorite in pegmatite	" "	" "
Zenmac Metal Mines	lots 13-21, con. I-III	" " "	" "	" "
Bathurst Tp.	Lanark Co., N1/2 lot 22, con. IX	Euxenite crystals in pegmatite dyke	high	sporadic distribution
Bangor Tp.	Hastings Co., lot 26, con. V	Uranothorite(?) in biotite in pegmatite	probably low	sparse, sporadic distribution
Burleigh Tp. Pole Star Mines	Peterboro Co., lots 23-25, con. XI and XII	Uranothorite, uraninite, meta-allanite and melano-cerite in pegmatite granite	" "	not seen
Butt Tp.	Nipissing dist., S1/2 lot 13, con. VII Mica Lake	Allanite, uraninite, euxenite, columbite in pegmatite dyke	" "	" "
Calvin Tp.	Nipissing dist., lot 22, con. IV?	Allanite and euxenite in pegmatite dyke	probably medium	small dyke, not seen
Bobjo Mines and Molybdenum Corp. of America	lots 19, 20, 21, 22 con. IX; lots 19, 20, S1/2 21, con. X; lots 21, 22, con. VIII; lot 23, con. IX; lots 22, 23, N 1/2 24, con. X	Euxenite, samarskite? and columbite? in pegmatite dykes	probably high	sporadic distribution
S.B. Bond	lot 22, con. IX	Euxenite and allanite in pegmatite dyke	probably medium	sporadic distribution
W. Stewart	lots 11, 12, con. I	Fergusonite in pegmatite	probably high	not seen
Cardiff Tp. Atlin Ruffner (Allanite property)	Haliburton Co., N1/2 lots 2, 3, con. XVI	Allanite masses in granite pegmatite	probably low	" "
Aumacho River Mines (Paudash Lake)	lot 22, con. IX	Allanite and uranothorite in pegmatite	" "	" "
Bicroft Uranium Mines (Centre Lake property)	lots 27, 28, con. XI	Uranothorite, uraninite, allanite, pyrochlore, etc., in granitic rock	" "	" "
(Croft property)	lots 30, 31, con. XIII, Herschel tp., lots 32, 33, con. XV, Faraday tp.	Uranothorite, etc., in granitic and pegmatitic rocks	" "	" "
Burma Shore Uranium	lot 7, con. XX	Uranothorite, uraninite, etc., in pegmatite and skarn	" "	" "
Canada Radium Corp. (Canada Radium Mine	lots 7-18, con. XII; S 1/2 lot 7, lot 8, con XIII; lot 11, con. XII	Uranothorite, uraninite, etc., in granitic pegmatite	" "	" "
Canadian Dyno Mines	lot 12, con. VIII	Allanite, uranothorite, uraninite, etc., in granitic rocks	" "	" "
Cardiff Uranium Mines, Cardiff Fluorite Mines	lot A, 1, N 1/2, lot 2, con. XVII; lot 2, con. XVIII; S1/2, lot 1, 2, lot 3, con. XIX	Uraninite in apatite-fluorite-calcite veins	probably medium	" "
Climax Molybdenum (W.S. Robertson)	S1/2 lot II, con. XI	Uranothorite and allanite in pegmatite	probably low	" "
Consolidated Thor Mines (Eels Lake)	S1/2 lot 6, con. VI; N 1/2 lot 6, con. V	Allanite and uranothorite? with magnetite in pegmatite	" "	" "
Consolidated Tungsten	S1/2 lot 31, con. XIII	Uraninite, uranothorite, etc., in pegmatite dykes	probably medium	" "
R.W. Doubt	N1/2 lot 10, con. II	Allanite, uranothorite, etc., at granite contacts	probably low	" "

Table VII (Continued)

Township and Name	Location	Type	Ratio Heavy/Light Earth	Remarks
Empire Oils and Minerals	N 1/2 lots 1, 2, con. XV, Cardiff tp.; lot 35, con. XI, Monmouth tp.	Uranothorite, uraninite and allanite in pegmatite	probably low	not seen
Fission Mines Ltd. (Richardson property)	lots 4-7, con. XXI	Uranothorite, uraninite, melanocerite etc., in calcite-fluorite-pegmatite	" "	" "
D.E. Foster (south of Deer Lake)	S 1/2 lot 20, con. XV	Uranothorite, allanite, etc., in granitic pegmatite	" "	" "
J. Gilbert	lot 9, con. VII	Uranothorite, etc., in pegmatite and contact rocks	" "	" "
Consolidated Halo Uranium Mines (Hogan property)	N1/2 lot 4, con. XVIII; S1/2 lots 4, 5, con. XVIII	Uranothorite, uraninite, betafite, etc., in pegmatite and contact rocks	probably medium	" "
Kemp Uranium Mines	lot 5, con. XIV	Uranothorite, thorite, etc., in granite and skarn	probably medium	" "
Kenmac Chibougamau	lots 6-8, con. XIV	Allanite, uranothorite, etc., in granite pegmatite etc.	probably low	" "
Milhol Exp. & Dev.	lots 10, 11, con. V	Allanite, uranothorite, etc., in granitic pegmatite	" "	" "
Mindus Corp. Ltd. (West Lake)	Central Cardiff tp. near West Lake	Uranothorite in granite and pegmatite	probably medium	" "
Molybdenum Corp. of America	lots 10, 11, con. XI; lots 16, 17, con. VIII	Uranothorite in pegmatite and contact rocks	" "	" "
Nu-Age Uranium Mines (Tripp property)	lot 8, con. XXI	Allanite, uranothorite, thorite, uraninite, etc., in pegmatite and contact rocks	probably low	" "
(Montgomery property)	lot 9, con. XXI	Uraninite crystals in fluorite-apatite-calcite vein	probably medium	" "
Topspar Fluorite Mines	lot 13, con. XXII	Uranothorite in calcite-fluorite pegmatite	" "	" "
Triton Uranium Mine	N1/2 lot 8, con. II	Allanite, uranothorite, magnetite in granite, pegmatite and contact rocks	probably low	" "
West Lake Mining Co. (Colbourne Lake)	S1/2 lot 9, con. XIII	Uranothorite, magnetite, etc., in pegmatite and calcite veins	" "	" "
Cavendish Tp. Cavendish Uranium	Peterboro co., southern part of Cavendish tp.	Allanite, uranothorite, uraninite and magnetite in granite	probably low	" "
Cromwell Uranium	lot 13, con. VI; N1/2 lot 14, con. V	Allanite, uranothorite and magnetite in granite	" "	" "
Drude Uranium	N1/2 lot 16, con. III, IX; S1/2 lot 14, con. XI	Allanite, uranothorite, and magnetite in granite	" "	" "
Kelbee Rare Metals	East of Pencil Lake	Allanite, uranothorite, and magnetite in granite	" "	" "
Macfie Exploration	N1/2 lot 8, con. IV	Allanite, uranothorite and magnetite in granite	" "	" "
Silanco M & R (Pencil Creek property)	N1/2 lot 19, con. X; N1/2 lot 21, con. XI	Allanite, uranothorite and magnetite in granite	" "	" "
(Wendover property)	lots 2-8, con. II, III	Uranothorite, fergusonite, melanocerite etc., in pegmatite and granite	probably medium	" "
Chandos Tp. Consolidated Uranium Corp.	Peterboro Co., lots 9-11, con. XVI, XVII; S1/2 lot 9, con. XVI	Allanite, uranothorite, bastnaesite, etc., in granitic rocks	probably low	" "
Conger Tp.	Parry Sound dist., lot 4, con. IX	Allanite crystals in pegmatite dyke	" "	sparse, sporadic distribution
Blackstone Lake	Parry Sound dist., lots 9, 10, con. IX	Calciosamarskite, thucolite and uraninite in pegmatite	probably medium	" " "
Opeongo Mining (G. Colautti)	lot 7, con. X	Euxenite, columbite and monazite in pegmatite	" "	sporadic distribution

Table VII (Continued)

Township and Name	Location	Type	Ratio $\frac{Heavy}{Light}$ Earth	Remarks
Davis Tp.	Sudbury dist., 1 mile east of Ess Creek station, C.N.R.	Allanite in gneiss	probably low	not seen
Dickens Tp. (Aylen Lake)	Nipissing dist., lot 27, con. V; lot 9, con. 13	Monazite in pegmatite dyke	" "	" "
Dill Tp.	Sudbury dist., NW ¼ of N1/2 lot 2, con. II	Toddite in pegmatite dyke	probably medium	sparse, sporadic distribution
Dungannon Tp. Normingo Mines	Hastings co., lot 14, con. XVI	Uranian thorianite in pink calcite marble	" "	not seen
Faraday Tp. Bonville Gold Mines	Hastings co., lots 21, 24, con. A; S1/2 lot 23, con. B.	Uranothorite, pyrochlore (ellsworthite) in pegmatite	" "	" "
Faraday Uranium Mines	lots 16, 17, con. XI, on highway 28, 5 miles southwest of Bancroft	Allanite, uranothorite, thorite uraninite, in granitic rocks	" "	" "
Greyhawk Uranium Mines	lot 10, con. XII	Uranothorite, uraninite, allanite magnetite in pegmatite	" "	" "
Pacemaker Mines & Oils	lots 12, 13, con. X	Uraninite, uranothorite, pyrochlore in pegmatitic rock	" "	" "
Silver Crater Mines (Basin property)	Hastings co., lot 31, con. XV	Betafite in apatite-fluorite-calcite body	" "	" "
(Baumhour-Campbell)	lots 27-30, con. XV; lots 27-29, con. XIV	Uranothorite in granite and contact rocks	" "	" "
Foley Tp. Anson-Cartwright (Isaacs)	Parry Sound dist., lot 13, con. II	Allanite and fergusonite in pegmatitic rock	probably high	" "
Fraser Tp. (R. McCoshen)	Renfrew co., Fraser tp.	Allanite occurrence	probably low	" "
Galway Tp. Crystal Lake W. Blott	Peterboro co., lots 23, 24, con. XI; S1/2 lot 24, con. XII	Uranothorite and uraninite in pegmatite	probably medium	" "
Silver Crater Mine (Crystal Lake property)	lots 21, 23, 25, con. X; lots 23, 24, con. IX, etc.	Allanite, uranothorite, thorite in pegmatite	probably low	" "
Gibson Tp.	Muskoka dist., at Hollow Lake	Allanite occurrences	" "	" "
Glamorgan Tp. Nu-Cycle Uranium Mines	Haliburton co., lots 26-28, con. II 1.6 miles south of Gooderham	Allanite and uranothorite with magnetite in pegmatite	" "	" "
Nu-World Uranium Mines	lot 20, con. II, 3.7 miles south of Gooderham	Uranothorite in granitic pegmatite	" "	" "
Hagar Tp. E.A. McKerral	Sudbury dist., W1/2 lot 10, con. III	Priorite in pegmatite dyke	probably high	sparse, sporadic distribution, small dyke
Hagarty Tp.	Renfrew co., lot 13, con. A	Allanite occurrences	probably low	not seen
Harvey Tp. Gray Wolf Exp. Co. (Nogies Creek property) C.P. Cziraky	Peterboro co., lot 29, con. XVI, on east side of Nogies Creek	Radioactive, rare-earth-bearing mineral in magnetite in granitic gneiss	low	" "

Table VII (Continued)

Township and Name	Location	Type	Ratio $\frac{Heavy}{Light}$ Earth	Remarks
Roy Kennedy (Big Nell Mines)	lot 26, con. XVI, east of Nogies Creek	Uranorthorite and magnetite in pegmatite dykes	probably low	not seen
(Cavendish option)	lot 18, con. XII; lots 17-20, con. XI, XII	Thorite and uranothorite in granite pegmatite	" "	" "
Henvey Tp. Ambeau Mine	Parry Sound dist., 1/2 mile northeast of Britt station, C.P.R. (lot 4, con. A.)	Euxenite, thucolite and uraninite in pegmatite	probably medium	sparse, sporadic distribution
Bessner Mine	lot 5, con. B	Uraninite, thucolite and allanite in pegmatite	" "	" " "
Britt Station	1/4 mile southeast of Britt station, C.P.R.	Allanite, euxenite, thorianite, thorite in pegmatite	" "	" " "
Key River and Pickerel River	Henvey tp.	Allanite occurrences are reported	probably low	not seen
Herschel Tp. W.A. Patterson (Little McGarry Lake)	Hasting co., lots 17, 18, con. XVI, 5 miles west of Maynooth	Euxenite-polycrase in biotite in pegmatite	probably high	" "
Peter-Rock Mining (Hickeys Settlement)	lot 39, con. VIII, Hastings road, north of Bancroft	Pyrochlore, euxenite, allanite and uranothorite in pegmatite	probably medium	large dyke, not seen
Standard Ore & Alloys (Baptiste Lake)	N1/2 lot 26, con. V.	Uranothorite in drill core in pegmatite	" "	not seen
Loudon Tp. H.D. Tomlinson	Nipissing dist., lot D, con. V	Thorite in pegmatite	probably medium	not seen
Loughborough Tp. Long Lake (Foxton Mine) (M.J. O'Brien)	Frontenac co., lot 11, con. IX, west shore of Long Lake	Euxenite and gadolinite in pegmatite	high	sparse distribution
Loughrin Tp. Plexterre Prospecting (J. Plexman)	Sudbury dist., Loughrin tp. about 20 miles east of Capreol	Euxenite, polycrase, etc., in pegmatite dyke	probably high	not seen
Lutterworth Tp.	Haliburton co.	Allanite occurrence with magnetite	probably low	" "
Lyndoch Tp. Eneas Lake	Renfrew co., lot 30, con. XV, 1.3 miles north of Eneas Lake	Columbite, fergusonite, euxenite, etc., in pegmatite	probably medium	sporadic distribution
Quadeville	lot 23, con. XV, 1.1 miles north of Quadeville	Lyndochite, euxenite, columbite, etc., in pegmatite	" "	" "
	lot 23, con. XXIII	Lyndochite, monazite, etc., in pegmatite	" "	not seen
	lot 25, con. XV	Columbite, lyndochite and monazite in pegmatite	" "	" "
Machar Tp. (Carl Palangio)	Parry Sound dist.	Allanite in pegmatite	probably low	" "
Mattawan Tp. Mattawan-Feldspar	Nipissing dist., lot 29, con. III, 5 miles w. of Mattawa	Euxenite crystals in pegmatite dyke	probably medium	sporadic distribution
Monmouth Tp. Acmac Mining Corp.	Haliburton co., N1/2 lot 33, con. XIV	Uranothorite and thorite in graphic granite	" "	not seen
Canadian All Metals	lots 6, 7, con. IX	Pyrochlore and uraninite in pink carbonate rocks	" "	" "
Desmont Mining Corp.	lot 31, con. XVII	Uranothorite and uraninite in pegmatite	" "	" "
Fairly Red Lake Gold Mines	N1/2 lot 4, con. III	Allanite and uranothorite in granite	probably low	" "

Table VII (Continued)

Township and Name	Location	Type	Ratio $\frac{Heavy}{Light}$ Earth	Remarks
Jesko Uranium Mines (Hadlington Lake)	lot 14, con. IV, etc.	Allanite, uranothorite etc., in pegmatite and calcite	probably low	not seen
Long Ridge Uranium	lot 13, con. XII, etc.	Uraninite crystals in marble	probably medium	" "
Nu-Age Uranium (Old Smokey Property)	lots 7, 11, con. X., etc.	Uranothorite in calcite veins	" "	" "
Rare Earth Mining Co.	lot 20, con. VIII; lots 19, 20, con. VI, etc.	Allanite, uranothorite, fergusonite, etc., in pegmatite and contact rocks	probably low	" "
Roford Mines	N1/2 lot 13, con. XIII	Uranothorite, thorite in marble	probably medium	" "
Saranac Uranium Mines	S1/2 lot 24, con. X, 0.4 mile south of highway 500	Thorite and zircon in granite pegmatite and skarn	" "	" "
Silanco M & R (Tory Hill property)	S1/2 lot 32, con. VI	Uranothorite in calcite veins and pegmatite	" "	" "
Urotomic Mines	N1/2 lot 19, con. IV	Uraninite and uranothorite grains in marble	" "	" "
Wadesa Gold Mines	N1/2 lot 5, con. VI near Irondale River	Uraninite crystals in marble	" "	" "
Monteagle Tp. Carr-Quirk-Mellish	Hastings co., S1/2 lots 4, 5, 6, con. I	Allanite and uranothorite in pegmatite	probably low	" "
Dwyer	lot 21, con. VII	Euxenite in pegmatite	probably high	" "
MacDonald Feldspar (Phillips-Doubt Cloudmount Mines)	lots 18, 19, con. VII; lots 16-20, N1/2 lot 21, con. VII, near Hybla	Cyrtolite, pyrochlore (ellsworthite), allanite, uranothorite, etc., in pegmatite	" "	sporadic distribution
Quirke	lots 11, 12, con. IV	Uranothorite in pegmatite	probably medium	" "
Thompson	lots 4, 5, con. VII	Uranothorite in pegmatite	" "	sparse, sporadic distribution
Woodcox Mine (Metro Minerals)	lot 17, con. VIII	Columbite, pyrochlore (ellsworthite), allanite, hachettolite, calciosamarskite and betafite in pegmatite	" "	" " "
Monteith Tp. Seguin Falls	Parry Sound dist., lot 21, con. B, north shore Lower Fry Lake	Allanite crystals in pegmatite	low	sporadic distribution
Murchison Tp. Cameron Mine	Nipissing dist., lot 22, con. VIII, 8 miles northwest of Madawaska	Allanite and euxenite in pegmatite	probably low	sparse, sporadic distribution
Thomas G. Hamilton	north of Madawaska River	Allanite in pegmatite dykes	low	small dykes, heavy dissemination
Madawaska Feldspar	lot 14, con. IV; lot 16, con. V	Fergusonite in biotite in pegmatite	medium	sparse, sporadic distribution
Portland Tp. Wilks Mine (J.C. Dunlop, Hoyle Mining Co.)	Frontenac co., near Verona	Allanite occurrence	probably low	not seen
North Burgess Tp. Cenosite	Lanark co., lot 8, con. V	Cenosite in mica pegmatite	high	" "
J.P. Quinn	lot 23, con. VI	Euxenite occurrence	probably high	" "
Raglan Tp. Craigmont Mine	Renfrew co.	Allanite, euxenite, uraninite in pegmatite	probably medium	sparse, sporadic distribution
Richards Tp. E. Betz	Renfrew co. lot 2, con. XIV	Euxenite, fergusonite and uraninite in pegmatite	probably high	not seen
Sabine Tp.	Nipissing dist., lot 28, con. I	Euxenite in pegmatite	" "	sparse, sporadic distribution
Servos Tp. Shorland	Sudbury dist., lot 6, con. VI	Priorite occurrence	" "	not seen

Table VII (Continued)

Township and Name	Location	Type	Ratio Heavy/Light Earth	Remarks
South Sherbrooke Tp. Orser-Kraft	Lanark co., lot 13, con. V, 3 miles south of Maberly	Euxenite, etc., in pegmatite	high	sporadic distribution
Manitou Islands Beaucage Mines	Nipissing dist., Lake Nipissing	Pyrochlore, uraninite, monazite, etc., in carbonate contact rocks about diorite	probably medium	not seen
B. QUEBEC - Southern Part				
Callieres Tp. (St. Siméon)	Charlevoix co., lot 7, rge. II sw., etc.	Allanite, fergusonite xenotime and uraninite in pegmatite	probably medium	sparse, sporadic distribution
Baie St. Paul	Charlevoix co., about 1 mile west of Baie St. Paul village	Polycrase(?) allanite(?) in feldspathic rock	" "	not seen
Derry Tp. Back Mine (Canada Flint & Spar)	Papineau co., lot 14, rge. II	Allanite, euxenite, uraninite, thucolite, and thorite in biotite in pegmatite	" "	sparse, sporadic distribution
Glen Almond	lot 3, rge. II; lot 4, rge. II	Euxenite in pegmatite	probably high	" " "
Wallingford Mine (M.J. O'Brien)	lot 7, rge. I	Allanite, uraninite and thucolite in pegmatite	probably low	" " "
Deux Montagnes Tp. Quebec Columbium (Molybdenum Corp. of America)(Kennecott Copper Corp)	Oka-Latrappe area, 8,000 acres in St. Joseph and l'Annonciation parishes	Niobium and rare-earth minerals in complex of carbonate and alkaline rocks	" "	not seen
Oka Rare Metals	5,738 acres in St. Joseph and St. Benoit parishes	(same as above)	" "	" "
Columbium Mining Products	2,000 acres in l'Annonciation parish	" " "	" "	" "
St. Lawrence River Mines	360 acres in l'Annonciation parish	" " "	" "	" "
Bouscadillac Gold Mines	2,200 acres in St. Benoit, St. Joseph and l'Annonciation parishes	" " "	" "	" "
Other companies	many occurrences	" " "	" "	" "
Harvey Tp. (David Pednault)	Chicoutimi co., about 6 miles east of St. Fulgence	Uraninite(?) with magnetite in pegmatite	probably medium	sparse, sporadic distribution small grains
Hull Tp. H.H. Harris	Gatineau co., lots 22-24, 25 N-26N, rge IX; lot 22S, rge. X	Uraninite and betafite in pegmatite	" "	(same as above)
Fortune Lake	on parkway north of Fortune Lake	Columbite and samarskite (annerodite) in biotitic rock at contact of pegmatitic dyke, yttrian garnet in pegmatite	" "	sporadic distribution
Meach Lake group (H.H. Harris)	lot 22N-28N, rge.X, lot 23S-25S, lot 26-28, rge. XII	Betafite and uraninite in arfvedsonite pegmatite and contact rocks	" "	" "
St. Pierre de Wakefield	N1/2 lot 29, rge.IV	Allanite and euxenite in pegmatite	" "	" "
Kensington Tp. L.F. Smith (Opawica Explorers)	Gatineau co., lots 10-16, rge. I, east of Gatineau River	Euxenite, fergusonite, uraninite and pyrochlore in pegmatite	probably high	not seen; small dyke reported
Lytton Tp.	Gatineau co., lot 26, rge. I, west of Grand Remous	Euxenite grains in pegmatite	" "	sparse, sporadic distribution; small dyke
Desert River	near Pine Chutes on Desert River	Allanite, uraninite, euxenite in pegmatite	probably medium	not seen
Bjarne Kvendbo	Gatineau co., lots 25-40, rge. I; lots 18-47, rge. II; lots 23-46, rge. III; lots 35-45, rge. IV	Rare earths, thorium in quartz veins reported	?	" "

Table VII (Continued)

Township and Name	Location	Type	Ratio $\frac{Heavy}{Light}$ Earth	Remarks
Maisonneuve Tp.	Berthier co., lots 1, 2, rge. II, 10.1 miles northwest of St.-Michel-des-Saints	Samarskite, euxenite, fergusonite in pegmatite	high	sporadic distribution
Normand Tp. (Lac à Baude)	Laviolette co., 465 feet east of Lac à Baude	Allanite crystals and veins in pegmatite	low	" "
Pied des Monts	Charlevoix co., near Lac Pied des Monts	Uraninite and euxenite in pegmatite	probably medium	sparse, sporadic distribution
St. Catherine Tp. (A. Houle)	St. Maurice co., lots 60-71-N, rge. I, II	Uraninite, uranothorite, fergusonite, thucolite, and allanite in pegmatite	" "	not seen
Templeton Tp. Battle Lake (Wallingford)	Gatineau co., lot 5, rge. XIII, 1/4 mile north of Battle Lake	Euxenite, uraninite and monazite in pegmatite	probably high	sporadic distribution
McGregor Lake (Wallingford)	S1/2 lot 20, rge. XII	Euxenite in pegmatite dyke	" "	sparse, sporadic distribution
Villeneuve Tp. Villeneuve Mica Mine	Papineau co., lot 31, rge. I, near road	Monazite and uraninite in pegmatite	low	" " "
West Portland Tp.	Papineau co., lot 2, rge. V, near Notre Dame de la Salette	Euxenite and allanite in pegmatite	probably medium	" " "
Wexford Tp. Richard Chartier	Terrebonne co., near Lac Masson	Euxenite in pegmatite	" "	not seen
Other Occurrences Arbic Occurrence (P. Arbic)	Labelle co., near Lièvre River about 1 mile from Mont Laurier	Allanite occurrence in pegmatite	probably low	" "
Calumet Tp. Huddersfield Tp. Litchfield Tp.	Pontiac co., " " " "	Radioactive mineral occurrences in pegmatite dykes, crystalline limestone and other contact rocks	probably medium	" "
Lepine Depot Occurrence (F.B. Watson)	6 miles northwest of Lepine Depot, north of Maniwaki	Allanite and monazite in pegmatite	probably low	" "
Pope Lake Occurrence (A. Duquette)	Labelle co., north of Pope Lake	Allanite occurrence	" "	" "
Portland Tp.	Papineau co., lot 13, rge. III	Allanite occurrence in pegmatite	" "	" "