AN INVESTIGATION OF ROCK ALTERATION IN THE FLINFLON ORE-BODY

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AN INVESTIGATION OF ROCK ALTERATION IN THE FLINFLON ORE-BODY BEING A DISCUSSION OF THE PROCESSES INVOLVED IN THE FORMATION OF THE FLINFLON ORE-BODY.

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CHAPTER ONE.

INTRODUCTORY.

The Flinflon Mining Camp lies in the Pas Mining district, Northern Manitoba, Canada, at approximately Latitude 54°45', Longitude 102° west from Greenwich.

The ore-body is about seven miles east of the Second Meridian, and lies on the Saskatchewan-Manitoba boundary the major portion being in the latter province. Complete reports of the district, its history, physiography, and general geology have been given by Dr.E.L.Bruce, Dr.R.C. Wallace and others. (See Bibliography). A brief description of the discovery and subsequent development of the property would, however, seem pertinent to the present discussion.

The Flinflon and Mandy ore deposits were discovered in 1915. The latter, though smaller, had early attention owing to the high quality of its ore, and the war-time prices prevailing for copper. In consequence it received wide publicity and has been well described. (See Bibliography). Unfortunately, while there are points of similarity between the two ore-bodies and a probable correspondence of origin, these bodies do not warrant a close comparison in the present state of knowledge of this field. In fact, Dr. J.E.Spurr, considers that only the latter phases of formation of the

Mandy ore are contemporaneous with those of the Flinflon body. (The Ore Magmas, Chap.II -J.E.Spurr)

The Flinflon body has been thoroughly explored by diamond drill to an average depth of 900 feet, and has proved to be a wedge-shaped, almost vertical lens with the broadest portion, which has a biconvex horizontal cross-section, at the surface.

Drilling was actively carried out during the years 1916-17-18. Little surface work, except the few shallow trenches of the original discovery, was done during this time, and so specimens of both rock and ore types (apart from drill cores, regarded as private and confidential) lacked completeness and accuracy. In order to check the results of valuation by diamond drilling, some 1,600 feet of deep mining was undertaken in 1920. This underground development was intended to be of a temporary nature only, and the shafts and drafts were subsequently allowed to fill with water. The writer had the opportunity of visiting the mine during operations of underground exploration in the summer of 1920 to obtain specimens both of the representative ore types, of the barren country rock, and of the neighboring rocks of various geologic ages.

CHAPTER TWO.

STATEMENT OF PROBLEM.

The problem to be discussed is really a two-fold one, namely, to discover the source of the ore as far as the Flinflon ore-body was concerned, and to ascertain whether results of such study would be of use in furthering prospecting in this region.

To understand this problem at all, it became evident that the method would have to include a careful study of the changes of the surrounding rocks of various ages, their effects, and the intensity of their effects, as well as the changes apparent in the ore-body. It is evident that those alterations which have affected later rocks would also have affected the ore-body in the older rocks to some extent, and might mask the true changes in the rocks responsible for the mode of formation of the ore. The interesting field of progressive changes within the ore-body itself was not attempted, as mine development was not sufficiently advanced to make such a study, with its attendant careful mapping and measurements. This should prove a fascinating study for the future investigator, as there are many separate problems, which the present small amount of investigation prove to exist. For example, the ore stops abruptly on the western wall. What was it that proved an impassable barrier to the ore bearing solutions?

The present investigation involved the macroscopic and microscopic study of representative specimens of the rocks of all the various geological formations in the district, (especial care being taken with those contiguous to the orebody), and macroscopic investigation of the ore.

CHAPTER THREE.

ALTERATION IN VARIOUS GEOLOGICAL FORMATIONS OF THE DISTRICT, AND THEIR APPARENT EFFECTS ON THE ORE-BODY.

Under this heading the agencies common to all the rocks of the district, and the significant differences will be dealt with. A full description of the rock types is confined to Appendix A. The general geologic relations of the Pre-Cambrian in the district are as follows:-

LATER GRANITES	KAMINIS GRANITE
	GRANITE GNEISS
	HYBRID GRANITES
INTRUSIVE CONTACT	
UPPER MISSI SERIES.	ARKOSE
	CONGLOMERATE
LOWER MISSI SERIES.	SLATE
	GREYWACKE
	QUARTZITE
	CONGLOMERATE
UNCONFORMITY	
	CLIFF LAKE GRANITE PORPHYRY
INTRUSIVE CONTACT	
KISSEYNEW GNEISSES	SEDIMENTARY AND IGNEOUS GNEISSES AND SCHISTS.
AMISK SERIES.	LAVAS, TUFFS, AGGLOMERATES, AND DERIVED SCHISTS.

The Kaminis Granite has been intruded to a very slight extent by epidotic and calcareous solutions forming tiny veinlets. Many of the minerals in the granite have weathered and fracturing of the minerals has taken place.

An important occurrence of this granite will be discussed in connection with the rocks adjacent to the ore-body.

The Granite Gneiss Series have been greatly altered, the ferromagnesian minerals being more highly affected. Pressure has produced slip planes in these rocks subsequent to solidification, and along these planes chlorite is found. Cubes of pyrite have formed along the joint planes, presumably derived from the last hot solutions of the Kaminis Granites.

The Hybrid Granite is merely a stoping contact between the Kaminis and earlier rock types, so highly altered that neither rock can be definitely identified. They show an amazing variety of forms in a small area. Numerous calcite veinlets, some quartz and pyrite occur.

Upper Missi Series. These consist of arkose and conglomerates, which vary from moderately sheared to fresh types. The calcite found in the Kaminis Granite does not appear to have affected these rocks to any great extent, though present, but pyrite and chlorite have been introduced in minor amounts.

Lower Missi Series. The Lower Missi slates are the only occurrence close to Flinflon Lake. They lie about seven miles south-easterly. The materials have been derived from the Amisk Volcanics, and point to a long period of erosion with subsequent folding and pressure. Calcite and quartz were introduced along the joint planes, and also appear to be due to solutions similar to those affecting the Kaminis Granite.

Cliff Lake Granite Porphyry. In this rock-type the results of shearing action and great pressure subsequent to consolidation are much more pronounced. Those quartz phenocrysts, which are not actually crushed, are rounded and show shadowy extinction. Calcite and a minor amount of pyrite have been introduced, as in the younger rock types.

Lamprophyre Dykes. These appear to be placed rather lower in the geologic table than warranted. There is little schistosity or shearing, which would lead to the belief that they are younger than the Cliff Lake Porphyry. The Lamprophyre and Cliff Lake Porphyry have not been found in contact, nor have these dykes been found in contact with the Missi series. They are older than the Kaminis Granite, as Dioritic phases of the latter have been found cutting them. (The Diorite has in turn been cut by quartz veinlets). Calcite veinlets and scattered cubes of pyrite are common, and small pockets of chalcopyrite are to be found. The last point is significant. It will be noted that Dr.E.L.Bruce does not attempt to place these dykes in his geological table of formations, so was possibly in doubt as to their exact position in geological time.

The Kisseynew Gneisses, lie far to the north of the district, and opportunity was not afforded to study them.

Amisk Volcanics. These are a series of lava flows, tuffs, and agglomerates, with derived schists. The amount of distortion and alteration which these rocks have suffered is very great, much more marked than in any of the younger types. Tilting has taken place to such an extent that there is a strong probability that many of the flows have been overturned, and are repeated in position at the surface by such action. Dragfolding is strongly marked----in places on a large scale. Calcite veinlets are common, in addition to much calcite derived from decomposition of the felspars. Rock alteration is marked throughout the series, but sufficient original rock is generally left to indicate the type from which the present rock is derived. This is true, save where intense shearing has been brought about, as in the rocks of the Flinflon ore zone, where the origin of the rocks becomes more difficult to determine. Here, save for the presence of a large horse of country rock, are schists entirely composed of secondary minerals. The rock in the horse gives some evidence of the origin of these rocks, and this, combined with minor differences in macroscopic appearance of other specimens, gives the main clue to that origin.

From the above description of the rocks in the district, it will appear that all the rocks, from the oldest lavas to the youngest granites have been intruded by tiny calcite veinlets. One possibility is that these are derived from meteoric waters percolating through the overlying Ordovician Limestone, which has since been removed by erosion. This particular phase of calcitization, therefore, may be ruled out of the consideration of rock origin. All the rocks have undergone certain katamorphic changes, resulting in the production of chlorite from ferromagnesians. Chloritization, however, is progressively more pronounced as one proceeds from the younger to the older rocks. There is a great difference in the amount of chloritization and sericitization even between the amygdaloidal lavas, and their sheared equivalents in the ore zone. There is also a marked progression in the amount of shearing and development of schistosity from the youngest to the oldest rocks. This is to be expected, for, as already pointed out, all movements affecting the younger rocks must have affected the older also, but many movements in the older were either prior to or concurrent with the formation of the younger.

CHAPTER FOUR.

ROCKS THAT APPEAR TO BE IMMEDIATELY CONNECTED WITH THE ORE-BODY.

In working from the general to the particular, it will be of interest now to state the types which are immediately adjacent to the ore-body, and define as far as possible their relationship.

For clearness, the rocks and mineralization of the ore-body will be described first, the order adapted being that of geographical rather than time relationship. Map 1978 makes this more clear.

The rocks in which the ore-body lies are a series of ancient lava flows (Types 1-3-4-5-6-7-8-18-20-22). They were probably extruded below shallow seas, as pillow lavas are found in places, notably on the trail to Happanot Lake and a narrow bed of tuff was mined in Number Two shaft. It is possible, --- may even probable --- that, in Amiskian times, these rocks were elevated and submerged several times, as the amygdaloidal lavas have a superficial similarity to recent amygdaloidal lavas in surface flows. (E.G.Mount Katmai, Alaska). These rocks then underwent intense folding to their present almost vertical position. The individual flows were not, as far as can be proved, of great extent, but were numerous. They cannot be traced over any great distance, and this would account for local and marked differences in strike.

As determined from drill records, the ore-body occupies a strongly marked shear zone striking 330° and dipping from 60° to 70° north-easterly, with a pitch to the south at a low angle. The ore consists of two main types, the "Disseminated" and the "Solid" Sulphides, a distinction of degree but not of difference of origin. These are replacements of the original rock, after the schistosity had been induced. To quote Dr.F.J.Alcock,"The presence of unsupported masses of rock in the ore-body, some of them schistose with the plane of schistosity parallel to that of the wallrock, and the character of the disseminated ore, consisting, as it does, of country rock partly replaced by sulphides, can be explained only by replacement."

The ore-body and factors immediately connected with it will be discussed in a later chapter. Within the upper part of the ore-body, there is a large horse (Type 3) which has proved resistant to erosion and forms a prominent feature of the landscape. This rock is of interest, as it is the only one immediately adjacent to the ore-body, (clearly not intrusive but a part of the original lava) which shows any trace of the original mineralization. This rock was a more massive phase which resisted the forces inducing schistosity. Its homogeneity and hardness are also responsible for its subsequent resistance in some measure to the glaciation during the last glacial epoch.

On the flanks of this horse of altered diabase are alteration products which are of interest in connection with the subject of glaciation. These are (1) Porous leached rock, (2) Powdered quartz resulting from weathering of same, (3) Red ochre,-- a hydrous iron oxide, (4) Yellow ochre, (5) Disintegrated pyrite. (Types #1-15-13-14-12 respectively). They are the results of weathering since glacial times, as is apparent when a study of these phenomena with certain additional phenomena resulting from excavation of the ore-body is made. Native copper was discovered at a depth of 60 feet in Number Two shaft, when the shaft passed from the horse to the solid sulphides. Unfortunately, this native copper was not identified until after it had been brought to the surface, as the senior mine officials all happened to be absent at the time. The mineral has been formed in beautiful dendritic crystals and is the result of leaching and subsequent redeposition. The absence of secondary copper minerals such as chalcocite and covellite leads one to infer that all secondary minerals had been swept away by the intense glaciation which the district has undergone, and forms the principal criterion for assuming that this copper has been formed in post glacial times. Additional light is to be found in the position of the secondary iron minerals and leached rock. The powdered sulphides lie to the north of the horse, where the toe of the glacier would first lift up to slide over the horse. Then the glacier powdered a pumicelike material, leaving a residue of powdery quartz. This is found closer to the horse, and probably was at a slightly higher altitude. This shows that leaching of the sulphide body was active before glacial erosion, but the presence of a mass of friable, porous leached rock (Type #1) on the flank of the horse, which the glacier would have removed, certainly points from its position to leaching subsequent to glaciation.

To the south of the horse, another type of leached rock (Type #7) is found. Here the original sulphides were less thickly disseminated. Casts of pyrite cubes are found. The rock, a Sericite Schist of a bleached and rust stained appearance, grades down into Sericitic Quartz Porphyry (Type #5). In the latter rock, phenocrysts of strained and fractured quartz are all that is left to prove the original structure. Pyrite has been introduced along the planes of schistosity, and is clearly subsequent to the forces which produced shearing. This type is dealt with in some detail in a later page, as it makes up an important part of the ore-body. It is higher in pyrite in comparison with the Chlorite Schist (Type #6) to the west, which is higher in chalcopyrite.

The Chlorite Schist (Type #6) is composed entirely of a mass of soft secondary minerals, and none of the original structure remains. Slip planes are commonly developed. This is probably due to its softness and shows that it took longer to adjust itself to a condition of stability. Movements in this rock would certainly show to a greater extent than in the harder surrounding rocks. The chlorite schist has various minerals scattered through it in tiny vugs, in addition to the chalcopyrite (Type #9). Well developed lath shaped crystals of clear glassy selenite, and tabular calcite crystals are found (Type #10), and lenticular quartz veins containing crystalline zincblende (Type #11). A peculiar feature of this rock is the suddeness with which the chalcopyrite dies out to the west. When a certain plane in the schistosity is passed, there is no more chalcopyrite. The reason for this is not apparent, as the rock appears to be homogenous throughout. This is one of the interesting problems yet to be solved in connection with the Flinflon Ore-Body.

Within this main type chlorite schist is a band that probably owed its origin to tuffaceous material. (Type #4). The rock has also been altered to a chlorite schist, but the grain of the rock is much finer, and the cleavages are consequently much more regularly developed, The appearance is so strongly that of an ash slate or cleavage tuff, that there is little doubt as to its origin.

It is to the north-east of the horse, and vertically below the porous leached rock that the greatest ore deposition took place. This consisted of a beautifully banded and intimate mixture of pyrite, zincblende, and chalcopyrite (Type #2), with interstitial quartz and calcite. In general the first named mineral seems to predominate, but where the sphalerite predominates locally, a beautiful chocolate colour is produced. This seems to be in irregular shaped patches rather like joint blocks. Galena is found in vugs, but is comparatively rare.

Further to the north-east, a dyke of quartz porphyry (Type #18) intruded the original rock mass. This type carries very low values, and is evidently the wall along which the mineralizing solutions flowed. This rock was not the source of the mineralization. If this had been so, the greenstone to the north-east of the dyke would have been heavily charged with sulphides to the same extent as to the south-west, but this is not the case. Such pyrite as is found is in scattered cubes and octahedrons, evidently a part of the original magma of the quartz porphyry, and not a replacement. Apparently, the Sericitic Quartz Porphyry (Type #5) was an offshoot dyke from Type #18, but being at an angle to the plane of schistosity, was shattered and schisted, allowing the mineralizing solutions to percolate along its schist planes rather than damming and directing the path of the solutions as was the case in Type #18.

The altered amygdaloidal basalt flows (Type #8) on the hills to the north-east were, as far as can be gathered, the parent type of the rock in the shear zone of the ore-body. This will be discussed more fully later. This type represents a series of flows with marked local differences, rather than one homogenous flow. This being true, it is probable that the shearing force acted more strongly on some less competent member, which then formed the shear zone in path of least resistance. On Callinan's Point, close to the Lamprophyre (Type #19), the phenocrysts of the altered amygdaloidal basalt are epidotic rather than quartzose.(Type #20). This shows a typical difference in the local flows; (It is not to be inferred that there is a genetic connection between the lamprophyre and the amygdaloidal lava; such is not the case, as offshoots from the lamprophyre into the lava take the form of Hornblende veinlets --- not Epidote.)

The evidence of the later phases of igneous avtivity closest to the ore-body, lies in the Hornblende Diorite Porphyrite dykes (Type #16) cutting the altered amygdaloidal basalt (Type #8) on the hillside to the north-east. Dr. Alcock found one of these dykes, and the author another. The exposures are not extensive, and their connection with the formation of the ore-body, if any, is obscure. The rock can be readily distinguished by its white weathered surface, similar to that often found in diabase dykes. The mineralization is comparatively fresh, which seems to imply no probable connection with the quartz porphyry (Type #18). Much of this mineralization can readily be spotted with the naked eye, such as the ophitic arrangement of hornblende crystals. The joint planes have been intruded by calcite, shearing planes are slightly developed, and some of the minerals have shown a tendency towards alteration. This is no more marked, however, than in the case of the Cliff Lake Quartz Porphyry, and possibly these dykes should be given a place far higher in the scale of geological time than the author has assigned to them in Appendix A, Page 9.

The other adjacent evidences of igneous activity are the Lamprophyre dykes before referred to (Type #19) and

and the Chloritised Soda Granite (Type #21). To one or other of the magmas of these rocks must the origin of the Flinflon ores be assigned, and for this reason they are perhaps the most interesting types described. The Lamprophyre dykes are noted (1) on the south-east shore of Flinflon Lake, lying west of the ore-body, (2) on Creighton's Point, also west of the ore-body (3) on Callinan's Point, and (4) on the Point and Bay to the north of Callinan's Point. The rock consists of massive, coarsely crystalline hornblende and augite. These minerals have undergone a certain amount of alteration, breaking down to minerals of simpler molecular structure. Chlorite, calcite and epidote veinlets have intruded the rock. One point worthy of notice is the chalcopyrite contained in the Lamprophyre, noted by Dr. F.J.Alcock. (G.S.C.Summary Report 1922, Page 34C). This seems to indicate a point of origin for the copper content of the ore zone, but if it can be proved that a younger igneous rock is in the immediate vicinity, the probability is that the chalcopyrite is intrusive into the Lamprophyre.

What are the evidences of intrusion of a younger rock? In the extreme north-west corner of MAP Number 1978 there is plotted a lamprophyre dyke. It is to be specially noted that if the strike of the ore-body were to be produced, such a line would cut this body of rock. In other words this is the rock which may be most easily conceived to be the source of the ore. The natural assumption is that a large continuous dyke of lamprophyre runs from the north west corner down through Creighton's

Point and parallel to the ore-body to the south end of Flinflon Lake.

But there is a younger rock. On following up the claim line shown on the map, there is evidence of a marked and progressive change in the character of the intrusive, from the Lamprophyre to a light pinkish grey rock with the appearance of a typical felsite. From the coarser grained part of this latter rock, the Chloritized Soda Granite specimens were obtained. (Type #21). This type consists mainly of quartz and oligoclase. The total area of this rock exposure is not large. The effects of chilling, such as finer grained texture, are most noticeable in the centre. This is apparently the roof of a small granite batholith which just reaches the surface. The point at the highest altitude is the centre, which must have been closest to the intruded rocks. Such an assumption would account for the chilled centre, similar evidences of chilling having been removed from the southern edge of the boss by subsequent erosion. The contact is masked in places by overburden, but the gradational change into the Lamprophyre mapped by Dr. Alcock points to a certain amount of assimilation of the Lamprophyre by the intrusive Granite. There is yet further field evidence that this granite is actually younger than the Lamprophyre. On the north side of Callinan's Point, the Lamprophyre is cut by a fine grained, reddish aplite dyke about four inches wide, showing ophitic texture. Subsequent to this, there was a slight movement resulting in block faulting with development of chlorite along the shearing planes. Quartz was then injected. This narrow dyke, from its position, would seem to be an early offshoot of the granite batholith, which had extended some distance from its source. The quartz is probably the last stage to crystallize from the magma.

Now, if this last assumption is correct, and all the field facts point that way, we have a very interesting bearing on the mode of formation of the ore-body. As previously mentioned, quartz stringers or lenses have been found in Number One shaft. These are similar in appearance to the quartz mentioned above. If this quartz is the last phase of crystallization from the magma, then the fact that the quartz in the shaft contains well-crystallized zincblende tends to confirm the supposition that the sphalerite found in the ore-body was intruded from the last upheavals of the small batholith which further fractured the semi-solidified ore-body (Dr.R.C.Wallace, Canadian Mining Institute Bulletin #54, page 888.)

The dynamic processes which have been dealt with may be summarized briefly. First a series of basic lava flows were poured out on an unknown floor. These were subjected to intense folding with the development of a plane of weakness in a less competent member. Into this plane of weakness was injected a granite batholith. The first upheavals increased the weakness of the incompetent member, brecchiation took place and a shear zone was formed. This was accompanied by intense mineralogical changes of a katamorphic nature, breaking down more complex molecules into simpler forms. As the batholith came closer to the present surface, hot liquid solutions were given off, which penetrated the shearzone and replaced much of the material. These solutions were heavily charged with pyrite and chalcopyrite. The latter tended to penetrate deeper, though no evidence has been produced as to the order in which these two have occurred. The final emanations from the magma were accompanied by a further, but slighter, upheaval, and were in all probability accompanied by zincblende injections into the zone of weakness. Then an intense and prolonged period of weathering took place, the latter phases of which were removed by the last great glacial epoch. There is evidence of weathering both before and after the final retreat of the glaciers, the results of which are the oxidation and leaching of the sulphides and deposition of native copper at or just immediately below the water table.

CHAPTER FIVE.

ROCK ALTERATION BY THERMAL PROCESSES WITHIN THE ORE-BODY.

Alteration has proceeded to such a degree within the ore-body that evidence of the original mineralization must be looked for only in the surrounding rocks. Unfortunately, as indicated in the previous chapter the surrounding rocks cannot be considered a homogenous mass. They are, rather, a series of flows, none of which can be proved to be of notable extent. They vary considerably in composition and texture. Since the rocks in the shear zone were much less resistant to shearing, it is reasonably to suppose that they also differed to some degree in chemical and mineralogical composition. From this it follows that only an approximation of the exact processes involved in ore deposition can be arrived at.

The only feasible scheme is to compare the entirely altered forms within the ore-body with the partially altered rock in the horse, and also with the relatively unaltered amygdaloidal basalt. The term "relatively unaltered" is used advisedly, for it must be born in mind that these are among the oldest known rocks, and all have undergone a degree of alteration which would be considered intense in a younger geological formation. After much thought, the rocks selected for comparison are (1) Chlorite Schist from Number One shaft (Type #6): (2) Altered Diabase from the horse (Type #3), taken from Number Two shaft: (3) Altered Amygdaloidal Basalt (Type #8) taken from 400 to 600 feet to the east of Number One shaft. The Sericitic Quartz Porphyry (Type #5) from Number One shaft and Porous Leached Rock (Type #1) will also be considered. The last named rock is especially considered, as it gives an idea of the structure of the ore, minus the sulphides.

I

Description of Original Mineralization as determined from the Surrounding Rock. (A) From Altered Amygdaloidal Basalt, (B) From altered Diabase in the Horse.

(A). The Altered Amygdaloidal Basalt is described in Appendix A, page #8. The amygdules are chiefly quartz, containing hair-like crystals of apatite, but there are also associated masses of epidote and magnetite. In the case of this epidote, it is probably an original constituent, derived from hot aqueous vapours within the lava. The groundmass is mainly a felted mass of secondary hornblende. Vestiges are found, however, of original augite, hornblende, biotite and orthoclase felspar. The processes of alteration of the augite included first uralitization, followed by complete alteration to chlorite.

This emphasizes the difficulty of establishing a satisfactory basis for comparison, as this, the freshest rock in the vicinity, has already undergone such great changes. The best that can be done is to compare the rock types and show, as far as possible, the changes which differentiate one type from another.

The mineralization of the altered amygdaloidal basalt sums up as follows:-

PRIMARY	Augite	Trace
	Hornblende	"
	Biotite	"
	Orthoclase felspar	"
	Quartz	6.2%
SECONDARY	Chlorite	28.3
	Hornblende	56.6
AMYGDULES	Quartz	8.3
	Epidote & Magnetite,	Trace.

(B) The Altered Diabase in the horse is described in Appendix A, page #6. The rock still shows original crystalline structure though most of it is masked by secondary mineralization. Of this structure, however, there still remain traces. Rough outlines of the phenocrysts and some primary quartz are found. The phenocrysts have suffered a change amounting to partial digestion, as well as alteration of the mineral content in place, as is indicated by the ragged crystal boundaries. They have altered from an orthoclase felspar to kaolin and sericite. The groundmass shows an arrangement of felspar casts altered to kaolin and quartz which is distinctly indicative of ophitic arrangement in a normal fresh diabase --- together with a mass of ferromagnesians which have altered to hornblende, chlorite and leucoxene ---- and the minor amounts of quartz already mentioned. Introduced into this were quartz and sericite veinlets, evidently derived from the magmatic waters during the process of ore formation.

Summing up the mineralization of this type we have:-

PRIMARY	Quartz	Trace
SECONDARY	Kaolin	26.2%
	Sericite	6.1
	Hornblende after augite	8.9
	Chlorite after hornblende	37.8
	Felspar (unidentified)	Trace
	Leucoxene after ilmenite	1.5
INTRODUCED	Sericite	2.0
	Quartz with apatite inclusions	8.1

II

Turning from the relatively unaltered and partially altered types to the wholly altered type adjacent to and included in the ore, the Chlorite Schist (Type #6), we find a different state of things. Again the petrography is summed up in Appendix A, page #3. Here we find a complete alteration of the original constituents, and a re-arrangement of the secondary platy minerals in parallel order, giving rise to schistose structure. The secondary mineralization is quartz and chlorite, quartz crystals being surrounded by chlorite. Slip planes have been developed in this soft fissile type, in which chlorite has either been introduced or has recrystallized, for it is in optical continuity. Some minerals are clearly introduced. Of these the most important is quartz with minor amounts of calcite and pyrite. The calcite is similar to the many small veinlets affecting all the rocks of the district, and the introduced quartz is evidently of the same generation as that found in Type #11. The quartz is referable to that last phase of extrusion from the magma of the chloritized soda granite (Type #21), which carried the zincblende.

Summing up the mineralization of the Chlorite Schist we find:-

SECONDARY	Quartz	48.0%
	Chlorite	35.0
INTRODUCED	Quartz	15.0
	Calcite	1.0
	Pyrite	1.9

The Sericitic Quartz Porphyry, (Type #5) is also of interest. Whereas from a basic rock-type, chlorite schist developed, from an acidic type such as the quartz porphyry a sericitic schist was produced. A few quartz phenocrysts are left showing strain shadows, and these give evidence as to the type from which the rock is derived. The main secondary mineral is sericite. Sericite is also either introduced or recrystallized as veinlets. Epidote in cloudy aggregates is derived from some source not immediately obvious.

The sericitization is closely bound up with the introduction of pyrite into the ore-body. This type carries very heavy sulphides (in places up to 69%) mostly crystalline pyrite which has formed along the schist planes. Quartz has been introduced, similarly to the chlorite schist. This rock is summed up under the "low pyrite" phase, which represents about 90% of the rock:-

ORIGINAL Quartz Phenocrysts	-	1.0%
SECONDARY Epidote		3.0%
Sericite		75.0
INTRODUCED Pyrite		4.0
Quartz		18.0

The rock is described more fully in Appendix A, pages 4 & 5.

The Porous Leached Rock (Type #1) (described in Appendix A, page #7) is, as has been stated before, the solid sulphide type with the sulphides leached out. In appearance it resembles a rotten pumice, and for practical reasons connected with the method of transportation, the more solid portions only were obtained. These naturally represent the more highly siliceous phase. The rock disintegrates so readily that a microscope examination was not practicable, but chemical analyses and determination of porosity of a fairly solid, firm specimen were made with the following results:-

Porosity 12.5%

Result from analysis		Recalculated less porosity.
$Si\ O_2$	94.068	82.290
Fe_2O_3 & Al_2O_3	1.515	1.325
MgO	.426	.373
CaO	2.462	2.154
Loss on Ignition	1.083	.947
TOTALS	99.554	87.096

This rock consists, therefore, of quartz with some iron oxides left from the reduction of the sulphides, and introduced calcitic material of the ordinary type.

A comparison and examination of the minerals gives a clue to the exact process involved in rock alteration and formation of the mineralized zone. For this purpose, a mineral summary follows.

MINERALS		ROCK NUMBERS				
		EIGHT.	THREE.	SIX.	FIVE.	ONE.
PRIMARY	Augite	trace				
	Hornblende	"				
	Biotite	"				
	Orthoclase Felspar	"	trace			
	Quartz	6.2%	"			
SECONDARY	Chlorite	28.3	37.8	35.0		
	Hornblende	56.6	8.9			
	Kaolin		26.2			
	Sericite		6.1		75.0	
	Leucoxene		1.5			
	Quartz			48.0		82.2
	Epidote				3.0	
INTRODUCED	Quartz		8.1	15.0	18.0	
	Sericite		2.0			
	Calcite			1.0		3.5
	Pyrite, etc.			1.9	4.0	14.0

This table of mineral content shows that while only traces of original mineral content are to be found in Type #8, they are almost entirely lacking in the other types. A comparison between #8 and #3 shows a big loss in hornblende, but a gain in chlorite, kaolin and sericite. The kaolin and chlorite were probably derived from the hornblende and the small amount of sericite represents an acid phase, but what was the secondary hornblende? As metasomatic processes are a direct function of the time involved, this function must be taken into account, but as shown some hornblende and chlorite are actual alteration products in place.

The changes between #3 and #6 are even greater. The change which has been introduced is entirely similar to that usually attributed to hydrothermal alteration. While the chlorite is fairly constant, there is a tremendous gain in quartz, showing that the waters were highly silicic as well as chloritic.

One similarity between all these types lies in the abundant development of chlorite, which indicates, though it does not prove, a common origin as basic rocks. This is further corroborated, however, by the fact that Type #6, which is an altered acid intrusive, has no chlorite but sericite is abundantly developed, from a combination of quartz and acid felspar. These hydrous minerals indicate that abundant water accompanied the change. To do its work so thoroughly, the water must have had free circulation, and have been hot, or have acted over a long time. We find that where the condition was most favorable for free circulation, in the shearzone, the alteration was most intense. From the relation of the shearzone to the last great intrusive, the chloritized soda granite, this water must have been hot. It must have been rich in silica, and in the sulphides, for rock #1 shows a complete alteration to quartz and sulphides. The interaction was between a liquid solvent and a solid (the original rock mass), and each would affect the other. In this case, in addition to the altered mineralization of the rock, there should be an effect on the solvent. This is so. Both in the chloritic and sericitic types, tiny veinlets of chlorite and sericite respectively mark the path of the solutions.

Another feature of interest is the comparative affinity of the chloritic type to chalcopyrite, and of the sericitic type to pyrite. The former mineral has penetrated further westerly from the main path of the solutions. This path, as before noted, was largely directed and dammed to the northeast by the Quartz Porphyry dyke (Type #18). It is apparent that the original rocks determined the nature of the replacement --- chloritic types resulting from the basic rocks and sericitic types from the acid.

While it is realized that the validity of making chemical deductions from figures based on mineral analyses is doubtful, yet it may be of interest to make an inspection of these figures for a rough comparison with the results arrived at from the foregoing mineral study. These figures are only approximate for two reasons. First, the chemical formula for many minerals such as hornblende, augite, and chlorite, is not a definitely fixed quantity. Secondly, the mineral analysis is an approximation which is necessarily based on the slides examined and, while these were carefully selected, a difference of several percent in the calculation of the oxides might be expected.

The figures so computed from microscopic analysis appear in the table below. Rock Number One is added for convenience, though the figures in this case were derived from chemical analysis.

ROCK NUMBER	EIGHT	THREE	SIX	FIVE	ONE
SiO_2	45.300	37.026	71.750	51.974	82.297
Al_2O_3	11.550	20.066	5.005	28.800	(1.325
Fe_2O_3	10.300	18.850	21.535	4.119	(
MgO	18.150	1.005			.373
CaO	7.500	6.730	.570	.621	2.154
Na_2O		.254			
K_2O	.525	1.1427		8.850	
H_2O	4.800	7.851	.350	3.426	
Loss on Ignition		4.400	1.430	2.136	.947
TOTAL	99.025	99.1503	100.64	99.926	87.096

From the figures given above for chemical composition, it appears that silica in types #6 and #5 has greatly increased (and still more so in type #1) over types #8 and #3. A comparison of types #8 and #6 gives the change involved in the formation of the ore-body. The chemical composition of Type #8 is that of a normal basalt. Iron has increased relatively in Type #6, due to additional chlorite and pyrite which have been introduced. Lime and magnesia both show a reduction. As the hornblende broke up, these may have formed more soluble decomposition products and have been removed. Looked at in this light it appears to be a typical case of basalt grading into a chloritic schist, though rock flowage and subsequent anamorphism due to hydrothermal action have so completely destroyed the original structure of the latter type. The features which specifically point to igneous origin of the chlorite schist are the excessively high silica, and the dominance of lime over magnesia.

The chemical criteria are, of course, merely subordinate to the evidence offered by the actual minerals. As stated before, the presence of hydrous platy minerals so highly developed indicates the mashing of an igneous rock in the presence of water. The extent to which this has been carried out and the area covered shows that the water, to act so completely, must have been hot and free moving.

CHAPTER SIX.

SUMMARY AND CONCLUSIONS.

From the foregoing, certain assumptions and some definite conclusions can be made as to the formation of the Flinflon ore-body. This body owes its origin to hot hydrous solutions, highly charged with silica and sulphides of various metals. The first action was a replacement and alteration of schistose rock with deposition of copper, iron and lead(?) sulphides. The shearzone produced by the intrusion of the main body of a nearby batholith provided a channel for free circulation of the solutions, which, on account of the proximity of the point of origin, were hot. The point of origin was the roof of a batholith, of soda granite outcropping close by and in direct line with the strike of the ore-body. The last emanations from the magma were quartz charged with zincblende, which in places penetrated and partially replaced blocks of ore broken by the slight movement accompanying these last injections. The quartz porphyry immediately adjacent to the ore-body was not the point of origin, but acted rather as a dam along which the solutions flowed. Parts of this system of dykes at an angle to the path of the schisting force were highly altered as well as schisted, and replaced by ore solutions. The influence of the lamprophyre dykes, if any, is not clear.

Confirmatory evidence lies in the fact that similar small batholiths of Kaminis granite in the district have segregations of sulphides at their margins. A notable instance lies on an island three miles southeast of Baker's Narrows on Lake Athapapuskow. As one approaches the southwest end of the intrusion, sulphides become more and more noticeable, with a deposit of pyrite carrying some gold at the extremity.

This district is one in which, from the standpoint of the prospector, geology is of paramount importance. While the district has already been shown to contain many deposits of metallic sulphides, much of the region is masked by swamps or muskegs. The softness and relative ease of weathering of the sulphide bodies would tend to make them form depressions, and it is generally accepted by the prospectors in the locality that the probabilities are that many valuable deposits are masked by muskegs. As these spruce swamps are extensive, and can only be prospected in winter, or by diamond drill, any phenomena which may be observed along the margins (even though no ore is observed) will be of value. Since hydrothermal solutions tend to work upwards from the batholiths, the probabilities for finding ore will be greater adjacent to small batholiths of Kaminis granite, rather than to large bodies of that formation. In the larger bodies, the sulphides probably have been removed during the long period of erosion. It is also of interest to bear in mind that the batholiths in question are in general too small to map, and are likely to be found in any of the older formations. The Amisk series, being the oldest and most highly deformed rocks, form the readiest channels for circulation of hydrothermal solutions and therefore should receive the most careful attention. Any formation, however, which is older than the Kaminis granite, and which contains lines of weakness which may prove possible paths of penetration for the ore-bearing solutions, should prove a fertile ground for prospecting. The nature of the paths for the solutions will have an influence on the type of the deposit. An instance of this is found in solid quartz veins carrying chalcopyrite, found two and a half miles northeast of Baker's Narrows on Lake Athapapuskow. The strong walls of comparatively fresh greenstone have resisted replacement in this instance. The essentials for encouraging prospecting ground for copper deposits appear to be a shearing to give a path for the solutions, and the proximity of a Kaminis granite boss.

In conclusion, the writer wishes to acknowledge his indebtedness to the kind offices of Dr. R.C. Wallace, who, as Commissioner of Northern Manitoba, afforded an opportunity to visit the property, and also to Professors De Lury and Burwash for many valuable pointers during the laboratory work. Particular thanks are due to Professor Wallace, who also gave valuable assistance at an important stage of the field work, and access to field notes and other private data of importance.

APPENDIX A.

Rocks and Ores of the Flinflon-Schist Lake Area, Pas Mining District, Manitoba.

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PETROGRAPHIC AND MINERALOGICAL DESCRIPTION OF COLLECTION.

INTRODUCTORY. The collection comprises a full suite of the rock and ore types of this new mining district. This pamphlet is intended as a descriptive guide to the collection, and also forms an appendix (APPENDIX 1) to the paper entitled "An Investigation of Rock Alteration in the Flinflon Ore Body."

The system of numbering is that adopted in the field. Consecutive numbers were given as specimens were obtained. These numbers will be retained, but the order in which the specimens are described will be as far as possible in their correct stratigraphical position. This will conform to the Geographical table prepared by Dr. E. L. Bruce. (Memoir 105, #87 Geological Series, #1716 Geological Survey of Canada —— Amisk-Athapapuskow Lake District, page 9.).

QUATERNARY.	NO SPECIMENS.	
UNCONFORMITY		
PALEOZOIC	ORDOVICIAN	Dolomite
UNCONFORMITY		
PRE-CAMBRIAN		Kaminis Granite Granite Gneiss Hybrid Granitic Rocks
	INTRUSIVE CONTACT	
	UPPER MISSI SERIES	Arkose Conglomerate
	UNCONFORMITY	
	LOWER MISSI SERIES	Slate Greywacke Quartzite Conglomerate
	UNCONFORMITY	
		Cliff Lake Granite - Porphyry
	INTRUSIVE CONTACT	
	KISSEYNEW GNEISSES	Sedimentary and igneous gneisses and schists.
	AMISK SERIES	Lavas, tuffs, agglomerates and derived schists.

Of the above the Kisseynew Series is not represented in the collection and the Upper and Lower Missi Series are represented by one specimen each, due to the shortness of time available and relative inaccessibility.

Table of Consecutive Numbers.

1. Porous Leached Rock, Flinflon, from horse.

2. Mixed Sulphides, Solid type, Flinflon #2 shaft.

3. Altered Diabase, Flinflon #2 shaft, horse type.

4. Chlorite Schist, Flinflon #2 shaft.

5. Sericitic Quartz Porphyry, Flinflon #1 shaft.

6. Chlorite Schist, Flinflon #1 shaft.

7. Sericitic Schist, Flinflon, South end of horse.

8. Altered Amygdaloidal Basalt, Flinflon, 400'-600' East of #1 shaft.

9. Chalcopyrite in Chlorite Schist, Flinflon #1 shaft.

10. Calcite and gypsum in Chlorite Schist, Flinflon #1 shaft.

11. Zincblende in Quartz, Flinflon #1 shaft.

12. Pyrite, sulphides, Flinflon, north of horse.

13. Haematite, Flinflon, west of horse.

14. Yellow Ochre (Limonite), Flinflon, north-east of horse.

15. Quartz powdered, Flinflon, north-east of horse.

16. Hornblende Diorite Porphyry, Flinflon 550' east of #1 shaft.

17. Sample of core, Flinflon Mine.

18. Quartz Porphyry, Flinflon #2 shaft.

19. Lamprophyre, Flinflon Lake, Callinan's Point.

20. Altered Amygdaloidal Basalt, Flinflon Lake, Callinan's Point.

21. Chloritized Soda Granite, Flinflon Lake, D.P. of M.C. 10-421.

22. Chloritized Keratophyre, Flinflon 1/4 mile east of mine.

23. Granite Gneiss, A9., Flinflon Lake, 1 mile west on Creighton Creek.

24. Upper Missi Conglomerate, Ross Lake.

25. Cliff Lake Quartz Porphyry, Cliff Lake, 1/4 mile east.

26. Zincblende, Mandy Mine, Schist Lake.

27. Sericite Schist, Mandy Mine, Schist Lake.

28. Lower Missi Slate, Schist Lake, north-east Arm.

29. Hybrid Granite, Schist Lake, north-east Arm.

30. Sideritic Schist, Schist Lake, north-west Arm.

31. Kaminis Granite, Lake Athapapuskow, Island at north of Tinosn Narrows.

32. Ordovician Dolomite, south shore, Lake Athapapuskow.

33. Chalcopyrite, Mandy Mine, Schist Lake.

Description of Rocks and Ores in Order of Stratigraphic Succession.

SIX CHLORITE SCHIST, Flinflon #1 Shaft.

Macroscopic. A dark green, soft fissile schist, containing blebs of chalcopyrite disseminated throughout. Polished slip planes almost black in colour are characteristic. The rock has a soft greasy feel. This forms the footwall of the mine, and the portions richer in chalcopyrite constitute the "Disseminated Ore Type."

Microscopic. Fine grain hypidiomorphic texture. The original structure cannot be determined, the rock now being a schistose felt of secondary minerals. Quartz and chlorite form the main rock-mass, the quartz crystals being surrounded by chlorite. The slip planes are formed by chloritein optical continuity. Calcite and pyrite have been introduced, and finally small quartz veins cut the rock. Since the rock lies in a zone of strong hydrothermal alteration, there is no safe basis on which to state an origin for the rock, though from field relations, it is assumed to be an altered lava.

NINE CHALCOPYRITE IN CHLORITE SCHIST. Flinflon #1 shaft.

Macroscopic. Similar to SIX, but with Chalcopyrite strongly disseminated. This is the "DISSEMINATED SULPHIDE TYPE" of ore. Blebs and irregular veinlets replace the rock, following more or less the laminations of the schist. Occasional cubes of pyrite which are older than the chalcopyrite are found. Average Assay values are Au. = 0.02 ; Ag. = 0.59; Cu.= 5.99%

TEN CALCITE AND GYPSUM IN CHLORITE SCHIST. Flinflon #1 shaft.

Macroscopic. There were small vugs and openings in Type SIX, which were coated first with crystalline pyrite. This was covered by a network incrustation of flesh-coloured calcite, which weathers to a pale brown colour. Later there were deposited clear glassy colourless selenite crystals, in long prisms and shorter more tabulate crystals. Sulphur was deposited last in a fine flour. Perfect specimens are rare. The specimens in the collection are mainly solid calcite, showing in some cases one or more of the features discussed.

ELEVEN ZINCBLENDE IN QUARTZ, Flinflon #1 shaft.

Macroscopic. Fine grained, waxy gray-green quartz cuts Type FIVE in irregular veins up to two feet wide. Crystalline sphalerite is distributed in stringers throughout the quartz, principally at the edges of the quartz veins. The zincblende is accompanied by some chalcopyrite and minor amounts of galena. Masses of granular pyrite appear to be older, but relationship is doubtful. Cubes of pyrite are also found through the rock-mass, but have not been identified in the quartz. The Zincblende is accompanied by sericitisation, and is also found surrounding small red garnets. All this mineralisation is previous to the formation of the slip planes described under Type SIX.

FIVE SERICITIC QUARTZ PORPHYRY. Flinflon #1 shaft.

Macroscopic. A light gray, schistose rock with very small grains of pyrite scattered throughout. It feels slightly unctuous due to presence of sericite. This type extends from to 20' level to the 200' level in this shaft, and is locally known as "Disseminated Ore." Average values for the specimens are Au. = 0.03 ; Ag. = 0.475 ; Cu. = 2.126 %

Microscopic. This rock was originally porphyritic, the highly schistose structure being secondary in character. Pyrite occurs in bands parallel to the schistosity, both in cubes and in roughly cubic masses. Phenocrysts of slightly fractured quartz show strain shadows. The ground-mass is epidote and sericite, while sericite, quartz and pyrite have been introduced. There are no evidences of former structure save the phenocrysts, but it is presumed that the epidote and sericite were produced from plagioclase felspars. 75% of the rock is sericite. The original was probably a quartz porphyry similar to Type EIGHTEEN.

SEVEN SERICITE SCHIST. Flinflon, south end of horse.

Macroscopic. This is a white-coloured, extremely fissile rock, which has a bleached look, and is in spots much rust stained from decomposed pyrite. It is both brittle and rather soft. This occurs in the top twenty feet of #1 shaft, and much was removed to make room for the blacksmith shop and power plant. It grades into Type FIVE, and is that type with the sulphides leached out.

Microscopic. A fine textured mass of sericite crystals in highly schistose arrangement, cut by small quartz veins which cross the strike of schistosity. Some of the original quartz remains as fine grains in the sericite mass, showing strain shadow. All the rest of the original mineral was changed to sericite. Pyrite was intruded in cubes and grains along the schist lamellae, being subsequently altered to limonite. Square casts show that much has been removed by leaching. Quartz veinlets are the youngest generation. The sericite is about 67% of the rock, which is close to the sericite content of Type FIVE.

FOUR CHLORITE SCHIST. Flinflon #2 shaft.

Macroscopic. A light gray-green rock, soft, highly fissile, with a soft unctuous feel. The rock has two well marked cleavage direction at 30°.

and cleaves in more regular planes than does the Chlorite Schist, Type SIX, to which it is most closely allied. It is possible that it was originally a Cleavage tuff, or ash slate, deposited in a thin bed, during a short period of shallow submersion below sea level.

Microscopic. The rock is almost entirely composed of fine grained chlorite, with highly schistose arrangement. The texture is remarkably even throughout. Grains of pyrite and quartz roughly elongated are introduced parallel to the schistosity.

THREE ALTERED DIABASE, Flinflon #2 shaft, horse type.

Macroscopic. This rock forms a large horse in the centre of the ore body (Bruce, op. cit. p. 71). A dark-green, massive, semi-crystalline rock. The specimens vary slightly, some showing the phenocrysts more markedly than others. These Phenocrysts are light in colour, with irregular outline. Joint planes have had calcite veins introduced, and in places show rust stains from decomposed pyrite. Cubic crystals of pyrite are occasionally found scattered throughout. The rock stands out as a conspicuous boss, due to greater resistance to weathering.

Microscopic. Rock is of medium texture, and most of the structure is of secondary minerals. Outlines of the original phenocrysts remain, with traces of cleavage at right angles. These phenocrysts are now represented by kaolin and sericite, and were probably orthoclase felspar. Minerals present are:- Primary. Quartz, showing strain shadows.

Secondary. Kaolin, 26.2%; sericite 6.1%; Hornblende after augite, 8.9%; Chlorite after Hornblende, 37.8%; Leucoxene after ilmenite, 1.5%; also a trace of felspar, which may be primary.

Introduced. Sericite and quartz interstitial. Hornblende is pseudomorphic after Augite, outlines of the face remaining. Some of the sericite occurs in veinlets.

From the coarseness of the crystallization, the nature and shape of the phenocrysts, and the remnants of ophitic (lath-shaped) texture in the altered felspars of the ground-mass, it may be concluded that the original rock was a diabase dike twenty to thirty feet wide. This has proved more resistant to weathering, though not to chemical alteration, presumably due to the difference in texture, from that of the surrounding rocks.

<u>EIGHTEEN</u> QUARTZ PORPHYRY. Flinflon #2 shaft.

<u>Macroscopic.</u> A light gray schist with clear glassy quartz phenocrysts which have a somewhat round cross-section. The rock is hard and rather brittle. It is slightly fissile and tends to break upon three well defined planes at 90°, 90°, and 70° respectively to each other. Crystals of pyrite showing both the cube and the octahedron forms are found scattered throughout . The rock strikes 144° and dips 72° east, so that it overlies all the rocks previously described, and lacking evidence to the contrary may be assumed to be younger. The belt of fresh porphyry is about eleven to twelve feet wide in the east ends of the cross-cuts from both #1 and #2 shafts.

<u>Microscopic.</u> This is a fine grained Porphyritic rock with schistose ground-mass. The ground-mass of sericite represents about 54% of the rock total. The phenocrysts are of clear quartz, slightly eroded at edges which are entered by the ground-mass.

Pyrite and quartz were introduced, the pyrite being later.

<u>ONE</u> POROUS LEACHED ROCK. Flinflon from horse.

<u>Macroscopic.</u> A highly porous white rock. The harder and less porous parts are a pale gray or blue colour. The leached portions are presumed to have been filled with sulphides. A chemical analysis gives the following results :- SiO_2 - 98.33%; Fe_2O_3 & Al_2O_3 - 1.00% ; MgO - 0.50%
This rock has presumably been derived by leaching of Type TWO, SOLID

SULPHIDES, and it is possible that native copper found at the forty foot level is reprecipitated after being leached from this rock. The rock is found on the surface on the east side of the horse, and strongly resembles a pumice. It is easily broken down, and makes a good road metal where used on the property. The porous spaces form 30% to 35% of the total rock-mass.

FIFTEEN QUARTZ, POWDERED. Flinflon, north-east of horse.

Macroscopic. The white powder is quartz derived from the crushing of Type ONE. The crushing might have been due to normal weathering or to glacial action. It is probable, however, that the powder is of post-glacial origin, since the glaciers came from the north-east, and cleaned of all loose material. This is a type of surface decomposition closely connected with Types TWELVE and FOURTEEN.

EIGHT ALTERED AMYGDALOIDAL BASALT. Flinflon, 400'-600' east of #1 shaft.

Macroscopic. Massive dark-green rocks. Amygdules are white, granular quartz, which is more resistant to weathering than the ground-mass. Pillow structure may be seen in places. The Type has a wide distribution as will be seen in the discussion of Type TWENTY. Jointing is pronounced, taking place ina great variety of directions.

Microscopic. This is a medium grained, hypidiomorphic amygdaloidal lava, in which the ferromagnesian minerals have recrystallized in part to a felted mass of secondary material. The amygdules are quartz containing apatite hairs, with associated masses of granular epidote and magnetite. The only original mineralization in the ground-mass are traces of Augite, Hornblende, Biotite and Orthoclase Felspar. Uralitization then took place, as is shown by the pale zones in centre of fresher augites. The Hornblende from augite is in a felted mass, 56% of the total rock-mass. This changes into chlorite, and all gradations from pure hornblende to pure chlorite may be seen.

TWENTY ALTERED AMYGDALOIDAL BASALT. Flinflon Lake, Callinan's Point.

Macroscopic. Dark-green compact rock similar to Type EIGHT save that the amygdules are a pale green colour and that certain phases show small veinlets of lamprophyre as well as a certain amount of absorption from the large adjacent lamprophyre dyke. In distribution this Type is a direct continuation of Type EIGHT.

Microscopic. This is a fine-grained amygdaloidal lava, so much altered that the original structure is merely indicated by the presence of the amygdules, while the ground-mass is a felted mass of secondary ferromagnesian minerals. The epidote phenocrysts form 25.0%, the ground-mass being Hornblende = 36.0%; Chlorite = 33.0% with minor amounts of sericite, calcite and magnetite which probably result from the decomposition of augite. The phenocrysts also show a tendency to change to chlorite. Veinlets of Hornblende cut the rock.

SIXTEEN HORNBLENDE DIORITE PORPHYRITE. Flinflon 550' east of #1 shaft.

Macroscopic. This is a dark-gray, crystalline porphyry. The phenocrysts show an ophitic arrangement of lath-like Hornblende crystals. The joints are filled with very small calcite veinlets. The weathering of the exposed surfaces is white, and strongly resembles the weathering of diabase dikes, save that the Hornblende phenocrysts show up black against the white background. This weathering penetrates for 1/15 of an inch. The rock occurs in a dike cutting Type EIGHT. This dike is eighteen inches wide, strike 100° and dip 52° North. Dark, chloritized slip planes occur in this Type.

Microscopic. This is a fine-grained porphyritic rock, with fine hypidiomorphic ground-mass. The Hornblende phenocrysts form 22% of the rock. These have changed in places to chlorite and calcite. The ground-mass is mostly Oligoclase felspar (59.0%) which shows a tendency to change to epidote. Quartz is present in the ground-mass up to 2.0%.

SEVENTEEN SAMPLE OF CORE. Flinflon Mine.

Macroscopic. These core samples may be of any of the Types mentioned in the above paragraphs. This Type was included to give a rough idea of the method of exploration used in blocking out the ore body. The cores are waste cores, that is to say, they did not show valuable material and were rejected. The drilling was done with a type AA diamond drill. Forty-four bore-holes were sunk, a total of 25,664 feet of drilling, and down to the five hundred foot level, sixteen million tons of ore have been blocked out. This drilling has been checked by a total of sixteen hundred feet of shaft, cross-cut, drift and stope, showing the results to have been very accurate.

TWO MIXED SULPHIDES. SOLID TYPE. Flinflon #2 shaft.

Macroscopic. This ore type consists of Pyrite, sphalerite and chalcopyrite, in well marked bands of fine-grained solid material. In general, the pyrite predominates, though locally the sphalerite bands may be the major constituent. The bands vary from a fraction of an inch to several inches in width, and are really intimate mixtures of the three minerals, taking the colour of the predominating mineral. This forms the "Solid Ore". Values are roughly Gold = .14 ozs; Silver = 2.6 ozs; Copper = 1.802 %. Zinc is present but not determined.

FOURTEEN YELLOW OCHRE. (LIMONITE). Flinflon, north-east of horse.

Macroscopic. A fine yellow powder produced by oxidation of the sulphides. This Type, together with Types TWELVE and THIRTEEN are surface weathering products. The presence of these weathering products led to the discovery of the Flinflon Mine, so that the interest in these Types of pulverized material lies principally in their value to the prospector. There are hardly sufficient quantities of either Types FOURTEEN or THIRTEEN to make them valuable as paint bases.

<u>THIRTEEN</u> HAEMATITE. Flinflon, west of horse.

<u>Macroscopic.</u> This is a maroon-coloured powder of haematite, resulting from weathering of the sulphides. It occurs on the surface at the west side of the horse, and was probably the first sign of mineralization seen by the discoverers of the Flinflon Mine.

<u>TWELVE</u> PYRITE. SULPHIDES. Flinflon, north of the horse.

<u>Macroscopic</u> Finely powdered sulphides, with little or no weathered material. This material was taken from the first trench dug. There was about four feet of this material above Type TWO.

<u>TWENTY-TWO</u> CHLORITIZED KERATOPHYRE. Flinflon, 1/4 mile east of Mine.

<u>Macroscopic.</u> A dark-gray, fine-grained, crypto-crystalline rock with dark phenocrysts of irregular outline. This Type is very massive, with few joint planes, and is interbedded in Amygdaloidal Basalts similar to Type EIGHT. It gives a ringing sound when struck with a hammer, and apparently represents an interflow extrusion between the periods of the Amygdaloidal lava flows.

<u>Microscopic.</u> A porphyritic fine-grained rock, with Phenocrysts up to 24 mm. in diameter. A secondary structure is introduced by a slightly schistose arrangement of secondary chlorite in the ground-mass (30.0%). There was also mechanical strain involving fracturing of the phenocrysts, the fractures being filled with Biotite and Chlorite, an alteration of Biotite. The phenocrysts form 25% of the rock-mass and are composed of Oligoclase-Albite felspar. The ground-mass is also Oligoclase-Albite (35%) with Chlorite, presumably from Hornblende by analogy to adjacent rocks, and a small amount of leucoxene. Small quartz and epidote veinlets were introduced.

<u>TWENTY-SEVEN</u> SERICITE SCHIST. Mandy Mine, Schist Lake.

<u>Macroscopic.</u> A light-gray schist, with scattered crystals of pyrite.

Small quartz phenocrysts are observed in some specimens, but not in all. Colours vary from light to dark gray. Rock is of medium hardness and fissility, and is cut by veinlets of calcite. This is the country rock of the Mandy Mine.

Microscopic. The texture is fine-grained, hypidiomorphic. The schistosity is secondary. The calcite veinlets are roughly parallel to this schistosity. Quartz forms 50% of the rock-mass. Most of this quartz is in fine grains, which have been slightly crushed, producing tails in the direction of schistosity. Some of the larger masses may have been phenocrysts, but this is not clear, nor can the amount of introduced quartz be determined, though much has clearly been introduced. Secondary minerals are represented by Sericite (20%); Leucoxene and Epidote. The sericite is interstitial and optically continuous. Veinlets of Calcite (30%), sericite and quartz cut the rock-mass.

TWENTY-SIX ZINCBLENDE. Mandy Mine, Schist Lake.

Macroscopic. Solid banded sulphides with zincblende predominant. The ore has a rick chocolate brown colour, and consists mainly of fine-grained sphalerite. Streaks of chalcopyrite are found throughout. Small inclusions of schist occur, and in small vugs and seams white iron sulphate has developed as a secondary product.

THIRTY-THREE CHALCOPYRITE. Mandy Mine, Schist Lake.

Macroscopic. Solid banded sulphides of fine grain with chalcopyrite predominating. Bands consist principally of chalcopyrite, with zincblende which may be recognized by the chocolate colour of the bands, and minor amounts of pyrite. This is the ore that was shipped to Traill, B.C. for smelting. Average smelter returns on this Type ran between 17% and 20% Cu. The banding of all these solid sulphide types is believed to be due to successive periods of mineralization and to selective precipitation.

Since this material has been on the dump for a year, much of the surface shows beautiful peacock irridescences in gold, red, blue, green, etc. from shallow oxidation products.

<u>THIRTY</u> SIDERITIC SCHIST, Schist Lake, north-west Arm.

<u>Macroscopic.</u> This is a highly fissile schist. The predominating colour is a pale pink, while the joint planes are dark green. The rock is too fissile to make good microscopic sections, but an examination of a polished surface showed that the main part of the rock is a pink carbonate high in iron (Siderite). Around the pink grains considerable sericite has developed parallel to the schistosity. Strong shearing then took place, with development of chlorite along the fractures and in joint planes. This was slickened by subsequent movement. Pyrite and chalcopyrite were later deposited in vugs and fissures, as well as calcite on the chlorite.

<u>NINETEEN</u> LAMPROPHYRE. Flinflon Lake, Callinan's Point.

<u>Macroscopic.</u> A coarsely crystalline, dark-green, massive dike rock, varying in texture from fine-grained at the edge of the dike to very coarse at the centre. Maximum width is over forty feet. Side stringers run off from the main dike into the country rock. The main mineralization appears to be hornblende. Small cubes of pyrite are scattered throughout. The rock weathers more readily than the surrounding rocks, giving a rounded appearance to all plucked faces.

<u>Microscopic.</u> The rock is coarse textured, hypidiomorphic, the secondary structure being confined to development of calcite-chlorite veinlets. Augite (4%) has altered to Hornblende, calcite and magnetite. Hornblende with some augite forms 63% of the rock-mass. This hornblende also alters to calcite, and some crystals show zonal bleaching. Traces of garnet, biotite and quartz are present. Chlorite, calcite and epidote veinlets have been

introduced. The total calcite is 20%. No serpentine was found in the sections examined, but this mineral is reported as present by Dr. E. L. Bruce. (Amisk-Athapapaskow. p. 69).

AMISK VOLCANICS. All the above rocks are included in the Amisk Volcanic Series, though possibly some of the ores and certainly the weathering products are much younger. This is in conformity with G.S.C. map #1726.

TWENTY-FIVE CLIFF LAKE QUARTZ PORPHYRY. Cliff Lake, 1/4 mile east.

Macroscopic. A coarse grained granite porphyry. The phenocrysts on weathered surfaces are sugary white quartz, but when freshly fractured this quartz is a pale bluish colour. Some phenocrysts have been crushed by shearing strains. The ground-mass is laminated slightly and appears to be altered. Rock is intrusive into the greenstone series, and there are many schist inclusions. Jointing is marked, and there is a general appearance of mechanical strain subsequent to the consolidation of the rock.

Microscopic. The rock is of coarse grained porphyritic texture, the original structure being hypidiomorphic, with a very coarse ground-mass. This was subsequently cut by veinlets of calcite, and a slightly schistose arrangement was produced by crushing of the quartz and felspar crystals. The primary minerals were Quartz (54%) Albite (15%) Oligoclase (25%) and Hornblende (1%). The felspar in part has altered to epidote and sericite, while the Hornblende has altered to chlorite, Calcite and a small amount of pyrite have been introduced.

LOWER MISSI SERIES

TWENTY-EIGHT LOWER MISSI SLATE. Schist Lake, north-east Arm.

Macroscopic. A highly fissile, green slate. Jointing is marked. Some of the laminae are curved. The original bedding planes may be distinguished in places by colour differentiation. Calcite veinlets fill the joint planes. The rock is typically soft, and the average of the beds is about one inch.

Microscopic. The rock is of very fine-grained texture. Traces of bedding planes are seen in the slides at 22° and 50° angles to the strike of the schistosity. Angular fragments of Oligoclase and broken quartz pebbles are included in a matrix of Biotite (60%), Epidote (20%), and Quartz (20%). Calcite and quartz veinlets are introduced. The materials have apparently been derived from the decomposition of Amisk Volcanics.

UPPER MISSI SERIES

TWENTY-FOUR UPPER MISSI CONGLOMERATE. Ross Lake.

Macroscopic. The specimens are of the matrix, which is practically a greywacke varying between pale green and pale red in colour. Well rounded white quartz pebbles are scattered throughout, with a gravel of quartz and jasper. Further to the east is a belt of conglomerate with pebbles from 2" to 6" in diameter. These boulders are quartz, chert or granite. Evidences of bedding are slight, confined mainly to bands of coarser pebbles.

Microscopic. Rock consists of a fine-grained schistose matrix, showing flow structure around pebbles and minor drag folds. The pebbles are quartz, slightly eroded at the edges. Some of these are crushed, giving quartz tails which in extreme cases follow the plications of the matrix. There are a few pebbles of serpentine with actinolite, probably derived from hypersthene. The matrix is mainly Biotite with 20% quartz. The rock was subjected to great pressure, subsequent to which pyrite and chlorite were introduced in minor amounts.

HYBRID GRANITIC ROCKS

TWENTY-NINE HYBRID GRANITE, Schist Lake, north-east Arm.

Macroscopic. The rocks have been produced by the intrusion of Granite

Gneiss into sediments of the Missi series, with partial assimilation. The rocks apparently cooled before assimilation was complete, forming a non-homogeneous mixture, which grades from a coarse red or gray granite, through a coarse grained basic rock, to a fine-grained basic rock, which in turn grades into a massive greenstone type. Tourmaline and garnets are sometimes found. The various phases may grade into one another imperceptibly or the contact may be sharply defined. The specimens may show one or more of these phases, but all afford good illustrations of this absorption phenomenon.

Microscopic. No microscopic examination could be of value in determining the character of a rock which is essentially non-homogeneous. One phase examined proved to be a coarse grained, hypidiomorphic rock, cut by quartz stringers, and veinlets of calcite and serpentine. Of the primary minerals there was 23% quartz, 10% of Oligoclase and Albite, and some Hornblende, Biotite and Augite. The felspars tended to weather to epidote and sericite, while chlorite and serpentine were derived from the ferro-magnesians. The quartz shows shadow strains so that pressure must have occurred subsequent to its formation.

GRANITE GNEISS SERIES

TWENTY-THREE GRANITE GNEISS. A9. Flinflon Lake, 1 mile west on Creighton Creek.

Macroscopic. This is slightly gneissose Biotite granite of pink grey colour. This has been subjected to pressure, with chlorite developed along the consequent slip planes. There is a wide absorption border along the contact between the Granite Gneiss and the Amisk Volcanics, in which the colour of the rock grades from black to pinkish gray. Pyrite crystals have weathered out forming rust along the joint planes.

Microscopic. A medium to coarse grained, hypidiomorphic rock, which has suffered fracturing in the quartz and ferro-magnesians. Primary minerals are - Quartz 22%; felspars 62% (orthoclase, albite, microline, labradorite); biotite 2.5% hornblende. The felspars show a strong tendency to alter to sericite, calcite and epidote. Cubes of pyrite are scattered throughout.

KAMINIS GRANITE

TWENTY-ONE CHLORITIZED SODA GRANITE. Flinflon Lake D.P. of M.C. 10 - 421.

Macroscopic. This rock occurs in a batholith or dome intruding both the Amygdaloidal Lavas, Tye TWENTY, and the Lamprophyre, Type NINETEEN. It has well marked absorption borders, and has also silicified the lamprophyre, changing the latter to a hornblende diorite. The fresh granite is pinkish gray in colour, and varies from very fine grain to medium. Erosion has proceeded to slightly below the roof of this batholith. This is the closest granitic intrusion to the Flinflon ore body, and appears to be in direct genetic relationship. Small cubic crystals of pyrite are scattered throughout.

Microscopic. A medium grained, hypidiomorphic rock. The interior of the felspars has altered to finer alteration products, and the whole is cut by veinlets of calcite. The primary minerals are - Quartz 12% and Oligoclase 51%. The quartz shows shadow strains in places. The interior of the felspars has been altered to Sericite and calcite. Chlorite, calcite and sericite is all that remains of the original ferro-magnesians. Pyrite and calcite were introduced.

THIRTY-ONE KAMINIS GRANITE. Lake Athapapuskow, Island north of Tinean Narrows.

Macroscopic. Coarse grained, fresh red hornblende-biotite Granite. This is a well jointed rock, of pleasing flesh-red colour. Alteration on the surface and along the joint planes has taken place to a depth of about 1/16th of an inch.

Microscopic. This is a very coarse grained, hypidiomorphic rock, in which the felspars and hornblende have undergone great alteration. The primary minerals are - quartz 21%, felspar 45% (Albite and Oligoclase), biotite and hornblende. Felspars have altered to epidote and sericite, and have also suffered mechanical fracturing. Both Biotite and Hornblende have altered to chlorite. A large amount of the Hornblende has also gone over into serpentine, with actinolite and magnetite. Orthoclase is also present, but, owing to the cloudy nature of the alteration, the amount is indeterminable. Calcite veinlets cut the rock and small cubes of pyrite are found.

ORDOVICIAN

THIRTY-TWO ORDOVICIAN DOLOMITE. South shore Lake Athapapuskow.

Macroscopic. The specimens vary as they were not all taken from the same place. The colour varies between light buff, a mottled pink and buff, and a salmon pink. The composition is about the same throughout, a magnesian dolomite. It is probable that the pink colour is due to iron being present in the ferric state, as the buff limestone is rather higher in iron content. The grain is fine and compact, the beds varying in thickness from a few inches to several feet. The strata are flat lying, superincumbent upon the rather irregular Pre-Cambrian surface.

POROSITY. A Method for the Determination of Pore Space in Rocks.

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Problem. In working with pumice, partly indurated gravels, and leached rocks, it is sometimes advisable to gain some estimate of the volume of air space or pores, in ratio to the total volume. Practical applications lie in the examination and inspection of concrete work, and in the coke industry.

The problem that led to the method to be discussed, was the approximation of the material removed by leaching from a pseudo-pumice taken from Flinflon Mine, Northern Manitoba.

Difficulties. Some of the practical difficulties to contend with in the determination of pore space are obvious. (1) The irregularities on the surface of a rough specimen belong either to broken vesicles or to the normal fracturing of the rock. Of course the former should be included in any calculation of the total volume, while any system that includes the latter will give too high a pore ratio. (2) Another important difficulty is that many, possibly the majority, of the interior spaces are completely sealed to the action of any liquids employed. Thus, any method that depends upon saturation of the mass, such as Dr. Sterry Hunt's method, must be unsatisfactory. (3) There is a certain difficulty in cutting porous rocks to any definite shape, while retaining a true proportion between the porous spaces and the total volume of the rock. Dust will lodge in some pores, while the tearing away of rock-mass will unduly enlarge others. In addition, the cutting requires special saws and considerable skill. (4) The addition of foreign matter, such as varnish or wax for sealing the pores, is objectionable as adding a second factor to be determined.

Alternative Methods. Several alternative methods were considered. All have advantages, but all have grave objections, and a fine discrimination between advantages and objections had to be made in choosing a method. Perhaps the most generally used is to cut the rock to definite proportions (i.e. square it) and weigh the known volume. The rock would then be saturated with hot water, cooled and the volume of water absorbed computed from the change in weight. The method attributed to Dr. T. Sterry Hunt (Trans. A.I.M.E. Vol. XII, P. 112) is similar but does not necessitate cutting to size. This method involves weighing in air, saturation, and then weighings in air and in water. In these two methods the saturation requires the use of an air-pump, and considerable boiling in water.

Again, a given volume of rock, (obtained by cutting to a cube) might be pulverized, and the volume of the fine powder noted. This would give pore space by difference. Another simple method would be to note the volume of liquid required to saturate a rough sample. Then, after careful drying , a thin covering of wax would be applied, and the volume computed by immersion.

Method Used. The method of solving the problem will be described in some detail.

A fair sample of the pumice-like rock was selected. There were no extraordinary indentations on the surface, which was brushed free from loose rock particles. 95% Ethyl Alcohol was selected as the immersion agent, since very little air is included, in comparison to water, and it gives a much flatter meniscus in the graduate.

The rock was first soaked in alcohol. This filled the vesicles that could be easily reached, and the soaking was continued until, with a strong lens, no more air could be observed to escape. The prepared sample was now dried by gentle heat for a short time so as to reduce it by the amount of air space that would occur in the fractured surface of any rock. (This might be objected to as giving too low an estimate of pore space, but since the tendency is to get the pore space too high, it acts as a factor of safety. The heating might be omitted with advantage). The second immersion was made in a large graduate which contained 200 ccs. of alcohol. The alcohol was then drawn off with a pipette until the 200 mark was again reached, and the amount drawn off was carefully measured . This amount represents the TOTAL VOLUME of the rock.

The rock was then dried for three hours at 100° C. to drive off the alcohol. The dried rock was then pulverized to about 60 mesh at which fineness the pore space in the powder was considered negligible, in relation to the whole. The powder was introduced into a graduate filled with alcohol and its volume noted. By deducting the volume of the mineral matter from the total volume, THE VOLUME OF THE AIR SPACE was computed.

<u>Disadvantages.</u> The principal difficulty lies in the fact that the sample was necessarily large. This involved the use of a very large mouthed graduate in getting the total volume, and the consequent difficulty of reading the meniscus' level.

There is a difficulty also in getting rid of the air in the powder, which makes the mineral volume too high. This is offset by the loss of material, as impalpable dust, in grinding. Another minor error is loss of alcohol by evaporation. With care all these errors should be small.

<u>Advantages.</u> The main errors can be offset by choosing large size

samples. This reduces the mathematical value of small errors in considering the total per centage. If the sample is narrow, it can be fitted better into a graduate, so as to reduce the size of graduate required and overcome some of the difficulty of reading the meniscus.

Again, by this method no special apparatus not found in the least equipped scientific laboratory is required. The objections to applying waterproof coatings, and to cutting the sample to size, are eliminated, while the pulverizing lays open all interior sealed pore spaces. While the method does not pretend to any very refined accuracy, it is doubtful whether such accuracy is scientific or desirable, since computations of any two samples may vary over one percent. The advantages in the petrological laboratory of this method are speed and simplicity.

Sample Analysis of Porosity.

#1. Volume of the whole is 35.0 ccs.
Volume of the powder is 22.5 ccs.
Whence volume of pore-space is 12.5 ccs. by difference.
Which gives the pore space percentage of the total volume = 35.7%

#2. Volume of the whole is 35.0 ccs.
Volume of the powder is 22.5 ccs.
Whence volume of pore space is 12.5 ccs. or 36%

#3. With a slightly more dense sample of the same rock results were; Volume of whole 26.9 ccs.; volume of powder 18.0 ccs. and volume of pore space 8.0 ccs. or 30.76% which was about what would be expected by inspection.

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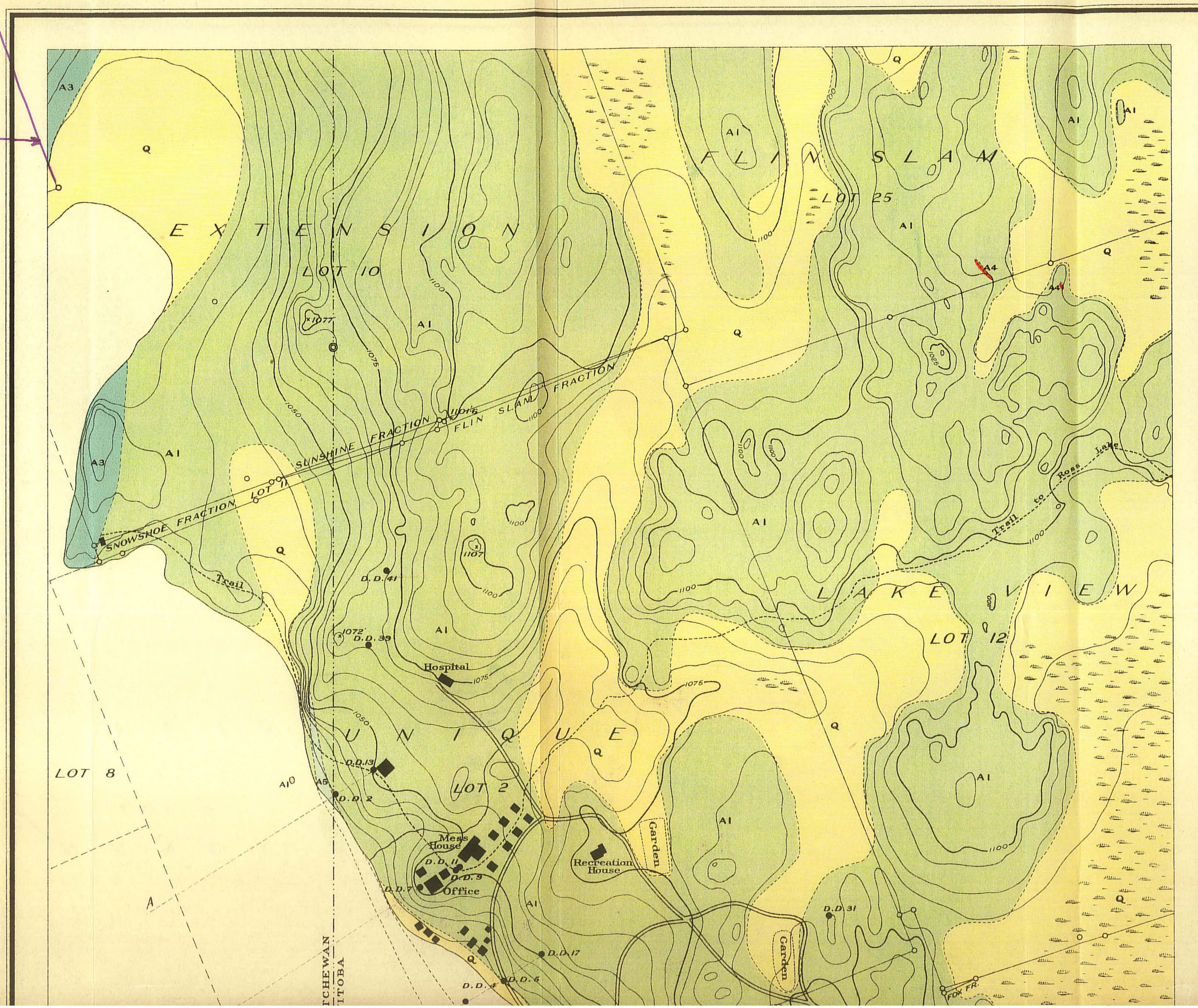
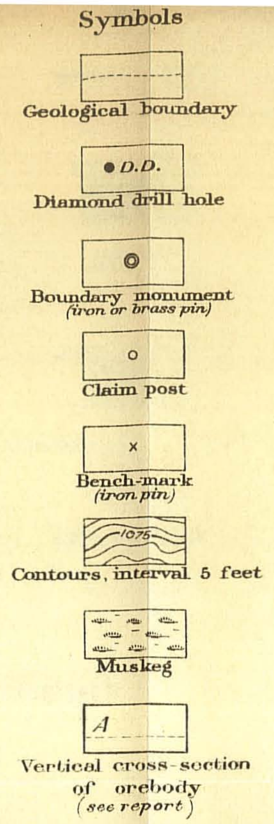
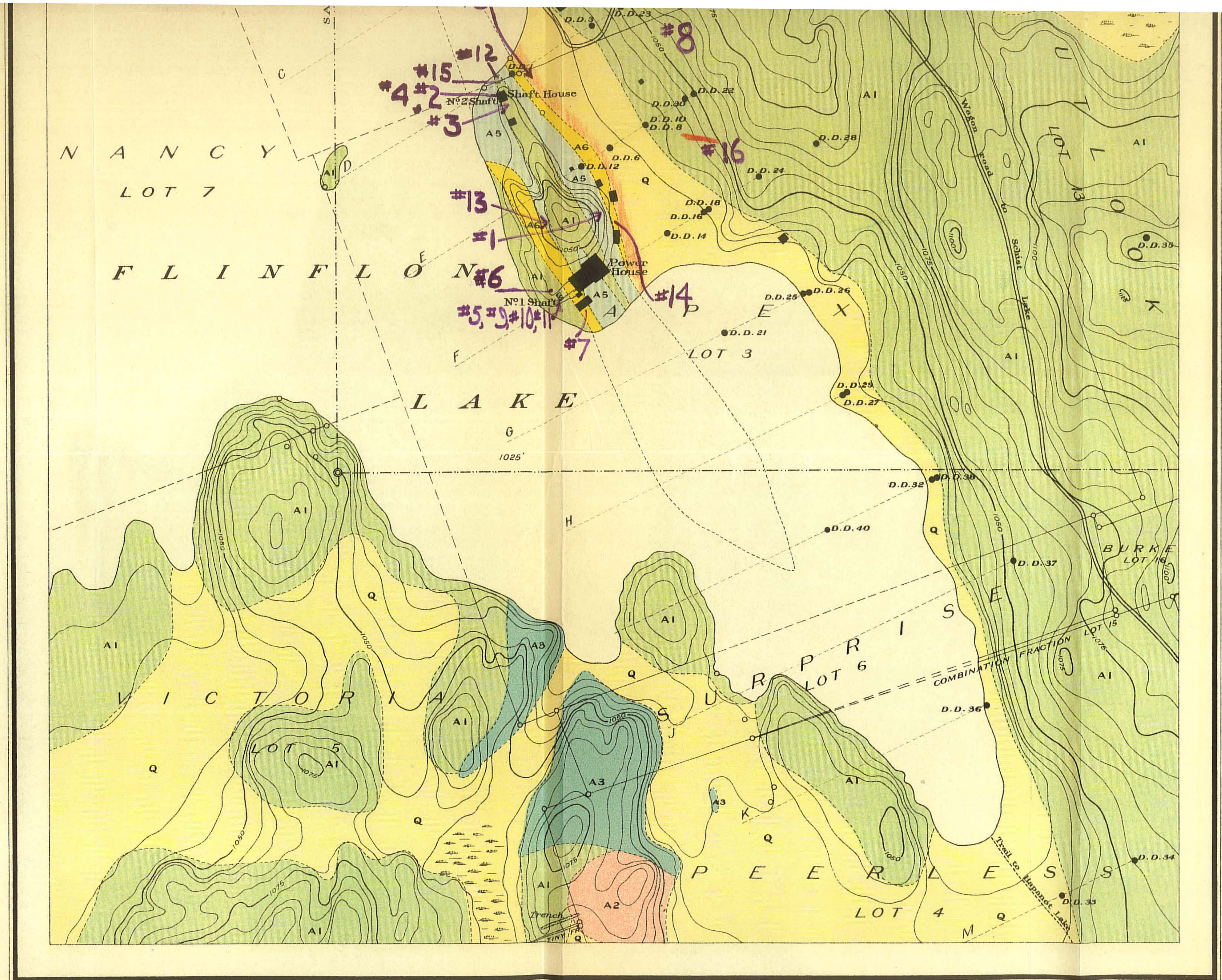


LEGEND

QUATERNARY	PLEISTOCENE	Q	Clay and drift
PRECAMBRIAN		A6	Disseminated sulphides
		A5	Solid sulphides
		A4	Diorite
		A3	Lamprophyre
		A2	Quartz-porphyry
		A1	





C. O. Senécal, *Geographer and Chief Draughtsman.*
A. Joanes, *Draughtsman.*

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PART OF THE FLINFLON GROUP OF CLAIMS, MANITOBA AND SASKATCHEWAN.

Scale of Feet
100 50 0 100 200 300 400 500 600 700 800 900 1000

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