Mineral potential of the Rankin Inlet

A detailed study of the Rankin Inlet-Ennadai volcanic belt by the Geological Survey of Canada has turned up evidence of a wide variety of mineralization of possible economic potential.

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The Rankin Inlet-Ennadai belt has been the subject of mission oriented geological research by the Geological Survey of Canada via the authors since 1970 (Ridler, 1971; Shilts, 1971). A great deal of information has been collected and in part published (Ridler and Shilts, 1973, Ridler, 1974; Shilts 1974).

This paper will attempt to summarize and extend the results in terms of the belt’s mineral potential.

The first part of the paper concerns volcanic stratigraphy and metallogeny and is the responsibility of the first author, the second concerns till geochemistry of the active zone and is the responsibility of the second author.

Topical research in geology is very dependent on the quality of pre-existing information. The authors owe much to Davidson (1970a, 1970b), Bell (1971), Eade (1964) and Heywood (1973) whose efforts provided the 4 mi. scale geologic base maps, and to the late G.M. Wright whose 16 mi. scale reconnaissance map (Wright, 1967) has proven to be invaluable. The availability of aeromagnetic and air photo coverage was also critical.

Answers to important questions bearing upon the mineral potential had already been provided by the foregoing geologists – answers such as the Archean age of the belt (Davidson, 1970a), the presence of abundant iron formation (Wright, 1967; Davidson, 1970b), presence of felsic volcanics (Davidson, 1970a) and so on. The aim of the research was to go considerably beyond that.

Field procedure
Areas which featured a high degree of outcrop and lithologic variety, great stratigraphic thickness and a low intensity of metamorphism and deformation were selected for detailed stratigraphic analysis (Fig. 1). Chip samples taken across a few tens of feet of strike width of each visually recognizable volcanic rock type or every now and then in zones of visually uniform lithology were chemically analysed for the 13 major oxides. All mineralization of possible economic significance encountered was documented and grab sampled. Reconnaissance mapping and sampling in support of the structural interpretation and mineralogy remote from the detailed cross-sections was also carried out.

Volcanic model
The particular model used as a working hypothesis is predicated on Goodwin (Goodwin, 1968) and the geology of the Timmins, Kirkland Lake, Noranda area (Ridler, 1970; Hutchinson, Ridler and Suffel, 1971). Briefly, extensive, thick plates of intermediate to mafic pillowed and massive lavas are overlain by lenses of intermediate to felsic pyroclastics. Derived clastic sediments commonly are associated with the felsic volcanics or mantle the entire pile. Co-eval high-level intrusions accompany the volcanism.

Exhalite model
Volcanogenic chemical sediments, exhalites (Ridler, 1973b; Hutchinson, Ridler and Suffel, 1971), accompany the volcanism at all levels but major zones tend to occur at significant time breaks late or at the end of felsic volcanism. Proximal exhalites tend to be associated with felsic volcanic centres while their distal correlative may be associated with adjacent mafic volcanics, sediments or other felsic volcanics. Exhalites display systematic geographic variation in their anion content (Goodwin, 1962). Central zones of sulphide facies are surrounded by intermediate carbonate and flanking oxide facies (Fig. 2). The areas defined by such a pattern are called basins and are much larger than the individual volcanic cycles or complexes. On the other hand, the metal population of exhalites appears to be a function of proximity to an exhalative centre.

The questions, then for which we sought and, with a high degree of certainty, obtained answers were: (1) what is the stratigraphy, style and composition of the volcanism? (2) what is the structure of the Belt? (3) are carbonate and sulphide exhalite facies present, are they gold rich, and what is their distribution? (4) where are the felsic volcanic centres, if any, especially relative to exhalite facies distribution? and (5) how can geochemical drift prospecting help in understanding exhalite distribution?

General geology of the belt
The Rankin Inlet – Ennadai belt comprises the Archean Kaminak group (Davidson, 1970a) of volcanics and sediments and a compositionally heterogeneous group of mostly Archean plutonic rocks resembling the Superior Province in Northwestern Ontario but lying in the middle of the Churchill Province (Fig. 2).

Overlying the Kaminak group with marked angular unconformity lies an assemblage of gently-deformed stable-platform sediments (Bell, 1968; Wright, 1967) and thin but extensive basaltic (Ridler, 1972; 1974 in preparation), principally the Hurwitz group of Archean age. The entire Precambrian assemblage, the Kaminak sub-province (Davidson, 1972), is flanked to the north and south by zones characterized by mylonites and higher-grade metamorphic rocks derived from the...
Figure 1. Simplified geological map, eastern Rankin Inlet-Ennadai belt, District of Keewatin

SAMPLED SECTIONS &
STRUCTURAL X-SECTION A-B

LEGEND

- Potel-Quartziite Lake Belt, Hurwitz Gp.
- Felsic to mafic plutons
- Felsic volcanics, exhalite + clastic sediments. No B is predominantly a sedimentary unit
- Mafic to intermediate volcanics and silts

Formation No increases with decreasing stratigraphic age

CENTRE OF RASRST IN RONTEN
1. Peter Lake
2. Moger Lake
3. Quartzite Lake
4. Turenant Lake
5. Holbe Lake
6. Cooperwater Lake
CENTRE OF MAFIC VOLCANIC
- North Lake
- Southern Lake

SOURCES OF INFORMATION
R. N. Howard, 1972, 1974

Figure 3. Simplified geological map, eastern Rankin Inlet-Ennadai belt, District of Keewatin

LEGEND

- Potel-Quartziite Lake Belt, Hurwitz Gp.
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CENTRE OF MALIC VOLCANIC
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2. Moger Lake
3. Quartzite Lake
4. Turenant Lake
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6. Cooperwater Lake
CENTRE OF MAFIC VOLCANIC
- North Lake
- Southern Lake

SOURCES OF INFORMATION
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Fig. 1 Sampled Sections and Structural X-Section A-B

Fig. 2 Exhalites in an Archean Volcano-Sedimentary Complex

July, 1974
rocks of the Kaminak sub-province during the Hudsonian Orogeny (Davidson, 1972).

Thus, the Rankin Inlet – Ennadai belt differs from its analogues in the Superior Province in that it is not bounded by belts of metasediments and granitoid plutons.

The Rankin Inlet – Ennadai belt is enormous, perhaps second only in size in the Canadian Shield to the Abitibi belt of Ontario and Quebec. It stretches for 400 miles from Hudson Bay to Snowbird Lake and is at least 150 miles wide.

In the area examined, and ignoring post-Archean cover, volcanics comprise 44% of the surface area, similar to the Abitibi belt at 49% (Goodwin, 1972). On the other hand, the proportion of plutons is higher, 46% versus 32%. The difference is made up in the sediments, which constitute 16% of the Abitibi belt but only 10% of the Rankin Inlet – Ennadai belt. The supracrustal rocks of the Rankin Inlet area itself may be part of the upper Aphebian Hurwitz group (Ridler, 1974) and therefore not part of the Archean Rankin Inlet – Ennadai belt at all.

Hurwitz group
Hurwitz group rocks are post oxyatmoverion (Roscoe, 1973), locally contain hematitic quartzite, and are crudely correlative, according to work currently in progress, with the rocks of the Cape Smith – Wakeham Bay belt and the Labrador Trough of New Quebec and Labrador. In the study area they occupy probable semigrabens aligned more or less parallel to the tectonic grain of the Churchill Province (Davidson, 1972). A much less extensive group of locally pyritic quartzites, the Montgomery Lake group, lies unconformably beneath the Hurwitz group (Eade, 1974). It may be pre-oxyatmoverion and, thus, crudely correlative with the Huronian of the southern Shield.

Alkaline stocks
Also aligned more or less parallel to the grain of the Churchill Province and perhaps associated with the basement structure controlling the disposition of the Padlei-Quartzite Lake Hurwitz belt is a group of latest Archean, weakly to strongly alkalic (1973a) one of concrete carbonato-alkaline (1970c).

Kaminak group
The structure, although complex, is generally less, rather simple (Fig. 3). It is of an east-west, olde5,m young antcline, locus of intrusive massifs. These are crudely concordant, a regional scale discordant locus present, in part, a complex.

A hypothesis along the axis indicates that the style is vertical interference principal synclines (Figs. 4, 5), structural style of Superior Province, trending parallel to the Hurwitz group. The lineaments have been recognized, have widely varying, have been recognized.

Metamorphism
The metamorphic style of the Kaminak Kenoran (Davidson, 1972) that is, pervasive alteration of greenschist to slightly higher grade, is typical of the plutons. The thin section, no lowertent, and preserved fabrics is not good, primary volcanics, scoria, scoria, phenocrysts, not readily preserve.

Folding indicative small scale for cleavage, transverse structures, bounding foliation spread.

Composition of volcanics
Four hundred in the volcanics occluded sections are published (Ridler, 1974). The composition of the volcanics and possesses from basalt through.

In addition, site-felsic volcanics are differentiated

Fig. 3 Structure

Fig. 4 Idealized Structural Section of the Kaminak Group along A-B (Fig. 1)
strongly alkaline stocks (Ridler, 1973a) one of which possesses a discrete carbonatite phase (Davidson, 1970c).

Kaminak group
The study area is a semiparallel to the Churchill Province (Fig. 1). A much pyritic area is beneath the Huronian Group (Fig. 74). It may strongly alkaline stocks (Ridler, 1973a) one of which possesses a discrete carbonatite phase (Davidson, 1970c).

Thus, the lavas of the Kaminak group are a typical assemblage of rather chemically mature, calc-alkaline volcanics, compositionally identical with those of the Abitibi belt, of the same age by zircon uranium-lead dating (Wanless, pers. comm.), and about equidistant from the protocontinental centre (Goodwin, 1968) of the Superior Province. They are also compositionally similar to the volcanic rocks of modern island arcs, such as Japan, although no tectonic analogy is implied.

Metamorphism
The metamorphic pattern in the core of the Kaminak sub-province is relic Kenoran (Davidson, 1970b, 1972), that is, pervasive lower to middle greenschist with narrow zones of slightly higher grade in the aureoles of the plutons.

Thin section examination suggests that no lowermost greenschist is present, and preservation of primary rock fabrics is not good. However, delicate primary volcanic structures, such as pillows, scoria, amygdules, variolites, phenocrysts, breccia, and spinifex are readily preserved.

Folding induced features such as small scale folds, foliation, fracture cleavage, transposition of primary structures, boudinage, kinking, intersecting foliations, and so on, are widespread.

Composition of volcanics
Four hundred and twenty samples of the volcanics collected along the indicated sections (Fig. 1) have been analysed, and over 100 of the analyses are published (Ridler & Shilts, 1973, Ridler, 1974). The overall composition of the volcanics is sub-alkaline (Fig. 5), and possesses a complete spectrum from basalt through to rhyolite.

In addition, the suite basalt-andesite-felsic volcanic, straddles the tholeiite/calc-alkaline boundary as indicated on Fig. 6. Neither diagram suggests the presence of more than one major differentiation series. The overall com-
Clusters for each of the common calc-alkaline lava types are present, basalt, andesite, dacite, rhyodacite and rhyolite (Fig. 7). However, felsic lavas are much more abundant in the examined portion of the belt than in similar belts in the Superior Province. Of the analyses, thirty, or roughly 7% qualify as rhyolites according to Fig. 7. Taking all felsic compositions into consideration, the ratio of mafic to felsic volcanics by area in the Abitibi belt is 12:1, in the Lake of the Woods-Wabi- goon Belt 7:1 (Goodwin, 1972), but in the Rankin Inlet - Ennadai belt 3:1!

**Volcanic stratigraphy**

The volcanic stratigraphy of the belt is poly cyclic and contains five cycles. There are exhalite zones present in each felsic phase. Numerous top determinations and excellent outcrop have provided the opportunity to work out the relative ages of each cycle or complex. As indicated, they progress from the oldest in the west to the youngest in the east (Figs. 2 and 4). The analogous structural/stratigraphic relations appear to obtain across the belt but are currently unresolved.

Discovery of features associated with and diagnostic of felsic volcanic centres at several localities has led to recognition of several such centres (Fig. 8).

Pertinent features include: relative thickness, relative coarseness of fragmentals, presence of rhyolite flows, proximal rather than distal exhalites and flanking volcanicogenic conglomerates (Fig. 8). No criteria suggesting subaerial deposition have been found, rather the reverse. Pertinent criteria such as the intimate association with indubitably subaqueous phenomena—pillow lavas, exhalites and turbidites, and the high volatile content support an entirely subaqueous origin. Nevertheless, depths may have been relatively shallow as judged by the presence of giant amygduloids locally and ephemeral islands (Davidson, 1970b) may have poked above the “universal” Archean ocean. Prominent felsic centres exist in the vicinity of Spi and Quartzite Lakes. Less well documented ones are present at Maguse River, Munro Lake and Copperneedle Lake (Fig. 8) (Ridler and Shilts, 1973).

All available information on the distribution of the abundant exhalites of the study area has been compiled (Fig. 9). Individual occurrences of each type - carbonate, both banded and Larder Lake type, oxide and sulphide are indicated. Anomalously high gold analyses are also indicated.

A spot may represent anything from a tiny occurrence to a major zone extending for several miles. No attempt has been made to separate zones of different ages at this time, but it is a recognized problem. Locally, as is characteristic of exhalites, compositional variation is extreme, yet, it is clear from these data that, at the very least, the boundaries separating flanking oxide from a central trough of simple geometry but complex composition can be defined. A simple explanation is that original basin geometry controls the regional exhalite facies pattern such that deeper portions with lower oxygen pressure permit carbonate and sulphide deposition.

What is the distribution of each cycle relative to the established exhalite facies pattern and to the belt as a whole? The oldest known complex (Fig. 2, units 1 and 2) is characterized by a relatively mafic basal plate and a granolithic carapace which together mantle the Henninga batholith. Exhalites are present at two levels (Fig. 9). However, the suspected felsic centre (Fig. 8) lies south of the carbonate/sulphide facies. The felsic lavas lense out and interdigitate with an adjacent basal plate to the north and west but the distal portions of the two main exhalite zones persist well into the neighbouring mafic plate (Fig. 9).

The second complex or cycle (Fig. 2, units 3 and 4) mantles the Kaminak batholith. It possesses a major felsic volcanic centre, perhaps attaining a peak thickness of 17,000 ft. This centre includes an occurrence of polymetallic, proximal sulphide exhalite complete with a dalmatianite alteration pipe at Spi Lake (Boldy, J., pers. comm.). It lies well within the central carbonate/sulphide facies and has been the subject of recurrent exploration interest (Fig. 8).

The original volcanocone shape appears to be preserved at today's erosion level (Ridler and Shilts, 1973, Fig. 5). There appear to be two significant exhalite zones within the centre (Ridler, 1974), while in the flanking, thinner distal portions a single major banded exhalite zone of complexly varying composition occurs consistently at or near the top all around the batholith (Fig. 9).

In addition, a Larder Lake-type carbonate zone or, possibly zones, with one known ore-grade gold occurrence associated with quartz and arsenopyrite veining (Ridler and Shilts, 1973) occurs within the felsic unit (Fig. 9). Its stratigraphic position, and relation to the other exhalites constitute an enigma at the present time.

The third complex (Fig. 2, units 5 and 6) possesses a large felsic volcanic centre replete with rhyolite in the vicinity of Quartzite Lake (Fig. 8). Coalescing endogenous domes fea-
Fig. 8 Features of Felsic Volcanic Centres (Continued from page 36)

type of till anomaly may be caused by another metallogenic type, nickel and copper sulphides associated with ultramafic lavas and sills, is real, but cannot be assessed without further field studies.

This apparent paradox is explained if one accepts the exhalite concept of sulphide deposition as illuminated by the first author for the Rankin Inlet – Ennadai belt. This concept suggests that economic sulphide mineralization will most likely be found in discontinuous masses in discrete stratigraphic zones within otherwise metal-poor felsic volcanic piles.

Within the associated intermediate to basic volcanic sequences, exhalative mineralization will be widespread, but dispersed because of the much greater bulk of country rock associated with higher rates of deposition of basic volcanic and associated rocks. Thus, areas underlain by basic volcanic rocks may have offered many small pods of sub-economic exhalite mineralization to glacial erosion, causing till and derived stream and lake sediments in these areas to be uniformly high in trace metal content, particularly in copper and nickel.

The concentration of sulphide bodies as “plums” within narrow exhalite zones in the felsic pile, on the other hand, causes anomalies to show up only sporadically in the areas of felsic outcrop if samples are collected on a reconnaissance scale of one per one-half square mile. Areas of more square miles further south have been investigated by the Geological Survey of Canada, and the apparent paradox would be explained.

Aside from the need for integrating drift prospecting and rock studies, the Keywin program was directed to several recognized ore potential areas taken in carrying out a structural examination of the terrain.

The first step in any important direction is the recognition of the same by recording of structural directions, till fabric, and trace metal concentrations.
The point of this discussion is that the aerial extent and magnitude of the anomaly are not necessarily related to its economic importance, and, in fact, the reverse may be true. Without access to the theories of environments of ore deposition, structural interpretations, and good maps of lithologies (i.e., integration of drift and bedrock studies), interpretation of the apparent paradoxes of drift geochemistry would be difficult or impossible.

Aside from the importance of integrating drift prospecting with bedrock studies, the Keewatin project has led to several recommended steps to be taken in carrying out a drift prospecting program in perennially frozen terrain.

The first step is to establish the important directions of glacial movement for the sample areas. This is done by recording drumlin orientations, striation directions, end moraine orientations, till fabric, esker orientations, paleocurrent directions in ice-contact stratified drift, and configuration of indicator trains of distinctive rocks, minerals or trace-elements. The last type of data is the most important as it can serve as a model for trend and magnitude of indicator trains of detritus derived from economically important outcrops.

In the Kaminak Lake area, several of the flow indicators were abundant (GSC publication 73-74), but there was some question as to how important earlier ice-flow directions might have been in distributing glacially transported sediment. A train of distinctive garnets from an altered syenitic intrusion was outlined and indicated that the southeastward flow direction indicated by drumlins, striations and moraine orientations was the most important direction to consider when trying to trace anomalous samples to their source.

The second step must be to ensure that all glacial and post-glacial sediment types can be recognized easily by the samplers. In the perennially frozen terrain of Keewatin, this step is easy because different types of patterned ground are related to specific sediment types (Shilts, 1974a). Thus, sample sites can be located on the correct sediment by studying air photographs before the actual sampling is done.

Mud boils are characteristic of surfaces underlain by till (or, in limited areas, by marine or freshwater silty clay) and, because till is the most useful sediment for reconnaissance drift prospecting, sites characterized by mud boils and associated solifluction features were chosen for sampling.

The next step is to study the weathering characteristics of the minerals of economic significance. In the Kaminak area, sulphide orebodies were the target, but sulphide grains in till were found to be almost completely destroyed in the active (seasonally thawed) layer. Because of the cyclical overturn of muddy till caused by mud-boiling, soil profiles are very
poorly developed on till, and iron and manganese oxides/hydroxides that could scavenge cations released by weathering of the sulphides are rare.

Phyllosilicates ("clays") in the -2μ fraction of tills do, however, have a fair capacity to scavenge cations, so this fraction was chosen to be separated and analysed.

The theory behind this procedure is that the clay-sized particles have scavenged amounts of mobile cations that are roughly proportional to the amounts of cations contained in the sulphides before they were oxidized and destroyed. This assumption has been substantiated by comparing clay and heavy mineral suites from above and below permafrost (Ridler and Shilts, 1973).

In this study, heavy minerals from unweathered, frozen samples were high in copper and zinc, whereas clays were low in these same components. The reverse is true for unfrozen, weathered samples from the active layer.

The final step involves laying out sample grids over areas of felsic volcanism within the regional sulfide facies exhalite zone. Grids should include areas of other rock types for comparison. In the Kaminak area the reconnaissance grids were constructed of sample points on one-mile centres. Approximately 2,000 square miles of the Rankin Inlet - Ennadai belt were covered at this spacing.

Areas with promising anomalies or areas known to have favorable showings were sampled at much smaller
er intervals of a quarter-mile to less than 100-ft centres. Figure 10 shows anomalous areas related to possible copper mineralization. Most of the anomalies are related to favorable exhalite horizons or to areas of disseminated copper mineralization within the Kaminak batholith (Ridler and Shilts, 1973).

Closely spaced sampling around known mineralization and around anomalies unrelated to known mineralization in the Spi Lake area led to the discovery of several boulders of zinc-lead-silver-rich float on an island in the lake as well as several new, well-defined anomalies (Fig. 11) (Shilts, 1974c, Ridler, 1974). Close sampling on the island and on adjacent islands has led to the outlining of a small but very zinc-rich glacial train that seems to indicate a source for the float beneath the lake. A second anomaly, trending into the main body of Spi Lake and potentially related to a stratigraphically higher exhalite horizon is also worthy of note.

**Conclusion**

The Kaminak sub-province possesses several metallogenic packages of note. Those which at our current state of information appear to have a real but lesser economic potential are:

- Basal uraniumiferous and/or auriferous pyritic quartzites and conglomerates of the Montgomery Lake group,
- Uranium, niobium, copper, phosphate, diamond and/or rare-earth mineralization in the late Archean alka-line-carbonatite province.

Nickel mineralization associated with differentiated gabbroic-ultramafic sills or ultramafic lava sequences (Eckstrand, 1974) is of somewhat greater importance. Examples are known at Rankin Inlet, Ferguson Lake, Southern Lake and the Ferguson River.

The discovery last summer of spinitex texture in an ultramafic lava west of the study area and the correlation of the Ferguson Lake belt with the origin of the Rankin Inlet — Ennadai belt (Eade and Chandler, 1974) has enhanced the economic potential of this metallogenic type.

Clearly, the greatest potential of the Belt is indicated by the documentation of the metallogenic environments favoring the occurrence of or actual discovery of occurrences of:
- iron formation, especially as discussed by Davidson (1970b),
- gold rich exhalites of whatever facies (Ridler and Shilts, 1973; Ridler 1973a),
- porphyry gold, by inference always associated with the preceding, and
- polymetallic massive sulphides, particularly in the Kaminak Lake area (Ridler and Shilts, 1973).

It is our opinion that drift prospecting has proved to be a useful exploration tool in this environment and when used sensibly and with adequate bedrock information it should be a powerful exploration guide in most glaciated environments.

The rise in metal prices recently, the increase in basic geologic information on the belt, and the increasing tempo and degree of sophistication of exploration are increasing the certainty of and decreasing the time before a major discovery.

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CMJ’s cover: The rich Kidd Creek mine of Ecstall Mining at Timmins, Ont. is owned by Texasgulf Inc., which is now in turn effectively controlled by the Canada Development Corp., a government agency. This relationship might be the basis for a mining equipment manufacturing industry in Canada, according to an article in this issue.