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ECONOMIC SIGNIFICANCE OF CARBONATITE DEPOSITS at OKA, QUEBEC, and IRON HILL, COLORADO

GEOLOGY 409

K. A. KOMENAC 1971

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INTRODUCTION

Carbonate rocks, in association with alkaline intrusive complexes, have been known for some time, but only recently has it been realized that the carbonate rocks may be petrogenetically related to the alkaline intrusives; that is, both may have been derived from the same magma.

The purpose of this project was to familiarize the author with some of the characteristics of carbonatites, and to examine the geology and mineralogy of carbonatite occurrences at Oka, Quebec, and Iron Hill, Colorado.

Rock specimens from the Oka complex were kindly supplied by Dr. Gower.

CARBONATITES IN GENERAL

DEFINITION (Verwoerd,1966)

Carbonatite: "granular rock consisting of primary calcite, dolomite, ankerite, or other rock forming carbonates as primary constituents.... and exhibiting the primary features of intrusive rocks."

The rock is called sövite if the carbonate is primarily calcite and beforsite if the carbonate is primarily dolomite.

PRINCIPAL CHARACTERISTICS (based on Heinrich,1966)

1. The association of carbonatites is restricted to alkalic undersaturated to saturated igneous rocks, to alkalic ultramafic igneous rocks, or both.

2. The environment of emplacement is continental, cratonic, or peripheral cratonic, with close relationships to zones of major faulting in many cases.

3. Carbonatites range in age from Pre-Cambrian to present.

4. Carbonatites are normally usually in the form of plugs, dikes, veins, or cone sheets, and rarely, concordant intrusions and lavas. Usually, carbonatite bodies are circular to oval in plan, with a diameter of 1-3 miles. Commonly the carbonatite with related alkalic rocks forms a concentric, ring type structure, with carbonatite at the centre. An ideal sequence

of rings would be syenite-- foyaite - ijolite - pyroxenite or dunite - carbonatite. There may be more than one centre in a single complex. The contacts between layers are usually vertical or nearly vertical. Later carbonatite dikes often cut the central fractures to form cone sheets. The carbonatite dikes often cut the associated alkalic rocks and country rocks.

5. Many carbonatite bodies show features characteristic of other intrusive rock masses, such as chilled margins, xenoliths, cross-cutting contacts, and apophyses. Some also show evidence of having been formed at least partially by replacement; examples are pseudomorphs and corroded reliefs. Volcanic carbonatites are represented by both flow and pyroclastic types.

6. Almost all carbonatite-alkaline complexes are surrounded by an aureole of wall-rock alteration called fenitization.

7. Carbonatites and the related alkalic rocks characteristically contain unusual concentrations of Ba, Sr, CeRE, P, Ti, Nb, F, Th, and Zr. Most common accessory minerals are magnetite, apatite, biotite, aegerine soda amphibole, and alkalic feldspar. Minor accessories include pyrochlore, perovskite, rutile, zircon, strontianite, and rare earth minerals.

8. The isotope ratios C^{13}/C^{12} and Sr^{87}/S^{86} of carbonatites differ from those of limestones and marbles but are similar to those of bassaltic rocks.

ECONOMIC SIGNIFICANCE

Carbonatites constitute a large reserve of Nb, mainly as pyrochlore. Previously Nb was obtained mainly as columbite from pegmatites, alkalic granites, and their placers. Niobium (Columbium) is used mainly in high temperature steels for aircraft and rockets, and in atomic power plants (Rowe, 1958).

Some carbonatites contain major accumulations of Rare Earth elements of the Ce group. Carbonatite complexes also represent a major type of Thorium deposit.

Carbonatite complexes, with their associated veins and accumulates, contain economic and potentially economic deposits of Fe (magnetite-hemetite), Ti (rutile, brookite, ilmenite), Mn, Cu, apatite, barite, flourite, vermiculite, nepheline, and carbonate rock.

PETROGENESIS

Their exists the usual disagreements between geologists advocating a metasomatic origin for carbonatites, and those advocating a magmatic origin. Most of the recent literature is in favour of a magmatic origin for most carbonatites. Some convincing arguments in favouf of a magmatic origin were given by Verwoerd (1966), who concluded:

a. Carbonatites intrude mainly in the form of a melt which later undergoes varying degrees of modification by replacement.

b. Bassaltic magma is probably the most likely parent magma.

c. Most of the associate alkaline silicate rocks can be derived in several ways from a primary bassaltic magma.

IRON HILL, POWDERHORN DISTRICT, COLORADO

GENERAL

The alkalic rock complex near Powderhorn, Colorado, contains one of the largest single reserves of both Columbium (Niobium) and titanium in the United States, as well as significant amounts of rare earth elements and thorium.

The U.S. Bureau of Mines drilling and surface sampling program in 1957 estimated that the complex contained over 100 million tons of average grade 6.5% TiO_2 and 11.7% Fe.

Drilling programs, by DuPont, in 1957 and 1958, indicated a columbium reserve of over 100,000 tons of Cb_2O_5.

STRUCTURE

The alkalic complex (Fig.1) is roughly pear-shaped in plan and is believed to be cone or funnel-shaped in section (Fig.2). It covers approximately 12 sq. miles. About 70% is underlain by pyroxenite which is intruded and/or replaced by concentric nepheline and melilite bearing rocks, magnetite-perovskite concentrations, biotite rich zones, and carbonatite. The central carbonatite covers approximately 2½ sq. miles.

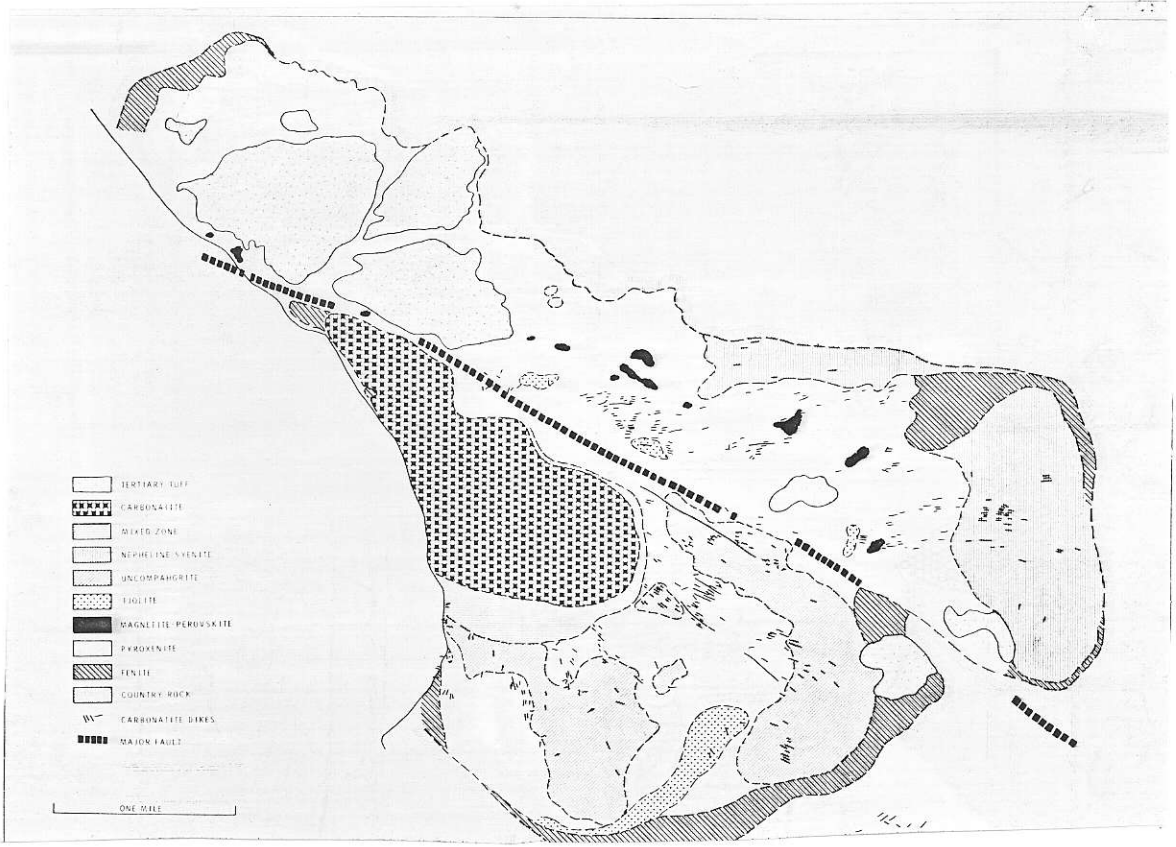


Figure 1. Geologic map of Iron Hill Carbonatite complex. (Temple & Grogan, 1965)

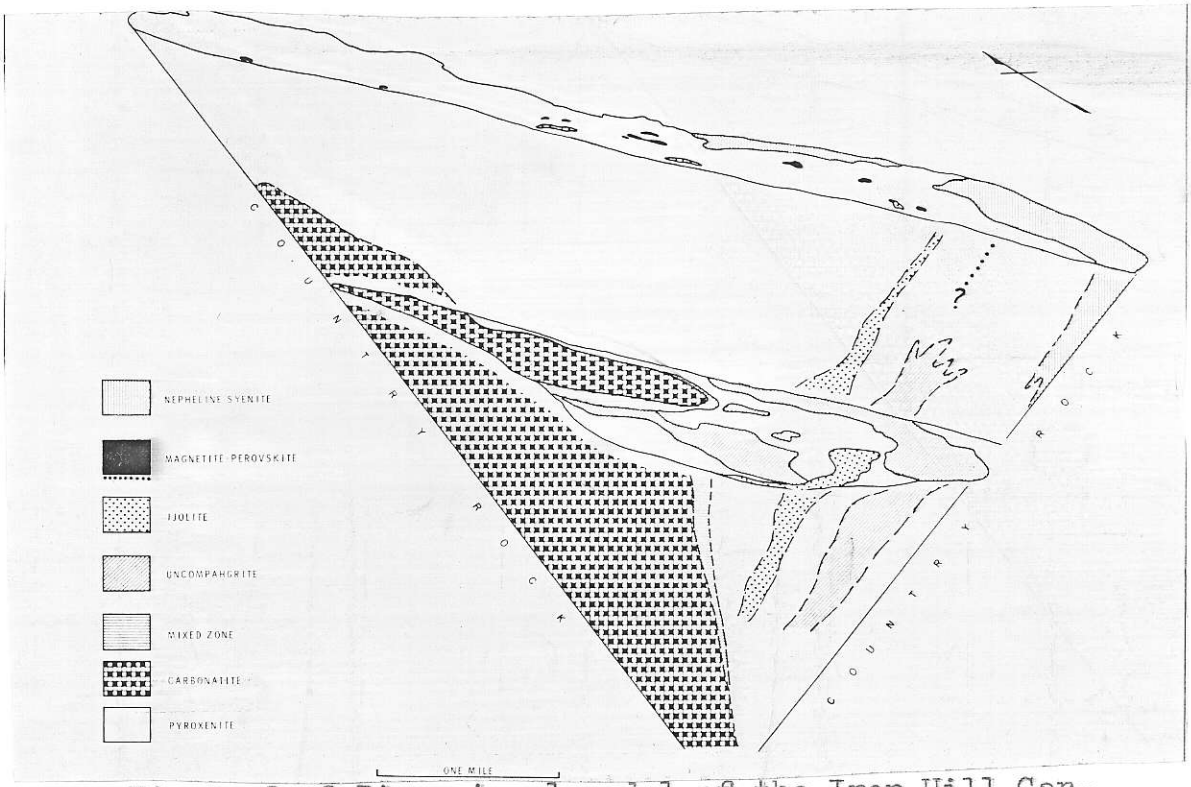


Figure 2. 3-Dimensional model of the Iron Hill Carbonatite complex. (Temple & Grogan, 1965)

The alkalic rocks are roughly concentric with the centre of the carbonatite, as is the flow banding within the carbonatite. Age relations and character of these rocks point to formation along concentric zones of heavy fracture.

Carbonatite cone sheets south of Big Iron Hill, and carbonatite dikes and thorium veins in the country rock (Pre-Cambrian Powderhorn granite) south of the complex are also concentric.

Carbonatite dikes seem to radiate outward from a common point on the north side of Big Iron Hill. These dikes are nearly vertical, and cut the inward dipping cone sheets. Slight movement has taken place along some of the dikes.

The complex is cut by a major WNW trending fault. This is probably related to the major Cimarron fault system. Smaller faults trending ENE, WNW, N, and NNE traverse the carbonatite. These faults are marked by massive jasper.

CARBONATITE ROCK TYPES

Several varieties of carbonatite occur in the central core of the complex. The dominant type is a brown, foliated, gneissoid, ankeritic dolomite. This rock is the principal columbium carrier. Pyrochlore occurs with fine granular apatite along shear planes, and replaces carbonate along grain boundaries. It generally occurs as euhedral, octahedral crystals varying from pale green to brown. Other minerals are magnetite, ilmenite, pyrite, zircon, rutile, monazite, and flourite. In general, biotite bearing rock is low in pyrochlore, except where cut by apatite stringers.

Massive white carbonatite occurs in pods and dikes in the foliated type. This carbonatite is dolomitic, but lower in iron than the foliated type. Appreciable amounts of strontium (2%) occur in this rock as well as biotite, pyrite, and other sulphides. Pyrochlore is rare.

Zones of altered carbonatite occur near jasper dikes. This type has foliation similar to the original but is soft and heavily iron-stained. This rock contains pyrochlore identical to that contained in the fresh carbonatite and has a concentration of barium and RE.

A mixed zone of carbonatite and pyroxenite lies between the main carbonatite and the surrounding pyroxenite.

DISTRIBUTION OF ELEMENTS

DISTRIBUTION OF ELEMENTS OF POTENTIAL ECONOMIC IMPORTANCE

Columbium (Niobium) occurs as pyrochlore in the foliated and weathered carbonatite, as perovskite in the magnetite-perovskite bodies, and as columbite in the thorium veins.

Titanium occurs as ilmenite in the magnetite-perovskite bodies, and as sphene in the pyroxenite and mixed zone.

Rare earth minerals are found in the sideritic carbonatite, dikes, weatherdd carbonatite, and magnetite-perovskite bodies.

Thorium occurs in the foliated carbonatite, magnetite-perovskite bodies, jasper dikes, sideritic carbonatite dikes and thorium veins.

Copper has been observed in small quantities as chalcopyrite in carbonatite, dikes, massive carbonatites, and mixed zone rocks. It is typically up to 0.2% Cu in biotite rich zones of the pyroxenite.

OKA REGION, TWO MOUNTAINS COUNTY, QUEBEC

GENERAL

The Oka complex of carbonate and alkaline rocks, about 20 miles west of Montreal contains deposits which are potential large tonnage sources of niobium (columbium). Up to 1955 more than 150 diamond drill holes were drilled into the complex, and much more work has been done since

The Oka complex is believed to belong to the Monteregian petrographical province, which is characterized by more or less circular shaped bodies of gabbro and nepheline syenites of post-Middle Devonian age. The country rock in the Oka region is mainly Precambrian gniesses, granulites, anorthosites, quartzites and fenites.

STRUCTURE

The Oka complex is roughly oval shaped, about 4 miles long and 1 to 1.5 miles wide. (fig.3) Evidence from surface exposure and drill cores suggest that the Oka complex was formed by a continueing succession of ring dike intrusions of alkaline and carbonate rocks. The complex is composed mainly of an intimate mixture of carbonatite, calc-silcate rocks, and alkaline silicate rocks. (fig.4) Several faults

and shear zones have been encountered, but they apparently are not related to the occurance of niobium minerals. Various types of breccias are common and in many places calcite has flowed into fractures within the silicate rocks.

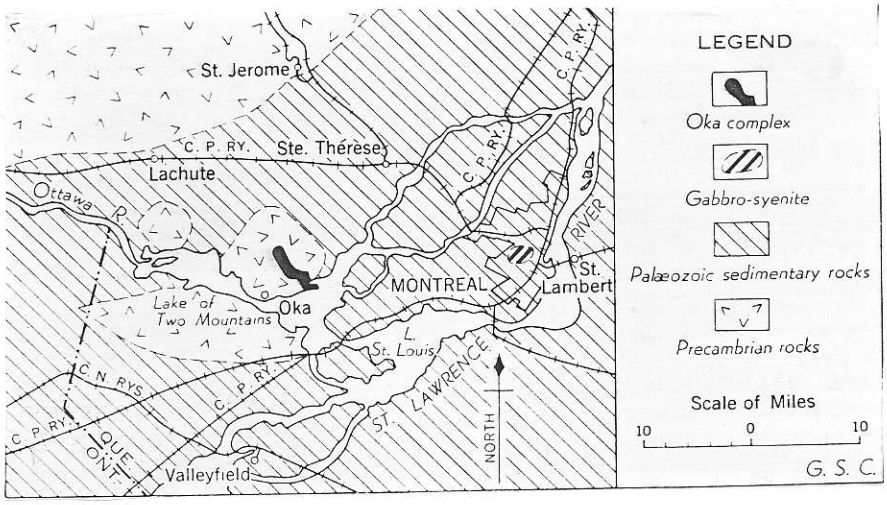


Figure 3. Geological sketch map of Oka region and vicinity, Quebec.(Rowe, 1958)

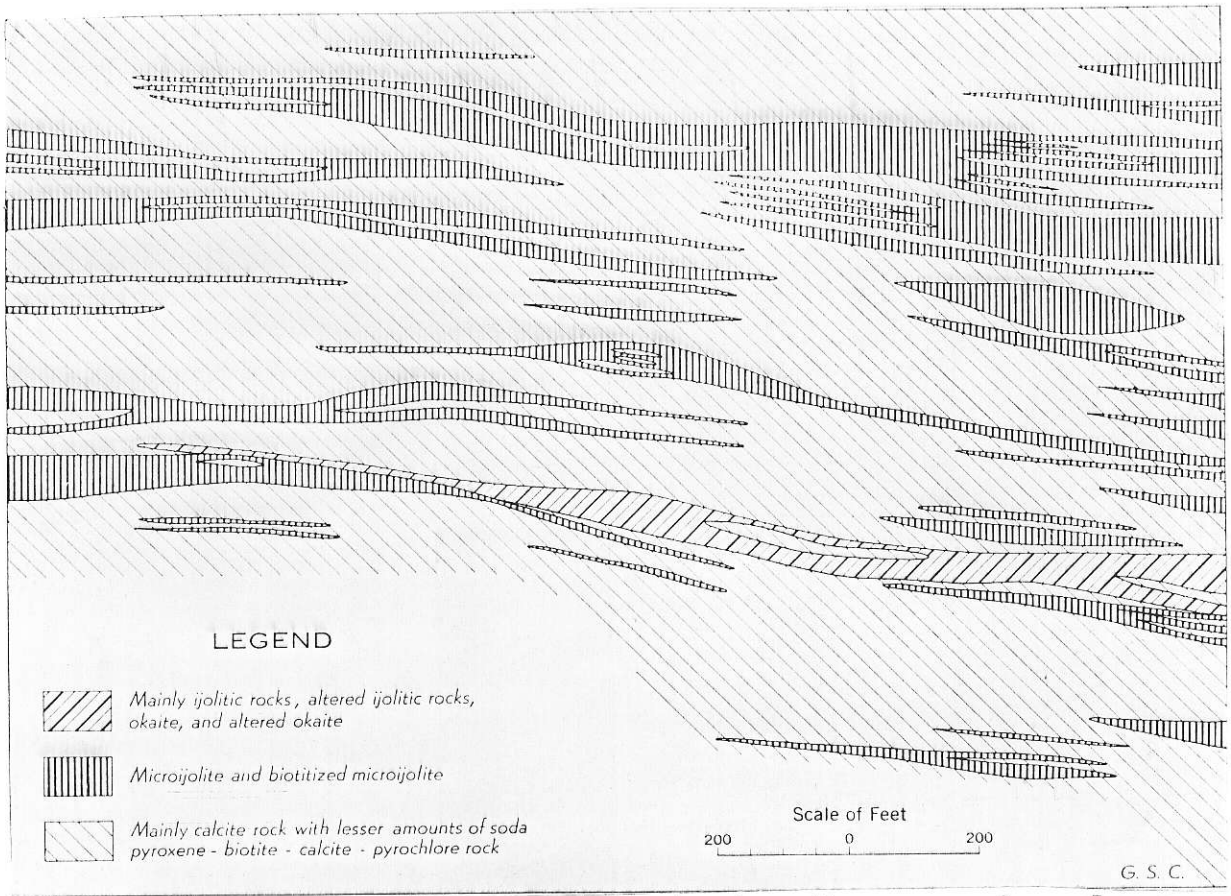


Figure 4. Composite plan showing the general geology of the Bond zone, Oka region, Que. (Rowe 1958)

CARBONATE ROCKS

The main carbonatite at Oka is composed of white to grey, medium to coarse grained calcite. Some of the carbonatite is composed almost entirely of calcite but most of it contains varying amounts of the accessory minerals apatite, biotite, magnetite, olivene, pyroxene, monticellite, melilite, pyrite, pyrrhotite, garnet, pyrochlor, perovskite, and niocalite concentrated in streaks, bands, and lenticles. Varieties of carbonatite are distinguished mainly by their accessory mineral content.

The northern part of the complex contains some dolomite rocks which do not outcrop, but were present in some drill cores. Carbonate veins occur in parts of the complex, some of which are calcite and others dolomite.

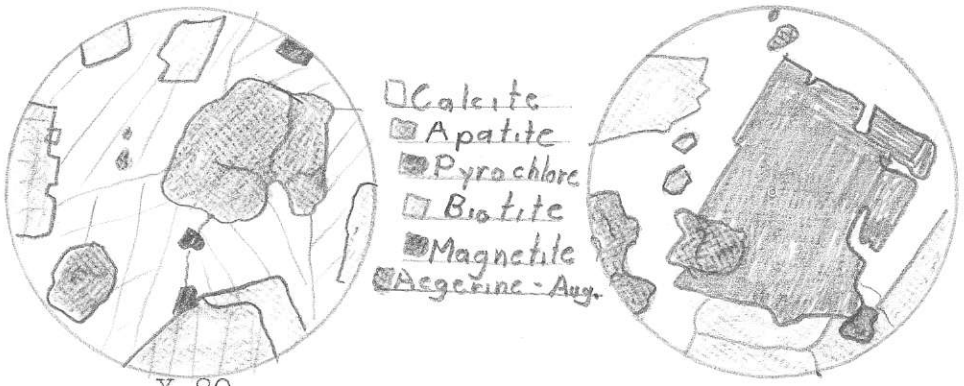
The most important rock of economic interest is the soda-pyroxene - biotite - calcite - pyrochlore rock. Aegerine-augite, biotite, and calcite make up the bulk of this rock, with pyrochlore present up to 20% in some places. Accessory minerals are magnetite, pyrite, and pyrrhotite. This rock usually occurs as lenses in the main carbonatite. Lenses of rock greatly enriched in apatite also occur.

A melilite - hauyne - biotite rich rock, sometimes containing nepheline was first described by Stansfield in 1923. this rock which is called Okaite is described in detail by Davidson (1962). Other minerals which occur in Okaite includemagnetite, apatite, perovskite, pyrite, garnet, and pyroxene. It is usually medium bluish-gray in colour with a glassy to greasy lustre. Calcite rich varieties are lighter in colour.

The Oka complex also includes ijolite, urtite, jacupirangite and other alkaline silicate rocks which will not be discussed.

NIOBIUM MINERALS

Pyrochlore is probably the most important niobium mineral in the Oka complex. It usually occurs as brownish-red grains and crystals up to 5 m.m. in size. In thin section the pyrochlore was reddish brown and isotropic. A few of the crystals appeared to be zoned. Inclusions of biotite, apatite, and calcite were noted. Biotite adjacent to pyrochlore was commonly bright orange-red in thin section. The pyrochlore was contained mainly in the soda-pyroxene - biotite - calcite rock. (figs. 5&6)



X 80

Figure.5. Oka S22-68 Plane light

X 80

Figure 6. AD-64 Plane light

Niobian perovskite occurs as subhedral grains and cubic crystals up to 7 mm. in size. It is a dark purplish-gray in hand speciman, with a sub-metallic lustre. In thin section perovskite is reddish brown, nearly isotropic, and exhibits very complex twinning under crossed nicols. It occurs mainly in the altered okaite and may be rimmed by secondary columbite. (fig. 7) Inclusions of biotite, calcite, and apatite are not uncommon.



Figure 7. Oka trench 9 crossed nicols X80

The minerals niocalite, which occurs in calcite rocks from the Bond zone, and betafite, which occurs in the ijolite rocks, were not observed in the thin sections.

Polished sections from several rock types were prepared and examined but proved to be less helpful than the thin sections. Magnetite with exolved ilmenite, pyrite, and pyrrhotite were observed.

CONCLUSIONS

Alkaline intrusive rocks, with their related carbonatites are the host rocks for unusually high concentrations of rare elements which were previously found , in economic concentrations, onlyin pegmatites,alkaline granites, and their placers. Some of the elements that may be concentrated in carbonatites are niobium, thorium, rare earths, iron titanium, uranium, magnesium, copper, and barium.

The carbonatite complex at Iron Hill, Colorado, is one of the United States' main sources of columbium, titanium, thorium, and rare earth minerals.

THe carbonatite and related rocks near Oka, Quebec are mainly noted for their substantial reserves of niobium.

Carbonatites occur on all continents except Australia and Antarctica, with the greatest number of known carbonatites located in Africa. Carbonatite deposits throughout the world are remarkably similar in size, shape, composition, and relation to surrounding rocks. They almost invariably produce magnetic and radioactive anomalies, properties which greatly aid the search for these rocks.

No mineralography!

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