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REPORT
on the OKA PROPERTY
QUEBEC

GM 69788

J. A. GOWER - MARCH/56

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REPORT ON THE

OKA PROJECT

QUEBEC

SUMMARY and CONCLUSIONS

The niobium deposits at Oka, Quebec are contained in a carbonate complex about seven square miles in area and at least 1000 feet deep. Forty-five percent of this, about 2000 acres, is owned or held under option by Molybdenum Corporation of America. Thirty percent of the remainder underlies the Trappist Monastery for which surface rights are at present unobtainable.

Diamond drilling has indicated enriched areas on the Bond zone containing 23,000 tons per vertical foot of pyrochlore-perovskite-niocalite bearing rock grading 0.64% Nb_2O_5, and a total of 40 million tons of material grading 0.40% Nb_2O_5 in a minable block. So far only 10% of the favourable rocks have been tested.

The deposit is favourably situated with respect to markets, power and transportation. Much of it could be mined by low cost open-pit methods.

Oka is probably the largest and richest niobium deposit known in North America at the present time. Possible by-products are thorium, uranium, iron, rare earths, apatite and agricultural lime.

EVALUATION OF THE PROPERTY

WORK DONE UNDER KENNCO'S DIRECTION

Kennco's examination of the Oka property began in early 1955. Previous work by the Molybdenum Corporation of America, consisting of geophysical surveying, trenching and reconnaissance diamond drilling had indicated the presence of niobium-bearing rock but little was known of any structural or other control.

To solve this problem the surface geology and the drill cores were studied in detail. The results of this study form the basis of the following geological report on the property. Valuable assistance was rendered by Molybdenum Corporation of America's personnel and is gratefully acknowledged.

A map of a scale of 1 mi. to the inch was prepared, in part from government reports and in part from original work (see Map No. 1). The property map (No. 2) shows the observed and inferred geology of the property on a scale of 1000 feet to the inch. All outcrops are shown in solid colour. Inferred geology is shown by light shading.

Drilling had started on the Bond zone and was completed during the examination period. Twenty-four holes were drilled for a total footage of 20,000 feet. The zone was at first roughly outlined by flat holes at 300 foot intervals, then steeper holes

at 100 foot intervals were drilled to block out tonnage, verify grade, and delimit the zone more accurately.

The alkaline complex covers an area of 4,500 acres. The Kennecott - Molybdenum property covers about 45% of this or 2,000 acres. To date only 10% of our ground has been tested by drilling to a maximum depth of 900 feet. Holes on neighbouring ground have encountered mineralization at over 1,000 foot depth. The tonnage potential of favourable rock containing niobium values to 1,000 feet is in the neighbourhood of 10 billion tons of which our share would be 4 1/2 billion tons. This estimate does not take grade into consideration.

To provide material for metallurgical testing bulk samples in the form of NX drill core were taken across the center of the Bond zone (see Maps 3 and 4). Larger samples were obtained by open-cutting across the zone. (see Maps 3 and 4)

DESCRIPTION OF THE MANNY ZONE

The Manny zone was tested by the Molybdenum Corporation before Kennecott's participation in the property. Because of the lack of outcrop lithological trends were not known and most of the trenches and drill holes are parallel to the strike of the foliation. Although large tonnages of niobium-bearing rock grading 0.3% Nb_2O_5 are indicated, the details of the geology of the zone are not known. The niobium values appear, at present, to be very erratically distributed and continuity of high-grade zones cannot be demonstrated.

Molybdenum Corporation's figures for Manny zone ore are 40,000,000 short tons to 300' depth grading 0.3% Nb_2O_5. This grade is based largely on their own chemical assays which are probably 20% high.

The chief ore minerals of the Manny zone are pyrochlore, containing 30-50% Nb_2O_5, and betafite, containing 32-35% Nb_2O_5.

DESCRIPTION OF THE BOND ZONE

The surface expression of the Bond zone is a low ridge about half a mile long standing about 150 feet above the valley floor. A pronounced radioactive anomaly coincides with the ridge. The niobium-rich rocks follow this anomaly in general but not in detail. Outcrops are sparse but overburden is shallow.

The mineralized zone is a tabular body about 2000 feet long, 400-600 feet wide, and at least 600 feet deep. Within this zone are enriched sections, the largest of which is 1500 feet long and 100-200 feet wide. Although our deepest drill hole intersection was at a depth of 590 feet, an intersection is reported at over 1000' depth on Coulee-Headway ground in the extension of the Bond zone to the south.

The geology of the Bond zone based on drill core study is shown in Map No. 3. The chief marker is a steeply-dipping sheet of altered okaite which persists over the entire length of the

zone. Parallel to this are narrower and less continuous bands of brecciated and altered ijolite. The composition of the calcite-bearing rocks is complex and variable but for clarity in showing correlation all varieties of calcite-bearing rocks are grouped together.

A plot of niobium values in the Bond zone (Map No. 4) shows the relation of mineralization to rock type (compare Maps 3 and 4). The highest grade and largest body is elongate parallel to the trend of the okaite and ijolites and to the foliation in the marbles.

The principal ore minerals of the Bond zone are pyrochlore, containing about 50% Nb_2O_5, perovskite, containing about 22% Nb_2O_5, and niocalite containing 16% Nb_2O_5.

The ore minerals have formed in response to varying geological environments, the most important being temperature. The order, from highest to lowest temperature is niocalite, perovskite, pyrochlore, betafite. Although sections can be formed containing principally one ore mineral, most zones contain mixtures of two or more. In addition to this complication, the host rocks have a complex distribution. If large scale mining is anticipated attempts to mine various ore types selectively may be difficult and even on a small scale it will difficult to mine a uniform ore mineral assemblage and host rock type.

METHODS OF CALCULATION OF ORE RESERVES

Owing to ore-dressing and economic considerations, it is not possible at this stage in the development of the property to classify material definitely as ore but only to indicate what is assumed to be ore.

Cut-off for open pit ore has been taken as 0.25% Nb_2O_5, and for underground ore as 0.50% Nb_2O_5. Tonnages were calculated in the following manner:

1) Sections were taken across the Bond zone in the plane of each drill hole.

2) The average grade in each section was determined by weighted assay across the mineralized zone.

3) Areas of probable ore in the sections were measured by planimeter. All ore was projected to surface but not to a greater depth than 550 feet in the case of open pit ore or the depth of the drill hole intersection in the case of underground ore.

4) Blocks were calculated by extending each section half way to the next - in most cases 50 feet either way. In no case was ore projected more than 150 feet along strike (see Map No. 5). Drill holes were given equal weight in the calculations.

This drill spacing was justified because of the remarkable uniformity of grade over long distances both along strike and down dip. The more closely spaced detailed drilling indicated no change in grade although the lateral extent and depth of the orebody were extended somewhat.

An example of this is the recent open cut for the second large bulk sample sent to Kennecott Research Center. The

grades of the drill hole intersection and of the open cut are identical even though a projection of up to 800 feet is involved.

ORE RESERVES

Calculations of grades and tonnages of Bond zone ore are presented in the following ways:

Indicated

1) Grade and tonnage available from the richest continuous part of the zone assuming that the body is to be mined from underground, with cut-off at 0.5% Nb_2O_5, and minimum mining width of 15 feet.

2) Grade and tonnage of the Bond zone assuming that the mineralized zone is to be mined from an open pit with cut-off at 0.25% Nb_2O_5, and minimum width of 100 feet. Table 1 shows the grades and tonnages indicated to date.

TABLE 1

ORE RESERVES - BOND ZONE

	OPEN PIT				UNDERGROUND		
Zone	Depth of Dev.	Short Tons	Grade	T.V.F.	Short Tons	Grade	T.V.F.
Main (#1)+ F. W. zone	550'	23,520,405	.425	43,500	4,533,400	.65	15,639
					442,933	.64	1,117
#2	350'	11,016,117	.34	32,672	548,267	.49(Mt. Bleu) .54(McG)	5,520
#3	275'	1,022,800	.34	2,925			
#4	265'	1,494,000	.36	6,786	225,200	.69	1,400
Totals		37,053,322	.40	85,883	5,749,800	.64	23,776

Assay maps of various types have been and are being prepared. These support the values reported above. A contoured plot of assay values indicates the shapes and sizes of individual ore bodies which when referred to the corresponding geological map show the relation to structure maps included in the back of the report.

Certain factors regarding the selection of blocks should be mentioned.

1) Maximum depth on underground ore was taken as the actual depth at the drill hole intersection. The distance of projection to the surface varies slightly but would average about 300'. The result is the same as if the grade were projected 150' on either side of the drill hole but it is felt to be more reliable because the rock above the hole is favourable whereas nothing is known of the rock below the drill hole.

2) For open pit ore a slightly less conservative view has been taken in that all ore zones have been projected to - 200' altitude. (a vertical depth of about 450' to 550')

REPORT ON THE

OKA PROJECT

QUEBEC

LOCATION and ACCESS

The property held under option by the Molybdenum Corporation of America, lies on the north side of the confluence of the St. Lawrence and Ottawa rivers, thirty miles west of Montreal, Quebec. The Oka area is served by road and railway. Paved highways cross the property and the Canadian National railway reaches a point about four miles away. Power is available by a 22Kv line crossing the south end of the area.

Living quarters are available at Oka and in the surrounding district. An abundant labour supply is obtainable from Montreal, a city of over 1 million inhabitants.

A possible shipping point exists at the south end of the property at the river side.

AREA and TITLE

The ground known as Schedule "A" is held by the Molybdenum Corporation of America under an agreement with the Montrose Syndicate of Montreal. The remainder of the property, known as Schedule "B" is held under option from the Montrose Syndicate until March 1956 at which time 90% of the mineral rights of four blocks of 400 acres each can be purchased for $75,000 per block. Each block of 400 acres must be contiguous but may be selected from any portion of schedule B.

The outlines of Schedules "A" and "B" are shown on the property map accompanying this report.

HISTORY

Early in May 1953 Mr. Stephen B. Bond, Canadian Representative of the Molybdenum Corporation of America, examined a small iron showing exposed in a four foot square open-pit on ground held by F. Manny of Montreal. His observance of radioactivity and of an occurrence of a rare earth mineral in a nearby outcrop prompted him to option the four unpatented claims held by Manny.

A radiometric assay of 3% U_3O_8 equivalents on material submitted by Manny to the University of Montreal led a professor of that institution, Paul E. Riverin, and his partner, John Gourd, to stake about 8000 acres surrounding Manny's claims. Mr. Bond optioned that ground as well.

Work started in June 1953 on anomalies outlined by geiger and dip needle surveys. By the end of the year 3000 feet of trenching had been completed and samples from the trench bottoms sent out for assay. Results showed niobium values of about 1% over 100 feet.

Drilling began in February 1954 on the enriched zones suggested by the assay and geophysical anomalies, and about 40 million tons of niobium bearing rock grading about 0.3% Nb_2O_5 were developed.

The following summer geophysical work was accelerated and a very strong anomaly was discovered on lot 216, a farm owned by J. P. Dufresne. Drilling started on this zone, named the Bond zone, in February 1955 and large tonnages of high grade material were developed - to date about 6 million tons of .65% and 40 million tons of .4% Nb_2O_5.

Geophysical work and geological mapping have continued to date, and large bulk samples have been taken for metallurgical test.

The discovery of the Oka deposit by S. B. Bond of Molybdenum Corporation and its recognition as a potential niobium property were the result of 10 years of investigation and experience in the niobium field. Mr. Bond was guided by the characteristic mineral assemblages, the rock types, the presence of radioactivity and the occurrence of rare-earths. He recognized the latter by the use of a pocket spectroscope. It is of great credit to Mr. Bond that he was the one man out of several competent geologists who visited the property to recognize it as something more than a magnetite occurrence.

The recognition of the huge potential of Oka in its early stages of development by Mr. Hammond of this company was prompted by a knowledge of the geology of other niobium occurrences in Canada and an astute evaluation of the rather limited information available about the property at the time. He recognized the significance of the magnetic and radiometric anomalies and of the geological environment. Although the high-grade Bond Zone ores were not known at the time the appearance of

the cores of the holes being drilled suggested an improvement in grade over previous holes and a better possibility of a large ore body.

MINERAL DEPOSITS

REGIONAL SETTING

The niobium-bearing rocks consist of a complex of carbonate rocks and associated ultra-alkaline intrusives in which extensive brecciation has occurred. These rocks are surrounded by an assemblage of metamorphosed sedimentary and igneous rocks of apparent Precambrian age ranging in type from quartzite through quartz-feldspar gneisses to anorthositic and gabbroic rocks. These have been named "Morin Series" or "Morin Anorthosite". (Osborne, LaChute area, Quebec Bureau of Mines. 1936)

The regional structure of the Morin Series at Oka and the trends of the foliation in the complex are discordant. In other words the complex has no apparent structural dependence on that of the Morin Series.

The rocks of Morin Series at Oka are domed up into an almost circular range of hills overlain on the fringes by sandstones and limestones of Paleozoic age. The marble complex forms an elongate valley surrounded on the east, north and west by higher ground.

The contact between the marble and the Morin Series is poorly exposed but has been cut by a drill hole. This shows a contact zone of a rock intermediate in composition between anorthosite and ijolite (i.e. composed of plagioclase and soda-pyroxene.) It may be an altered

anorthosite or may represent an incompletely contaminated magma. The magma may have been of basaltic composition. Partial contamination by limestone would produce a partially desilicated anorthosite. More complete contamination would produce the ijolite rocks of the complex. It is inferred that the contact has a dip of 70° to 90° (toward the complex.)

The complex itself, although incompletely exposed, covers about 5 miles by 1-1/2 miles on the surface, and extends beyond 1000 feet in depth. By far the greatest proportion is composed of carbonate rocks (probably 75% or more), the remainder are silicate rocks of unusual and variable composition but are characteristically so deficient in silica that quartz is completely absent and feldspar is very rare. Various names have been used to describe and differentiate these rocks and they will be described below.

The rocks of the complex are divided on the basis of probable origin and subdivided according to useful mappable units. The igneous and igneous-looking rocks are 1) ijolite series, 2) lamprophyre, 3) okaite, 4) nepheline syenite. The rocks of probable metamorphic and metasomatic origin are: 1) crystalline limestone, 2) calc silicate hornfels and skarn, 3) impure marble intermediate between 1 and 2.

The rocks of probable hydrothermal origin are: 1) biotite replacement rocks, 2) bleached rocks of various types, 3) breccias, 4) mineralized skarns, breccias and marbles.

IJOLITE - Ijolite is the name applied to any feldspar-free plutonite containing more than 50% nepheline. Modern usage has established a so-called ijolite "series", subdivided according to relative amounts of light and dark coloured constituents into urtite - more than 70% nepheline; ijolite proper 50 - 70% nepheline; melteigite 5 - 50% nepheline; jacupirangite less than 5% nepheline.

All varieties can be found at Oka, but so far a systematic variation has not been noted. Brecciated altered ijolite is an important host rock for niobium mineralization.

Petrographic Description - The rocks are coarse to fine-grained granular with a green to greyish-green colour weathering differentially to show pyroxene and nepheline as the chief constituents. The two occur most commonly in approximately equal amounts and are evenly distributed. Near the large okaite bodies on Husereau's farm, the grain size is greatly increased and the pyroxene content is more than 50%, producing a variety to which the name melteigite may be applied. This type is tentatively interpreted as a higher temperature "gabbroic" variety compared with the normal "diabasic" type. Urtite - the nepheline-rich type occurs sporadically and is interpreted as an "anorthositic" phase.

OKAITE This name is applied to a coarse-grained melilite-bearing rock occurring at Oka in a variety of textures. In part, the name follows Stansfield's original definition "a grained igneous rock containing melilite and hauyne". No hauyne has been found and the original definition must be considered invalid. The name should be retained, however, because of the

importance of the rock as a lithologic unit. It may be considered synonymous with turjaite, at least in part. Inasmuch as turjaite contains nepheline, perhaps Stansfield's nepheline-okaite should be dropped in favour of turjaite, the name okaite being restricted to the melilite-rich variety (say over 70% melilite).

Okaite is interpreted from field and petrographic study to be a "hybrid" or "contaminated" rock. It is extremely variable in texture and composition and because of its sheet-like occurrence is thought either to represent sill-like injections or to be the result of thermal metamorphism and replacement of an argillaceous limestone.

Okaite is of great use as a temperature indicator and as a horizon marker. It is closely associated with all known mineralized zones and has probably acted as a temperature control as well as having a damming effect on ore solutions.

Petrographic Description - In hand specimen, the okaite is variable both in texture and composition. Composition ranges from almost pure melilite to a nepheline-biotite-rich rock with less than 25% melilite. Calcite, perovskite, magnetite and apatite are present in minor amounts normally, but may be locally very abundant.

Melilite is a difficult mineral to recognize without considerable experience. It has a tendency to a greasy lustre and it is colourless to honey-coloured to grey. It may be euhedral, appearing as stout tetragonal prisms with distinct basal cleavage, but is normally anhedral to massive.

In many outcrops it is altered to a white, buff or green aggregate of vesuvianite, nepheline and occasionally zeolites.

The origin of okaite is in doubt, but as stated above it is most likely a hybrid or a metasomatic rock. If the former is the case, it has resulted from extreme contamination of a magma by limestone. If the latter is the case, it is the result of metasomatism of shale horizons in limestone.

LAMPROPHYRE - Lamprophyre dykes occur in the area within the marble complex and in the surrounding gneisses. Inasmuch as they show little relation to ore they will not be discussed in detail.

True alnoite is probably the chief type of lamprophyre present. This is a feldspar-free lamprophyre with biotite or corroded augite and olivine phenocrysts. The leucocratic mineral is melilite. The largest accessible exposure is near the okaite on Husereau's farm, but a larger one is reported on the Trappist Monastery grounds. Similar lamprophyres are found in the drill cores but no serious attempt has yet been made to correlate them.

Petrographic Description - The ground mass in most lamprophyres is grey or black. Phenocrysts, rock fragments and amygdules are the rule. Biotite phenocrysts are dark brown (titaniferous) and are probably iron-rich. Pyroxene phenocrysts are black in hand specimen: brown, non-pleochroic in thin section. Optical studies show it to be titanaugite. Calcite is present as amygdules. Some of the rock is a breccia composed of fragments of country rock in a lamprophyric cement. The lamprophyres

cutting the Morin anorthosites are finer grained with smaller phenocrysts. Many have a greenish tinge.

CRYSTALLINE LIMESTONE or CARBONATITE

Carbonate rocks are the commonest type at Oka and also the most important host rock for ore. The most abundant variety is a coarse-grained rock composed of calcite with about 15% of dark minerals, usually one or more of the following:- biotite, magnetite, pyroxene, olivine, monticellite, vesuvianite, melilite, perovskite, pyrochlore and apatite. It has a foliation formed by orientation of plates of mica, parallel layers of dark minerals, or alternating layers of coarse and fine grains.

The origin of the foliation is in doubt. If the rocks are igneous, the foliation could be the result of flow layers in the moving semisolid magma. If the rocks were originally sedimentary, the foliation could result from stratigraphic variations.

The variation in mineralogy of the lime silicates in the marble is thought to be significant. Bowen (Journal of Geology 1940) shows that certain minimum temperatures are required to form lime silicate minerals. These then can be used to outline metamorphic zones around a source of heat. Of the fourteen minerals on his list, eight at least are present at Oka. These with their minimum temperatures of formulation are:-

Talc	$<$ 200°c
Tremolite-Actinotite	200°c
Olivine	250°c
Pyroxene	270°c
Wollastonite	450°c

Monticellite	560°c
Melilite	600°c
Larnite (?)	800°c

Relating ore mineralogy to the associated lime silicate, the following zones are indicated.

ORE MINERAL	ASSOCIATED MINERALS	TEMPERATURE OF FORMATION
Niocalite Perovskite (anhydrous)	Melilite, monticellite ‡ pyroxene	400 ? to over 800°
Pyrochlore (OH. brg)	Pyroxene, olivine	250 - 450
Betafite (H_2O brg)	Biotite, calcite	< - 250 (100°)

Further study is contemplated in the search for pyrochlore-rich zones.

Crystalline marble grades into calc-silicate hornfels and skarn with an increase in silicate content and a decrease in carbonate content. These frequently contain more magnetite, apatite and niobium minerals, probably resulting from the action of hydrothermal solutions on marble. In the breccia zones many of the rock fragments are partially converted to hornfels or skarn.

Some of the marble is pure white and almost completely lacking in dark minerals. For convenience, this has been called carbonatite but it may be hydrothermal rather than magmatic.

At such high temperatures as existed at Oka, large amounts of carbon dioxide gas must have been formed. The pressure of this gas was great enough to explode the roof of the chamber, especially around the margins of the complex. Carbonatite is intimately associated with the

breccias so formed, even some outside the main carbonate complex.

Some of the carbonatite contains large crystals and crystal aggregates of pyrite and locally abundant earthy masses up to an inch or two across, composed, according to a report from the Federal Bureau of Mines, of an aggregate of strontianite, barite and ancylite $(CeLa)_4 (Sr, Ca)_3 (Co_3)_7 (OH)_4 . 3H_2O$. This mineral contains up to 55% rare earth-principally Ce, La and Di. It may be regarded as hydrous equivalent of bastnaesite with Sr replacing some of the Ca.

HYDROTHERMAL ROCKS

Biotite Replacement Rock - The most abundant hydrothermal rock is the type known as biotite replacement rock. It is composed entirely of iron-biotite and white calcite with little else except ore minerals. These are betafite, pyrochlore, magnetite and apatite in varying proportions. In some instances, the biotite replacement rock is richly mineralized but it is not the most favoured host rock.

Bleached Rocks - Although these rocks are quantitatively insignificant they are of use in that they indicate hydrothermal alteration. One type is altered okaite. The colour of the rock is markedly lightened by the alteration of melilite to vesuvianite.

The rocks adjacent to the anorthosite contact to the west of the Bond zone are bleached to a greyish-white porcelain-like mass containing either very fine-grained kaolinized feldspar, or in some cases nepheline.

BRECCIAS

Most of the rocks at Oka have been brecciated to some extent. Brecciated ijolite is an important host rock for niobium mineralization. Brecciated Okaite is less so but may be important locally.

Brecciated rocks of almost every description are found in the explosion breccias within and surrounding the complex and in breccia zones within the anorthosites.

The breccias were studied by Grimes-Graeme (un - published Ph.D. thesis, McGill University 1935). The author's conclusions were that the breccias were of volcanic origin formed at Monteregian time by explosion due to build up of pressure of CO_2 at elevated temperatures. This is most probably true in some instances, but perhaps not all. Some of the breccia fragments are well-rounded pebbles and boulders and may be part of an intra-formational conglomerate.

SKARN ROCKS

The skarns are composed of various lime and magnesium silicates, calcite, magnetite, biotite and apatite and are mineralized principally by pyrochlore and perovskite, but occasionally by betafite. They are best developed at ijolite-marble contacts and are commonly wider on the hanging wall side of the ijolite. They have a characteristic texture of closely interlocking prismatic aegirine-augite crystals. This material is in all probability hydrothermal, not only because of its occurrence with hydrothermal minerals, but also because it can only be made synthetically under hydrothermal conditions.

The mineral assemblages of the skarns are complex and variable, but the most common is: calcite-pyroxene - biotite - apatite - magnetite - pyrochlore - forsterite - pyrite.

Such a complex assemblage is to be expected from theoretical considerations. Where eight components are present (as in this case) eight mineral phases may be developed.

STRUCTURE

The structure of the marble complex is incompletely known. Bedrock is exposed in less than 1% of the area and where details of structure can be mapped, they are extremely complex.

The following description of the structure is little more than a guess but in the absence of more information is offered as the best description available at the present time.

Foliation exists in some of the rocks. Based on observations of the attitudes of the foliation, the overall picture suggested is an arcuate structure with almost vertical dips. The arc covers five or six miles and subtends an angle of about 240°. It conforms roughly to the shape of the complex itself. Substantiating this structure are ribbon-like sheets of okaite and ijolite parallel to the strike and dip of this foliation.

Two interpretations of this observed structure are possible. The first is that the okaites and ijolites are ring dykes and cone sheets and the marbles are carbonatite intrusives related to Monteregian igneous activity. The second is that the entire mass is metamorphic and the okaites and ijolites are metasomatized shaley layers in the limestones.

In detail the shapes of the known ore bodies conform to the foliation but, in the Bond zone at least, there are other controls. The mineralized zone as a whole cuts across the foliation at a low angle. Its direction is parallel to that of a late nepheline syenite dyke which may be filling a late shear plane. Openings in such a direction could act as ore feeders with replacement working out along favourable horizons.

Linear elements are absent in the marbles. Thus nothing is known of the plunge of various formations.

The details of the shape of the main Bond zone ore body are also not known although its continuity has been indicated by drilling and by radiometric surveys. The plunge suggested by the drilling to date is to the north at an angle of 10° or less.

LITHOLOGICAL and OTHER STRUCTURAL CONTROLS

The trends of the known ore bodies are parallel or nearly so to the foliation in the marble and to the attitudes of the ijolite and okaite sheets. The reason for this is not known but it may be that the ijolite and okaites are sills and their high temperature gave rise to elongate isotherms which in turn controlled ore deposition. Another interpretation is that the marbles are actually igneous and their foliation is the result of flow layering, flowage being chiefly upward. Accompanying waves of mineralizing fluid would have travelled in the same direction or nearly so and thus the ore bodies would more or less follow the flow layers.

Variations in porosity and permeability have evidently had an effect on ore deposition. Fresh okaite and ijolite are very poorly

mineralized. Brecciation of both okaite and ijolite produces a permeable rock favourable to mineralization. Permeability may also be related to competency of brecciated rocks. Ijolite is very brittle and fractures readily; okaite is very tough but when altered is somewhat brittle; limestone tends to deform plastically under stress, but skarn and hornfels are brittle.

ORE TEXTURES:

The ores at Oka are so widespread that it is to be expected that a great variety of textures and structures would be developed. Such is indeed the case. At least forty minerals occur in the complex (excluding ten or more additional in the surrounding rocks) and many of the minerals are extremely rare as far as world wide occurrence is concerned but quite abundant at Oka. The chief reason for this is of course the unusual enrichment of the so-called "trace" elements;- namely - Zr, Nb, Ta, F, Cl, rare earths, Sr, Ba, S, Th, U, P, Ti and possibly others.

In the Bond zone several thin sections have been studied briefly. Most of these show discrete grains of pyrochlore in a great range of sizes from a few microns up to over a millimeter. Many of the crystals are corroded and pitted. In some of the biotite-rich material pyrochlore may be locked inside biotite books - although this is more commonly true of betafite.

Pyrochlore is the niobium-rich member of the pyrochlore-microlite series and is one of many rare element niobate-tantalates which have similar occurrences, properties and chemical compositions.

Pyrochlore is isometric and occurs in octahedral or modified octahedral crystals. It is usually metamict (i.e., the structure is destroyed by auto-radioactive bombardment of the constituent atoms) with a rough pitted surface and a waxy lustre. It has poor octahedral cleavage, a hardness of 5 - 5-1/2 (lower in altered material), and a specific gravity of 4.2 - 6.4.

Its formula is A_2, B_2, O_6 (O, OH, F) where A = Na, Ca, K, Mg, Fe+2, Mn, Sb, Pb, (?) Ce, La, Pi, Er, Y, Th, Zr, U and B = Nb, Ta, Ti, Sn(?) Fe+3 and W (?).

A semi-quantitative spectrochemical analysis by the Department of Mines and Technical Surveys gave:

Nb and Th as the major constituents	10 - 100%
Ti and Al as minor constituents	1 - 10%
Zr, Fe, Mn as strong Traces	.1 - 1%
Mg, Si, Ca, Y, La, Ce as traces	.01 - .1%
Pb, Sc, Cu, V, Ba, Sr as faint traces	.001 - .01%

Na was not reported but is almost certainly present as a major constituent.

Using these figures a rough analysis of the Oka pyrochlore can be estimated.

$(Nb, Ta)_2O_5$	50%	(Cb:Ta = 14:1)
ThO_2	10%	
Na_2O	10%	
CaO	15%	
TiO_2	10%	

Al_2O_3	3%
ZrO_2	0.8%
FeO	0.5%
MnO	0.5%
Remainder Totals	.2%
	100.0%

This means that a pyrochlore concentrate from pyrochlore minerals of this composition cannot contain over 50% Nb_2O_5 and will carry important amounts of Th, Ti and possible U (which although not reported by the Department of Mines is present with Th is the ratio $^{Th}/_{U}$= 3/1.

PEROVSKITE:

According to Zimmerley the Bond zone ores carry perovskite and pyrochlore in about equal amounts. Unfortunately the core samples were consolidated by the testing laboratory and their spatial distribution is not known. In order to determine the distribution of perovskite and pyrochlore detailed petrographic work on a representative cross section of the ore body is required.

It is hoped that the distribution of perovskite and pyrochlore can be related to some readily observable megascopic feature. The Th, U, content of perovskite is much less than that of pyrochlore. A high assay on non-radioactive rock may then be taken to indicate the presence of perovskite.

Perovskite is a calcium titanate. Niobium may replace Ti

up to Nb: Ti = 2:5 (about 26% Nb_2O_5). Zimmerley reports Oka perovskite to contain 30% Nb_2O_5 but this value may be high. The Mines Branch of the Geological Survey of Canada reports 22% Nb_2O_5.

The mineral occurs at Oka in the form of cubes (in the marbles) or octahedra (in the okaite) or in tiny irregular grains. Rowe reports most grains under 1mm. diameter. It has a submetallic lustre but is less splendant than magnetite. It is black or almost so in hand specimen but in thin section or in splinters has a dark brown colour. It has no cleavage, irregular fracture and a grey streak. Quite frequently it shows complex lamellar twinning. Hardness is about 5-1/2, S. G. = 4.0 + - higher in cerian and niobian varieties. Coarse-grained material is easily identified by crystal shape and streak.

The crystal form is only pseudoisometric. It is probably monoclinic and crystals may be noticeably biaxial. The lamellar twinning also indicates a degree of symmetry lower than isometric. Spectrographic analyses by the Department of Mines and Technical Surveys suggest the following composition:

$$(Ca, Na)(Ti, Nb)O_3$$

The TiO_2 content is probably about 40%, the Nb_2O_5 content about 20% and the CaO content about 35%.

Perovskite forms in igneous rocks only when Si is so deficient that none is available to form sphene.

The minimum temperature of formation is not known but the associated minerals suggest that it is probably about 400° C. Some

research on this point is warranted.

Perovskite grains include and are associated with biotite, calcite and apatite in the skarn rocks with melilite, monticellite, magnetite and biotite in the okaite and with pyroxene and nepheline in the ijolites. Thus it can be a somewhat ubiquitous mineral and may form, not so much as the result of a certain pressure-temperature environment, but in response to a particular chemical environment over a limited temperature range. If water vapour and fluorine are lacking neither pyrochlore nor betafite can form. If the titanium content is low, perovskite cannot form.

Perovskite thus tends to occur in a water and flourine-free environment with abundant titanium and sufficient Ca or Na. It would be expected to occur then with melilite, magnetite, pyroxene, nepheline, monticellite, calcite, and possibly pyrochlore, pyrrhotite, but not likely with betafite, apatite, biotite, hydrothermal calcite, or forsterite. It would never form with quartz, feldspar, sphene, hornblende, muscovite and other silica-rich silicates.

Some simple mineral assemblages involving perovskite are known at Oka. One of these is the assemblage magnetite-perovskite which forms part of a small ore body grading about 0.6% Nb_2O_5 on the property of Oka Rare Metals Limited to the northeast of the marble complex. Another assemblage is calcite-perovskite-monticellite. This occurs in a zone cut by D. D. H. 4 to the south of the britholite occurrence, as well as in some holes on the Manny zone.

A third important ore mineral has been discovered independently by the Kennecott Research Center and by the Mines Branch at the Geological Survey of Canada. The mineral is a niobium-bearing calcium silicate (about 15% Nb_2O_5) and is perhaps a new species, tentatively named niocalite.

The mineral appears to be confined to a narrow zone of carbonate rock adjacent to the okaite marker in the Bond zone extending from D.D.H. 22 to 36 (about 500 feet). In some sections (e.g. D.D.H. 35) it appears to be the principal niobium mineral and Zimmerley reports that it forms 50% of the niobium content in the bulk sample sent from the vicinity of drill hole NX-3.

The mineral can be identified in hand specimen although it does bear resemblance to soda-pyroxene and other lime silicates. It characteristically occurs in prisms with a diamond shaped cross section. Optical properties reported independently by the Department of Mines and by Kennecott Research Center differ somewhat and suggest the possibility of variable composition of the mineral. Properties determined by E. H. Nickel of the Department of Mines are: Optic angle 56°optic sign-negative, indices of refraction - 1.700, 1.721, 1.730, density 3.32, hardness 6, crystal system orthorhombic, cell dimensions - a=7.39A, b=10.45A, c=20.46A, twinning about X, $Z^1 \quad Z^2 = 47°$. Zimmerley gives optic angle 43° indices of refraction 1.705, 1.718, 1.720, optic sign-negative, density 3.4.

Partial analyses show a content of about 16% Nb_2O_5, 29% S_1O_2, 43% CaO and 1.7% F. Calculation of the probable formula suggests a similarity to woehlerite ($NaCa_2$ (Zr, Nb) F, Sl_2 O_8) but with no sodium. An approximate tentative formula is Ca_4, Nb, F, Sl_2, O_{10}. The composition does not fit any of the SiO_4 type of lime silicates.

Further work is contemplated on this mineral.

The ore minerals at Oka are not easily recognized in hand specimen. Pyrochlore closely resembles garnet and can also be mistaken for magnetite when fine grained. Perovskite is very inconspicuous when disseminated among other dark minerals. It is difficult to estimate grade from visual examination especially if the rock is fine grained.

ORE GENESIS

Paragenesis

The sequence of events leading to the formation of the Oka mineral deposits is probably as follows:-

1) deposition of sediments limestone either below or above Morin Series.

2) cover by younger sediments.

3) metamorphism, intrusion of Monteregian rocks, conversion of limestone to marble, hornfels and skarn.

4) brecciation of ijolites.

5) intrusion of lamprophyre and nepheline syenite dykes.

6) hydrothermal alteration - replacement of ijolite rock by biotite, aegirine-augite, calcite.

7) introduction of Fe, P, F, Ti, Cb, Ta, U, Th.

8) deposition of hydrothermal minerals - probable order:-

Niocalite, Perovskite, Magnetite, Pyrrhotite, Pyrochlore, Betafite.

9) low temperature alteration

10) erosion.

The source of the niobium mineralisation is closely related to that of the associated intrusive rocks. The method of concentration of Nb and Ta together with Ti, Fe, rare earths, Na, P, F, Th and U has been the subject of debate for many years.

The most widely accepted theory and the one presently subscribed to by the writer is that these elements being of different ionic radius, charge, or both, are not readily accepted in the cation sites of the rock forming silicates but are excluded to be finally concentrated in the late pegmatitic phase. Regarding the rocks in question the entire mass has effectively been placed in a pegmatite-like stage because of the contamination of the magma by limestone leading to the early crystallization of high-temperature calcium and magnesium silicates whose structures exclude the elements listed above.

This late pegmatitic liquid then becomes the mineralizing fluid. It may or may not boil but it penetrates any permeable rocks and deposits pyrochlore and other minerals in favourable host rocks mainly as a consequence of falling temperatures.

RELATION to TOPOGRAPHY

Some use has been made at Oka of topography. Ridges and knolls have rock exposures or shallow overburden and are composed of massive crystalline limestones, ijolites, or okaites. Biotite replacement rocks normally underlie shallow depressions but because of deep overburden in the eastern part of the marble complex, depressions in that section mean little.

The marble complex occupies a shallow but extensive depression at least 5 miles long and varying in width from a mile to one and a half miles. On either side of this valley, the Morin anorthosites stand about 300 feet higher than the marbles and about 500 feet higher than the surrounding countryside.

In detail, topography is of little use, but in the overall picture it outlines the favourable rocks quite well.

MINERALOGICAL CONTROL

The mineralogy of both the host rock and the ore is influenced by the temperature, pressure, and bulk composition of the deposit at the time of its formation. The occurrence of niobium ores with a characteristic mineral assemblage demonstrates this influence. In some cases key minerals whose minimum and /or maximum temperatures of formation are known can be selected from these assemblages and used as guides to type and grade of mineralization.

The minerals associated with various niobium ores at Oka have been described above. In the highest grade material niocalite is the chief ore mineral. It is found mainly with calcite and magnetite. The most abundant ore mineral is pyrochlore. Its associated minerals are aegirine-augite, biotite, pyrrhotite, magnetite, garnet, apatite, and calcite. Here, pyrrhotite and aegirine-augite are the key minerals. Pyrrhotite has long been used as an indicator of a temperature range of 300°C to 500°C. Pyroxene has a minimum temperature of formation of 270° C but is converted to wollastonite at 450°C and to melilite at 600°C.

The relationship between magnetite, limesilicates, biotite, and niobium values can be shown by a plot of grade versus dark mineral content. (Fig. 1)

A similar plot for radioactivity versus grade (Fig. 2) shows no systematic variation. In detail grade of columbium mineralization does not depend on radioactivity, mainly because of the variable perovskite, niocalite, pyrochlore ratio.

FRACTURES, SHEARS, JOINTS and FAULTS

Very few shear zones have been found at Oka but where they do exist they are mineralized. A shear zone in altered okaite about four feet wide was intersected by D.D.H. S-9. It carries about 0.5% Nb_2O_5 in a hematite-anatase (TiO_2) rock which is a product of hydrothermal activity in the shear.

A nepheline syenite dyke cuts obliquely across the foliation in the Bond zone. This dyke is parallel, not to the individual ore

horizons, but to the long dimension of the Bond zone as a whole. This suggests that the fracturing giving rise to the nepheline syenite also permitted the introduction of mineralizing fluids, which, on arriving, spread out along favourable horizons in the marbles.

DEVELOPMENT

The property has been developed in the following ways-

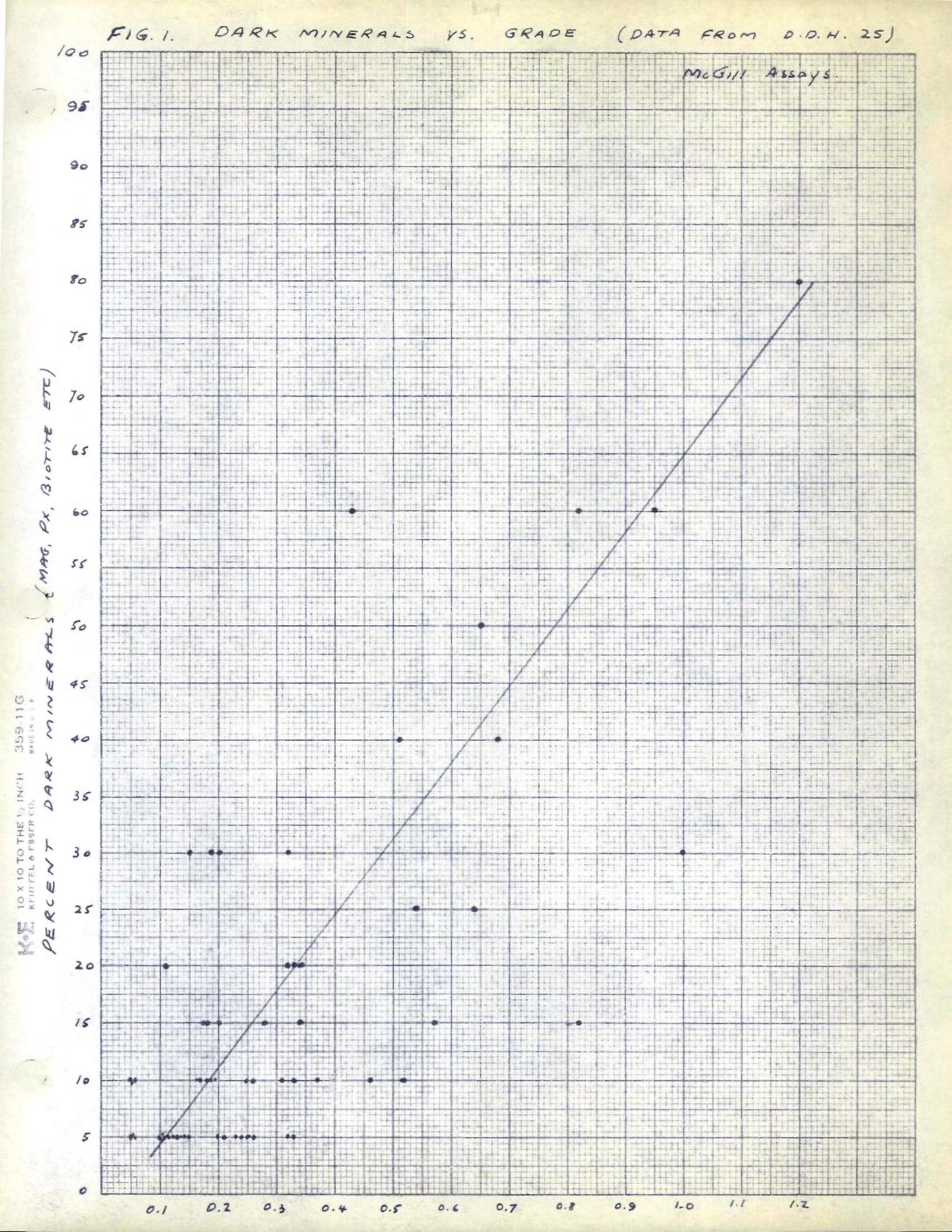
1) Diamond Drilling - The bond zone has been thoroughly tested by about 20,000 feet of AX and 2,200 feet of Nx drilling. In addition, a large test pit has been excavated near D.D.H. NX3 to provide 60 tons of typical ore, ten tons of which have been shipped to the Kennecott Research Center. A second sample of 40 tons in the vicinity of D.D.H. S-36 is now being taken.

Previous drilling of an exploratory nature amounts to about 10,000 feet most of which is confined to the Manny Zone. Molybdenum Corporation of America report the development of 40 million tons of 0.3% Nb_2O_5 material to a depth of 300 feet.

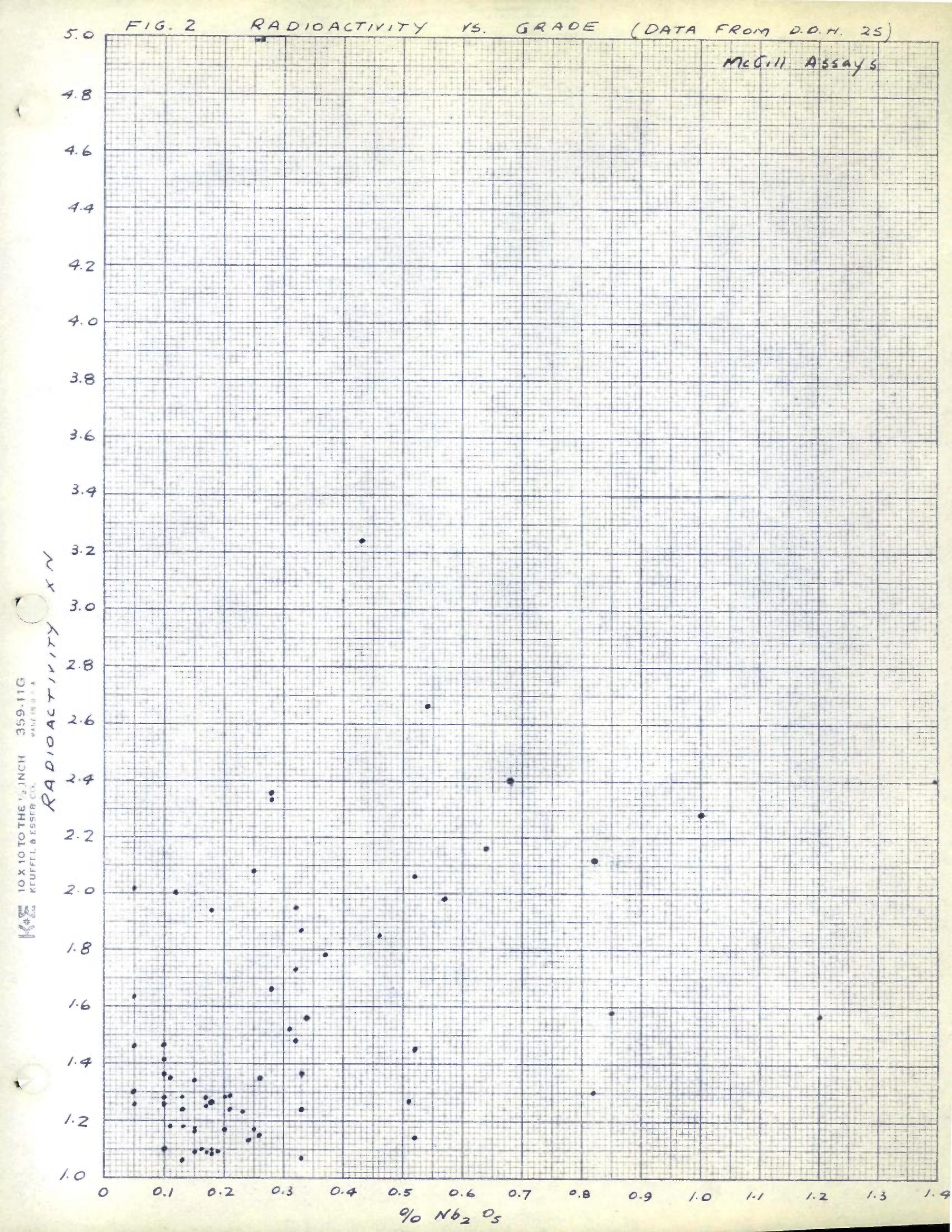
2) Trenching- The Manny Zone has been extensively trenched but the trenches more or less follow the rock trends and do not cut directly across the lithology. A ten ton sample was taken from on of the trenches for metallurgical testing by Molybdenum Corporation lab at Mountain Pass, California.

3) Assaying- A fully-equipped X-ray fluorescence laboratory was set up in July 1955. So far over 700 assays have been made, plus 50 or so check assays. Results show fair agreement with other labs. A

FIG. 1. DARK MINERALS VS. GRADE (DATA FROM D.D.H. 25)



KEUFFEL & ESSER CO. 359-11G MADE IN U.S.A. 10 X 10 TO THE ½ INCH


FIG. 2 RADIOACTIVITY VS. GRADE (DATA FROM D.D.H. 25)
McGill Assays
RADIOACTIVITY x N
% Nb_2O_5
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
10 X 10 TO THE INCH 359-11G
KEUFFEL & ESSER CO.

discussion of the results of analysis will be found in an appendix to this report.

4) Metallurgical Tests - Samples of "ore" ranging from a few hand specimens to twenty tons have been sent to various laboratories for testing. The data are presented in the form of a table (table 2) showing the name of the laboratory, the amount and type of material sent and the date for each sample. Kennecott Research Center has been conducting thorough metallurgical tests on Bond zone ore, some of the results of which are already available.

Verbal reports from Mr. Bond indicate that other labs have obtained results similar to those of Kennecott. Their methods of concentration are believed to be similar.

J. A. Cower.

TORONTO, Ontario
March 16, 1956.

ASSAYING FOR NIOBIUM

GENERAL

In addition to the various chemical methods several new techniques have been developed. These are colorimextric and X-ray methods of various types. The choice of method depends on cost, time required, tolerance permitted, and availability of men and equipment, any one of which may be the deciding factor.

Chemical methods may be gravimetric, volumetric or colorimetric. Details of various procedures may be found in the literature.

1. C. F. Hiskey, L. Newman and R. H. Atkinson "Analytical chemistry of Niobium and Tantalum" Analytical Chemistry 24, 1988 (1952)

2. W. R. Schoeller Analytical Chemistry of Tantalum and Niobium, London, Chapman and Hall, 1937

3. R. H. Atkinson, J. Steigman and C. F. Hiskey "Analytical Chemistry of Niobium and Tantalum," Analytical Chemistry 24, 447 (1952)

Gravimetric analysis requires that Nb and Ta be separated from interfering elements, chief of which are Ti and Zr. The separation is made difficult by the fact that Nb and Ta do not form simple water-soluble ions. However by a method of chlorination using octochloro-propane the Ti may be removed as a chloride (see Hiskey C. F. et al 1952 a, b)

Colorimetric methods are known and are used by the Kennecott Research Center. Details of their procedure are not known

but judging from the results of a series of assays the method is probably accurate. The time and quality of technique required are not known.

A volumetric method is described (U. S. Government Pub. # 15239 (1948)) but little is known about its limitations or advantages.

X-ray fluorescence methods may be subdivided into various types:

Direct 1) - using an external standard

2) - using an internal standard

a) of another element

b) of the same element (the addition method)

Indirect (combined chemical and X-ray)

1) - simple fusion

2) - fusion and chemical precipitation

The direct method using an external standard is recommended by the makers of the General Electric XRD-3 X-ray fluorescence unit as being satisfactory for routine work where the sample matrix is uniform. It is not used extensively because of its obvious disadvantages. There is no assurance that conditions are the same for the X-ray of the sample and the standard.

The internal standard methods are at present used more than all others together. The internal standards commonly employed are molybdenum or zirconium for niobium and copper or hafnium for

tantalum. These are added in the form of powdered oxides and mixed mechanically. The addition method makes use of additions of the elements sought. This obviates errors due to elements interfering with the standard and to varying molybdenum and zirconium content of the samples. This method is in use at Oka as well as at Quebec Metallurgical Industries in Ottawa.

The procedure is as follows:

1) A set of standards of varying niobium content is prepared in advance.

2) The sample is scanned to check for interfering elements.

3) A weighed amount of sample and 0.5% standard in Al_2O_3 powder are thoroughly mixed. This serves material from o to 1.0%.

4) The mixture is spectrographed and the intensity measured. Corrections for standard and background are applied, and the corrected intensity gives the niobium content.

A simplified fusion method is recommended by at least one maker (R. E. L.) and a fusion-precipitation method is used by Kennecott Research Center. This is described in a paper by Mortimore, Romans and Tews. (Applied Spectroscopy Vol. 8 No. 1)

A 100-mg sample is fused with excess sodium peroxide in a nickel crucible. The fusion product is dissolved in water and hydrochloric acid, a little hydrofluoric acid and some boric acid are added. An internal

standard, consisting of zirconium and hafnium oxides dissolved in strong sulphuric and hydrofluoric acids, is added.

The Zr, Nb, Hf, and Ta are precipitated as hydroxides with concentrated ammonium hydroxide. The product is boiled. The precipitate is allowed to settle, the liquid decanted and the filtered precipitate ignited.

The oxides are ground to minus 200 mesh and the sample combined with starch and pressed into a mold to form a thin wafer of uniform size and density. The wafer may be retained after analysis.

The advantages of this method are many:-

1) Errors due to differences in particle size are eliminated.

2) Errors due to insufficient mechanical mixing are eliminated.

3) The prepared sample can be retained for future check.

4) Rich samples are more easily handled than with direct methods.

5) Possible interfering elements are largely eliminated.

The chief disadvantages are the additional time required and the need for trained chemists and chemical equipment.

SOURCES of ERROR

So far as is known no evaluation has yet been made of the various sources of error inherent in X-ray methods. It is generally known that gravimetric analysis is subject to error through coprecipitation of titanium and loss of niobium and tantalum. This may have been the cause of a 25% discrepancy between chemical and X-ray assays of Oka ores which existed up to the autumn of 1955. This discrepancy has now been eliminated apparently by changes in the chemical methods but no details are at present

available.

In X-ray methods systematic errors may be present depending on the nature of the matrix, the grain size of the sample and the characteristics of the X-ray unit. Some of these may be avoided by the use of the additional method - especially matrix variations and interfering elements.

Dr. G. R. Webber of McGill University reports that the response curve for various Nb_2O_5 additions is not linear as might be expected but curves at high intensities in a similar manner to spectrographic working curves.

Intensity can reach a certain maximum value, in this case determined by the saturation of the geiger tube. The response tails off exponentially. It may still be used in this range but must be carefully calibrated. Its degree of accuracy is also much less.

A large number of possible errors exist in X-ray methods in general but by frequent calibration and reassay many of these can be avoided. Considering cost, time, accuracy and availability of men and equipment X-ray analysis appears to be the most efficient method available at present. The choice of X-ray method depends largely on the type of ore, the preference of the operator and the grade.

The method in use at Oka is thought to be the most satisfactory compromise between simplicity of procedure and accuracy of results.

STATISTICAL TREATMENT OF SAMPLING AND ASSAY DATA

It is desirable in any treatment of data to know how reliable the data are. It is also desirable to know, once having decided on the degree of precision required, how many measurements are necessary to reach this precision.

Statistical methods can be applied only to precision (reproducibility) not to accuracy. As far as accuracy goes, we can only use an average value or the most frequently occurring value.

Regarding niobium assays a statistical approach is useful in the following instances:

1) to determine the size of sample necessary to give better precision than that obtainable in the actual X-ray measurements.

2) to determine the degree of grinding necessary in sample preparation.

3) to determine the number of counts required in the spectrographic measurements.

4) to determine the number of assay runs required for a given precision.

5) to calculate the standard deviation of assay results.

6) to compare and evaluate results of assays from various laboratories.

7) to determine upper and lower detection limits.

Applications of statistical methods to Oka ores has been tried with some success. A few cases of interest are described below.

SAMPLING AND ASSAYING AT OKA

The following sampling procedure is used at Oka. The boxed cores are tested radiometrically at six inch intervals using a P.R.C. scintilation counter and slotted lead shield. The core is then marked for sampling by the geologist using rock type and radioactivity as guides. The core is split and the sample bagged. The samples are crushed in a Braun chipmunk jaw crusher, mixed for ten minutes in an Abbe laboratory mill and divided into four equal parts. One-quarter of the original samples is pulverized to -115 mesh in a Bico pulverizer type UA with specially designed molybdenum alloy plates. The pulverized sample is screened through a type 38JR Tyler Hummer electric screen and the oversize re-pulverized and rescreened. The sample is mixed for ten minutes and split into four parts.

The samples are assayed by the direct addition method described above. They are weighed on a Christian Becker analytical balance, mixed with the standard and further ground in a Fisher automatic mortar grinder for 15 minutes. The X-ray procedure has been previously described.

The following personnel are employed:-

One assayer,
One man to weigh and mix samples,
Two men in crushing room,
One man to split core (part time).
One man to measure radioactivity (part time).

About 10 assays can be completed in a day. The cost is estimated at $10.00 per assay.

In order to test the reliability of Mont Bleu assays check samples were sent out about once a month. A comparison of some of these is shown in Figure 3 and in Tables 3 and 4.

The standard deviation gives a measure of probable degree of precision of the various laboratories. Mont Bleu's standing should be considered in any appraisal of ore reserves based on their assays.

TABLE 2.

DATE	WEIGHT	SOURCE	LAB.	REPORT
Feb. 15/54	1000 lbs.	Trench #17 Manny Prop. Lot 312	Queens University	
Feb. 15/54	1000 lbs.	" # 9 Manny Prop. Lot 312	" "	All reports
Nov. 22/54	200 lbs.	" #17 Manny Prop. Lot 312	Mt. Pass Mine	
Feb. 25/55	10 tons	" # 9 Manny Prop. Lot 312	Jeffrey Mfg. Co.	to be sent
Mar. 15/55	200 lbs.	" # 9 Manny Prop.	Mt. Pass Mines	to Moly.
Mar. 15/55	200 lbs.	" #17 " "	" " "	Head Office
Mar. 15/55	200 lbs.	" #17 " "	Colorado School of Mines	" "
Mar. 15/55	200 lbs.	D.D.H. #S-22 - Core	Mt. Pass Mine	" "
Mar. 15/55	200 lbs.	D.D.H. #S-22 - Core	Colorado School of Mines	" "
July 8/55	2 tons	Trench # 9 Manny Prop. Lot 312	Quebec Dept of Mines	" "
April 1/55	500 lbs.	Trench #17 Manny Prop. Lot 312	Wah Chang Corp.	" "
Sept. 20/55	750 lbs.	D.D.H. # N X 3 Core	Mt. Pass Mine	" "
Nov. 1/55	2411 lbs.	D.D.H. # N X 4 & # N X 5 core	Mt. Pass Mine	" "
Oct. 12/55	210 lbs.	D.D.H. # N X 3 Core	Norges Tekniske Hoiskole	" "
Sept. 1/55	2987 lbs.	D.D.H. # N X 1 & # N X 2 Core	K. Research Centre.	Kennecott
Nov. 8/55	660 lbs.	D.D.H. # N X 6 Core	Dept of Mines, Ottawa	Molybdenum Head Office
Dec. 14/55	22, 280 lbs.	Open Pit Lot #216	K. Research Centre	Kennecott
Dec. 22/55	20, 000 lbs.	" " " "	Mt. Pass Mine	Molybdenum Head Office

TABLE 3

COMPARISON OF NIOBIUM ASSAYS

Sample No.	Mont Bleu X-ray	Brooker X-ray	Q.D.M. X-ray	K.R.C. X-ray fusion	McGill X-ray	Lucas Chem.	Ottawa X-ray	Ottawa Col.	Q.M.T X-ray
1051	.50	.50	.47	.55	.52	.52	.44	.49	.51
1053	.12	.11	.12	.16	.11	.11	.12	.10	.10
1055	.50	.49	.42	.56	.45	.70	.49	.53	.46
1332	.55	.55	.62	.58	.54		.59	.64	.61
1395	.04	.03	.05	.06	.04		.05	.05	.04
1401	1.97	1.64	1.80	1.58	1.60		1.69	1.60	1.93
1458	1.05	1.13	1.80	1.13	1.15		1.39	1.42	1.11
1459	1.42	1.05	1.30	1.10	1.02		1.05	1.08	1.11
1461	.69	.69	1.10	.72	.70		.78	.73	.90

TABLE 4

ASSAY VARIATIONS

Sample No.	Average Value	Mont Bleu	Brooker	Q.D.M.	K.R.L.	McGill	Ottawa 1.	Ottawa 2.	Q.M.I.
1051	.50	.00	.00	- .03	+ .05	+.20	-.06	+.01	+.01
1053	.11	+.01	.00	+ .01	+ .05	.00	+.01	-.01	-.01
1055	.49	+.01	-.03	- .07	+ .07	-.04	.00	+.04	-.03
1332	.58	-.03	-.01	+ .04	.00	-.04	+.01	+.06	+.03
1395	.04	.00	+.02	+ .01	+ .02	.00	+.01	+.06	.00
1401	1.62	+.35	+.02	+ .18	- .04	-.02	+.07	-.02	+.31
1458	1.11	-.06	-.02	+ .69	+ .02	+.04	+.28	+.31	.00
1459	1.07	+.35	-.02	+ .23	+ .03	-.09	-.02	+.01	+.04
1461	.71	-.02	-.02	+ .39	+ .01	-.01	+.07	+.02	+.19
Arithmetic Sum		.96	.18	1.65	.29	.26	.53	.49	.62
Algebraic Sum		+.70	-.08	+1.45	+ .21	-.14	+.37	+.43	+.54
Standard Deviation ($S = \frac{(d)^2}{n}$)		.13	-.015	.28	.038	.039	.101	.10	.12
Average Deviation $A = \frac{d}{n}$		.06	.005	.18	.03	.03	.06	.05	.07

Memorandum to: W. P. Hammond.

From: J. A. Gower.

Subject: Further Data on the Oka Property

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1) Mineralogical Studies-

Work has begun on the details of distribution of pyrochlore, perovskite and niocalite in the Bond zone. The Molybdenum Corporation of America geologist will re-examine the core of the Bond zone and from visual inspection, radioactivity, and grade, he will attempt to estimate the distribution of values.

2) Assaying-

All of the McGill assays on Bond zone ores have been re-checked by the Mont Bleu laboratory. Good agreement was obtained in only a few instances. The lack of agreement led us to review our assay procedures and techniques, to check on the possibility of interference by other elements, and to seek independent checks from other laboratories.

Some 28 of the samples whose assays showed poorest agreement were sent out to Kennecott Research Center, to E. J. Brooker, and to the Quebec Department of Mines. The results indicate that Mont Bleu and Kennecott agree reasonably well but Brooker and Quebec Department of Mines are about 18% higher. The reason for this has been the subject of considerable investigation by the Oka assayer and so far he is unable to assign the error.

As far as we in Kennco are concerned agreement with Kennecott Research Center is all that is required but that still does not tell Molybdenum Corporation of America who is right.

It has now been definitely established that the geiger response is seldom linear and the mathematical method based on this assumption is not generally usable. Instead a calibration curve must be drawn which shows the actual response. This is most conveniently done on log-log paper, producing a family of parallel working curves which vary only in position, depending on geiger response (which varies according to changes in X-ray tube current).

3) Development-

Although diamond drilling has stopped, at least temporarily, geophysical mapping is being continued. Geiger and magnetometer traverses are being made across the contact of the complex and the Morin Series rocks. A large open cut 100' x 250' has been recently completed on the Bond zone in the vicinity of DDH 36 and a 50 ton bulk channel sample sent to Kennecott Research Center. The grade of both the drill hole intersection and the surface cut is 0.53% Nb_2O_5. An extra 50' of surface rock was taken to be sure the whole zone was crossed. This reduced the grade of the rock shipped to 0.45% Nb_2O_5.

Mapping of the open pit indicates some interesting and significant features bearing on the origin of the deposit as well as proposed mining techniques. The first is that up to 15' of weathered bedrock covers the fresh material below. This could be mined at an extremely

low cost and could provide about 500,000 tons on the Bond zone alone. The second is that the carbonate rocks in the zone exposed show a relationship to blocks of ijolite and skarn indicating that they flowed plastically around blocks of altered ijolite, hornfels and skarn and may therefore be younger than the ijolite. The skarns are thus interpreted as blocks of ijolite which on reaction with the carbonate "magma" are converted first to hornfels and finally by coarsening of grain size to skarn.

4) Statistical Data-

Graphs of various relationships have been prepared and are included for possible future reference.

Figure 1 is a plot of radioactivity versus uranium and thorium values. The correlation is so good that a reasonably accurate estimate of Th and U content can be made, based upon radioactivity of the core. Fortunately all core has been tested radiometrically and little further work is required to make the estimates. Fortunately also the Th:U ratio is fairly constant at about 2:1.

Figures 2, 3 and 4 are a set of graphs showing the distribution of values among various rock types. This shows not only how much of each ore type is present, but also the distribution of grade in the host rock. Marble, skarn and ijolite are the three types of host rock. A table (Table 1) showing the totals of footage and grade and their product indicates that marble provides over one-half the values but is rather low in grade (0.41%). Skarn and ijolite provide about equal amounts but the grade of the skarn is 1.05% compared with 0.53% for the ijolite.

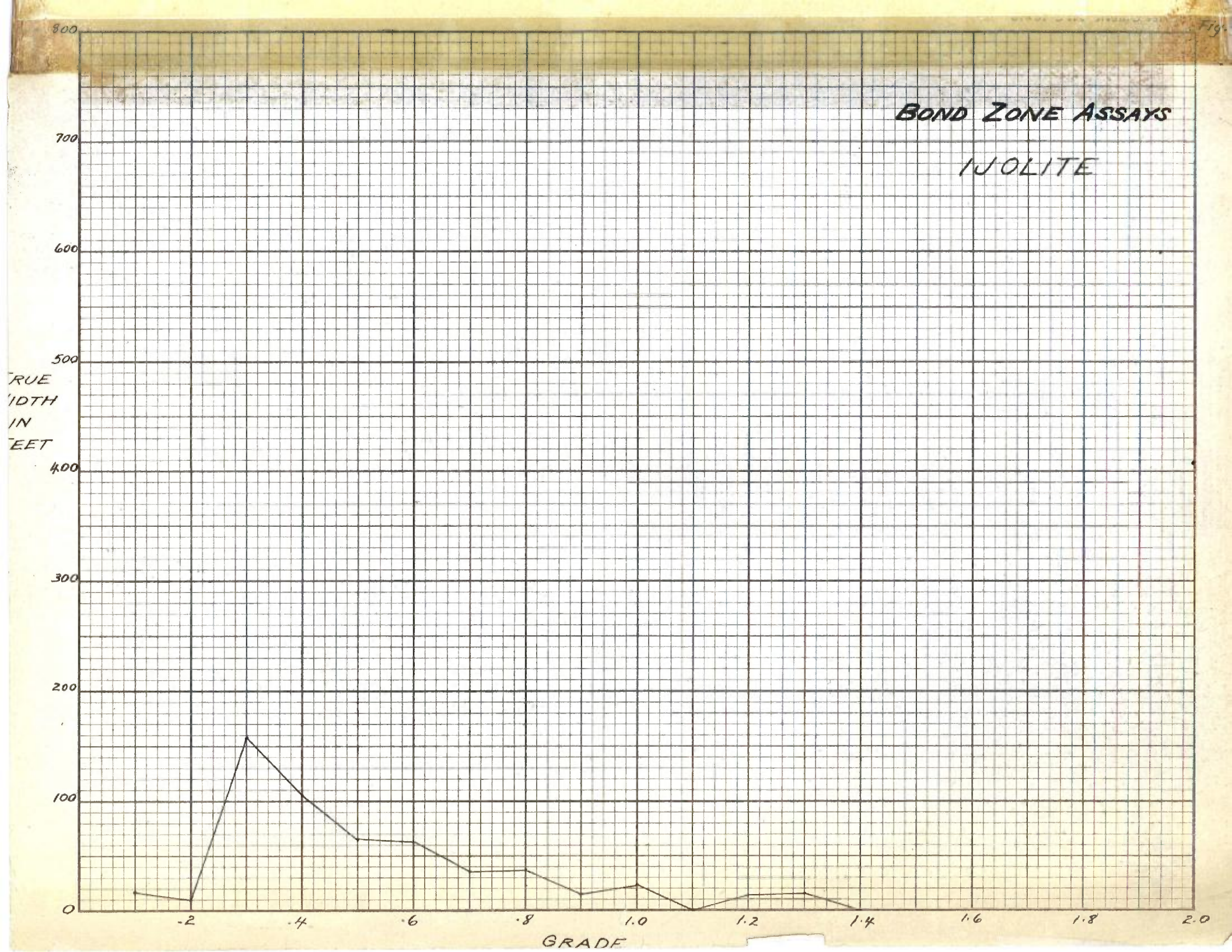
TABLE 1

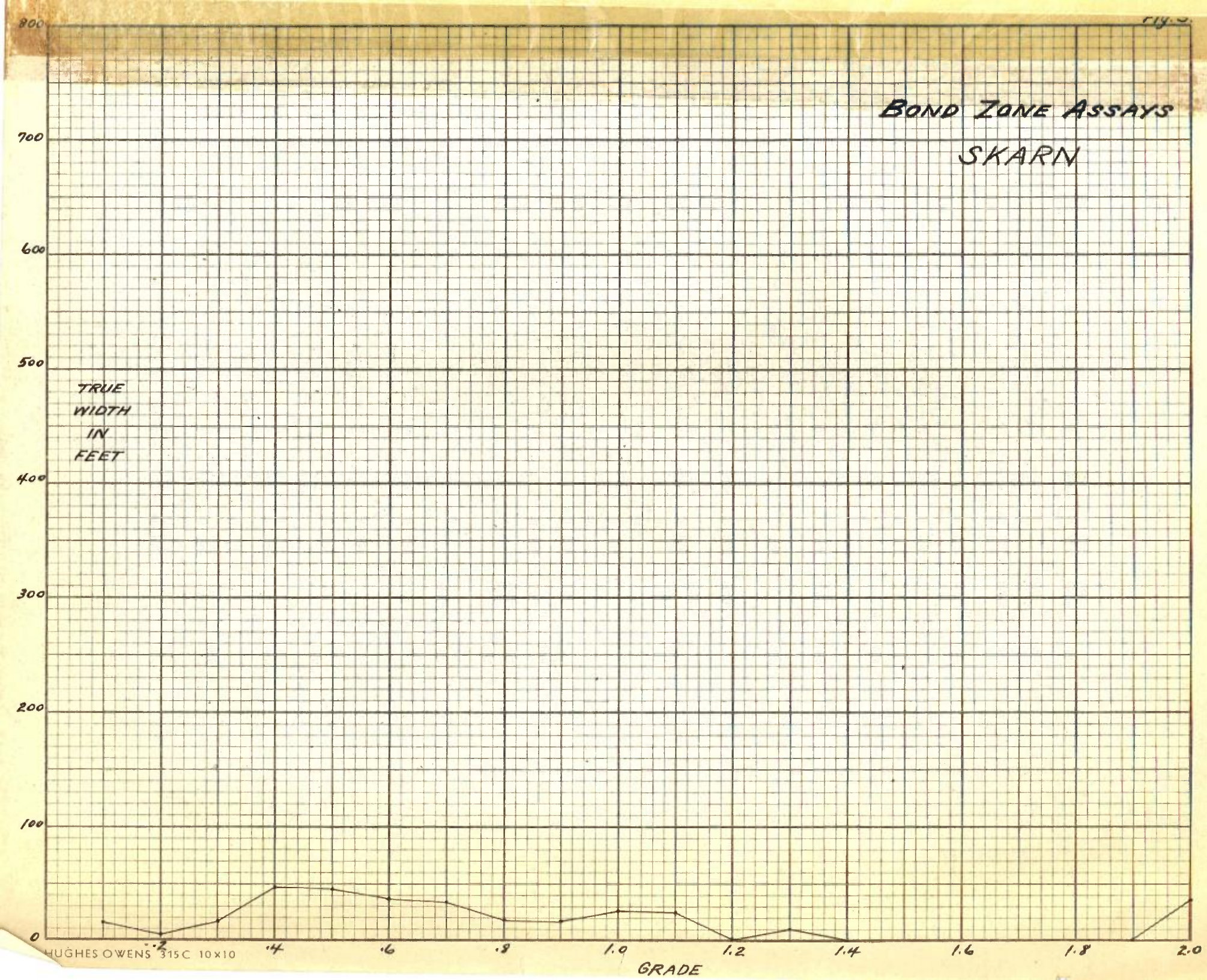
HOST ROCKS FOR NIOBIUM IN BOND ZONE

Host Rock	Footage	Grade	Ft. x Grade	% of total
Marble	1622	0.41	673	57.1
Skarn	244	1.05	257	21.8
Ijolite	470	0.53	249	21.1
			1179	100

J. A. Gower

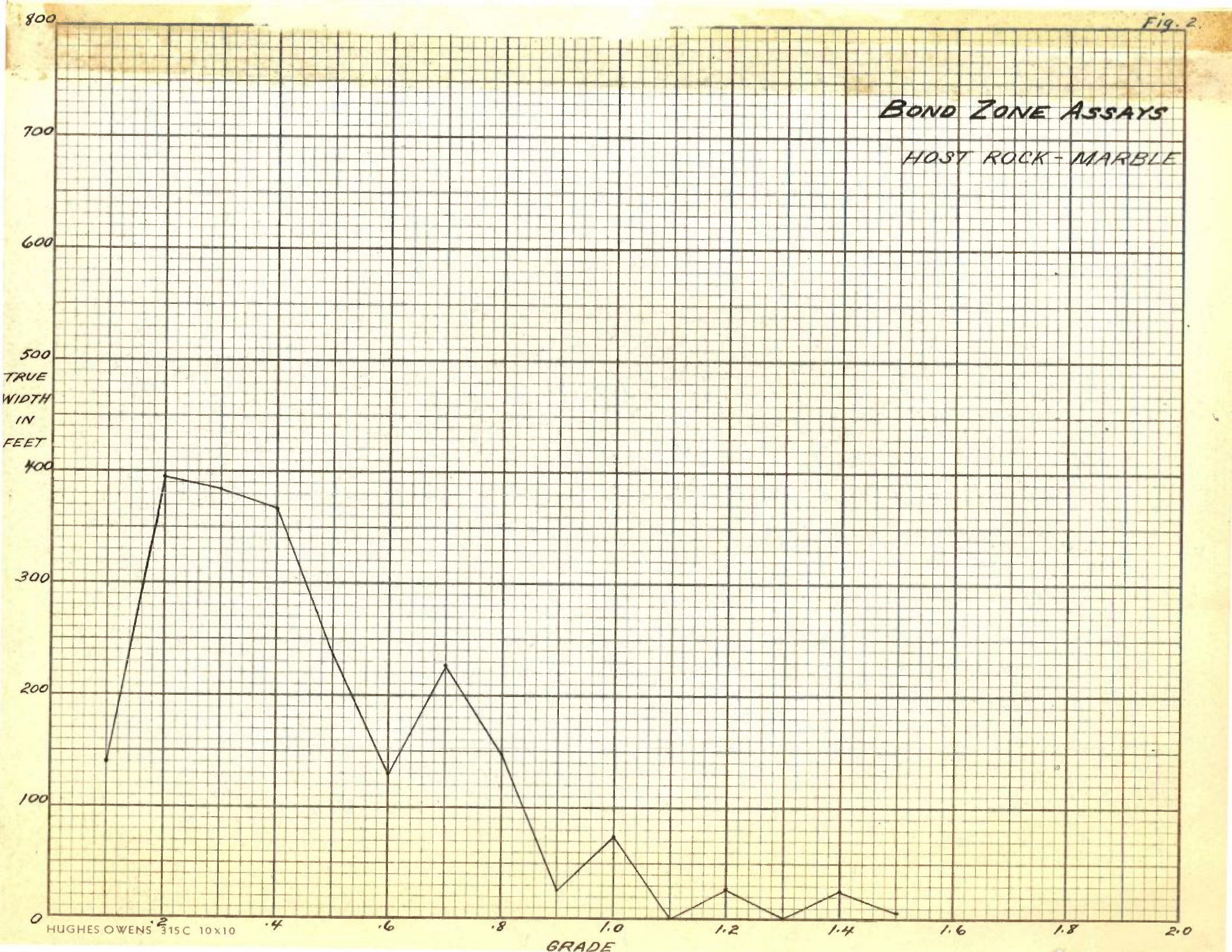
April 16, 1956.


BOND ZONE ASSAYS
IJOLITE
800
700
600
500
400
300
200
100
0
TRUE WIDTH IN FEET
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
GRADE



HUGHES OWENS 315C 10x10

Fig. 2.


BOND ZONE ASSAYS
HOST ROCK - MARBLE
800
700
600
500
TRUE WIDTH IN FEET
400
300
200
100
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
GRADE
HUGHES OWENS 315C 10x10

RADIOACTIVITY VERSUS URANIUM AND THORIUM VALUES

BOND ZONE

Fig. 1.

