CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 58-55

A MINERALOGICAL INVESTIGATION OF RARE EARTH CARBONATE ORE IN DRILL CORE FROM THE OKA, QUEBEC, PROPERTY OF QUEBEC COLUMBIUM LIMITED

by

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MINERAL DRESSING AND PROCESS METALLURGY DIVISION

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COPY NO. 11

APRIL 3, 1958

Industrial Confidential

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SUMMARY OF RESULTS

The diamond drill core described in this report contains from 1.5% to 4.4% rare earth oxides, and appreciable amounts of manganese, barium, and strontium. The rare earth minerals are ancylite, bastnaesite, and monazite. They are characterized by an extremely fine grain size and are commonly intergrown with other minerals.

The chief mineral in the ore is a coarse crystalline dolomite. Other minerals, including those present in small amounts, are strontianite, barite, siderite, calcite, apatite, pyrite, pyrrhotite, marcasite, sphalerite, galena, quartz, biotite, pyrochlore, and a zeolite.

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INTRODUCTION

During the past two years mineralogical investigations have been conducted on ores from the Oka region of Quebec, including some from the property of Quebec Columbium Limited, formerly held under the name of the Molybdenum Corporation of America. These mineralogical studies have been concerned chiefly with niobium ores. The present report deals with rare earth carbonate ore from the property of Quebec Columbium Limited.

The rare earth carbonate samples were received from Mr. S. B. Bond, general manager of the company, in October, 1957. The samples consisted of several pounds of split diamond drill core and about 20 lb of coarse open pit fragments. This investigation is restricted to a mineralogical study of the diamond drill core fragments which are relatively fresh as compared to the somewhat weathered and altered samples originating from the open pit. The drill core samples represent a continuous 25-ft length of core from Drill Hole S-1, 275 to 300 ft, bagged in 5 ft lengths; and an additional 5 ft length from Drill Hole S-47, 325 to 330 ft.

PROCEDURE

The macroscopic characteristics of the ore were assessed by an examination of the diamond drill core fragments under a low-power binocular microscope. A few of the fragments were selected for thin sections and for mineral concentration. The thin sections were prepared from fragments which covered the range of mineralogical compositions, and the mineral concentrates were prepared from fragments which contained the purest minerals. The remainder of the ore, comprising the six 5 ft lengths of drill core, was crushed, sampled, and submitted for chemical analysis.

The thin sections were studied under a petrographic microscope. The minerals which occur in such extremely fine-grained aggregates as to be practically indistinguishable from one another in thin section were identified by their X-ray diffraction patterns which were obtained from material removed from the thin sections. X-ray diffraction analysis was also used to corroborate optical determinations and to identify minerals too soft and porous for thin sections.

The mineral concentrates were produced by heavy liquid and magnetic separations, and their purity was assessed by X-ray powder diffraction. Only those concentrates in which one mineral alone could be detected were subjected to spectrographic analysis.

One polished section was prepared from an ore fragment containing abundant sulphides, and was studied under an ore microscope.

DETAILS OF INVESTIGATION

Chemical Analyses

Manganese and rare earth oxides were analyzed by wet chemical methods, whereas the barium and strontium were analyzed by X-ray spectrograph. The results, listed in Table 1, show that the manganese in the samples is relatively constant at a level of about 5%. The barium content varies between 1% and 8% and does not appear to bear a systematic relationship to the other elements analyzed. The strontium variations, however, are roughly parallel to those of the rare earth oxides, which suggests a genetic relationship between them.

TABLE 1

Analyses of Drill Core Samples

	S-1 275-280 ft	S-1 280-285 ft	S-1 285-290 ft	S-1 290-295 ft	S-1 295-300 ft	S-47 325-330 ft
Mn	4.87%	5.12%	5.69%	4.80%	4.99%	5.56%
Ba	5.6	4.2	2.5	2.5	1.2	8.4
Sr	2.9	2.2	2.0	5.4	4.1	1.8
R.E. oxides	2.98	2.80	1.88	4.36	2.36	1.52

Mineralogical Description

General

The samples consist largely of coarse, white, crystalline dolomite. The other minerals, which are enclosed by the dolomite, generally fall into two extremes of grain size: the coarse-grained minerals with a grain size comparable to that of dolomite and which occur as isolated grains; and cryptocrystalline (extremely fine-grained) aggregates composed of one or more minerals. These cryptocrystalline aggregates are in general so fine-grained as to be practically opaque in thin section, and the individual components cannot be resolved under the microscope. They vary greatly in hardness, and range from hard, dense aggregates to porous, earthy masses which crumble readily at the slightest touch (Figure 1). Some of these porous aggregates contain small vugs several millimetres in diameter which are surrounded by incrustations of tiny euhedral crystals. These vugs suggest the solution of one or more of the original minerals in the rock, and the subsequent deposition of the present assemblage.

Some of the rock chips contain minerals pure enough to enable small amounts of them to be concentrated for semi-quantitative spectrographic analysis. The results of the analyses are given in Table 2.

Carbonates: Dolomite, Ancylite, Bastnaesite, Strontianite, Siderite, Calcite

Dolomite, as noted above, is the most abundant mineral in the samples, and comprises from 75 to 90% of the rock, as determined by heavy liquid separations. Table 2 shows that the dolomite contains fairly large amounts of iron, manganese and strontium. These elements are probably present, at least in part, as

TABLE 2

Semi-quantitative Spectrographic Analyses of Some Minerals Concentrated from the Diamond Drill Core
(In percent)

	Dolomite	Strontianite	Barite	Ancylite	Bastnaesite
Ca	p.c.	10	15	9	8
Mg	15	0.4	4	0.7	0.7
Fe	5	0.7	1.5	1.0	4
Mn	4	0.5	2	0.5	0.7
Sr	2	p.c.	2	20	2
Ba	0.5	10	20	7	5
Ce	0.4	n.d.	0.8	p.c.	p.c.
La	0.3	0.03?	0.4	20	15
Yb	n.d.	n.d.	n.d.	0.007	0.05
Y	0.004	n.d.	0.006	0.04	0.3
Sm	n.d.	n.d.	n.d.	1	2
Dy	n.d.	n.d.	n.d.	0.03	0.08
Gd	n.d.	n.d.	n.d.	0.04	0.2

Note: p.c. means principal constituent; n.d., not detected.

substitutions for calcium and magnesium in the dolomite structure rather than as foreign inclusions, because the refractive indices of the dolomite are considerably higher than those of pure dolomite, which is to be expected with the substitution of these elements. Since no other manganese compounds were found in the ore, it can be concluded that the fairly uniform content of manganese in the ore is due to the presence of this element in the dolomite. The relatively small amounts of barium and rare earths noted in the spectrographic analysis of the dolomite concentrate may be due to intergrown impurities.

Other carbonates in the ore include ancylite, bastnaesite, strontianite, siderite, and calcite. Ancylite and bastnaesite are the two rare-earth-bearing carbonates in the ore and, together with monazite (described below), are responsible for the rare earth content of the ore.

Ancylite is a hydrated basic carbonate of strontium, calcium, and the cerium group of rare earths, and has a formula approximating $(Ce, La)_4(Sr, Ca)_3(CO_3)_7(OH)_4 \cdot 3H_2O$. In addition to the elements included in the formula, the spectrographic analysis in Table 2 indicates a high barium content. This may well be due to intergrown barite, however, since these two minerals are frequently intergrown in the ore and are difficult to separate because of their extremely fine grain size.

Bastnaesite is a fluo-carbonate of the cerium group of rare earths, and its formula is $(Ce, La)(CO_3)F$. The other elements noted in the spectrographic analysis may also be due in part to other minerals present in the concentrate.

Ancylite and bastnaesite are cryptocrystalline in all the samples studied, and are frequently intergrown with each other (Figure 2) and with other minerals, particularly strontianite and barite. Both ancylite and bastnaesite exhibit a wide range in colour and texture. Ancylite varies in colour from white to tan, yellow, and pink; bastnaesite, from white to light green, orange, and chocolate brown. Their textures vary from compact and dense to earthy, porous, and powdery. Figure 1 shows some of the soft, porous ancylite intergrown with strontianite and barite.

Although the bastnaesite and ancylite are always fine-grained, some of the cryptocrystalline aggregates of these minerals contain larger grains of other minerals. Figure 3 shows ancylite with larger barite grains, while Figure 4 shows a similar relationship of bastnaesite and calcite. These coarse grains may be remnants of primary minerals incompletely replaced by the rare earth carbonates.

The strontianite has several modes of occurrence. Some of the grains are large and comparable in size to the dolomite grains. These large grains generally have a clouded appearance (Figures 5 and 6), which is probably due to submicroscopic inclusions. Some of the strontianite occurs as very fine-grained cryptocrystalline material interstitial to the dolomite, and varies from compact to soft and porous. As such, it is commonly intergrown with other fine-grained minerals, including barite, monazite and siderite, and varies in colour from white to yellow and light green. Some of the fine-grained vug incrustations consist largely of tiny strontianite crystals.

The spectrographic analysis of the strontianite concentrate indicates the presence of appreciable amounts of calcium and barium. Although these elements may be due to other minerals present in the concentrate, strontianite is able to accommodate these elements in its structure, as substitutions for strontium.

Siderite and calcite occur in relatively minor amounts. All the siderite observed is extremely fine-grained. It occurs as vug incrustations and as interstitial material to coarse mineral grains, as shown by Figure 7, and is sometimes intergrown with other fine-grained minerals, especially quartz and strontianite. The siderite varies from white to tan, and some of it is soft and earthy.

The calcite occurs both as coarse grains and as a component in some of the fine-grained mineral mixtures. It is closely associated with the rare earth minerals, as shown by Figures 4 and 9.

Phosphates: Monazite, Apatite

Phosphates are represented by monazite and apatite. All the monazite observed is cryptocrystalline, and is generally intergrown with other minerals. Figure 8 shows monazite intergrown with quartz; Figure 9 shows large calcite grains with abundant inclusions of fine-grained monazite, which suggests partial replacement of calcite by monazite. The colour and texture of the monazite exhibit variations similar to those noted for ancylite and bastnaesite, i.e. the colour varies from white to tan and yellow, and the texture from compact and dense to soft and powdery.

Apatite is present in relatively small amounts, and usually occurs as medium-sized crystals embedded in the dolomite. Some of the apatite which is interstitial to the dolomite grains has a colloform texture, which suggests that it may have filled pre-existing voids in the latter.

Sulphates: Barite

The only sulphate observed in the ore is barite. This mineral has a similar occurrence to that of strontianite; that is, as coarse grains, fine-grained intergrowths, and vug coatings. Some of the ancylite and bastnaesite aggregates enclose relatively large barite particles (Figure 3) which may be remnants from the incomplete replacement of barite by the rare earth carbonates. The calcium and magnesium content of the barite concentrate is unusually high, and can probably be attributed to intergrown dolomite and calcite.

Sulphides: Pyrite, Pyrrhotite, Marcasite, Galena, Sphalerite

The sulphides occur chiefly as individual crystals or crystal clusters scattered unevenly throughout the samples. The section from S-1, 295 to 300 ft is particularly rich in sulphides, and contains some massive portions. Pyrite, the most abundant of the sulphides, occurs principally as coarse, euhedral crystals. The pyrrhotite and marcasite are associated with the pyrite, and have irregular, branching forms. Much of the marcasite is soft and porous, and appears to have been formed from the replacement of pyrite. Galena is present only in minor amounts, and occurs as thin films on some of the pyrite crystals, and as individual grains. The sphalerite occurs chiefly as individual dark brown crystals scattered sparsely through the ore, although it is also present as narrow veinlets in the more massive sulphide section referred to above.

Other Minerals: Quartz, Biotite, Pyrochlore, Zeolite

Other minerals present in the ore in small amounts include quartz, pyrochlore, biotite, and a zeolite. Most of the quartz is very fine-grained and cherty, and some is finely intergrown with other minerals, including monazite and siderite. Some colloform quartz was also observed.

Some of the biotite is very dark in colour, and is generally rimmed and partially replaced by a lighter coloured variety. Only a few crystals of pyrochlore were observed, and these occur as dark brown isolated octahedra. A member of the zeolite group of minerals was found to be intergrown with strontianite in one sample. Its X-ray diffraction pattern is similar to that of chabazite.

CONCLUSIONS

The rare earth minerals in the drill core are represented by ancylite, bastnaesite, and monazite. These minerals are all cryptocrystalline and appear to have been formed by the replacement of the primary minerals (strontianite, barite, and calcite). The minerals regarded as primary are coarse-grained, and include dolomite (which is the principal rock component), most of the sulphide minerals, pyrochlore, and some of the strontianite, barite, calcite, quartz and apatite.

The minerals considered to be secondary include the rare earth minerals, siderite, zeolite, marcasite, and the fine-grained variants of strontianite, barite, calcite, quartz, and apatite.

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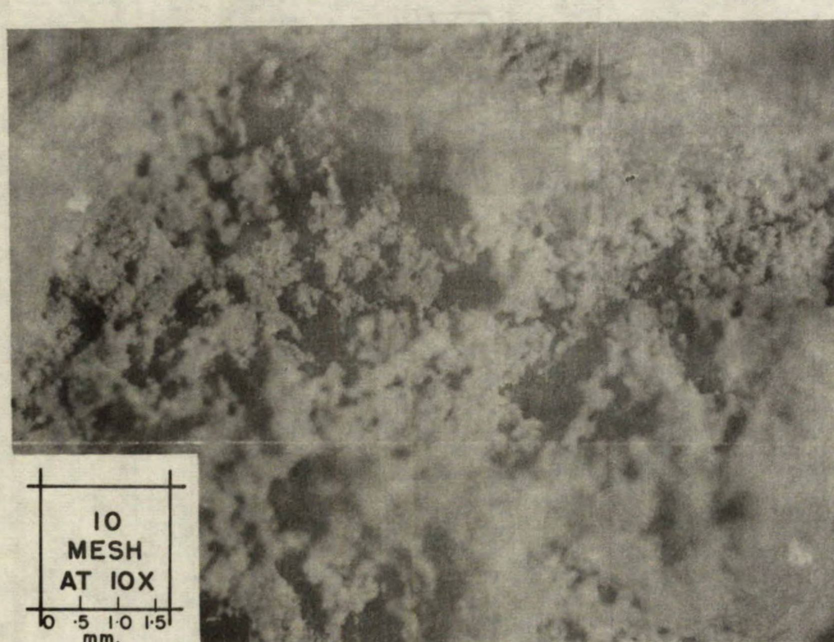

Figure 1 - Soft, porous aggregate composed of ancylite, barite, and strontianite. Oblique illumination.

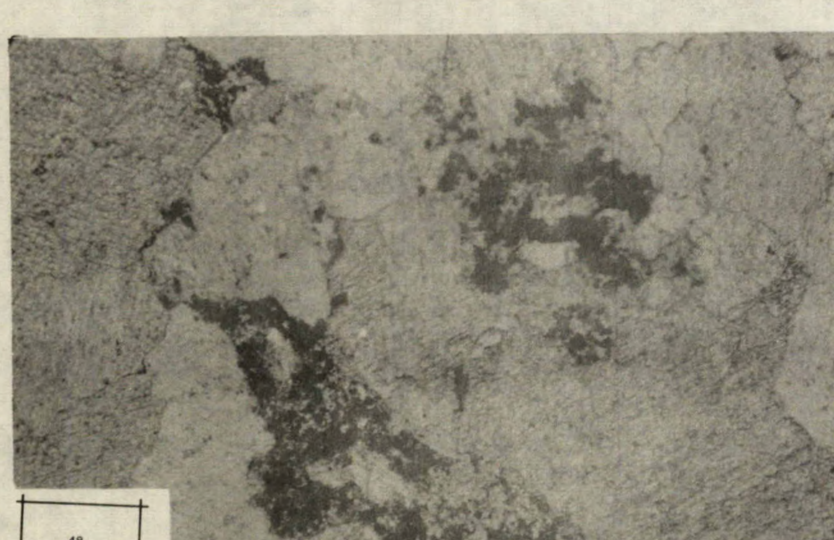

Figure 2 - Thin section showing fine-grained ancylite-bastnaesite intergrowth (black) in coarse dolomite (medium grey). Plane polarized light.

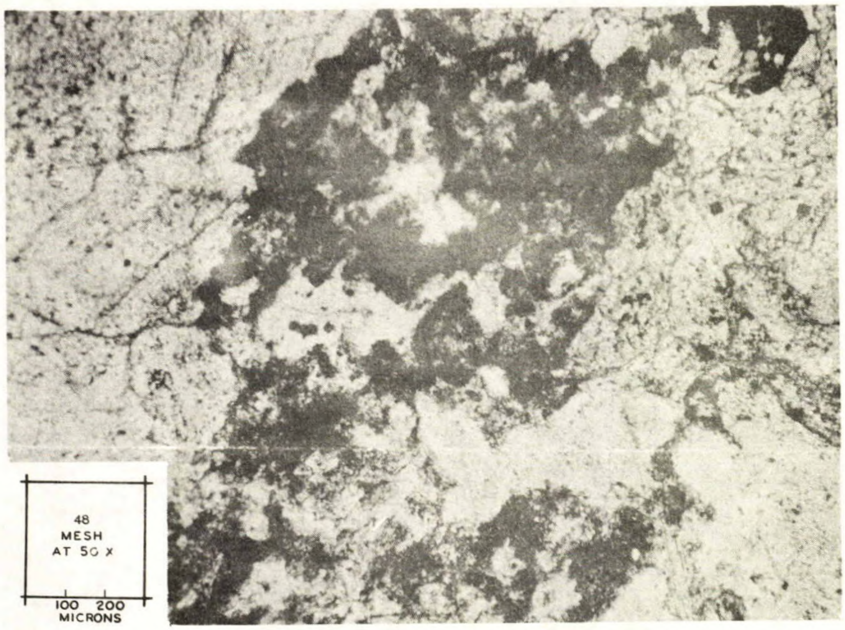

Figure 3 - Thin section showing fine-grained ancylite **(black) with barite inclusions** (white). Adjacent light grey mineral grains are dolomite. Plane polarized light.

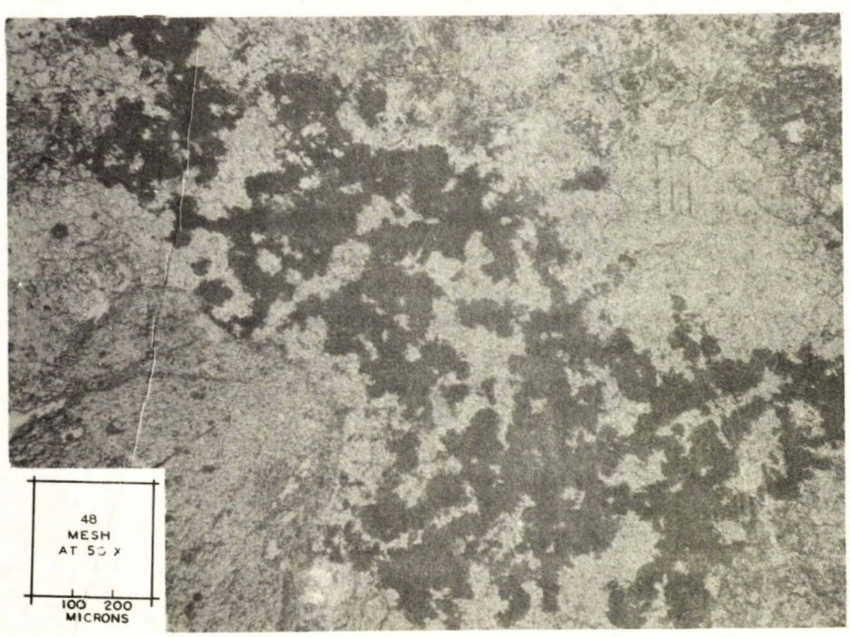

Figure 4 - Thin section showing intergrowth of fine-grained **bastnaesite** (black) and calcite (light grey). Plane polarized light.

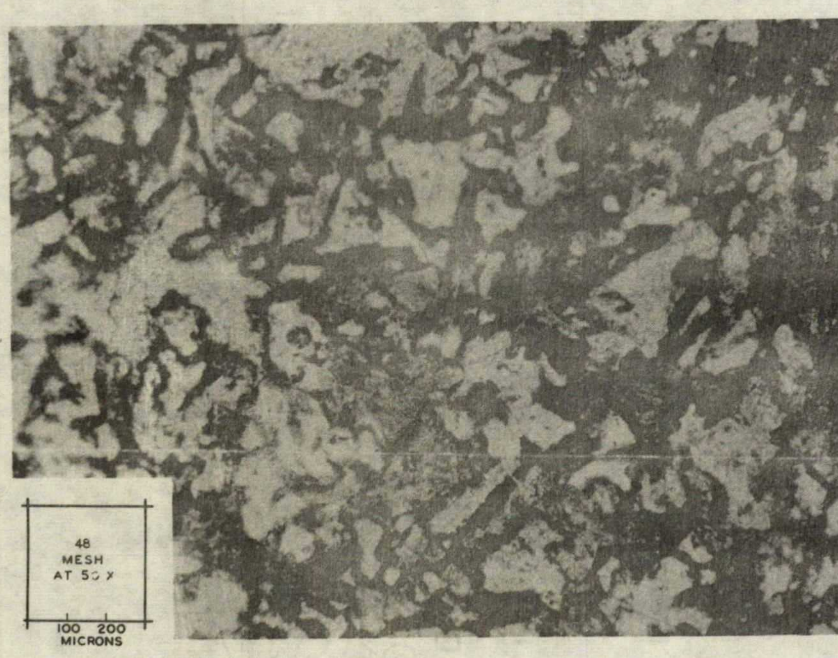

Figure 5 - Thin section showing grains of dolomite (white) and strontianite (medium grey), surrounded by fine-grained strontianite (black). Plane polarized light.

Figure 6 - Thin section showing euhedral crystal composed of cryptocrystalline strontianite (dark grey) with some calcite inclusions (white), enclosed by dolomite (medium grey). Plane polarized light.

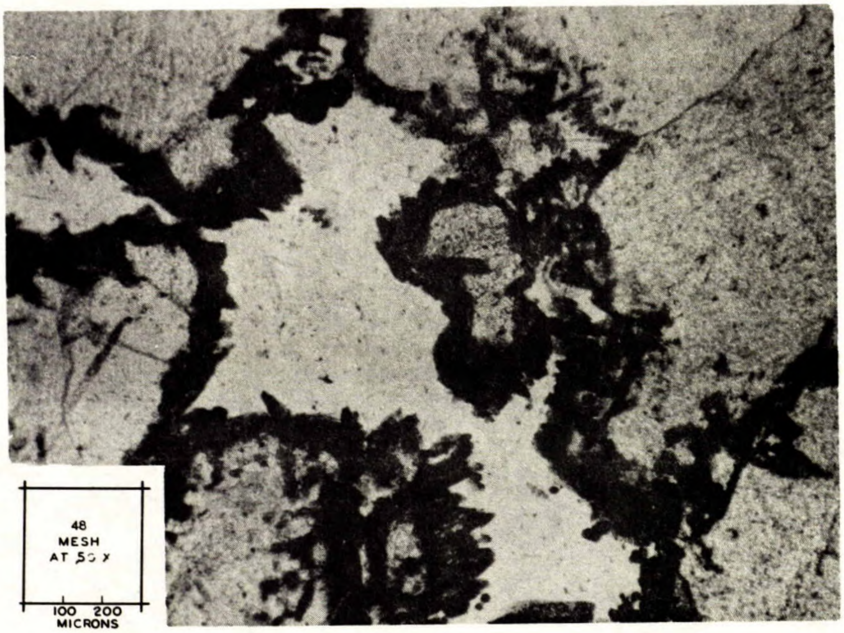

Figure 7 - Thin section showing dolomite (light grey) rimmed by **fine-grained siderite** (black). The central portion of the **photomicrograph** consists of fine-grained quartz **(white). Plane polarized light.**

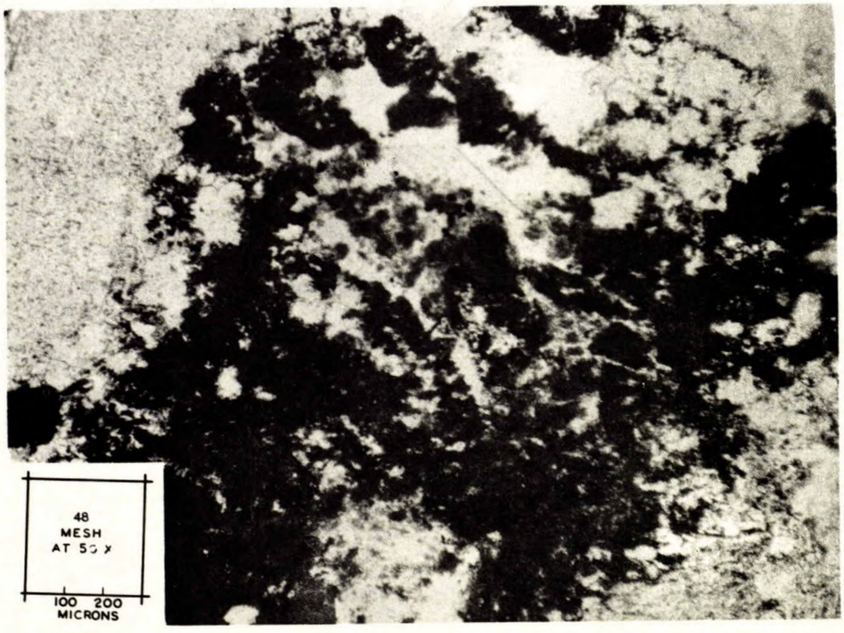

Figure 8 - Thin section showing intergrowth of **cryptocrystalline monazite** (black) and quartz (white). Plane **polarized light.**

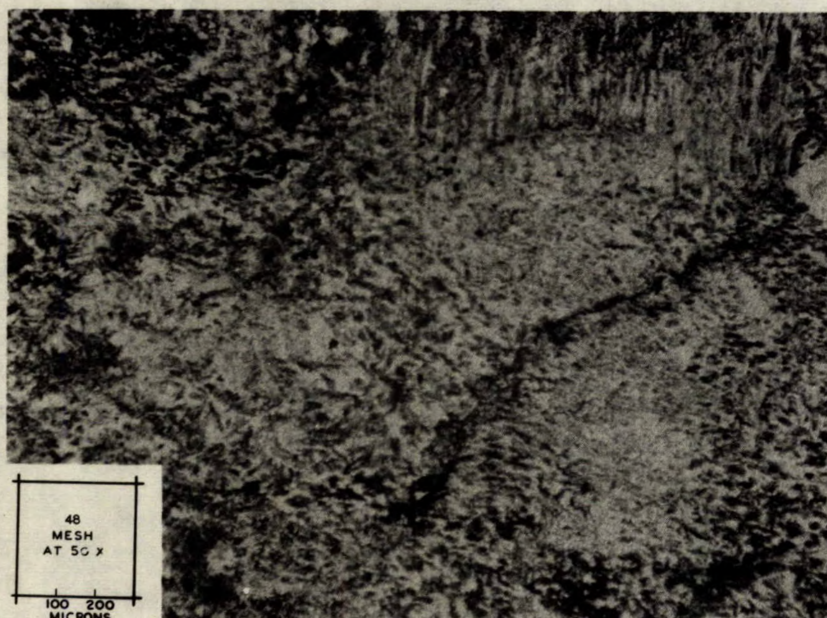

Figure 9 - Thin section showing coarse calcite grains (white) with abundant inclusions of fine-grained monazite (grey). Plane polarized light.

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