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GEOLOGY AND URANIUM DEPOSITS, QUIRKE LAKE-ELLIOT LAKE, BLIND RIVER AREA, ONTARIO

(Preliminary Report)

By

S. M. Roscoe

OTTAWA

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Price, 50 cents

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INTRODUCTION

The Blind River uranium deposits, sheet-like in character, are in gently-dipping, pyritic, quartz-pebble conglomerate beds in the lowermost part of the Huronian system. The history of discovery and development of these extensive uranium deposits has been well documented (Joubin, 1954) and will not be repeated here.

The town of Blind River lies on the north shore of Lake Huron, about 100 miles west of Sudbury and about 90 miles east of Sault Ste. Marie, on Highway 17 and the Soo Line of the Canadian Pacific Railway. Pronto Uranium Mine is about 12 miles east of Blind River. All of the other important uranium deposits are in the Quirke Lake-Elliot Lake area (townships 143, 144, 149 and 150) about 25 miles northeast of Blind River. The principal mining properties and the new townsite at Elliot Lake can be reached by a new road which leads north from Highway 17 a few miles east of Pronto. The area is also serviced by a seaplane base at Algoma Mills.

Field Work and Acknowledgments

In 1954 the writer was instructed to begin a comprehensive study of the uranium deposits of the Blind River region, with particular reference to their mode of occurrence, distribution, and origin. The project did not include conventional geological mapping, but it soon became apparent that special emphasis on the stratigraphy would be required because of its important bearing on the distribution of orebodies. Principal attention during 1954 and 1955 was therefore devoted to detailed studies of surface exposures in selected areas, to logging diamond drill cores, to collecting numerous samples for laboratory tests, to gathering other data from companies operating in the area, and to the preparation of a map showing subsurface data. This work was done throughout a large region north of Lake Huron, but was concentrated in the Quirke Lake-Elliot Lake sector of the Blind River area.

The present preliminary report deals chiefly with the stratigraphic and structural conditions, but also includes a short account of the ores and the problems related to their origin, which are being investigated further.

The writer was ably assisted in 1955 by P. J. Pienaar and W. D. Weber. Mr. Pienaar logged most of the deep drill-holes in the Quirke Lake-Elliot Lake area and made a study of crossbedding in the lower Huronian quartzites.

The writer is especially indebted to field staffs and officials of all of the companies operating in the area for making available to him a wealth of geological data obtained by them in their exploration work and for many courtesies extended to him and to members of his party.

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GENERAL GEOLOGY

Huronian sedimentary rocks unconformably overlie a pre-Huronian basement composed of granite and greenstone. The Huronian rocks include quartzite, greywacke, argillite, various types of conglomerates and minor limestone. They have been folded to form a syncline that plunges gently towards the west. The belt of Huronian rocks within the syncline is about 9 miles wide and about 4,000 to 5,000 feet thick in the central part. The rocks have been only moderately metamorphosed. They have been intruded by dykes and sill-like bodies of diabase. Gently-dipping reverse faults and steeply-dipping faults of small displacement cut the Huronian and pre-Huronian rocks.

PRE-HURONIAN ROCKS

Greenstone

The oldest rocks in the area are greenstones and minor lean cherty iron-formation. The greenstones include meta-volcanic rocks and meta-gabbro, chloritic and sericitic schists, and banded rocks of uncertain origin.

A broad belt of greenstone, flanked by granite, underlies most of the eastern end of the remnant of Huronian rocks in the Quirke Lake syncline. The north edge of this greenstone belt extends in a northwesterly direction from Whiskey Lake to the northeast corner of Quirke Lake. Its south border extends northwesterly from the Nordic Lake area under the cover of Huronian rocks. It is interesting, and perhaps significant, that the two known important ore-bearing belts lie along the north and south flanks of this greenstone belt. Little is known of the structure within the greenstone areas but schistosity, and attitudes of contacts and banding, where recognizable, strike westerly or northwesterly.

Granite

Apart from the above-described belt of greenstone, most of the pre-Huronian terrain in the region is comprised of granitic rocks that contain small, metamorphosed remnants of the invaded greenstone. The most typical granitic rock is a massive, medium-grained, grey hornblende granodiorite, but gneissic, porphyritic, pegmatitic, fine-grained, coarse-grained, and pink coloured granitic rocks are also present. A pink granite containing biotite, muscovite or both is not uncommon and is indistinguishable from the most typical phase of the much younger, post-Huronian granite.

The plagioclase of the older granitic rocks has been almost entirely altered, mainly to sericite. The potash feldspar is most commonly microcline, although orthoclase is not uncommon; no perthite was noted in the specimens of older granite studied although it is common in younger granites elsewhere in the region. Microcline and orthoclase are less sericitized than the plagioclase and the larger grains commonly have completely unaltered cores. Quartz is only slightly strained, in contrast to the strong strain effects present in quartz grains in the Huronian sediments. Mafic minerals are altered to amphibole, chlorite, epidote, and sericite.

Accessory minerals observed include: unidentified opaque minerals (probably iron oxides), titanite, apatite, and, rarely, zircon and monazite. The zircon and monazite are of special interest as these radioactive minerals are common as clastic grains in Huronian sedimentary rocks. They appear to be the main source of radioactivity in the granitic rocks studied. Minute unidentifiable grains of a slightly radioactive mineral are also present.

Fluorometric uranium analyses* on 13 samples of

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*Analyses by the Mines Branch, Dept. Mines and Tech. Surveys, Ottawa.

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granitic rocks show a U_3O_8 content of from 0.0003 per cent to 0.002 per cent. Preliminary results of thorium analyses suggest a thorium content in the order of about 3 times the uranium content. Granite outcrops show radioactivities varying from slightly higher than water background to about 10 times background. This radioactivity is higher than that of basic igneous rocks and fine-grained or calcareous Huronian sedimentary rocks, but lower than that shown by most of the coarse-grained clastic rocks in the lowermost Huronian formation.

RESIDUAL DEPOSITS ON THE PRE-HURONIAN SURFACE

The contact between pre-Huronian rocks and stratified Huronian rocks is commonly gradational. The transition zone may be only a few inches thick or it may be up to 50 feet thick.

The writer agrees with Collins (1925) that these gradational contacts represent residual soils developed by weathering of the pre-Huronian rocks prior to the deposition of Huronian sediments.

The thickest residual deposits are found overlying granite. Normal hornblende granite grades upward into a white rock with recognizable granitic texture, but lacking mafic minerals and containing plagioclase almost completely altered to sericite. Higher in the section the granitic texture disappears, microcline is partly replaced by sericite that commonly divides individual grains into fragments. The quartz grains remain similar in size and shape to those in the original granite. The ultimate development is a greenish rock containing quartz grains and very irregular grains of microcline "floating" in a structureless mass of sericite. The microcline is fresher than most of that in the original granite. The quartz grains are less strained than those in the overlying clastic sedimentary rocks, and also appear to be less strained than those in the underlying granite. Apparently the sericite matrix protected the grains from deformation during folding of the adjacent rocks. Probably the original product of weathering of the feldspars was kaolin which would be converted to sericite during subsequent deep burial and metamorphism. Monazite grains have been recognized in the granitic residuum and it is probable that this mineral and other resistant accessory minerals were considerably concentrated along with quartz in the residual soil. The change from the granitic residuum to the overlying transported sediments of the lower Mississagi formation is marked by a sharp reduction in the amount of interstitial sericite and by the presence of stratification and pebbles. Granitic residuum has been found overlying greenstone. It was probably moved to this position by soil creep.

Greenstone also commonly grades upward into a rock that may have been formed as a residual soil. This rock, commonly described as 'argillite', is dark green or grey and is composed of very fine-grained sericite and chlorite. Locally, faint banding is present, suggesting that here and there the residual clay was washed and redeposited. Lenses of this 'argillite' have also been found overlying granitic residuum and interbedded with clastic sedimentary rocks at the base of the Matinenda formation.

HURONIAN STRATIGRAPHY

General Statement

The Proterozoic sedimentary rocks of the north shore of Lake Huron region were divided by Collins (1925) into a lower, Bruce series, and an upper series which he correlated with the Cobalt series of the Cobalt district and which he believed to overlie the Bruce series unconformably. He divided the Bruce series, from bottom to top, into: the Mississagi formation, mainly quartzite; the Bruce boulder conglomerate; the Espanola formation, limestone and greywacke; and the Serpent quartzite formation. Type localities were not established for these formations, but Quirke Lake was one of the most important localities where details in the succession were studied.

Numerous drill-holes have now provided much more detailed information on the succession than was obtainable from the original surface mapping. It is desirable to redefine some of the stratigraphic units in the light of this new data. The importance of stratigraphic correlations in exploration for uranium ore makes it desirable that certain natural formational units in the lower part of the sequence be formally recognized and named.

Figure 2 shows the stratigraphic sequence, variations in the sequence between the north and south sides of the belt, and a proposed new system of nomenclature. The sequence shows a cyclic repetition of boulder conglomerate layers, each overlain by fine-grained sedimentary rocks which are in turn overlain by coarse-grained clastic sedimentary rocks. The bases of the boulder conglomerate layers are the sharpest of sedimentary contacts and the assemblages of formations between these particular contacts form natural groups which must have genetic significance.

The most important change in terminology here proposed is that the Mississagi unit be elevated from formational rank to group rank and that its base be defined to be the base of the lowermost boulder conglomerate. Newly-defined formational units are tentatively given names of lakes where there are prominent outcrops of these formations. It is suggested, however, that the type sections for the various formations be taken from representative drill-hole intersections and that an effort be made to preserve the type core sections.

Group A - "Elliot" Group

The lowermost group (A) of Proterozoic rocks, tentatively called the "Elliot" group, includes formations which unconformably overlie pre-Huronian rocks and underlie the lowermost boulder conglomerate. The group is up to 950 feet thick along the south flank of the syncline but thins in a northerly direction and is absent in most places along the north flank.

Matinenda Formation

The Matinenda formation comprises the basal and major part of the Elliot group. It is composed of coarse-grained, poorly-bedded clastic rocks, including: quartz grit, feldspathic quartzite, arkose, and quartz-pebble conglomerate. Variations in grain size and degree of sorting, and thin partings of sericitic siltstone show the bedded character of the rock. Beds are discontinuous and lenticular, from a few inches to 3 feet thick, and typically show torrential crossbedding. The primary dip of this crossbedding is, almost without exception, to the east, southeast or south, and shows that the direction of transport of the sediments was from the northwest toward the southeast. Small channels, scoured in the sediments and subsequently backfilled with crossbedded sediments, are common.

The rocks contain little or no authigenic cement. Interstices between quartz and feldspar grains are filled with smaller clastic particles of these minerals and with sericite and some chlorite.

The character of the lowermost rocks varies from place to place. In some places, a basal conglomerate is present. This may be a single layer of greenstone or 'argillite' pebbles. More rarely, as under the northwest part of Quirke Lake, a thick bed of arkosic polymictic (mixed) conglomerate may be present. This rock consists of pebbles and cobbles of quartz, greenstone and, more rarely, granite in an arkosic matrix. In many places, either quartz-pebble conglomerate or arkosic grit with scattered quartz pebbles rests directly on the basement rocks or on residuum derived from basement rocks. Massive, fine-grained, light grey feldspathic quartzite is another rock type found at the base of the formation in many places.

Quartz-pebble conglomerate beds are most abundant near the base of the formation, in most places. Individual beds vary from layers of single pebbles to beds up to 3 feet or more in thickness. They show all degrees of sorting; pebbles may be widely scattered and of various sizes, or closely packed and closely sized within well defined conglomerate beds. The matrix between pebbles, however, is generally poorly sorted. Conglomeratic zones, consisting of interbedded conglomerate, conglomeratic quartzite and quartzite, may be up to 100 feet thick. In some places, there are two or more such conglomeratic zones. These may be separated by as much as 200 feet of quartzite that contains few conglomerate beds.

The upper part of the formation grades upward and laterally to the southeast into a massive, medium-grained, white feldspathic quartzite. This member in turn grades upward and laterally into the Nordic formation.

The Matinenda formation shows pronounced local variations in thickness as well as a general regional thickening from north to south (0 to 700 feet). These local variations in thickness are believed to reflect the original topography of the pre-Huronian surface. The thicker parts are interpreted as representing filled valleys, while adjacent thinner portions overlie hills and ridges on the buried pre-Huronian surface. Isopach maps show these valleys and ridges to have a southeasterly trend, parallel to the direction of transport as shown by crossbedding. The formation is clearly of alluvial origin.

The pronounced radioactivity of the Matinenda formation is apparently due mainly to monazite. The intensity of this radioactivity in the various rocks shows a very close correlation with coarseness of grain size and abundance of pyrite. Closely packed quartz-pebble conglomerate is particularly pyritic and radioactive with the radioactivity commonly due to disseminated high-grade uranium minerals -- 'brannerite', uraninite, and 'thucholite' -- as well as due to thorium in the ubiquitous monazite. The thickest, most closely packed, and most uraniferous conglomerate beds are found in relatively thick parts of the formation. That is, within or overlying pre-Huronian 'valleys'. Beds of conglomerate are almost entirely lacking in places where the formation is relatively thin and possibilities of finding ore deposits in such places are very poor.

Nordic Formation

The Nordic formation consists of interbedded subgreywacke quartzite, greywacke, siltstone, and argillite. The contact between it and the underlying Matinenda formation is gradational. The two formations interfinger through a transition zone which is up to 100 feet thick. To obtain data on the thickness of the Matinenda formation for isopach maps, it is necessary to be consistent in choosing the position of this contact. The writer arbitrarily places it at the horizon above which greywacke beds are thicker than the intervening quartzite layers.

The Nordic formation is up to 350 feet thick in the southern part of the area; it is absent in the north. It was apparently deposited in deep water at the same time as alluvial sediments were being laid down farther north and thus represents a deep-water facies of the Matinenda formation.

Group B - "Mississagi" Group

Group B - the "Mississagi" group - includes all formations between the base of the lowermost boulder conglomerate layer and the base of the Bruce conglomerate. The group thickens from north to south from a minimum of 650 feet at Quirke Lake to about 2, 300 feet in the south part of the sector. It is subdivisible into a lower formation - the "Whiskey" formation of interbedded argillite, siltstone and greywacke, and an upper formation -- the "Ten Mile" formation -- which consists mainly of feldspathic quartzite. The contact between the two is gradational.

Whiskey Formation

The Whiskey formation has a very distinctive and continuous basal member of conglomeratic greywacke, which contains rounded to angular pebbles, cobbles and boulders of granite, greenstone and other rocks. It is the most useful horizon marker within the lower part of the Huronian succession. In the southern part of the area it overlies the Nordic formation; farther north it overlies the Matinenda formation; along the north shore of Quirke Lake, it directly overlies the basement rocks. This polymictic conglomerate is very similar to the Bruce conglomerate and to conglomerate in the Gowganda formation. It varies in thickness from a few inches to about 200 feet. It is thinnest where it overlies the Algom-Quirke and Consolidated Denison ore zone. In the Quirke Lake area, thickest sections have been found overlying relatively thin and barren sections of the Matinenda formation. The conglomerate varies in character and in some places is difficult to recognize in drill core. Locally, rounded to angular boulders, some of them up to 3 feet in diameter, are closely spaced in a siltstone matrix. Elsewhere granite and greenstone pebbles and cobbles are sparsely distributed in a coarse-grained greywacke that contains abundant small quartz pebbles. The base of the member, or even the entire member, where it is thin, commonly consists of quartz-pebble conglomerate or grit with a highly sericitic dark green greywacke matrix. This rock contains disseminated pyrite and is slightly radioactive. South of Flying Goose Lake, thick sections of the boulder conglomerate member show crude banding and contain interbedded layers of massive greywacke, siltstone, subgreywacke and quartzite.

The argillite-greywacke member of the Whiskey formation consists of interbedded layers of argillite, siltstone, greywacke, subgreywacke, and minor grey feldspathic quartzite. In the Quirke Lake area, the lowermost part of the sequence is predominantly argillite, the central part laminated siltstone and greywacke with graded bedding, and the upper part interbedded greywacke and quartzite. In the southern part of the area, the sequence from bottom to top shows the following general pattern: predominantly argillite; predominantly greywacke with some quartzite beds; interbedded argillite, siltstone, and greywacke; and interbedded greywacke and quartzite. North of North Nordic Lake, outcrops of conglomerate or breccia are found near the top of the Whiskey formation. This rock has not been recognized in drill core and is apparently very limited in extent. It may be a tectonic breccia rather than a conglomerate.

The thickness of the Whiskey formation varies from about 100 feet at the Quirke mine to about 800 feet in the southern part of the area, with an average rate of thickening of about 100 feet per mile.

Ten Mile Formation

The Ten Mile formation is composed mainly of coarse-grained feldspathic quartzite. It is very similar to the Matinenda formation but is finer grained, less feldspathic, and better bedded. Most outcrops show torrential crossbedding with primary dips to the southeast showing that the direction of transport of sediments was from the northwest towards the southeast, similar to that of the Matinenda formation. Ripple-marks were noted in several places.

The formation is about 500 to 600 feet thick at the Quirke mine and at the north part of Quirke Lake, about 700 to 800 feet under the Consolidated Denison property, 900 to 1,200 feet thick under the central and southern part of Quirke Lake, 1,500 feet thick at May Lake and between Quirke Lake and McCabo Lake, and about 1,800 feet thick northeast of Elliot Lake. It thickens southward at a rate of about 250 feet per mile. It also becomes finer grained in this direction. Zones of coarse-grained, greenish quartzite containing thin beds of radioactive pyritic quartz-pebble conglomerate present near the bottom and top of the formation at Quirke Lake are absent farther south. Subgreywacke, greywacke, and argillite bands, which are present only in the central part of the formation at Quirke Lake, are abundant throughout the formation farther south.

Group C - "Quirke" Group

The "Quirke" group includes the Bruce conglomerate, the Espanola formation, and the Serpent formation. This group of formations, underlain by quartzite and overlain by boulder conglomerate forms a very distinctive sequence of rocks. Almost identical rock sequences are found in other widely separated parts of the north shore of Lake Huron region. Lithological correlations of these rocks with the Quirke group can be made with considerable confidence.

Bruce Conglomerate

The Bruce conglomerate is a polymictic boulder conglomerate containing rounded to subangular pebbles, cobbles, and boulders of light grey granite, greenstone, and other igneous and metamorphic rocks in a dark grey, medium-grained, quartzose greywacke matrix. It is very similar to the boulder conglomerate at the base of the Whiskey formation but is thicker in most places and more uniform in character. The contact between the Bruce conglomerate and the underlying Ten Mile formation is sharp in most places. The largest and most closely packed boulders, some of them up to 3 feet in diameter, are near the base of the formation. Commonly, there is a zone near the middle of the formation, containing only very sparsely distributed pebbles in greywacke that may show faint banding. Banded, pebble-free greywacke is also fairly common at the base and top of the formation. The matrix in the upper part of the formation is slightly calcareous. The Bruce conglomerate varies from about 60 feet to about 200 feet in thickness.

Espanola Formation

The Espanola formation is subdivided into three members. From lowest to highest, these are the Bruce limestone, the Espanola greywacke and the Espanola limestone.

The Bruce limestone is composed of banded, white limestone with thin partings of green siltstone. The rock is commonly crenulated and is very distinctive in appearance both in outcrops and in drill cores. The limestone grades into laminated calcareous greywacke at the top and bottom of the member. It is from 100 to 200 feet thick.

The Espanola greywacke is an assemblage of interbedded greywacke, siltstone, calcareous greywacke and calcareous siltstone. The lowermost 100 feet or so is a massive, fine-grained, dark coloured greywacke that is not very calcareous. Granules and small pebbles of quartz, feldspar, granite, greenstone, and argillite were noted locally near the top of the massive greywacke. This greywacke grades upward into interbedded calcareous siltstone and greywacke that is commonly brecciated.

Ripple-marks are common in the upper part of the member and in the overlying Espanola limestone. Most of these are oriented in an easterly or northeasterly direction.

The Espanola limestone consists of interbedded sandy limestone, calcareous siltstone, and dark grey, rusty weathering dolomite. The member is readily recognized in outcrops by the presence of layers of this rusty-weathering dolomite. In drill cores, it can be separated from the greywacke member only by its higher lime content and the presence of thin, hard, dark olive-green layers.

The total thickness of the Espanola formation is, in most places, 500 to 750 feet, but north of Elliot Lake the entire formation consists of only about 75 feet of white limestone.

Serpent Formation

The Serpent formation is composed of well-bedded, finely laminated, medium-grained feldspathic quartzite, with a characteristic dull white colour on weathered surfaces. The contact between Espanola limestone and Serpent quartzite is gradational, the Espanola limestone grading upward into a calcareous quartzite.

The Serpent quartzite is finer grained, better sorted, and more uniform in character than the Ten Mile quartzite. It also differs from the Ten Mile quartzite in that overgrowths on quartz grains and interstitial carbonate are commonly present. No radioactivity perceptibly above normal background has been noted in the Serpent quartzite.

The Serpent formation shows crossbedding in many places. This crossbedding generally is gently inclined to the major bedding and, for the most part, is not of the torrential type like that in the Ten Mile formation.

Pebble beds, most of them only one pebble thick, containing quartz, chert and granite pebbles are present in some sections at intervals through the formation. Conglomerate beds, of considerable thickness, containing granite pebbles and, rarely, cobbles in a quartzite or greywacke matrix are found in some places near the top of the formation.

There is little data on the thickness of the Serpent formation as only a few drill-holes have cut it from top to bottom. Most of these are south of Quirke Lake where the thickness varies from nearly 900 feet to about 400 feet. It is very thin near the west shore of Quirke Lake and north of Elliot Lake the formation is missing or extremely thin.

Group D - "Dunlop" Group

In order to maintain consistency in the system of nomenclature used in this report, the Gowganda formation together with quartzite formations that overlie the Gowganda in other areas are tentatively called the "Dunlop" group rather than the Cobalt series.

Gowganda Formation

The Gowganda formation is a heterogeneous assemblage of polymictic conglomerate, conglomeratic greywacke and siltstone, argillite, arkose and quartzite. The conglomeratic rock types, which characterize the formation, are very similar to the Whiskey boulder conglomerate, the Bruce conglomerate and other much less extensive conglomeratic layers found locally in the Espanola formation and in the Serpent formation. They contain rounded to angular rock fragments of all sizes in a matrix of greywacke or siltstone. This matrix is commonly finer grained and greener in colour than matrices in the lower conglomerates. Another difference is that granitic fragments in the Gowganda formation are generally pink, whereas those in the Bruce and Whiskey conglomerates are almost invariably grey.

The relations of the Gowganda formation to underlying formations of the Quirke group appear to be contradictory, in some places suggesting disconformity, elsewhere conformity.

The Quirke group where it underlies the Gowganda formation at Quirke Lake is up to 1,800 feet thick but near Elliot Lake it is only 125 feet thick. Nearly 1,700 feet of strata present at Quirke Lake, including the Serpent quartzite and all but the basal section of the Espanola formation, may be missing at Elliot Lake. Collins concluded that this 1,700 feet of strata were removed by erosion prior to deposition of the Gowganda formation, and that an important unconformity therefore existed between the Bruce and Cobalt series (Collins, 1925).

The basal layer of the Gowganda formation consists of well packed, faintly stratified, pebble or cobble conglomerate. The contact between this rock and the underlying Serpent quartzite is very sharp in many places. On an island in Ten Mile Lake, bedding or crossbedding in the underlying quartzite appears to be truncated by the overlying Gowganda formation. Angular blocks of quartzite and siltstone were noted in several places in the basal layer of the Gowganda formation.

The above features can be interpreted as evidence that an erosional unconformity is present at the base of the Gowganda formation, but apparent gradational contacts between the Gowganda formation and the Serpent formation in many places lend some element of doubt as to whether this unconformity is an important one. For example, south of Quirke Lake this contact is a thick zone containing interbedded quartzite and conglomerate. It is difficult to draw any definite boundary between the two formations. This relationship suggests an interfingering contact rather than an unconformity and is incompatible with the concept of a regional erosional break between the Bruce series and Cobalt series

Uplift and erosion of the Quirke group may have taken place locally prior to deposition of the Gowganda formation, but it also seems possible that sedimentation was essentially continuous over the whole area and that the strata apparently missing at Elliot Lake (or at least a large part of it) were never deposited in this section. It is hoped that further studies will resolve this problem.

INTRUSIVE ROCKS

Diabase

The Huronian and older rocks are intruded by numerous dykes and sill-like bodies of diabase. The larger sill-like bodies are up to 500 feet thick. Their structure is difficult to work out in detail but most intrusive contacts appear to dip slightly steeper than the bedding of the Huronian rocks. A large body, or compound intrusive, of diabase east of Quirke Lake appears to dip more gently than the bedding.

Most of the dykes are less than 100 feet thick and dip steeply. Many of them strike northwest and dip steeply north-east, parallel to an important set of faults. Others strike east-west.

Granophyre dykelets and segregations are common in some of the larger diabase bodies. At Rawhide Lake, about 9 miles north of the Quirke Lake-Elliot Lake area, small granophyre masses within a thick diabase sill contain abundant disseminated chalcopyrite and appreciable amounts of uranium. A similar occurrence has been found near Cobre Lake about 6 miles west of Rawhide Lake.

Intrusive bodies of diabase have not greatly altered adjacent wall-rocks. Quartzite may have a bleached appearance through a few feet next to a diabase dyke and may contain a little magnetite. Where diabase dykes cut ore zones, there is no obvious change in the tenor of the ore near the dykes.

Contacts of diabase dykes are commonly sheared. Many of the dykes may have been intruded along faults that have had later movements.

A number of small copper deposits have been found near Whiskey Lake closely associated with diabase dykes.

Lamprophyre

Thin lamprophyre dykes were noted in drill core, in all rock types.

Younger Granite

Younger or Killarnean granite is not known to occur within the Quirke Lake-Elliot Lake area. The closest known bodies of younger granite are the Cutler Batholith about 13 miles south of Elliot Lake and the Birch Lake granite about 25 miles to the east.

STRUCTURAL GEOLOGY

The form of the major Quirke Lake-Elliot Lake syncline has already been described. No important second-order folds have been outlined in the area.

Small-scale crumpling and brecciation is very common within incompetent rocks, particularly the Whiskey formation argillite and the Espanola formation (complex crenulation is characteristic of the Bruce limestone member of the Espanola formation). These features were probably formed by slumping prior to complete consolidation of the sediments.

Small drag-folds, cleavage which dips more steeply than bedding, and reverse faults with small displacements are also present within incompetent formations and were probably formed during the folding of the major syncline.

The more competent clastic sedimentary rocks have been deformed cataclastically. The following effects of such deformation in varying degrees of intensity are observable in thin sections: undulatory extinction in quartz grains; marginal granulation and even complete fragmentation of grains; fractures with displacements; rotation of grains; comminution of matrix material in grit and conglomerate. The crushed rocks have been rehealed by secondary quartz, mica and other minerals. Serrated boundaries between grains and granular texture within quartz pebbles (giving the pebble the false appearance of a pebble of quartzite) are common. The effects of cataclastic deformation are most obvious, if not most intense, within massive, poorly bedded, coarse-grained quartzite, grit and conglomerate in the Matinenda formation.

Bedding plane slips and slip planes which cut across the bedding at low angles (steeper than the bedding) are present in the Matinenda rocks in the Quirke mine. These may prove to be common everywhere in the Matinenda formation but might be most abundant where dips are relatively steep.

An important shallow angle reverse fault has been discovered in the Quirke Lake area by diamond drilling. Its projection to surface can be traced westward from the central part of Quirke Lake to the bend in the Serpent River. It dips about 30 degrees south (5 to 10 degrees steeper than the bedding) and flattens down dip (as does the bedding). Along a zone extending under Quirke Lake between the Spanish American and Can Met properties, the fault is within the Matinenda formation and causes repetitions of horizons (including quartz-pebble conglomerate beds) within this formation. It is not known whether the fault penetrates the basement rocks or not. If it does, the basement rocks at the line of penetration would be thrust up over a narrow wedge of Lower Matinenda rocks, precisely as the Matinenda formation is thrust over part of the Whiskey formation, the Whiskey over the Ten Mile, the Ten Mile over the Bruce conglomerate and so on at successively higher levels along the fault plane. Such repetitions of stratigraphic horizons in individual drill-holes establish the existence, extent, and attitude of the fault and incidentally illustrate the value of careful study of drill core within higher formations as well as within the ore-bearing Lower Mississagi formation. In Consolidated Denison drill-holes, the vertical separation of any given horizon at the fualt is 150 to 400 feet; in Spanish American holes, 90 to 200 feet. In both these areas, the overlap of any given horizon repeated on this fault is in the order of 800 to 1,600 feet. Displacement along the fault decreases towards the east.

There may be other important shallow-dipping reverse faults in the area. Repetitions of sections of the Whiskey formation are indicated in a drill-hole between Ouellette Lake and May Lake. There are also several repetitions of Bruce conglomerate, Bruce limestone and Espanola greywacke contacts in a hole at May Lake. Some of these repetitions might be due to folding or to steeply-dipping reverse faults.

Three general sets of steeply-dipping faults can be recognized in the area. These are: northwest-trending faults, north and northeast-trending faults, and east-west trending faults. Northwest-trending faults and lineaments which probably indicate faults are the most numerous and have the greatest displacements. One near Elliot Lake has an apparent displacement of about 400 feet with the northeast side moved down relative to the southwest side. Other less important northwest-trending faults, along the north shore of Quirke Lake and one in the Quirke mine show small displacements in this same sense, but there are some which have opposite displacements. Apparent displacements on northerly-trending faults are conflicting. Minor east-west trending faults with displacements of from less than one inch to 2 feet were noted in several places along the shores of Quirke Lake. The south side has moved down relative to the north side along these faults. Drill hole data in the western part of Consolidated Denison property suggest the presence of an important easterly-trending fault the north side of which is displaced down with respect to the south side.

URANIUM DEPOSITS

General Distribution and Character

Most of the uranium ore discovered to date in the area is within two separate "valley" structures or zones of abnormal thickness of the Matinenda formation. One of these "valley" structures extends southwestward from the Algom-Quirke mine and contains ore deposits along a length of about 5 miles which include the Algom-Quirke deposit, the Consolidated Denison deposit, Spanish American deposit, the Zenmac deposit, the Panel deposit and the Can Met deposit. The other extends northwestward from Algom's Nordic mine and contains ore deposits along a kncwn length of about 4 miles, including the Nordic deposit, the Lake Nordic deposit, the Milliken Lake deposit, and the Stanleigh deposit.

Thicknesses of ore zones are about 10 feet in most places but thicker sections are common and individual ore sections up to 32 feet thick have been reported. The ore deposits most typically consist of interlayered beds, 1 foot to 3 feet thick, of quartz-pebble conglomerate, conglomeratic quartzite, and pebble-free quartzite. Careful sampling is required to determine the thickness of rocks in the conglomeratic zone that can be economically mined. Some of the highly pyritic conglomerate layers contain several tenths of one per cent U_3O_8, and rare seams, a fraction of an inch thick, may contain up to several per cent U_3O_8. Conglomeratic quartzite contains much less uranium than highly pyritic conglomerate with closely packed pebbles, and pebble-free quartzite contains only very small amounts of uranium.

The ratio of thorium to uranium varies widely. In quartzite and pebbly quartzites it is as high as 3 to 1. In most ore deposits it is less than 1 to 1, and some uranium-rich conglomerate beds contain very little thorium. In general, pyrite content, uranium content and thorium content all show close relationships to sedimentary features but no clear relationships to structural features such as: folds, faults, or contacts of diabase dykes. Places have been discovered, however, where uranium values appear to cut across sedimentary rocks, and where rocks not normally very radioactive contain ore where they are in contact with rich conglomerate.

Description of Uraniferous Pyritic Quartz-Pebble Conglomerate

The ore conglomerate contains pebbles of quartz, a few chert and jasper pebbles, and, very rarely, pebbles of argillite, greenstone, and granite. Pebbles are from 1/4 inch to 2 inches in diameter, and are fairly well sized within individual layers. They are moderately rounded and, in the richest conglomerates, are tightly packed. The matrix contains abundant grains of pyrite, poorly-sorted granules and silt-size particles of quartz and feldspar, small plates of muscovite, sericite, chlorite and epidote.

The poorly sorted matrix of the conglomerate was probably not greatly modified by diagenetic processes. Secondary quartz is found at the rims of some quartz pebbles. Overgrowths are found on a few quartz and feldspar grains and a little carbonate is present in the matrix of some conglomerate samples. It is difficult, however, to distinguish between secondary minerals of authogenic origin and those related to later metamorphism and hydrothermal alteration.

The conglomerates and adjacent rocks have been markedly deformed, probably concomitantly with folding and thrust faulting in the Huronian rocks. The effects of such deformation have been described in the section on structural geology. Much of the pyrite has clearly crystallized or has been recrystallized subsequently to the deformation. Some of the uranium mineralization is also post-deformation in age. A highly pyritic sample from the Can Met property contains abundant chlorite which evidently replaced comminuted material in the matrix. Other minerals that appear to have crystallized late in various specimens studied include quartz, carbonate, epidote, titanite and fluorite.

Most of the uranium in the ore is within grains of an amorphous, or metamict, material. This material contains abundant inclusions of anatase and gives an X-ray powder diffraction pattern of anatase; after strong heating, it gives the pattern of brannerite - a uranium titanite - as well as an anatase pattern. This material is therefore referred to as 'brannerite' although it cannot be considered certain that it ever was in the form of crystalline brannerite. The 'brannerite' occurs as discrete rounded grains and also as irregular intergrowths with pyrite.

Uraninite[1] is abundant in some ores and is found as angular to

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[1]The terms pitchblende and uraninite are used by the Geological Survey of Canada to describe the two distinct varieties of uranium oxide which are found in nature, both of which have a UO_2-type crystal structure. Pitchblende contains less than 0.1 per cent of thorium and rare-earth oxides and is the typical urania mineral found in hydrothermal deposits. Uraninite, on the other hand, contains appreciable amounts of thorium and rare-earth oxides (usually more than 1.0 per cent) and is the variety of urania found in pegmatites, migmatites and granites. For further details see discussions by R. J. Traill in Canadian Mining Journal, Volume 75, 1954, page 66 and S. C. Robinson in Geological Survey of Canada Bulletin 31, 1955, page 60.

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subangular grains. Brecciated uraninite grains have been noted (Traill, 1954). 'Thucholite'[2], a uraniferous hydrocarbon, is

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[2]Thucholite is a hydrocarbon of variable composition named by H. V. Ellsworth to indicate its principal constituents, thorium, uranium, carbon, and hydrogen. Reference: American Mineralogist, Volume 13, 1928, pages 409 to 411.

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common along fractures in the ores and also in rocks a considerable distance away from ore conglomerate beds. The pitchblende variety of uraninite has been noted but has not yet been found in samples examined by Traill or the writer (Traill, 1954). Monazite and zircon, abundant in most ore samples, occur as rounded grains of detrital origin. Radioactive epidote (possibly allanite) and radioactive titanite have also been noted.

Marcasite occurs in place of pyrite in some ores. Pyrrhotite and chalcopyrite are common, particularly in conglomerate at the very base of the Matinenda formation. Magnetite has been reported associated with pyrite (Hart, 1955). Cobaltite has also been identified. Galena is fairly common. Molybdenite is found along slip planes in ore and in quartzite remote from ore deposits. Sphalerite is commonly associated with thucholite in veinlets. Trace amounts of gold, silver, chromium, nickel and vanadium are also present in the ores.

Origin

Our knowledge of these deposits is still far too incomplete to allow any forceful advancement of a theory of their genesis. It may be useful, nevertheless, to give a brief summary of the more credible hypotheses of origin which have been advanced.

Those who favour a placer origin suggest that the original quartz-pebble gravels contained hematite, ilmenite, magnetite, rutile, titanite, epidote, pyrite, and other sulphides, monazite, zircon and many other heavy minerals, including uranium minerals (possibly 'brannerite' and uraninite). Subsequent diagenetic and metamorphic processes effected a certain amount of solution, redistribution, and recrystallization of constituents with little change in bulk chemical composition or addition of new elements other than sulphur. Large quantities of the latter are, of course, required to convert iron oxides to pyrite.

The most serious criticism raised against this theory is that uranium minerals, particularly uraninite, are very unstable under weathering conditions and could not possibly have survived to become important constituents of the gravels (Davidson, 1955; Steacy, 1953). The most resistant radioactive minerals, such as monazite, contain much more thorium than uranium. Such minerals are also the most abundant radioactive minerals in most granitic rocks, which most commonly have a thorium-uranium ratio of about 3 to 1. If it be granted for the moment that it is unlikely that there were in the source area any large bodies of rock which contained resistant uranium minerals in greater abundance than thorium minerals, then it seems unlikely that extensive placer deposits which contain more uranium than thorium could have been formed. It is necessary, therefore, to consider possible mechanisms whereby the conglomerates could become enriched in uranium relative to thorium. Hydrothermal solutions or ground water, for example, may have dissolved uranium from adjacent country rocks and re-precipitated it in conglomerate; thorium might, at the same time, have been removed from the conglomerate.

Those who advocate a hydrothermal origin point out that huge quantities of sulphur must have been added to the conglomerates and suggest that the relatively minute quantities of uranium in the conglomerates were introduced in the same manner, probably at the same time and probably from some deep-seated source, rather than from adjacent rocks or from surficial waters.

If this hypothesis is true then it must be explained why the conglomerates were preferred exclusively to all other rocks and structures as hosts for the introduced uranium. Such a preference could be attributed only to a much greater permeability of the conglomerates as compared to other rocks at the time of the postulated uranium mineralization. Prior to consolidation, the quartz-pebble gravel with its poorly-sorted matrix was probably not much more permeable than overlying and underlying sands. It is difficult to speculate how the relative permeabilities of the two rock types might have been changed by diagenesis, by crushing, and by metamorphism.

Most of our present knowledge of these uranium deposits is of a qualitative nature. Quantitative data on mineralogy, chemical composition, structural relationships, ages of mineralization, and so on, may resolve the problem, but a consideration of the length of time that the same problem has been argued in South Africa would warn us against expecting a speedy solution to the problem of origin of the Blind River uranium ores.

Ore Reserves

The Quirke Lake and Elliot Lake zones are estimated by the writer to contain 320,000,000 tons of ore. This is based on the calculations summarized below:

Only those sections that contain 20 pound feet of U_3O_8 are included, that is: 2 pounds per ton (0.10%) U_3O_8 through a thickness of 10 feet, or 1.6 pounds per ton (0.08%) through 12.5 feet etc. Minimum thickness of ore included in the calculations is 10 feet; minimum grade, 0.07%. Continuity of ore is assumed between drill holes that are in some places very widely spaced. The maximum depth of ore included in this estimate is about 3,700 feet near the Stanleigh shafts. None of the potential ore in secondary conglomerate horizons or repeated on thrust faults is included. No allowance is made for ore omissions by diabase dykes or faults, for dilution, or for non-recoverable ore (support pillars, unsatisfactory rock conditions, etc.)

	Surface Area ($ft.^2 \times 10^6$)	Average Thickness	U_3O_8 Content ($lb. \times 10^6$)	Ore Content ($tons \times 10^6$)	Per cent U_3O_8
Quirke	190	15.2 ft.	605	250	0.121
Elliot	68	11.8 ft.	155	70	0.111
Total	258	14.3 ft	760	320	0.119

Mill Capacity (to be completed by 1958)

	Tons per day	
Pronto Uranium Mines	1,500	Mill operation started 1955
Algom Uranium Mines		
Quirke mine	3,000	Mill operation started 1956
Nordic mine	3,000	Mill operation started 1956
Consolidated Denison Uranium mines	5,700	
Can Met Explorations	2,500	
Northspan Uranium Mines		
Lake Nordic mine	4,000	
Panel mine	3,000	
Spanish American mine	2,000	
Stanrock Uranium Mines	3,300	
Stanleigh Uranium Mining Corp.	3,000	
Milliken Lake Uranium Mines	3,000	
	34,000	