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THE LEAD ZINC DEPOSITS OF RICHMOND GULF

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THE LEAD ZINC DEPOSITS OF RICHMOND GULF

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by

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of the requirements for the degree of
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INTRODUCTION

GENERAL STATEMENT.

The writer spent the field seasons of 1947 and 1948 in the Richmond Gulf, and the Manitounuk sound area on the East Coast of Hudson's Bay engaged in geological field work and prospecting.

This present work is an attempt to use aerial photographic survey of the area in conjunction with the writer's Notes, previous work done by other more experienced geologists in order to ascertain what, if any, is the relationship between structure, known granite rocks, stock and bosses which are considered to be intrusive to the lead zinc deposits of the Area.

LOCATION ACCESS AND CHARACTER OF THE AREA

The area under consideration is midway up the east coast of Hudson's Bay in Lat. $56^{\circ}24'$ and Long. $77^{\circ}30'$ some 460 miles north of Moosonee Ontario the nearest railhead.

The area is accessible by seaworthy small craft, ships, of any size and aircraft, the only limiting factor being weather conditions. The nearest settlement of any importance where supplies in quantity may be obtained is Great White River some 60 miles south of the entrance to Richmond Gulf. A small trader maintains a store at the head of Richmond Gulf on the Wiachewan River.

The coast and inland mountains throughout the area are picturesque in the Extreme. A high mountain range some 20 miles inland which are presumed to be composed of granites of unknown age and quartzites and arkosic rocks of the Huronian series. Nearer the sea a series of flat lying sediments dip 10° seaward with a cuesta of approximately 1600

feet in height facing to the land mass. This cuesta has been eaten into by erosion and long draws or valleys break through to the sea. These valleys do not rise much more than 500 feet above sea level, thus giving a series of capes or heads facing inland.

To the south, from Great Whale River for some 30 miles northward the cuesta valley has been invaded by the sea and this has produced a series of islands with cliffs facing towards the mainland, the low hills and beaches facing seaward.

Inland and in the valleys spruce is fairly heavy with some butts coming up to 10' in diameter, no other timber is encountered. Game is scarce. Although ptarmigan are obtainable throughout the summer, with geese and ducks in late September and October.

The Eskimos are to be found at various camp sites in the area. They are intelligent, helpful and willing workers.

EARLY GEOLOGICAL EXPLORATION

While the coast is part of the oldest known area in Canada scientific exploration has been very limited. The Hudson's Bay Company established a post at Little Whale River in the mid 1800's in order to pick up the Eskimo trade north of the Indian Country, and it was through the original curiosity of the managers at this post that the lead zinc deposits were brought to the attention of the late Dr. Bell who in 1877 made the first Geological Survey of the area. Ten years later A.P. Low reported on the area, later following this work by a traverse from Richmond Gulf to Ungava Bay in 1896, and finally completing his work in New Quebec, then the Northeast Territories, with a field trip down the east

coast of Hudson Bay in 1900.

Low in his report of iron ores of the Nastapoka Islands aroused interest in the steel industry of the United States, this led to a further investigation by C.K. Leith who in 1910 investigated and explored the coast and islands from Cape Jones to Cape Dufferin.

E.S. Moore visited the area in 1918 on his way out to the Belcher Islands but since that time until 1947 when Dr. E.H. Krancke made a short stay in the Manitounuk Sound area no further geological investigation has been done.

The lead zinc deposits in the area have been prospected, staked and investigated by many groups. Stakes dating as far back as 1877 have been found, however reports and literature concerning this are nearly nonexistent.

PRESENT DAY INVESTIGATION

In June 1942 the company which is at present attempting to exploit the area was formed. This organization obtained a concession from the Quebec Government undertaking to carry out the necessary work to hold the concession in good standing. The president and engineer in charge at the time of the operation, realizing that owing to the size of the concession that mapping and surveying by transit would be too slow and expensive, authorized an aerial survey of the property. This was done by A.E. Simpson and Company of Montreal, and carried out on Aug. 1st. 1946. Using a Norseman IV plane equipped with Fairchild 14" focal length aerial camera, with the plane flying at 14000 ft., the survey was completed in 1 day. The flight was made in 7 lines, each line being 35 miles long, the photographs themselves being on a scale of 1200 ft. to the inch. These were later reduced to 1320 ft. to the inch

and incorporated into a folio of 11 large photomaps 18" x 20". These photomaps were later used as a basis for making geological maps, sample maps, and survey maps for drill holes. The detail was such that a scale of 1000' to an inch for a grid allowed conspicuous points to be easily picked up and plotted.

It is from these base photomaps that the plotting of faults and other local structure has been done onto the kodatrace map herewith appended.

Further to the aerial survey the development company carried out considerable detailed prospecting and sampling, all samples being assayed for lead zinc and silver. During the summer of 1948, 42,000 feet of diamond drilling was completed in 3 widely separated areas. In all cases this drilling took place along and near to areas of faulting or fracturing, All cores were sampled and assayed for lead and zinc.

During the summer of 1947 Dr. E.H. Krancke carried out his investigation of the geomorphology of the region. This paper as yet unpublished while dealing with the entire east coast of Hudson Bay has several interesting observations on the area in question.

METHODS OF INVESTIGATION

Photogeology

It is from a small pamphlet published by the photographic Survey Company of Toronto with headquarters at De Haviland Field and other information obtained from Professor K.B. Jackson (Professor of Photogrametry) and Professor T. Wilson (Proffesor of Geophysics) that the writer's idea and

and information have been originally drawn, regarding the interpretation of photographs.

The use of aerial photography in preliminary geological investigations of inaccessible and unsurveyed areas is becoming more important as the search for mineral deposits gets away from easy avenues of access to the Hinterland such as rivers and railroads.

In areas of scanty vegetation, and this particularly applies to the hills and shoreline in and around Richmond Gulf, photography can be used any time of the year. Needless to say when vegetation is abundant spring and late fall are the best periods.

It is from photographs taken when outcrops are bare of vegetation that differentiation of rock types can be detected, foliation lineation, and faults can also be easily picked up by means of a good stereoscope. Detailed features such as small outcrops, minor faults, dikes and contacts in rock outcrops can only be seen if the outcrop is entirely bare of vegetation.

In choosing scale, which in this case was not under the control of the writer, both detail and stereoscopic relief must be considered. The Engineer may welcome 3000 feet to an inch, however on this scale the geologist loses detail. Under a stereoscope, photography made with a 14 inch lense has not as much topographical detail as that made with a 6 inch lense on the same horizontal scale. The extra relief gained by using a 6 inch lense is helpful in that outcrops stand out more clearly and eroded fault lines along slight gullies are more noticeable.

Enlargements have a definite place in consideration of photographic scales. It is possible to enlarge photographs $2\frac{1}{2}$ times scale without much change in definition. Beyond this lack of definition is a definite hindrance to geological interpretation. Resolution does not improve with enlargement but remains the same.

Normally a photo geology map of 1000 ft. = 1 inch is made first by making a lay down mosaic of 1000 = 1 inch photographs, using alternate prints. A very transparent plastic tracing paper (kodatrace) is then placed over the mosaic and by use of alternate prints not included in the mosaic a stereoscopic examination is carried out. Geographical detail and geological detail can then be drawn directly onto the (kodatrace). This is the simplest method. A modification of this method was used by the writer. The "kodatrace" was placed over the 1320' = 1 inch photomap and the area examined with a magnifying glass. The two photographs representing the area to be examined were placed a few inches from the detail being examined and viewed stereoscopically. This allowed the stereographic projection to be examined from all directions. It was found that the favoured direction for discerning detail varied from stereographic pair to pair. The detail, faults, foliation and bedding discovered on the stereo pairs were then traced onto the kodatrace covering the master photomap, which showed the same detail on a slightly smaller scale. Since the examination of the aerial photographs was primarily for faults, joints, and fractures this method proved very convenient. It should be noted here that glaciation has stripped the high land bare thus making the recognition of faults and joints relatively easy. Since only the rock

types (groups) seen in the area are those the writer knows exactly, and recognizes precisely where they outcrop, recognition of these groups from photographs alone was not attempted too seriously. It being felt that to state groups were recognized from the photographs when their aerial position was already known would not be strictly true. The above method is only good for vertical photographs and the larger the scale the better. Obliques of the same area if in sufficient quantity would have been of very great use in determining major features such as lineaments. No obliques have been taken of the Richmond Gulf area. It is however probable that obliques in the Richmond Gulf area would not have revealed very much since they in general can only be applied to the search for major lineaments over very large areas.

The following an excerpt from " Geological Air Survey" - G.W. Rooney part III "exploration", describes the uses of Aerial Surveys very well. "In exploration work the wealth of geological and topographical information which is immediately available from stereoscopic air photographs can be of great assistance in localizing the search for ore. By ground prospecting alone, acquisition of sufficient reconnaissance information may take months of exhausting and tedious work, necessitating the dispersal of valuable men and material with too often inconclusive results. -- De -- tailed mapping of mine properties is another most useful application of air survey to geological work "...The first stage in development of mining claims should be the preparation of a suitable base map showing all geological detail for the ensuing program of surface surveys and drilling programmes." It is with this latter thought in mind that

parts of this thesis have been attempted.

Recognition of Detail

In the detailed examination of the photographs taken in the far Worth the following can always be seen.

- 1) Bare rock
- 2) Partially covered rock
- 3) Covered areas (drift covered)

Each of the above three should be examined and in the case of (1) bare rock, the following can usually be clearly discerned.

- a) Bed Rock Features: Such as contacts, Joints, glacial striae. Bedding and strike of bedding.
- b) Dykes, pegmatites
- c) Intrusives in the major of mass of Bed Rocks.

In the case of partially covered areas (2) the following can usually be seen.

- a) Drift:- Features such as direction of glaciation
- b) Raised Beaches, Eskers, Moraines, etc.

And finally in the case of the completely covered areas linears which show through the drift can often be seen. These linears may be due to:

- a) Faults
- b) Foliation
- c) Glacial Features

By plotting the pattern of the linears, significant information about a region may sometimes be obtained.

It is by the careful plotting of all information

contained in sections 1, 2, and 3, when dealing with fault pattern and fractures can any information of any importance be obtained. A fracture pattern may develop which may be particularly significant to the ore deposition in the region under study, It is the writer's firm belief that this is particularly true of the Richmond Gulf area.

In the study of faults and joints, with aerial photographs, the relationship of the different types of faults to directions of pressure must be firmly grasped. Since in most cases it is impossible to determine the dip of a fault or joint from a stereoscopic examination the forms or shape and direction a fault takes must be related to the pressure direction. Definition of faults and the reason for these occurrences are wide and varying. A different term often being used for the same type of fault. However in 1942 Anderson published a very lucid account of the physical reasons for the 3 types of faulting and it is from this book that many ideas have been obtained.

Theory of Faulting - Anderson

Any stress acting at a point may be replaced by three equivalent but mutually perpendicular principal stresses. At each point there are 3 mutually orthogonal planes that includes two axes of principal stress each. These are the planes across which the normal stress act and across which no tangential forces act. (That is they are planes of no shear) the surface of the ground is obviously a plane of no shear since the shearing effects of wind and water are negligible. Thus ^{at} any point near to the ground surface at the time the ores acted the stress ellipsoid could only

have been oriented with one of these three planes parallel to the ground surface and this with either the major intermediate or minor axes of stress approximately vertical.

At each point there are two planes across which no normal stresses act and across which tangential stress is a maximum. Thus planes of maximum tangential stress bisect the right angles between the major and minor axes and include the intermediate axis.

When shear failure occurs in rocks it does not exactly follow the 45° planes of maximum tangential stress because failure depends upon normal stress across the plane of failure as well as upon tangential stress. Pressure across a plane tends to make shear failure less likely along the plane and in these circumstances it can be shown that in rocks shear failure, that is faults, make angles of about 25° - 35° rather than 45° with the direction of the maximum pressure.

In 1833 Navier suggested that this effect of normal stress upon shear failure is a constant for any material, although this is not precisely true Anderson does show that it is a satisfactory approximation and that in rocks shear failure, that is faults, make angles of 25° - 35° rather than 45° with the direction of maximum pressure.

In recognition of directions of force from faults and linear, Anderson's observations as summed up below are extremely helpful.

This suggests a means of identifying regional faults and the direction of pressure which causes them and can probably be applied to minor faults and fault patterns.

Anderson concludes that linears of thrust faults should be curved and normal to the pressure that caused them, trans-current faults (strike faults) should be straight and make angles of 25° - 35° to the pressure that forms them. (max. press. axis), while normal faults dip steeply and have a wavy intersection with the surface though not as wavy as a thrust fault.

Up to the present the word linear has been used frequently and will be used again in this paper. According to Wilson the word linear is to be used to denote a topographical line such as a valley, scarp, stream, river bank, or depression which may be straight or gently curving. Nearly every photograph shows such features. Their existence is seldom completely hidden by a covering of drift, and the pattern has been found frequently to suggest their common cause be it from foliation, faulting or glaciation.

Temperature Determination

Two other methods pioneered by Dr. F.G. Smith were used to investigate this problem. These deserve some description.

The geopyrothermometer a device which measures the absolute temperature of deposition of pyrite in an ore deposit and the "popping" or decrepitation method of obtaining the relative temperature of deposition of minerals in an ore deposit.

Both methods were used. Methods, use, and technique are more fully described in Economic Geology No. 8, 1948. (See Bibliography). Polished sections of ore minerals together with Dr. Smith's decrepitation methods have been combined to make a preliminary determination of the paragenesis of the common minerals and gangue.

GEOLOGY

General Geology

Cape Jones - Portland Promontory between Cape Jones and Portland Promontory the coast is remarkably smooth, forming a great semicircle of which certain stretches are sheltered by a single row of islands. A detailed and interesting report of this area is contained in a paper not yet published by E.N.Krancke some "Geomorphological Problems on the East Coast of Hudson's Bay ". The topography is everywhere the same. Steep cliffs facing the land, gently dipping slopes towards the sea.

The most interesting feature of the coast is a series of unmetarmorphosed sediments with sills and basaltic flows which fringe the edge of the granitic (?) masses of the Quebec mainland. The sediments have been variously called Anikie, Upper Huronian, Middle Huronian or locally the Nastapoka and Richmond series.

The contact between the Archaen basement rocks has been described by Low as an overthrust. As to this point the writer has examined two contacts of the sediments with the granite at Black Whale and Otaska Harbour. At both places the grey limestones rest directly on the granite without any trace of disturbance, However Low does mention the presence of a thrust surface at the mouth of the Clearwater River near Wiachewan Falls inside Richmond Gulf.

The surface of the granite shore near Cape Jones is the regenerated base of the proterozoic formations as is proved by numerous small joints filled with fragments of grey dolomite and chert. (Krancke p. 8).

From the Northeastern part of Manitounuk Sound northward past Richmond Gulf to the Longland River the sediments extend over considerable areas on the mainland forming bold cuestas covered with basalt.

The row of islands in Manitounuk Sound continues on the mainland as cuestas, and it is on the face of these cuestas from the Sound northward to Richmond Gulf and across Hazard that the lead zinc deposits have been exposed by erosion.

According to Krancke (p.10) "The Richmond Gulf Area is the most interesting part of the coastal section and the topography here shows clear indication of strong Tectonic movements. The sediments and diabase beds have been tilted in different directions and faulting has evidently taken place over a considerable area. "

"Richmond Gulf itself evidently represents a fault graben connected by fault lines, but as will be shown later with a definite relation to the folding of the Belcher Islands".

"The Belcher Islands are situated on an axial depression, the folding axis in the northermost part of the major islands dipping southward and in the southern part dipping northward. It is interesting to note that on the mainland opposite this axial depression we find the Tectonically disturbed region of Richmond Gulf. The fault graben of the area evidently corresponds to the latter." This corresponds to the idea of the line weakness along the Belcher, Richmond Gulf, Clearwater Lake and Larch River.

These structural relationships here have been brought forward in order to better understand the later parts of this thesis.

The sediments previously mentioned are completely unmetamorphosed and can be broadly broken down into upper and lower. The latter being almost entirely arkosic in nature, the former mainly limestones, and sandstones or a coarse calcareous conglomerate formed from the lower Arkoses.

At Richmond Gulf the upper series to the lower are structurally unconformable whilst on the Belchers some 70 miles westward Dr. E.S. Moore has pointed out that it is doubtful any such unconformity exists. Moore furthermore states that on the Belchers the upper group of strata are almost certainly equivalent to the upper strata on the mainland and islands.

Thus while on the mainland an erosional unconformity is evident the conformity on the Belchers would suggest that deposition in the Belchers was continuous whilst the series nearer the foreland suffered erosion during a period of diastrophism.

The following table of condensed formations taken from Young's "Iron Bearing Rocks of the Belchers" - page 16E is shown, in order to reveal the varying thickness of the beds on the Belchers and the mainland.

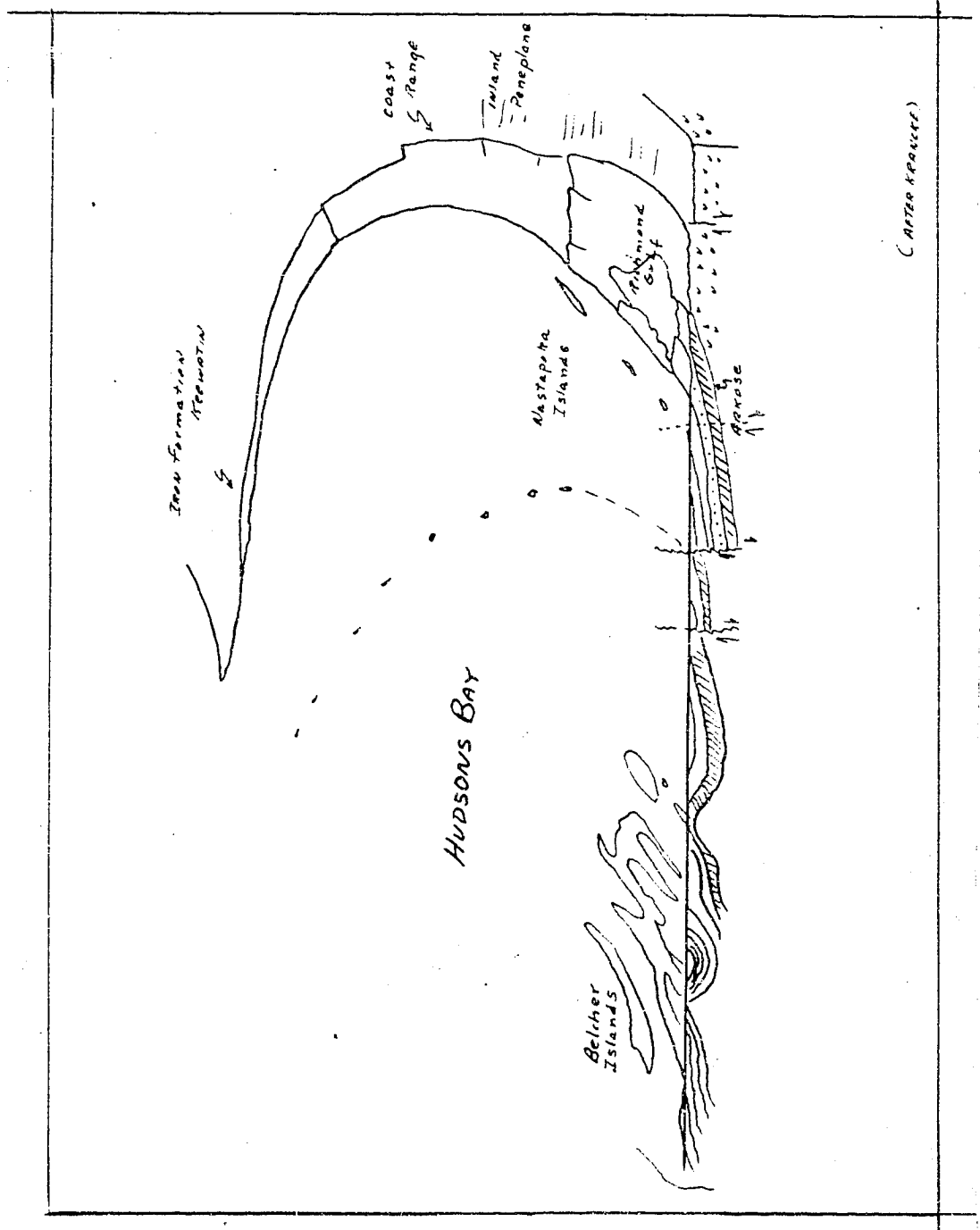
1. Castle Island, 40 miles south of Richmond Gulf.
2. Little Whale River, 10 miles south of the Gulf.
3. Richmond Gulf, south shore.
4. Richmond south shore.
5. Belanger Island opposite Richmond Gulf.
6. Belcher Islands.

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3. Cherty buff L. S., pyrite and galena (galena in first 10 feet)	100 feet
4. Dark silicious L.S. with partings of carbonaceous shale.	80 feet.
5. Fine grained dark and light gray S.S. with partings of Arenaceous shale	15 "
6. Light blue dolomite chert	3 "
7. Concealed.	15 "
8. Light gray fine grained S.S.	115 "
9. Light gray S.S. with rounded fragments of feldspar	10 "
10. Light gray S.S. thickly marked with brown spots together with green cherty beds and beds containing fragments of green jasper	105 "

Probable unconformity

11. Light pink arkose.	75 feet
12. Light and dark gray Arkose S.S. with ferruginous partings	55 "
13. Dark red ferruginous Arkose.	370 "
14. Sandrock with red greywacke.	60 "
15. Very dark red fine grained greywacke. Dark ferruginous Arkose flaggy	50 " 75 "
16. Ripple marked Arkose.	33 "
17. Light fine grained Arkose.	10 "

The rocks of all the Islands on Richmond Gulf are largely pink or red arkose with red and green micaceous argillites. All the beds show ripple marks and grade up into sandstone showing the elimination of feldspar.

Immediately opposite Richmond Gulf some 5 miles off the coast lies a small Island. This island, Belanger Island, is on the southern end of a chain of outer islands known as the Nastapoka group and after which the upper bedded series has been named.

For purposes of comparison the table of formations for the Mistassini Area, which also has lead zinc prospects is shown below.

TABLE OF FORMATIONS

Pleistocene and Recent

Sands and Gravels.

PROTEROZOIC

Mistassini Series

Iron formation

Temiscamie group

Arkose

Nastapoka ?

Quartzite

Unconformity

Albanel group

upper

grey dolomite

middle

sandy dolomite. Richmond ?

lower

yellow and buff

weathering dolomites

Lake Mistassini Group

grey dolomites

brecciated,

pre Mistassini

granite gneisses

post Mistassini

Intermediate intrusives

intrusives

rocks.

The following generalized section is obtained from A. P. Low's report of 1896 on the Nastapoka Islands:-

BELANGER ISLAND

1. Dark gray silicious dolomite and ankerite.....	56
2. Concealed	150
3. Silicious ferruginous shale:.....	35
4. Dark green diabase (Low calls this trap)	3
5. Dark green chert Flaggy	20
6. Tuff.....	25
7. Light gray S.S. and quartzite	94
8. Shales and quartzites.	97
9. Shaley sandstone	72
10. Silicious dolomite.....	8
11. Shale and sandstone.....	23
12. Concealed.....	
13. Green L.S., intermixed with apparently garnetiferous quartzite.....	
14. Yellow weathering dolomite	30
15. To sea level	20

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Low has considered this section as up faulted (overthrust) and that it is in reality a section from below or the same as the Nastapoka series as exposed on the mainland.

Low in fact describe it in this manner "The Buckling at the parallel faults on the islands, represents on a smaller scale what took place along a great line of fault which extends fully 300 miles along the east coast of Hudson's Bay from Cape Jones and caused the uplift of the Nastapoka Island. The uplift along this line of fault must have been several hundred feet while the horizontal movement was much greater than the uplift".

Leith in his report did not consider this to be correct and dismissed the idea of uplift by block faulting and called all above the unconformity the Nastapoka series and in doing this placed the Nastapoka Islands in stratigraphic sequence above the Nastapoka series on the mainland. Dr. E.S. Moore has accepted this theory and the fact that the section on the Belchers shows almost the same stratigraphic sequence as that of the mainland, and the Nastapoka Islands are placed above the mainland series, probably confirmed Leith's beliefs.

However later evidence given by Krancke shows that lines of fault do exist, (see diagram) and the possibility that the Nastapokas do occupy their present position by Tectonic movement must not be dismissed. However it is the author's contention that no thrust fault exists such as Low describes immediately underneath the Nastapoka series. It is more likely that a gentle fold exists beneath the Nastapoka Sound and that this fold was broken by block faulting described by Krancke. This lifted the islands to their present position. Whether this block faulting is tertiary is still open to doubt. Krancke bases his evidence for tertiary faulting to the lack of peneplanation in the district. However he himself states he is still desirous of further evidence to verify this decision.

Richmond Group

C.K. Leith in his paper "An Algonquin Basin in Hudson's Bay" has named all beds below the unconformity seen at the Gulf - the "Richmond Group".

These beds are coarse ferruginous arkoses grading upwards into sandstones and argillites, interbanded with some basic lavas. It is a group of ill assorted sediments deposited in low tide swept faces and exhibiting the wide variety of ripple marks

and current marks duplicated in tide flats today. Already the Richmond Group has limited extent compared to the upper Nastapoka group, the former dying out at the head of the Manitousuk Sound, whilst the latter group continues on southward for another 120 miles. Northward the extension of the Richmond group and Nastapoka from the Gulf is equally limited.

The Richmond group contains strata of poor iron ore, (highly siliceous hematite), seen in beds which both overlies and underlies the lavas.

The Arkoses are extremely compacted and in the lower members the rock looks almost identical to a reddish granite.

Nastapoka Group

This group, in which the beds carrying the lead zinc deposits are found, is remarkable in its difference from the Richmond series lithologically. Limestones, fine sandstones and dolomitic conglomerates and some shales compared to the almost continuous arkose and greywacke of the Richmond make it possible to differentiate visually between the two from a considerable distance even if the unconformity is not seen.

The lead zinc and pyrite deposits are carried in a limestone bed 10' - 20' feet thick which is filled with algal concretions. These algal concretions range from dimensions seen only in a microscope to some 3 feet in diameter. They have been replaced by chert and highly silicified thus making bed considerably more competent than the bed lying above or below. Whether the silicification took place prior to the ore or as a result of early ore deposition is yet to be determined and represents one of the many unsolved problems. These cherty beds have been regionally and locally fractured.

These limestone beds are covered by a very coarse dolomitic

conglomerate or agglomerate probably derived from the lower dolomites, interbedded with shales. The cross section below shows this intermingling.

Section Immediately Above Rubie Lake

Light green fine grained basalt	200'
Grey fine grained L.S.	4'
Cross bedded pink limestone	6'
White quartzite sandstone with dolomite limestone enclosed as pebbles	21'
Sandy shale	8'
Cross bedded limestone	2'
Black carbonaceous shale	5'
Light grey S.S. well bedded	25'
Concealed	100'
Cherty pink dolomite	50'
Mineralized bed	10'

If the series as exhibited on Belanger Island be placed immediately above this section the change from limestones through to shale, conglomerate cross bedded sandstones, thence back into silicious dolomite would indicate a fluctuating strand-line with strong off shore currents and deposition in fairly deep water and very close to the continental foreland with the foreland itself being peneplained rapidly.

Iron formation probably Keewatin age has been observed by the writer enfolded in the gneis's at Cape Jones, Krancke has also remarked on this in the Portland Promontary area. The iron formation presently seen on the Nastapoka Islands may very well represent the successive redeposition of this presumed Keewatin iron formation at a higher level, perhaps a secondary reconcentration from the ferruginous horizons of the Richmond series, in which sedimentary horizons the original Keewatin iron formation

had been primarily deposited.

ORE DEPOSITS

Historical Background

These ore deposits have long been known. They were originally noted and marked upon by the Hudson's Bay Company as early as 1744. At which date the Journal of Events of the East Main Post, then the most northerly administrative post of that company referred to the discovery of lead ore in the neighbourhood of Whale River (probably Little Whale)- "A great deal and amongst it several crystal stones. "

The deposits were again remarked on successively in Reports to the Company's London Offices in 1749, 1804, 1807, 1810, 1818, 1859, 1864, and 1866. That they were widespread and well known for a number of years is shown by the interest exhibited by the Hudson's Bay Company. Between the years 1859 and 1866 this company shipped some nine tons of "ore" to England. However when the post was removed to Great Whale River in 1890 interest died.

In 1946 active prospecting was begun once again. This prospecting began in the southern end of the lead zinc area at Little River, and worked northward to the Hazard (see map) and thence across to the northern side of the Richmond Gulf.

Economic Minerals

The ores consist of pyrite, galena, sphalerite, chalcopyrite, rhodocrosite, the gangue minerals are quartz, both in crystalline form and colloidal form, and calcite. The pyrite has been reported by Paul Hoffman as silver bearing. (Geo. Survey of Canada 1899). The galena is argentiferous and some samples carry about 2 oz. in silver. No free silver has been found nor have any of the silver ores. The sphalerite is dark and carries some iron.

Tourmaline and crystalline hematite have been found in one quartz vein cutting the intrusive boss which is exposed just inside the entrance of Richmond Gulf.

Low has reported a quartz vein over 6" in width cutting the lower strata of Flint Island which contains a great deal of crystalline siderite. Assays of the siderite showed a high maganese content.

STRUCTURAL RELATIONSHIPS

The lead zinc zone is in a brecciated, algal concretio-nary, cherty limestone bed about 10-20 feet thick. This bed has been highly resistant to erosion, and this has caused the surface and face of the bed to be remarkably smooth, and flat which makes for both good walking and easy prospecting. It would seem that the beds have been differentially eroded practically to their present condition in preglacial times. Glaciation then followed and cleaned the faces of the concre-tionary bed leaving it almost completely exposed for inspec-tion. This condition is prevalent throughout the area. Thus once across the High Land and down onto the bed itself travel becomes fairly easy and prospecting in the sense of sampling the bed, very easy. This means that the lead or zinc showing were sampled and sketched in a direct ratio of their availa-bility. It is thus possible that the lead showings now known along the escarpment are generally speaking all there are to know. If this is so, and realizing that the blank areas are not barren due to the lack of prospecting or to overburden it is possible safely to attempt to relate known geological structure to the known deposits.

All known deposits have been traced onto a large koda-trace map and from aerial photographs all visible faults,

joints, and fractures have also been marked onto this same map.

In the algal concretionary bed, the concentric cuplike concretions have been universally replaced by a silica, making the bed highly cherty. This has been highly fractured and brecciated, the amount of fracturing appearing to vary from place to place. This fracturing always appears in the shape of a rhomb with the long diagonal pointing seaward although varying in bearing from place to place. (See sketch). This rhomb shaped fracture pattern is particularly noticeable in the following places - Rubie Lake area, to the north of Rubie Lake, on the escarpment from which area samples 15. 16. 17 and 18 were obtained, Lake Monte and Marge, on the escarpment from which samples 43. 44. and 45. were taken, and on the north side of the Gulf. The enclosed photographs No. L8-33-31-28 and L6-11 show this very clearly.

From the examination of the drill cores from Nancy Island, Lakes Monte and Marge, and Little River, the mineralized bed is brecciated throughout and it is upon this brecciation bed that this rhombohedral pattern appears to have been superimposed.

From further examination of the map it would seem that only where the pattern is strongly outlined or whenever there is a strong fault or break is there any lead zinc mineralization. In fact in almost all the lead zinc zones exposed, breaks clearly extend through the mineralized zone. This is very noticeable at Rubie Lake, Lake Monte and Marge, and sample areas 5-8. 15, 27-28, 42.43.44.45., and 35.

The relationship of the faults (or joints) to the ore is born out by the fact that in diamond drilling at Nancy Island no hole near the fault or joint (see map) failed to produce lead zinc mineralization although some holes were rather lean, whereas south of the fault the great majority of cores showed only pyrite

in the core sections cutting the mineralized bed.

Rubie Lake further illustrates this probable relationship of faults to mineralization. The highest values in scopic examination were obtained here and a stereoscopic examination of photograph No. L6-11 will show three faults extending right across the area on a bearing North 3° W. approximately.

The Lake Monte and Marge area, where lead mineralization is fairly heavy, some very large specimens of galena, weighing up to 20 lbs., having been obtained, again shows this relationship.

Once again in the chalcopyrite mineralized area, sample area 15, 17, 18, several strong faults are seen, two of which intersect very close to the area #15.

Area #30, a galena zone, which on inspection from the ground level seems to lie wholly in a stream bed, viewed stereoscopically it is seen to be a major fault or joint along which a little torrent tumbles to the sea.

In zone #35, very heavy mineralization is known and once again the very strong line of fracture.

From the above so far it would seem the known ore is confined to:

- a) The brecciated Algal concretionary bed.
- b) An area of major fracturing (Rhombohedral)
- c) An area through which passes or is adjacent to a major break or fracture.

It has been suggested that the mineralized areas are located on the tops of possible anticlines and if as the writer believes the great valleys or draws represents the crests of these anticlines (see structure) then it would be reasonable to suppose the known ore zones would be grouped around the valley sides and valley entrances.

This belief may have some foundation but inspection again shows the deposits seen on the escarpment also seem to be in a probable synclinal areas. The writer believes the final, slight, north south folding was contemporaneous with or prior to the mineralization. The folding appears to have been very weak and the folds themselves may not have effected the deposition of the ores. In any case this would have to be proved by a very large amount of drilling and plane table work which is unlikely to be done for some years to come.

PARAGENESIS AND TEMPERATURE DETERMINATION

In the paragenesis of the ores, pyrite has been injected first and seems to be almost universally present throughout the brecciated concretionary bed. The lead and zinc is very much more localized and confined to the major lines of fracture. The extent of the pyrite and the absolute temperature of deposition, as determined by the pyrogeothermometer, of somewhere near 580° (the mean temperature of 10 tests) would seem to indicate that the mineral had been injected under fairly high temperature and pressure. However on examination of the same specimens of pyrite with the technique of decrepitation, a considerably lower relative decrepitation gave the following results.

2 Tests Cubic Pyrite from Nancy Island (Raw)

Test #1

Cent.

200° commenced popping
loud and clear

370° commenced new series

Test #2

Cent.

210° commenced popping
240° popping speed up

427° new series

Test #3

Pyrite cleaned with HCl and fluoric acid

225° began 1st. series of pops
300° began 2nd. series of pops
410° began 3rd, series of pops.

One series seems consistent, that around 225°C . The 2nd. series do not seem to have the close relationship.

It might then be inferred the oxidized surfaces of the pyrite decrepitated at about 225° , the 3rd. series is probably the temp. of deposition of the pyrite, about 400°C (relative to pressure considerations).

A test on the dark siderite gave a relative temperature of deposition of 325°C , while a third set of samples of galena gave a complex curve of three temperatures. One temp. of about 180°C , a second of 320°C , a third of 410°C .

From the above results it might be inferred that the galena and calcite were deposited somewhere near a relative temp. of 320°C . The 180°C curve temp. probably represents oxidized surfaces of the galena.

The deposition of pyrites at such high temperatures should have produced noticeable alteration in the limestone. It apparently has not done so, although thin section work may disclose some alteration.

If the temperature of $600^{\circ} + 20^{\circ}\text{C}$ is accepted as the absolute temperature of deposition for the pyrite and 410°C the relative temperature of deposition, then the pressure temperature relationship between these two would indicate a depth of burial of somewhere near 7000-7500 feet, or $1\frac{1}{2}$ miles of sediments. While it is difficult or even impossible to state from lithological evidence how much rock lay above the mineral at this point it is interesting to note that on the Belchers at the present time nearly 6000 feet of sediments lie above the Algal concretionary beds.

The work described above is insufficient for conclusive results but is recorded here as part of the evidence in support of the assumption that this deposit is mesothermal.

POLISHED SECTIONS

Paragenesis in polished sections of the ores at Rubie Lake show that pyrite most certainly came in first with quartz followed by sphalerite, galena, calcite, quartz and calcite and some pyrite probably exsolution from the sphalerite.

There seems to be three different periods of deposition and fracturing. Initially pyrite, and quartz were deposited both massively and in crystal form, later these were fractured sphalerite with galena and calcite injected, the whole in turn fractured and calcite with silica solutions finally injected. The silica solutions forming bountiful quartz crystals in vugs.

The deposition of pyrite and galena may have been marked by a large time break for the following reasons:

- a) pyrite seems to have penetrated throughout the brecciated zone. i.e. throughout the shale algal limestone horizon.
- b) The galena and zinc^{is} confined to the larger fracture pattern.
- c) The apparent differences in temp. of deposition the two ores.
- d) The difference in paragenesis.

ZONING

In any one ore, minerals have usually separated out in a certain well defined succession. (Lindgren-Mineral Deposits page 139).

In Hypothermal and mesothermal ores the succession usually is pyrite, arsenopyrite, sphalerite, chalcopyrite and galena (Lindgren - Mineral Deposits page 140).

If we look at the sketch on the opposite page this distinction is noticeable. Namely the predominance of the sphalerite

to the south running through chalcopyrite to an area in which only galena is prevalent. This indeed would suggest a decreasing temperature to the northward.

The variation of the $\frac{\text{Pb}}{\text{Ag}}$ ratio is unexplainable at the moment but is noted for its interest value. Worthy of note too is the overlap of the galena into the sphalerite zone.

The succession above, i.e. Zn, Cu, Pb, would place these minerals in zone 8. The "zinc zone". (A reconstructed vein system from surface to near batholith roof. After W.H. Emmons. Lindgren- Mineral Deposits, page 137). This makes them half way down the sequence and therefore mesothermal.

It is now a plausible assumption that the lead zinc deposits were probably mesothermal with a decreasing temperature gradient northward, i.e. the source lay to the south of Rubie Lake area.

STRUCTURE

Throughout the Richmond general structure series and Nasapoka series the presence of cross bedding, shale ripple marks, mud cracks, shows clearly that nearly all the deposits were laid down in shallow waters or sub aerial conditions. Leith and Moore have both assumed that the present Hudson Bay was a basin. The presence of the arc of sediments extending around the arc of the east shore of Hudson's Bay and across James Bay, to Cape Henrietta Marie, and the presence of iron formation on the White Bear Islands at the mouth of James and Sutton Lake in Northern Ontario certainly seems to confirm this view.

Professor Tuzo Wilson in (some geophysical aspects of the Canadian Shield pp. 723. Transactions of the American geophysical Union, vol. 29, 1948 No. 5) suggests the centre of Hudson's Bay was the core of the continent, upon which the successive geosynclines and ranges of the Precambrian were piled. This would imply

that after the first mountain range had formed around this core the sediments from this range would have discharged in two directions, (a) into the Belcher Basin and (b) towards the east into the present Atlantic, or the Labrador Trough, if this was already in existence.

With intensive diastrophism and an almost arid climate arkosic sediments from the foreland would have poured into the Belcher Basin in great fans at the mouths of the rivers. Further it is the writer's opinion that a permanent or long standing line of structural weakness exists along a line from the Belchers through Richmond Gulf and up the axis of Clearwater Lake and the Larch River. Thus not only would there be a basin in the present Hudson's Bay but also a trough extending into the present Quebec mainland with a series of major rivers discharging into and adjacent to this trough, very similar perhaps to that which is occurring today, at the mouths of the Nastapoka, Longland, Clearwater and Little Whale and Great Whale Rivers. The lower Arkosic beds show definite evidence of the almost arid climate, at this time as evidenced by the undecomposed feldspars.

This trough, along Belchers, Richmond, Clearwater Lake line, shows the greatest sedimentation and greatest orogeny, It is along and across this trough the greatest folding and faulting appear to have taken place.

Detailed Structure

On examination of photograph L8-23 the folded and plunging arkoses on Castle Peninsula jump to the eye. The beds have been apparently folded on an east west axis and plunge westward probably due to later folding on a North South axis. On looking eastward from Lake Monte and Marge the folding on this axis is

is very noticeable in the arkoses. At least four hills in the district owe their topography to this folding. Unfortunately these hills are too far inland to be seen on the aerial photographs although in the Rubie Lake area the arkose beds in photographs immediately to the east of the Lake show this influence. Cross folding has also taken place on a N.S. axis further complicating the structure in the Arkoses below the unconformity. On the hill to the south side of Richmond Gulf photo L8-33, the contact of the lower beds to the upper is near 15 degrees, the lower arkosic beds dipping 5° from the horizontal eastward and the upper beds dipping 10° westward. This unconformity is always distinguishable throughout the map area on the aerial photographs and can usually be recognized by a change of colour between the limestone beds and the darker arkoses.

The snow filled line which runs down the centre of the picture in L8-33 is assumed to be a thrust fault, probably an imbricate fault which is connected with a major movement which in the centre of Richmond Gulf area most likely is at the contact of archaen basement and the sediments. Movement does not appear to have been great. Worthy of note in this respect is that on the little unnamed point just west of the Hazard a thrust plane is exposed. This plane is in the basalt and dips towards the sea. Quartz filled tension cracks on either side of the plane are now very prominent. Direction of movement on the upper volcanics above the plane was eastwards. This was adduced by the concept of the strain ellipsoid. Other inferred thrust planes are noticeable near sample area.

Immediately to the South of the thrust fault just described a bed with rhombic patterns is clearly defined on photograph L8-33. It would seem that this pattern is the visible expression in the most competent beds of the thrust just indicated and appears only

in the silicified Algal concretionary horizon.

The pattern is considered to be a set of shear planes, which have intersected to give the rhomb. Following Anderson's theory of faulting the long diagonal should indicate the pressure direction. In this case it is always seaward although varying in bearing from place to place. The diagonal would then indicate the local pressure, although regionally this would not be necessarily true.

The presence of this rhombic fracture pattern at various places has been noted earlier in connection with the ore.

In an examination of the large map showing all the joints or faults, a change can be seen in trend of these faults or joints from place to place.

The change in trend is enumerated below working from north to south:-

1. The area north of the Hazard between line 8 and 10:- Most joints trending N.E. - S.W. with several strong breaks 35° to the main group.
2. The block immediately north of the Hazard:- A few joints the bulk of which parallel the coast, with one or two immediately north of the igneous boss at right angles to the coast.
3. Between the Hazard and the valley from which samples 21, 22, 23, 24, 27 and 28 were taken:- Beyond a few cracks at the edge of the Hazard a general trend towards the S.E.
4. The area between samples # 20, 22, 21, 27, 28:- An inferred thrust fault with tension cracks at right angles to the coast.
5. The area from a line drawn from sample #16 to Little Whale River:- A more easterly trend near Little Whale River.
Note the set of 4 joints near sample 9-12.

6. Little Whale River to Little River: Near south side of Little Whale River one prominent set of joints running nearly parallel to the coast and trending slightly towards N.N.E.
7. Towards the centre of the previous block and near Rubie Lake:- A very dominant set of joints or faults trending S.E. Across the Rubie Lake area.
8. South of Little River:- Joints or faults predominantly running N.E. - S.W. A change of nearly 90° to those north of the River.

The change in direction of the jointing visible on the basalt capping on the North and South sides of Little River is very noticeable. At the head of Little River a known plug of granite occurs. This granite knob is as high or higher than the basaltic cap at Rubie Lake. It appears to be intrusive into the arkoses, although physical evidence for this assumption has not yet been obtained.

An interpretation of the changing trend of these joints is offered and is accompanied by the map on the opposite page.

If we accept the fact that there is a regional dip to the sedimentary rocks and that these rocks have been thrust from seaward, then as movement took place regional folding and thrusting would have been along a N. - S. axis. The axis along which the greatest relief could have taken place would be East West, or at right angles to the coast. Should at the time of the orogeny granite plugs have been intruded along a line of weakness inland and near the edge of the sediments where they rested on the old foreland, then where the forward movement of the mass of flat lying sediments against the intruding or intruded granite occurred, a coupling effect would have taken place on either side of the plug. (See diagram). The result

would have been a series of tension cracks or joints that would appear to trend inward towards the plug. This certainly seems to be the case at Little River.

Further as the sediments were moved forward the most competent bed would be fractured and would fracture along vertical shear planes making angle of between 35° - 40° to the direction of pressure. This pressure would be local and not regional. Thus as the mass attempted to flow around the plug the regional forces would be thrown to the left and to the right of the plug and if this occurred we can expect to find the long diagonal of the fracture pattern oriented differently either side of the plug. This appears to be true for, to the south of the plug at Little River the long diagonal trends to the North of West where as on the N. side of Little River around Rubie Lake it trends a little to the S. of West.

Immediately opposite the plug the axis of relief would have been parallel to the coast and tension cracks should show up at right angles to the shoreline or parallel to the direction of pressure. In fact Little River does appear to follow a set of faults or cracks in this direction along its course.

The couples on either side of the plug would further give anticlinal axes along the long diagonals, with folding on either side of these lines. Immediately to the north on the point of Little River the volcanics (basalt) do in fact dip towards the north. (See photo). Furthermore if it is accepted that these has been folding on a roughly east west axis as well as thrust folding on a north south folding axis we may expect to find domes somewhere in the area at the intersections of these axes.

The small map which shows this has been made up by assuming that the minor breaks are joints or tension cracks and the major breaks are shear planes or transcurrent faults connected with the thrust normal to the granite mass and extending out of the area in

which there is no couple into the area where the coupling effect is dominant.

At the Hazard the sediments have been pushed against the granite knob now exposed by erosion and something of the same order described above has occurred.

In other areas namely near Little Whale River, and half way between Little Whale River and the Hazard this effect has also taken place.

The Hazard itself is believed to be an immense down dropped block perhaps due to lateral relief along the axis of maximum relief of the pressure which came on from the westward.

These anticlinal axes of the couples would give the local folding needed for the curving crests of the anti-clines which have been eroded down to draws or valleys, so prominent throughout the area.

The jointing together with the slight anticlines may have controlled the present topography of the countryside. In several places (Photo L6-11) can it be seen that the erosion has been controlled by almost invisible joint planes, which make an angle of nearly 45° to the coast.

It is beyond the scope of the present work to enter into the Geomorphology of the Area. The paper by Dr. E. H. Krancke is recommended for further reading.

Pleistocene

The general movement of the Labrador ice mass at its maximum in this region was westward. This is evidenced by the striations visible on all photographs. These striations universally have a bearing of between N. 80 E and S. 80 E. The mass discharged into Hudson's Bay and on meeting the Keewatin mass was deflected southward through James Bay. As the ice retreated movement of the

glaciers became complex.

Assuming Krancke is correct in his assumption that Tertiary movement raised the inland coastal mountains then the degenerating Labrador ice mass would have retreated up the valley of the Clearwater. During this retreat the glacier would have filled N. -S. Richmond Gulf Valley floor between the cliffs and the mountains, being fed by the main Clearwater glacier. As the ice further retreated the offshoot glaciers which broke through to the sea through the valleys retreated up these valleys leaving behind moraine deposits. These deposits were piled up against the glacier foot by wave action. This filled the valleys with cross bedded sands (beaches). There seems to have been a final quick retreat of the ice since the sand in these valleys has been left isolated.

Uplift following the glaciation has raised these wave washed moraine deposits to over 400 feet above sea level.

The main glacier then retreated up the N.- S. valley floor leaving moraines and outwash planes on this floor. (See Photo)

All the moraine material seems to be fine sands. No sooner had the ice left the Richmond Gulf and Valley than the rivers broke through to the sea, probably in their old preglacial channels. Uplift of over 400 feet of the land surfaces has left the topography as seen today.

OTHER DEPOSITS

A short summary of three lead zinc areas has been included since it is believed they have marked similarities to the Richmond Gulf deposits and may yet serve as a guide for any further work done in this district.

These deposits are:-

- a) Mistassini, N.W. Quebec.

b) S.E. Missouri.

c) Rico deposits, Colorado.

MISTASSINI

These ore deposits, not as yet explored to any extent, are found in the upper Huronian rocks of the Mistassini region. In this area the economic minerals lead zinc, nickel, and copper have all been recognized.

Sphalerite and galena are found in isolated masses, up to a foot in diameter, (very similar to the occurrences in Richmond Gulf), in a brown altered brecciated dolomite. A sparse mineralization of lead and zinc was observed in veins of quartz ankerite (siderite?). These veins are situated in the sandstones of the upper formation of the Temiscamie on the side of a basic to intermediate intrusive.

Pyrrhotite and chalcopyrite disseminated in the rocks adjacent to a flat diabase sill lying next to the basic intrusive were observed near Lac Coom.

Garnets have been found in a biotite gneiss. Description in preliminary report No. 211, Quebec Department of Mines is insufficient to recognize whether this biotite gneiss is metamorphosed phase of the Huronian.

An unmetamorphosed intermediate rock has been intruded about 1 mile west of Lac Coom. Crossing the most recent sedimentary rocks of the region it has a fine grained " salt and pepper " appearance. Immediately to the east of Lac Coom, nickel and copper are associated with rocks of the same type. The one observed igneous boss considered to be intrusive at the entrance to Richmond Gulf is very similar in appearance to the description of the Lac Coom intrusive. In this intrusive in Richmond Gulf, the high temperature mineral tourmaline, has been collected together with some chalcopyrite and magnetite, and specular hematite.

Preliminary report 211 contains little detail regarding orogeny except the region has been folded and thrust faulted on a N.E. S.W. line. Beyond this meager description no other detail is available.

The sedimentary rocks have been previously compared and show the remarkable lithological similarity of this region, to the Nastapoka and Richmond Sediments.

Similarity of relationship to the Richmond Gulf Deposits

They may be summed up thus:-

- a) Brecciated dolomite bed.
- b) Intrusive in Atea
- c) Lithological similarity of rocks.
- d) Presence of high temp.- minerals in intrusives.

S.E. MISSOURI

In a further search of the literature two other well known lead zinc districts seem to have some similarity to the Richmond Gulf deposits, one structurally and the other genetically.

The first of these are lead deposits of South Eastern Missouri as described by W.A. Tarr in Economic Geology, Vol. 31, page 726.

These deposits seem to occur on a gently sloping dome formed by paleozoic sediments surrounding the Precambrian igneous rocks of the St. Francis Mountains.

The original position of these paleozoic rocks has been disturbed by gentle folding and uplift with major faults striking N.W. N.E. and east of the igneous mass.

There are many smaller faults which cut the area, many of them having a displacement of only a few inches, some of many feet.

Some of these faults, some of which were sufficiently persistent to cross the entire thickness (450') of the Bonneterre dolomite. The joints are sufficiently persistent to form water channels into the mines. Surface connection is shown by the fact water fluctuates with rainfall.

The majority of the joints strike E.W. to N. 50 W. with a less prominent group N. 30 E. to N. 80 E.

The rolling contact of the Lamotte S.S. and Bonneterre dolomite produce differences in elevations of the Lamotte surface up to 30 or 40 feet.

In local areas the shattering has been so intense the dolomite appears brecciated, or may be disturbed throughout all the different phases of the dolomite, galena may be so abundant as to make up 75% of the rock, or so lean as to be unmineable.

Veins are surprisingly numerous of which there are two types of vein deposits, filled fissures and replacement veins.

For the most part all veins are less than 1/8" in thickness although they may be nearly one inch. Paper thin veins extend out the dolomite from the larger veins.

Replacement veins result where the galena has replaced the walls of a joint or fissure, they differ from filled veins in irregularity of outline and are variable in thickness. In the dense and much shattered dolomite both types of veins are found.

Cavity openings are common in the district and may be a foot or more across and accurately show the sequence of precipitation.

Tarr believes the source was in a magma that probably occurred within several thousand feet of the surface but which had several cupolas that penetrated nearer the surface.

Solutions ran along joints (faults) in the Precambrian

igneous rocks, although apparently these joints are not the present day faults which show no evidence of mineralization.

These joints may have been somewhat parallel to the present faults but there is no proof of this. The major joints in the dolomites and Lamotte s.s. furnished the mode of ingress into the formation and the other systems of joints roughly at right angles enabled the solutions to spread laterally from there. The solutions spread to the porous beds of dolomite.

It is seen that the location of the ores is primarily due to structural features. But that the features themselves coincide with the cupolas of the crypto batholithic magma from which the hot metal bearing solutions and gases rose into the jointed and faulted Precambrian and Lamotte sandstones and later into the Bonneterre dolomite.

The solutions appear to have been held in the Bonneterre dolomite by the heavy bed of impervious Davis shale.

Some Features of Similarity Between Richmond Gulf Deposits
and S.E. Missouri Deposits

- a) Joint system and brecciation.
- b) Possible similarity of slight rolls in bedding.
- c) Possible source of ore solutions.
- d) Flat lying sedimentary formation.
- e) Disturbance of original position of sedimentary rocks.
- f) Veins.
- g) Cavity openings.
- h) Rolls in Lamotte s.s. which may be duplicated? in the Richmond Gulf mineralized bed due to rolls induced in the limestone due to the undulating surface of the beds below the unconformity.

RICO - COLORADO

A second deposit which seems to show both a genetic relationship and slight structural resemblance to Richmong Gulf, is the Rico district of the San Juan Mountain area of Colorado.

The San Juan Mountains consist chiefly of volcanic rocks poured out over a basement of paleozoic and mesozoic sediments. The volcanic flows have a total thickness of many thousands of feet. Deep erosion has laid bare these flat lying flows to a depth of several thousand feet and exposed a number of intrusive stocks.

This vast and uplifted dome is traversed by a numerous system of strong fissure veins. While the vein systems bear the marks of deposition within a moderate distance of the original surface there are some features that tend to connect them with deposits formed at greater depth and in more direct genetic connection with igneous intrusions.

In the Rico district the Rico Mountains are a dome like uplift of sedimentary rocks ranging from Algonkian to Jurassic in age. Intruded by stocks, sheets and sills of monzonite.

The ore occupies minor fissures while structural faults are devoid of all metals. The deposits form lodes, bed veins, blankets and replacements.

The blankets are below the impervious shales. The abundant ore minerals consist of pyrite, galena, blende, chalcopryrite with a gangue of quartz, rhodocrosite, calcite and fluorite.

It is interesting to note that colloidal deposition is indicated in part and that when limestone was adjacent it was silicified and not silicated.

Spurr believes that fissuring and mineralization were caused by the dome like uplifts and that these were due to

deep seated intrusions not yet exposed by erosion.

Similarity of Richmond Gulf to Rico and San Juan appears to be mainly genetic.

- a) Dome uplifts (perhaps)
- b) Flattening beds with blanket.
- c) The presence of rhodocrosite.
- d) The similarity of ore zoning.
- e) Silicification of the limestone instead of silication (alteration).

CONCLUSIONS: Structure

Initially sediments from the Archaen foreland filled the Belcher Basin and Belcher Richmond Gulf, Clearwater Lake trough during Huronian Time forming the Present Richmond series. As this trough filled and was gradually depressed, pressure was exerted from north and south, folding the arkoses. Uplift followed and the upper part of the Richmond series was eroded and worked over. These sediments were then redeposited further to the south and North and out in the Belcher Basin. The trough sank once again and in relatively deep, quiet waters lower calcereous members of the Nastapoka group were deposited along the axis of the Belcher Richmond Gulf line. Whilst these movements were taking place basaltic flows and sills were being out-poured and injected over and between the beds.

By the end of Nastapoka, (Animikie or Keeweenawan time), thrust once again commenced accompanied probably by a phase of the Killarney revolution which further to the South on the continent was giving birth to another metallogenetic epoch.

This thrust may have been quite weak but sufficient to brecciate the most competent bed, in this case the concretionary bed and to impose differential stresses upon this bed in and

around the intruded granite stocks and bosses, some of which are not yet probably exposed by erosion.

These continuing differential stresses superimposed upon the already brecciated bed a set of fracture patterns. Intimately connected with these fracture patterns were a series of tension joints, which although discernable in the basalt and in the cherty bed, may not be present in the overlying beds or underlying incompetent beds owing to plastic deformation. These fracture joints may then have acted as lateral solution channels from the magma source. That the source is below and solutions do pass through the arkose is indicated by the fact that just inside the Hazard small quartz veins carrying galena run up through the arkose. It may well be that some of the larger tension cracks open up below the cherty bed into the arkoses and have also acted as a vertical passage way for the ores.

Where the thrust has full play i.e. outside the areas of the resisting granite the movement towards the foreland was greatest. This has led to a more intense brecciation of the bed and a more intense fracture pattern. The larger tension joints may have acted as the horizontal and vertical solution channels to the areas of fracture and only where these features occur together may any great lead zinc mineralization be expected. In this as far as the jointing is concerned the area bears some resemblance to S.E. Missouri.

Continuous fracturing was most certainly occurring while ore deposition was taking place, and from this might be deduced that as thrust pressure and the intrusive imposed themselves more and more on the sedimentary structure more extensive faulting and cracks showed up with increasing stress.

This meant that as the solutions cooled and pressure dropped access of the hot metaliferous solutions to the concretionary bed was being continually facilitated due to these movements. It is for this reason that the pyrite under higher pressure has penetrated the area throughout the brecciated zones and that the later lead and zinc with lower pressure and temperature are only found in the later fractures.

The fact that the Mistassini deposits seem to be definitely connected with an intrusive and their remarkable similarity to the Richmond Gulf deposits would lead to the assumption that Richmond Gulf deposits may have a similar relationship to an igneous intrusive.

If this is so then attention should be directed to all granite masses exposed by erosion, and are intruding the sediments. One such mass lies at the head of Little River. It is reported and appears (Photo) to intrude the arkoses but this can only be proved by further field work. However, the moderately high temperature minerals, of which quartz, tourmaline, chalcopyrite have been identified in another smaller intrusive mass in Richmond Gulf which the writer has personally inspected, leads to the belief that the source of mineralization was reasonably close. In this respect it is worthy to note that both Low and Keith report granite intrusive to the arkoses inside Richmond Gulf at the following places:-

- a) North end of Richmond Gulf.

- b) Wiachewan Bay.

- c)

In the case of (a) the granites intrude and have altered the sandstones and (b) the sandstones are baked to a white quartzite for about 50 feet away from the granite and are penetrated by small quartz veins.

While the galena has been found in large masses, due to the fact it seems to be only present in the fracture pattern the tenor of the ores will probably always be low. This will be due to the large amount of enclosing rock to be mined in order to extract the economic minerals from the fracture. However due to the remarkable persistence of the mineralization immense tonnages of low grade ore are probably present.

Summary of all Conclusions

- a) A mesothermal deposit which may be similar to Rico Colorado
- b) Structurally similar to S.E. Missouri lead deposits.
- c) Markedly similar to the Mistassini Lake deposits.
- d) The galena and sphalerite is almost confined to areas of fractures. Some of which can be seen in the photographs. This pattern representing minor vertical shear planes of thrust from the west.
- e) The solutions have been brought from their source by the system tension cracks or joints.
- f) The Temperature decreases Northward.
- g) The deposits may have been originally deposited under some 7000 feet of sediments.
- h) Pressure from the West caused differential stresses around the granite intrusives, which in turn caused folding along axes that the crest of these folds became the eroded valleys seen today.
- i) In places where the axes of the North South regional fold

cross the axes of local folding described in (h) above. Domes and effects may be found which may have entrapped higher concentrations of ore.

- j. Folding took place on a North South axis which partially contributed to the position of the Nastapoka Islands.
- k) Later block faulting, parallel to the coast later lifted the Nastapokas to the position in which they are now seen.
- l) Erosion of the softer rocks against the foreland produced a cuesta facing the Highland in a manner very similar to the Niagara escarpment of today.
- o) Post glacial uplift (pliocene) lifted the escarpment and the Islands to the present position.

Though the conclusions reached have been based on evidence which is both fragmentary and sketchy it is hoped they will stimulate further interest in this region and other regions of Northern Quebec with similar age relationships. The assistance and help of Professor G.B. Langford, Dr. F. Gordon Smith, Professor J.T. Wilson is gratefully acknowledged. The writer would also like to thank the Directors, Officers of Gulf Lead Mines, Ltd., whose provision of material contributed in the task of bringing this paper to completion.

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APPENDIX

ECONOMIC CONSIDERATIONS

Up to the present the ore values have not exceeded an average of \$8.77, lead and zinc values combined (Lead 19¢ Zinc 17¢). Of this 1, 000, 000 tons has been outlined in 3 (three) widely separated districts.

These were outlined as follows:-

	<u>Tons</u>	<u>Lead</u>	<u>Zinc</u>
Lake Monte	132,560	1.75	nil
Rubie Lake	578,690	1.07	1.26
Nancy Island	294,463	0.72	2.15

Each area at the present time is relatively inaccessible to any local shipping point. However sufficient capital investment and ore outlined of reasonably high value could overcome this local inaccessibility.

At present it would appear that the inaccessibility of the region itself will necessarily push the development costs above those expected in more accessible areas. One consideration however is very much in the areas favour. It is both the opinion of the writer and the opinion of Mr. James Cantly, ship operator and chartered of Montreal, that Richmond Gulf could be entered and used by 5,000 ton ships and probably a 10,000 ton ship. The ability to use ships of this capacity would keep the freight costs of the development phase well within \$15.00 a ton, (material shipped from Montreal or East coast ports) and at a later date ore or concentrates could be landed at East Coast U.S. or West Coast U.K. ports for between \$10.00-- 14.00 a ton. These figures are based upon latest available charter rates (Sept.) from Churchill to U.K. and Churchill-Newport News, Virginia.

Shipping in Hudson's Bay and straits can be carried on

from approximately July 25th. to Nov. 5th. These dates represent the average dates of opening the season of navigation at the eastern end, Nottingham Island, of Hudson straits. Shipments of ores or concentrates would not be too much of a problem provided the necessity of stock piling was accepted. This however would necessitate the need of maintaining a high physical inventory on ores, a situation which in a period of declining world markets might lead to financial distress, to a Company not provided with very large working capital.

With cheap charter rates cost of mining plant need not necessarily be much higher than that for less isolated areas. However the necessity of power development, dock sites, communication facilities, roads and , or cable ways, and amenities additional to those normally supplied to a working force in a less austere climate would lead to a further very large capital investment over that already required for the mill and mine equipment.

For this very large or very high grade ore bodies will be needed in order to give a desirable return on capital.

The development costs necessary for outlining these ore bodies, will, due to the very nature of the country, and amount of drilling necessary to penetrate to the ore horizon from the basalt cap, (some 490 feet.) be high. This will deterr any organization who has not a very large amount of idle capital readily available, and who is not willing to take very long term view.

That these deposits will be mined is without a doubt, when will depend on the march of world events. If as is so often hoped a long period of peace is now upon the world, then North American Capital will turn to deposits outside the Continental confines which may promise easier returns. If however, the present

period of stress is continued and intensified then these deposits will assume strategic importance. In view of the decreasing continental production they will then not only prove valuable but vital to the National interests of both the United States and Canada.

Favorable Areas for Ore Deposition

If, as has been stated tension cracks have acted as solution channels it may be that only those trending towards the granite boss carry good ore values, and that the tight faults and/or shears may be comparatively barren.

Certainly if the amounts of faulting or fracturing revealed on the basalt cap is indicative of favorable structure for ore deposition then the block bounded by Little Whale River and Little River would appear most deserving of the whole district for continued specialized attention.

In view of this all the area back of Rubie Lake should bear drilling or even drifting into the ore bed under the cliffs.

The following areas should be considered:-

1- The area marked A should be paid particular attention.

Photo No. L. 5-13.

2. Further areas worthy of interest are:-

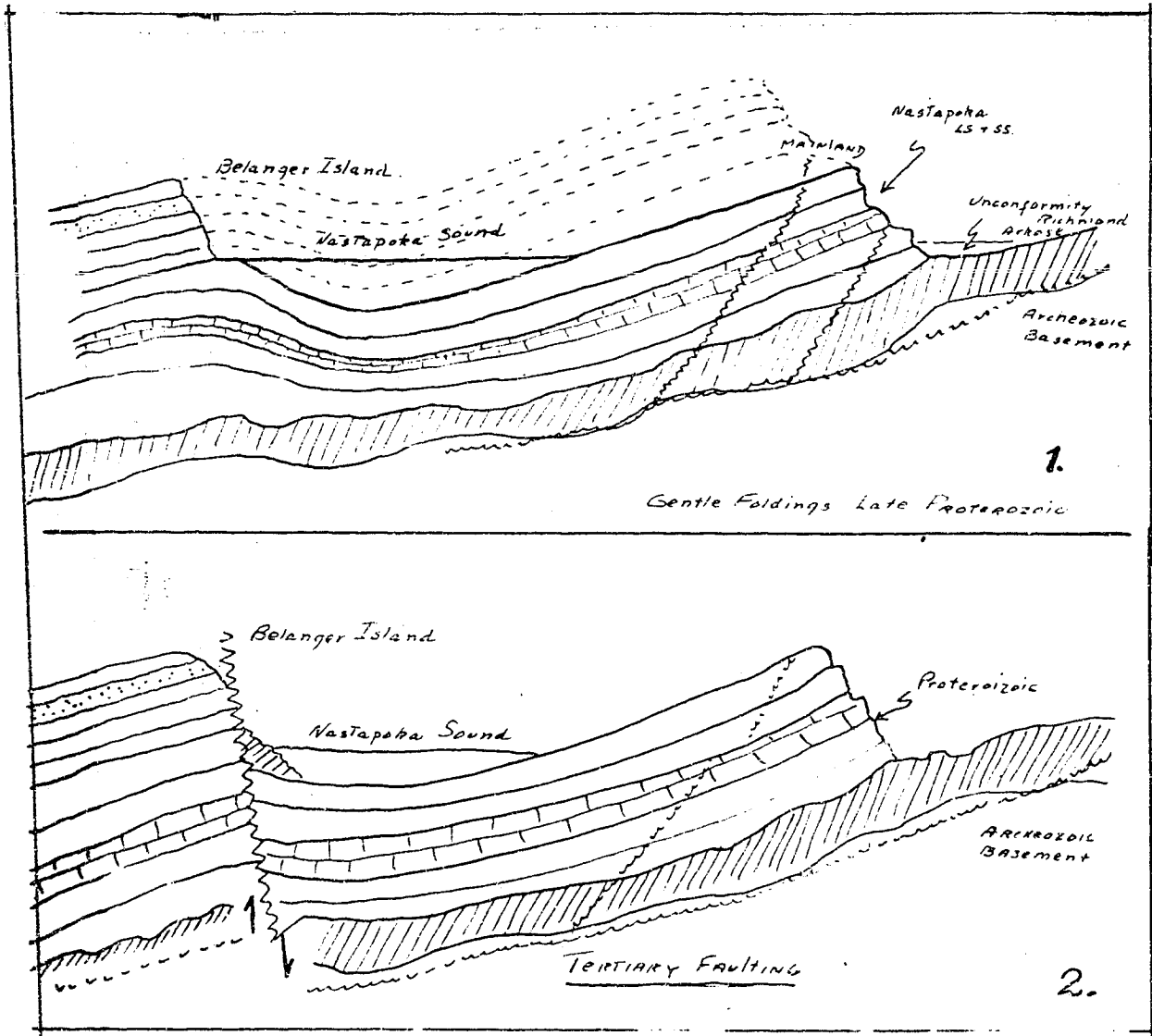
A.B.C.D.E.F.G.H.I.J.K.L.M.N in this order.

These areas all seem to show considerably higher concentrations of tension joints, in conjunction with presumed transcurrent faults.

As further drilling or geophysical work is completed the map exhibiting joints and fractures should be constantly consulted and new information plotted. Continual revision of ideas will be essential, until further factual information is obtained preconceived notions will prove dangerous.

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PROBLEMS

The following problems are put forward as a guide to further geological work in the area.

a) Thrust:- Whilst the thrust from the East most certainly took place and can be proved, more information is needed on:

- 1) All exposed horizontal thrust surfaces
- 2) All thrust faults exposed on a vertical plane (section)
- 3) Whether the thrust fault died out North and South of Richmond Gulf.

b) Folding:- Do the folds caused by the differential movement around the granite masses exist, and does any degree of folding along a North, South axis exist in the sediments on the mainland and on the islands ?

c) Depth of Nastapoka Sound:- Is the Sound very deep or shallow?

This information would give further clues to the stratigraphic position of the islands.

d) Depth and shape of the bottom of the Hazard:- If the bottom of the Hazard shows the same general shape as the surrounding cliffs, then the theory of a graben can be proved. This could easily be done by Echo sounding. The same applies to Nastapoka Sound.

e) What are the ages of the granites?, both inland, and those intrusive to the sediments,- Killarney or Algoman or both.

f) What is the age of the granite gneiss on the coast?, called by Krancke the migmatites.

g) By a conclusive test on a large number of samples find an answer to the temperature and gradient.

h) Which of the basalts are intrusive as sills and which are flows, and to further show which of these are Animikie (Late Huronian) in age and which are Keeweenawan.

1) Which fracture shown on the map drawn from the aerial photographs are tension or shear? What are dips to the fractures? Of the many seen intersecting the basalt face they appear all vertical, is this true?

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