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PAPER 72-25

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E.W. Reinhardt

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Report and 20 figures

E.W. Reinhardt

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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ABSTRACT

Three major northeast-trending breccia zones were recognized during 1:50,000 scale mapping: the northernmost zone occurs along the south shore of Wilson Island; a central zone follows a narrow channel separating the largest of the Simpson Islands; and a southern zone lies just north of Preble Island.

The fragments comprising the zone are varied but brown stromatolitic dolomite along with siltstone, subarkosic sandstone, and granite predominate. The sedimentary derivatives resemble the Hornby Channel Formation (Aphebian); the granitic fragments are identical to Archean granitic gneisses of the area.

The megascopic and microscopic features of the breccia suggest that the zones consist of networks of overlapping 'breccia pipes' formed largely by upward transport of fragmental material.

A speculative interpretation of breccia emplacement is presented. The driving force for brecciation is assumed to have been obtained from underlying magma and the actual fracturing that formed conduits was propagated through either explosive or hydraulic mechanisms involving fluids probably, gaseous. Gases could have been derived from either magmatic crystallization or interaction of hot magma and water already enclosed in the strata. Fluidization is cited as one process whereby fragments were transported from depth along pipe-like conduits. Upward movement of large blocks may have been accomplished by a more complex process following decompression.

Economic considerations in relation to breccia pipes are briefly reviewed; possible factors that could have controlled copper sulphide and radioactive mineralization in the East Arm are commented upon. Most breccia zones are characterized by quartz-carbonate veins and stockworks and these are considered to represent hydrothermal activity associated with breccia emplacement. A similar origin for copper and uranium deposition is suggested, although evidence of significant concentrations of these elements is as yet lacking.

RÉSUMÉ

Au cours d'un levé en vue de l'établissement d'une carte à l'échelle du 1:50,000^{e}, trois zones de brèches d'orientation nord-est ont été relevées: la première, la plus au nord, sur la côte sud de l'île Wilson, la deuxième, la zone centrale, suivant l'étroit plan d'eau qui sépare en deux la plus grande des îles Simpson et la troisième, la plus au sud, située un peu au nord de l'île Preble.

La zone comprend des éléments très variés où prédominent cependant la dolomie brune à stromatolite et le siltstone, le grès à faible teneur en feldspath et le granite. Les dérivés sédimentaires ressemblent aux éléments de la formation de Hornby Channel (Aphébien) alors que les granites sont identiques aux gneiss granitiques archéens de la région.

Les caractéristiques mégascopiques et microscopiques des brèches permettant de supposer que les zones consistent en un réseau entremêlé de « cheminées» formées principalement par entraînement de matériaux détritiques.

L'exposé offre une explication possible de la mise en place des brèches. On suppose que la formation des brèches est due à l'action des magmas sous-jacents et que la fissuration qui a créé les cheminées a été causée par des mécanismes explosifs ou hydrauliques mettant en cause des fluides probablement en partie gazeux. Ces gaz seraient venus soit de la cristallisation du magma, soit de l'action réciproque du magma en fusion et de l'eau, présente dans les couches. La fluidisation est l'une des voies par lesquelles les fragments de matériaux peuvent être transportés dans des conduits en forme de tube. Il se peut que le soulèvement des gros blocs ait été occasionné par une action beaucoup plus complexe, après la décompression.

L'exposé traite brièvement de certaines considérations économiques relativement aux cheminées de brèches, ainsi que des facteurs qui auraient pu influer sur la minéralisation sous forme de sulfures de cuivre et de matériaux radiocatifs dans le secteur d'East Arm. La plupart des zones de brèches présentent des veines de quartz et de roches carbonatées et des stockwerks dont on considère qu'ils témoignent de l'action hydrothermale associée à la formation des brèches. On propose que les minéralisations de cuivre et d'uranium ont une origine similaire, bien qu'il n'existe aucune preuve que ces éléments existent en quantités appréciables.

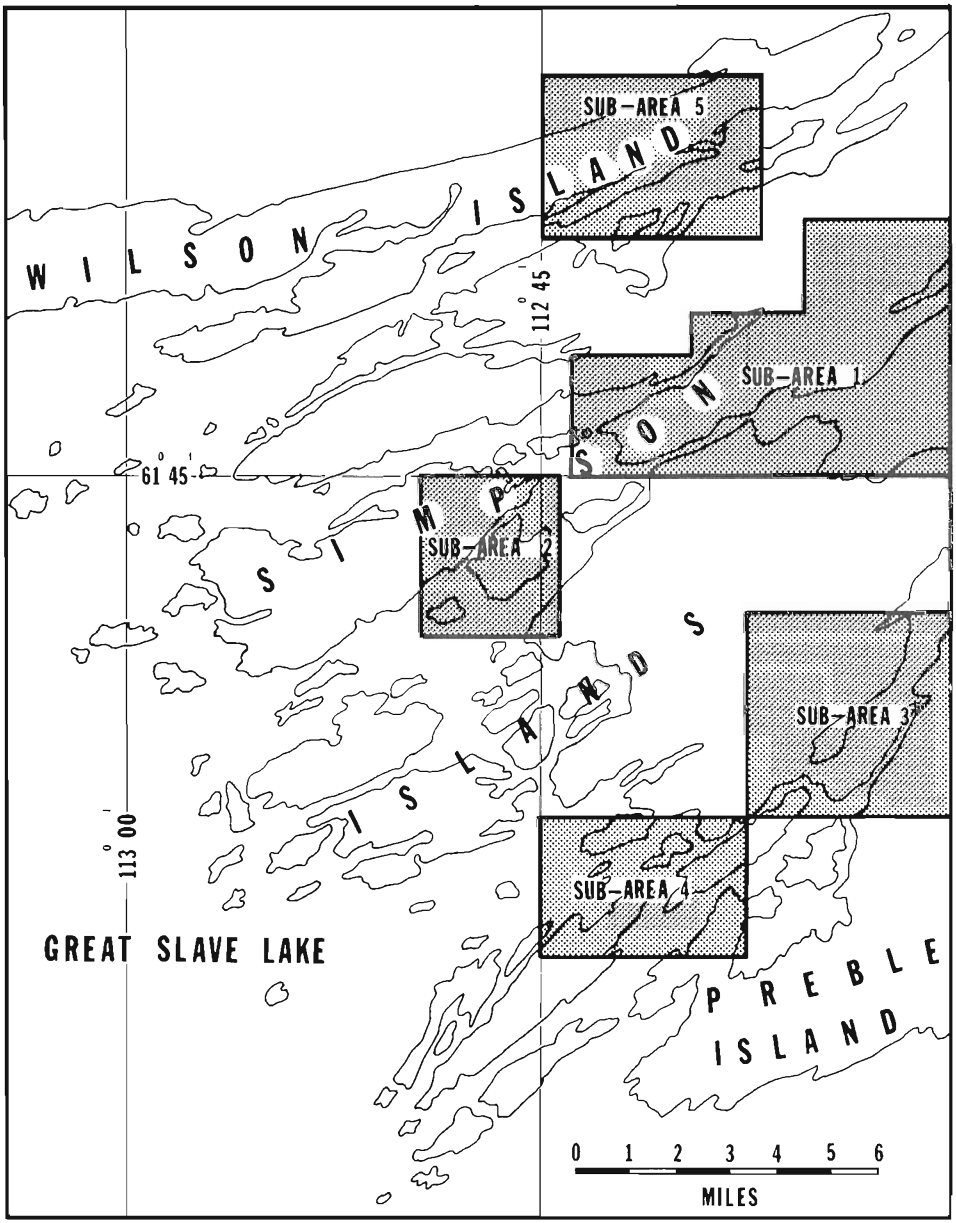

Figure 1. Location of sub-areas described in this report.

OCCURRENCES OF EXOTIC BRECCIAS IN THE PETITOT ISLANDS AND WILSON ISLAND MAP-AREAS, EAST ARM OF GREAT SLAVE LAKE, DISTRICT OF MACKENZIE

INTRODUCTION

In the summer of 1968 several unusual occurrences of breccia were found within the East Arm of Great Slave Lake during geological mapping (1:50,000 scale) of adjoining parts of the Petitot Islands (85 H/10) and Wilson Island (85 H/15) map-areas. These occurrences were briefly referred to as "zones of exotic breccias" in the summary account of the geology in the two above map-areas (Reinhardt, 1969a, p. 180). The present report provides better descriptions of these breccias, which are uncommon in the Precambrian regions of Canada, and at the same time presents a plausible sequence of events to account for their genesis. The descriptions are based on field data and specimens collected during the 1968 field season by C.A. Giovanella and the writer, both of whom were assisted by the remaining members of the latter's field party: Baxter Kean, Richard Lancaster, and Edward Lee.

Some appreciation of the background geology and spatial relations of breccia occurrences can be obtained from the following: Figure 1 of this report, Figure 1 of the summary account (op. cit., p. 178), and the original reconnaissance mapping of Stockwell (1936a,b). More detailed geological coverage at a scale of 1:50,000 is in preparation for the mapped parts of 85 H/10 and 85 H/15 and these maps will be available in the near future. For the present report, sketch maps outlining the known geology surrounding each occurrence of breccia were prepared directly from compilations being used in the drafts of the 1:50,000 scale geological maps; each breccia locality has been designated as a 'sub-area'. Although the map for each sub-area shows lithologic units and structural data, no attempt is made to provide complete lithologic descriptions or to interpret structural relationships beyond that required to illustrate the critical relationships with zones of breccia. A complete treatment of lithologies and structures will be reserved for subsequent publications. The lithologic descriptions of map-units then, with few exceptions, are combined in their definition on the map legends.

The concluding part of this report contains a brief consideration of the possibilities of economic resources being associated with zones of exotic breccia and is included as an aid to mineral exploration. Radioactive occurrences have been discovered in sub-area 1 by Vestors Explorations Limited (Northern Miner, September 24, 1970; Bottrill, 1971, p. 83). These and similar occurrences may or may not bear a relationship to the breccias and the possibility that other types of mineralization may be related to breccia emplacement must also be considered. The size of the area to be examined

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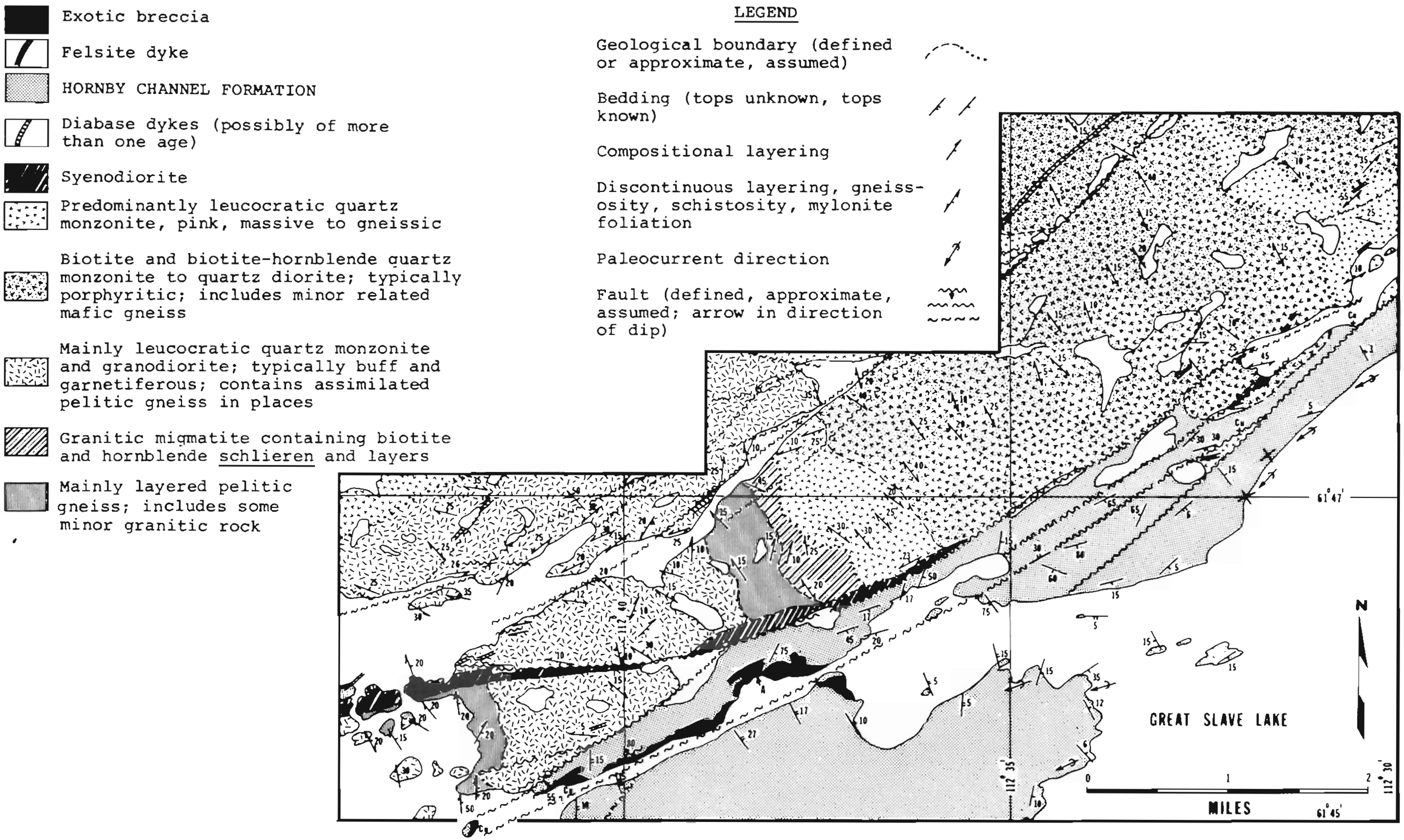

LEGEND

■ Exotic breccia

Felsite dyke

▨ HORNBY CHANNEL FORMATION

Diabase dykes (possibly of more than one age)

Syenodiorite

Predominantly leucocratic quartz monzonite, pink, massive to gneissic

Biotite and biotite-hornblende quartz monzonite to quartz diorite; typically porphyritic; includes minor related mafic gneiss

Mainly leucocratic quartz monzonite and granodiorite; typically buff and garnetiferous; contains assimilated pelitic gneiss in places

Granitic migmatite containing biotite and hornblende schlieren and layers

Mainly layered pelitic gneiss; includes some minor granitic rock

Geological boundary (defined or approximate, assumed)

Bedding (tops unknown, tops known)

Compositional layering

Discontinuous layering, gneissosity, schistosity, mylonite foliation

Paleocurrent direction

Fault (defined, approximate, assumed; arrow in direction of dip)

Figure 2. Sketch map showing the general geology of sub-area 1.
"Cu" – showings that contain traces of copper sulphides.

during the 1968 field season did not allow time for detailed work on mineral showings, although these were not ignored; no radioactive zones were recognized in the course of the field work. Evaluations presented by the writer are therefore based more on regional geological aspects than on exhaustive examinations of known mineral showings. Most of the ideas related to regional economic potential are highly dependent on the interpretation applied to genesis of the breccias, which in itself is not simple, and this introduces a definite underlying element of speculation. It is anticipated, however, that sufficient facts are included to permit independent assessment of the breccia origin and possible economic significance. The main reason for discussing mineralization is to suggest factors that may have acted as regional controls.

THE HORNBY CHANNEL FORMATION AT THE UNCONFORMITY WITH ARCHEAN BASEMENT

Some mention of the unconformity between essentially unmetamorphosed sedimentary rocks of the Hornby Channel Formation and granitic and metamorphic rocks loosely referred to as 'Archean basement' is appropriate at this point in order to avoid repetitive descriptions when dealing separately with each sub-area. The term 'Archean basement' includes metasedimentary and metavolcanic rocks deposited in Archean time but metamorphosed and migmatized during the Kenoran Orogeny (Stockwell, 1964). The granitic rocks that make up the major part of this basement complex are intimately associated with the metasediments and migmatites and are thought to represent products of partial melting of the latter strata under plutonic conditions during the Kenoran Orogeny. The main evidence supporting partial melting has been given (Reinhardt, 1969a, p. 177) and the chronology is documented by published K-Ar mineral ages of 2,555 m.y. (GSC 61-77) and 2,480 m.y. (Burwash and Baadsgaard, 1962).

Hoffman (1968) has recently revised the original stratigraphic nomenclature of Stockwell (1936a, b) that was applied to sedimentary and volcanic rocks in the East Arm of Great Slave Lake. Following the table of formations proposed by Hoffman (op. cit., p. 7), the Hornby Channel Formation is the lowermost formation of the Sosan Group which in turn belongs to the Great Slave Supergroup. Previously, strata comprising the Hornby Channel Formation were included in the "Sosan Formation" of Stockwell (1936a, b). Examination of the Hornby Channel Formation was only cursory during the present work because detailed study of stratigraphy, sedimentology, and paleocurrents had been independently undertaken by Hoffman (1967, p. 36), and because time was not available in view of the area to be covered in one field season. However, some appreciation of lithologies occurring near the base of the Hornby Channel Formation is required before a discussion of the origin of exotic breccias can proceed.

As noted previously (Reinhardt, 1969a, p. 180), the unconformity between the Hornby Channel Formation (referred to as "Sosan") and underlying Archean basement rocks, outcrops on a small island (61°45'N, 113°04'W) south of Wilson Island, Great Slave Lake. This is the only known location within the Wilson Island-Petitot Islands area where the unconformity is known to be exposed although an unconformable relationship is obviously the case across south Simpson Island* where the actual contact surface is obscured by drift. In the few observations made on the Simpson Islands, the dominant lithologies of the Hornby Channel Formation show little variation and consist of bedded subarkosic sandstone with lenses of quartz-pebble conglomerate. Festoon crossbedding is characteristic and direct measurements of current directions can be made where the strata have low dips. Further data on the Hornby Channel Formation can be obtained from Hoffman's work (1968, 1969).

An attempt to summarize the lowermost lithologies of the Hornby Channel Formation is given in Table 1. This summary is based on a few brief observations on the small island south of Wilson Island and indications of thickness are little more than educated guesses based on very crude calculations rather than actual measurements.

SUB-AREA 1

General Remarks

Exotic breccias in this locality occur along the narrow channel separating north and south Simpson Islands and the geology, as determined from 1968 field work, is shown in Figure 2. The writer's examination of breccias in this sub-area was brief (less than one day) and was concentrated mainly in the vicinity of point "A" (Fig. 2). Additional observations and data were taken mostly by C.A. Giovanella, during routine mapping.

Faulting

As indicated in Figure 2, northeast-striking faults are numerous. Previous discussions of faulting in the East Arm (Reinhardt, 1969a, p. 180) and adjacent south shore of Great Slave Lake (Reinhardt, 1969b, p. 19) suggests that the northeast-trending McDonald Fault system** was involved in movements spanning a considerable period of Precambrian time and the stresses promoting initial fracturing may well have been pre-Aphebian. Early movements are thought to be mainly transcurrent whereas the latest significant displacements appear to be mainly vertical. The strike-slip movement

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*The distinction between north Simpson Island and south Simpson Island is used in this report as a matter of convenience for the two largest islands of the Simpson Group (see also Fig. 1).

**The McDonald Fault system denotes the major system of faulting that forms a wide northeast-trending zone along the southeast side of the East Arm of Great Slave Lake.

Table 1

Lithology	Approximate thickness in feet	
	of unit	total from unconformity
Pebble subarkose, subarkosic and arkosic sandstone; varies in colour from buff to red; trace of thin siltstone beds in lower part	1000	1100
Conglomerate: clasts of granitic rocks, mylonitized granitic rock, white quartz, and jasper (pebbles); matrix of maroonish red siltstone and sandstone with visible white mica	50	100
Maroon to brown stromatolitic dolomite, silty and sandy dolomite, and maroon dolomitic sandstone and siltstone; minor conglomerate and coarse sandstone; red hematitic quartzose sandstone occurs near the base	50	50
UNCONFORMITY		
Altered granitic rock: pink to red, medium-grained, gneissic and in part brecciated*; biotite extensively altered to chlorite		
Less altered granitic rock: cream to buff, medium-grained, gneissic, biotite-bearing, some faint mafic schlieren		

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*A quartz-carbonate stockwork containing minor amounts of chalcopyrite and bornite occurs in the altered granite; traces of chalcopyrite and chalcocite in fractures were also found in one specimen of the overlying sedimentary rocks.

along the McDonald system appears to be dominantly dextral as indicated by a number of offsets. This sense of movement is further suggested within the present sub-area.

In the western part of the sub-area, the syenodiorite dyke is transected by a main fault which has produced an offset of about one mile. This particular fault also defines most of the northern boundary of the Hornby Channel Formation and separates this formation from Archean plutonic gneisses and granitic rocks exposed to the north. This relationship necessitates some vertical component of fault movement to account for the absence of the Hornby Channel Formation directly north of the fault. Whether the present arrangement was accomplished through one or more movement cycles cannot be ascertained from present information.

Further regional implications of major northeast-striking faults can also be noted (see Reinhardt, 1969a, Fig. 1). Preservation of the Hornby Channel Formation on south Simpson Island was due to the depression of a large fault block or slice relative to the adjacent block to the north. The south boundary of the depressed block is defined by closely spaced parallel faults whose exact movement pattern and history are probably complex (cf. Fig. 16).

Other possible effects of faulting in sub-area 1 are suggested by bedding attitudes in some of the Hornby Channel strata. On the north side of the narrow channel where faults are more prevalent, there is considerable inconsistency in strike direction, and local steepening of dip is common. In contrast, bedding on the south side of the channel has a uniform northerly strike with gentle dips to the east. From this one might interpret the folding of sedimentary strata on the north side as being related to more intensive faulting. However, an alternative explanation for this deformation can be postulated; namely, that it is a consequence of localized collapse resulting from upward transport of brecciated rock from lower levels. The arguments favouring such an interpretation will become obvious following the discussion on the mechanisms of brecciation and transport. Undoubtedly, structural mapping in greater detail would assist in evaluating alternative possibilities.

Some indication of the maximum age of movement for the main fault bounding the Hornby Channel Formation in the present sub-area can be estimated from two K-Ar biotite ages taken on samples of the syenodiorite dyke. The determined values, 2,170 m.y. (GSC 62-93) and 2,200 m.y. (Burwash and Baadsgaard, 1962), show reasonable agreement, and if these ages represent the approximate time of dyke emplacement, offsetting movement along the fault would have to be younger. This does not definitely preclude movement prior to intrusion of the syenodiorite, but if such had occurred, one would expect that the syenodiorite should somewhere cut the Hornby Channel Formation. It would seem more plausible that the syenodiorite occupies an earlier subparallel fracture system which was later displaced by the main fault shown in Figure 2. In addition, certain north-northeast-striking diabase dykes appear to be younger than the syenodiorite (although some may well be contemporaneous intrusions) and the presence of these suggests continued development of fractures. Most of these dykes are short and can be traced for a few hundred feet only (all could not be shown on Fig. 2) but notable exceptions exist, such as along the north side of the sub-area. Several of the narrow diabase dykes have intruded the syenodiorite in the southwest corner of the sub-area but none is known to cut the Hornby Channel Formation. This is especially obvious on south Simpson Island where northeast-trending diabase dykes terminate at the unconformity with the Hornby Channel Formation (note particularly the large faulted diabase dyke in Fig. 16). From these relationships one might conclude that emplacement of north-trending diabase dykes occurred between syenodiorite intrusion and deposition of the Hornby Channel Formation and that these dykes followed a fracture pattern derived within the same broad time interval. However, not all diabase dykes within the Petitot Islands–Wilson Island map-area can be assigned to this period of emplacement. Certain dykes within the Archean complex have a north-northwesterly trend and these probably belong to the Mackenzie swarm which recently has been radiometrically dated at 1,200 m.y. (Fahrig and Jones, 1969). Northeasterly offshoots of these younger diabases may also be present and this is the main reason for indicating more than one age of diabase intrusion in Figure 2. The above reasoning would suggest that the main fault bounding the Hornby Channel Formation, shown in Figure 2, represents a relatively late northeast-trending fracture that was formed prior to the emplacement of northwest-trending diabase dykes.

Some fault movement along northeasterly breaks probably took place following breccia emplacement. The main supporting evidence is the presence of small shears in certain exposures of breccia, some of which may define the boundaries over short distances, and the relationships in other sub-areas, yet to be discussed.

Description and Field Relations of Exotic Breccia

The overall delineation of exotic breccia in the narrow channel separating the two main Simpson Islands has been generalized in the illustration (Fig. 2). The actual pattern is far more irregular, but nevertheless the occurrences roughly follow the trend of the channel which may coincide with a fault.

Shoreline outcrops along the north side of the channel are characterized by breccia composed dominantly of angular carbonate fragments (see Fig. 3). The fragmental carbonate is mostly brown weathering, algal-bedded dolomite similar to that found at the base of the Hornby Channel Formation. Other characteristic lithologies of this formation that occur as breccia fragments are: maroon or greenish grey siltstone; red, buff or pink subarkosic sandstone; and light grey orthoquartzite (see Figs. 4, 5, 6, 7). Fragments not representative of the Hornby Channel Formation include: fine-grained, brick-red felsitic rock, and pink to salmon coloured, medium-grained granitic rocks. The felsitic material is identical to that found in a narrow dyke at location "A" (Fig. 2) and also to that seen occasionally as a breccia matrix. The granitic fragments are representative of rocks occurring in the neighbouring Archean terrane; the fragments presumably represent material transported from below the unconformity. Even though the breccias are always to some extent heterolithic, there is a tendency for one fragment lithology to dominate at any given location so that detailed mapping of breccia types should be feasible.

Definition of fragment size is complicated by the presence, in a number of places, of large blocks (see Fig. 8) of sedimentary rock with lithologies similar to the smaller fragments constituted in 'more conventional breccias'. The blocks appear to be set in a 'matrix' of normal breccia and, although their origin poses several problems, they are tentatively regarded as having been derived by the same processes as proposed for the smaller fragments.

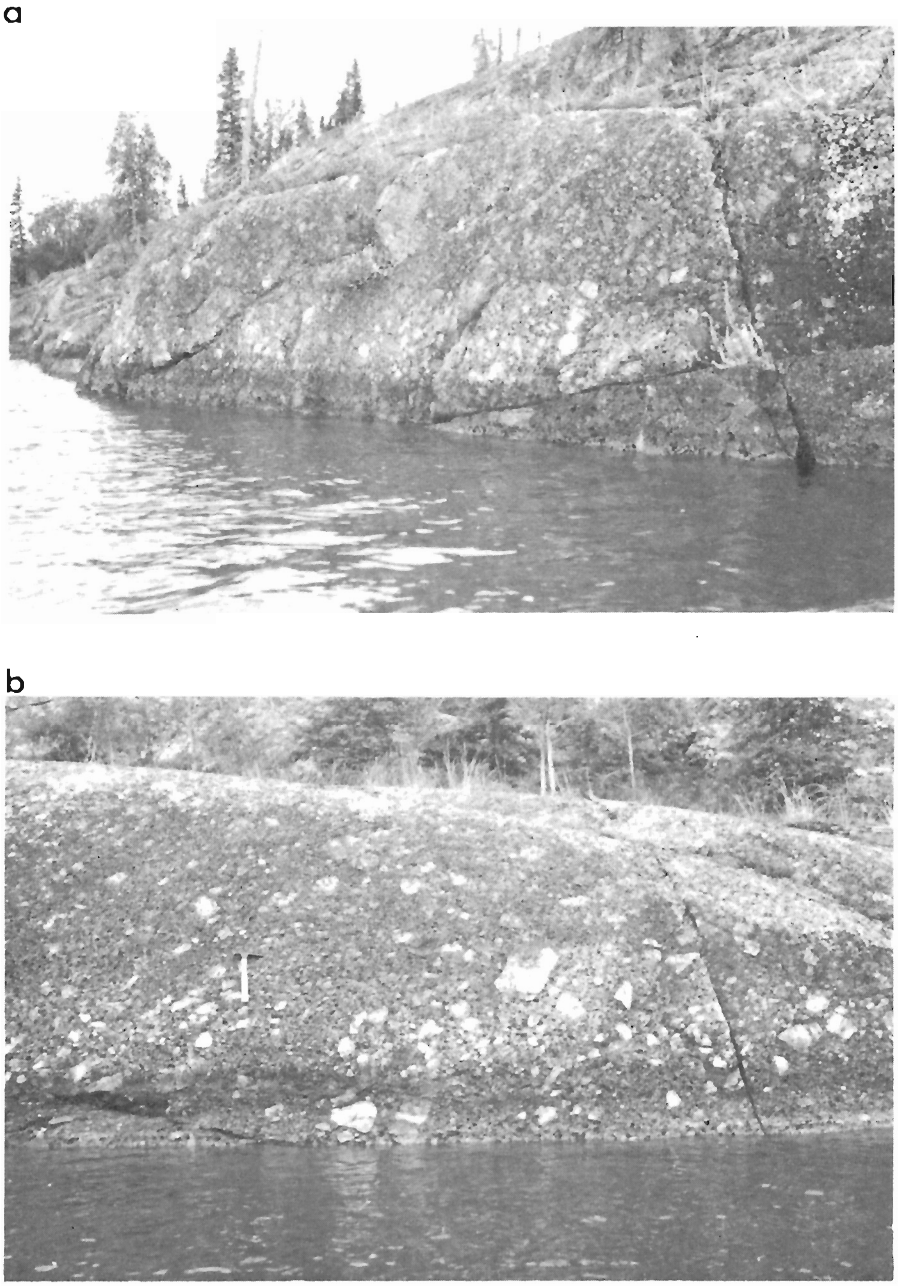

Figure 3a, b. Shoreline outcrops of exotic breccia composed dominantly of carbonate fragments. Location is approximately one half mile southwest of "A", Figure 2, sub-area 1. GSC photos 149846 and 149849.

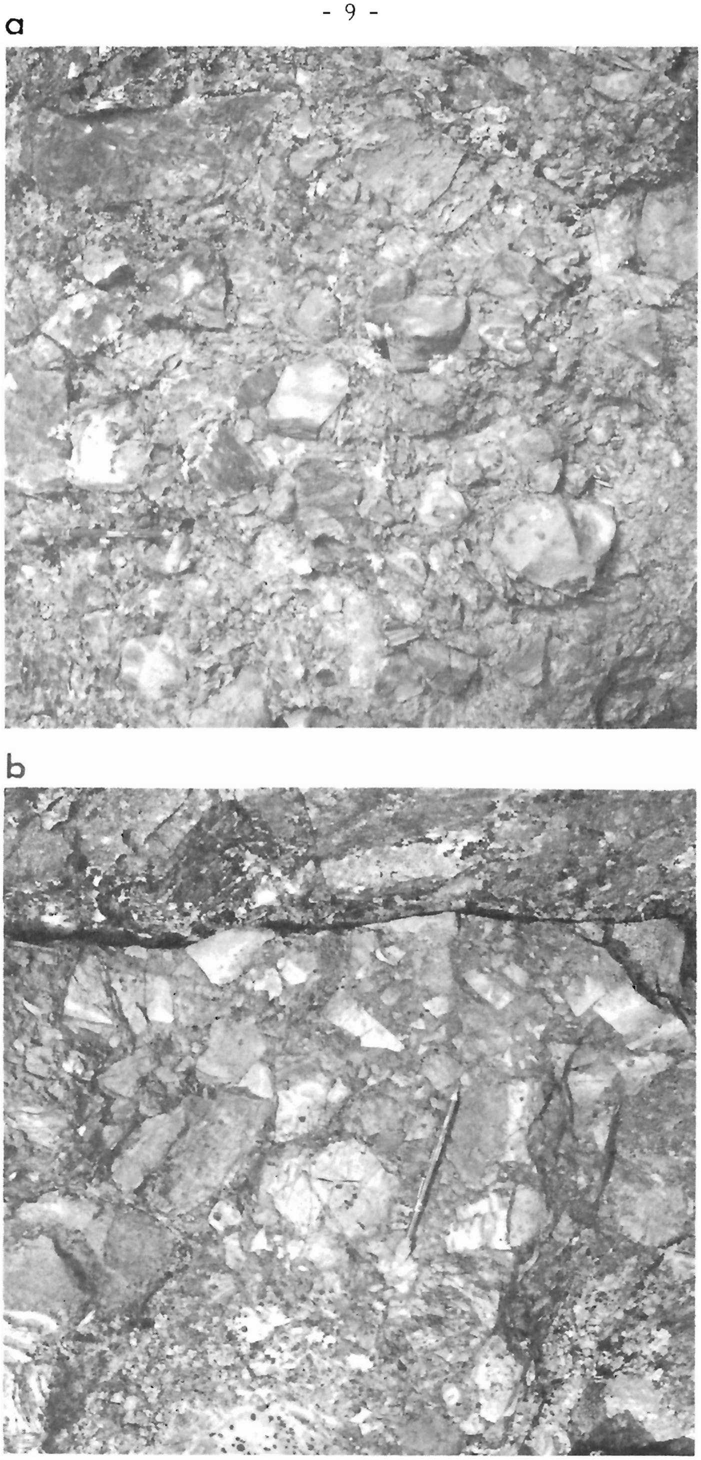

Figure 4a, b. Exotic breccia composed dominantly of fragments of algal carbonate with subordinate fragments of red siltstone. Same locality as Figure 3. Pencil in photograph is 8 inches long. GSC photos 149793 and 149791.

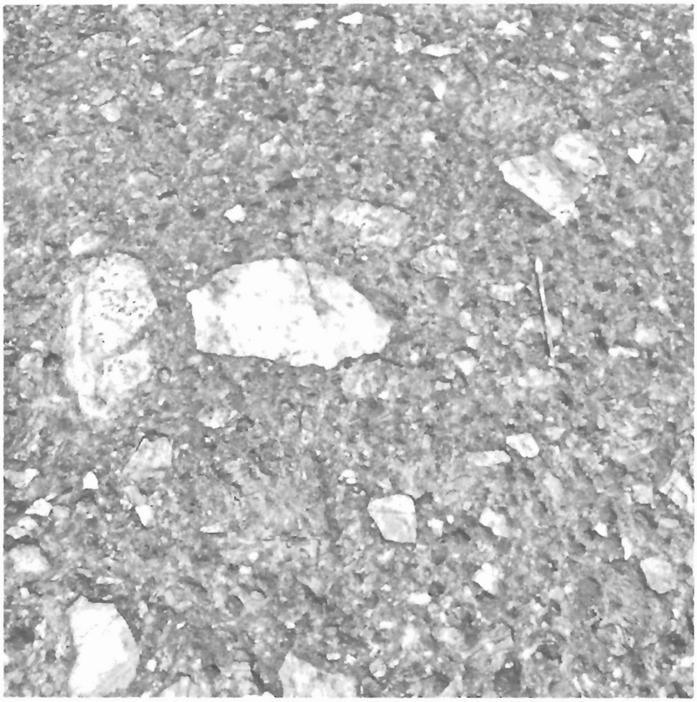

Figure 5.

Exotic breccia made up of mixed fragments. The major lithology is carbonate; subordinate lithologies include subarkosic sandstone and red siltstone. Same locality as Figure 3. GSC photo 149801.

Figure 6.

Pseudoconglomerate with large clasts consisting mainly of subarkosic sandstone (Hornby Channel Formation). Note that some clasts have been broken subsequent to rounding. Location is in the vicinity of "A", Figure 2, sub-area 1. GSC photo 149806.

a

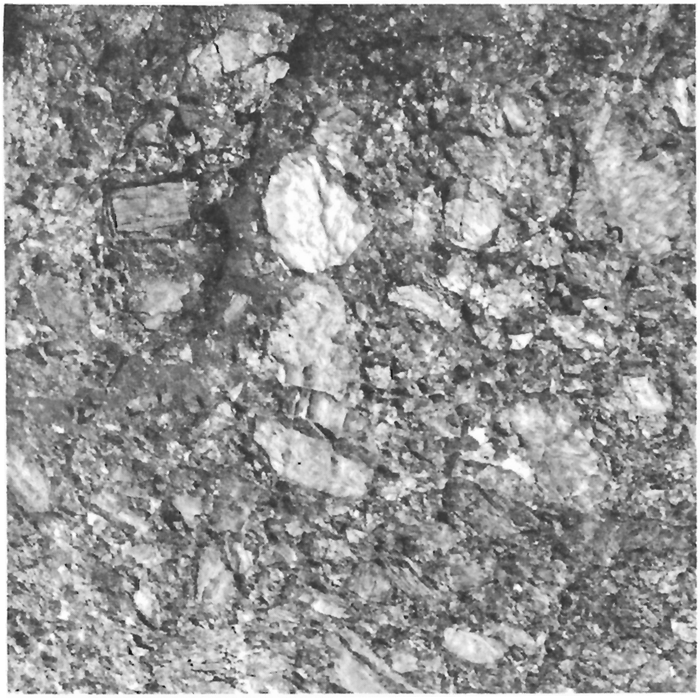

Figure 7a.

Displays the typical irregularity of outcrop surfaces due to removal or weathering of larger fragments and the wide range of fragment sizes. GSC photo 149745.

b

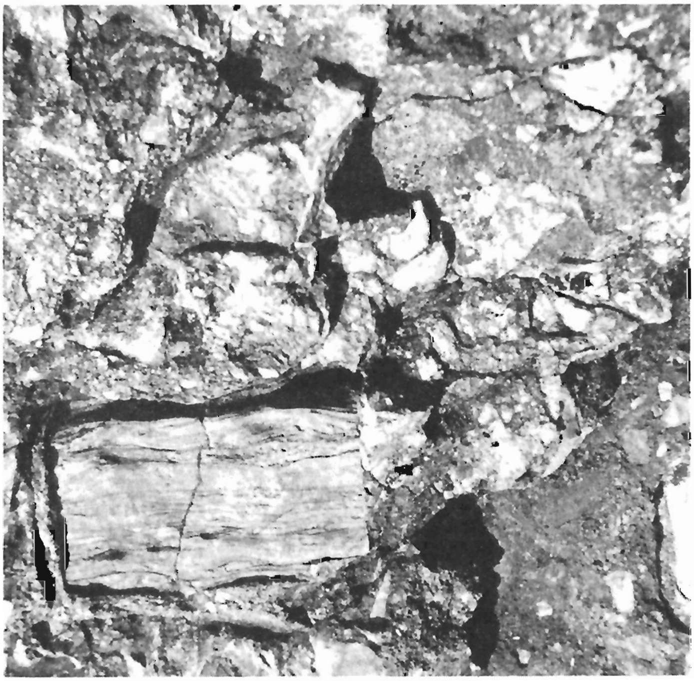

Figure 7b.

Close-up of same outcrop as in 7a, showing the chaotic matrix in more detail. GSC photo 149747.

Figure 7. Angular carbonate fragments in exotic breccia, one half mile southwest of "A", Figure 2, sub-area 1. Longest dimension of rectangular fragment in both 7a and 7b is about five inches.

Figure 8. Large fragmental block of bedded carbonate partly exposed through erosion; the enclosing breccia has normal sized fragments. Location is about one half mile southwest of "A", Figure 2, sub-area 1. GSC photo 149855.

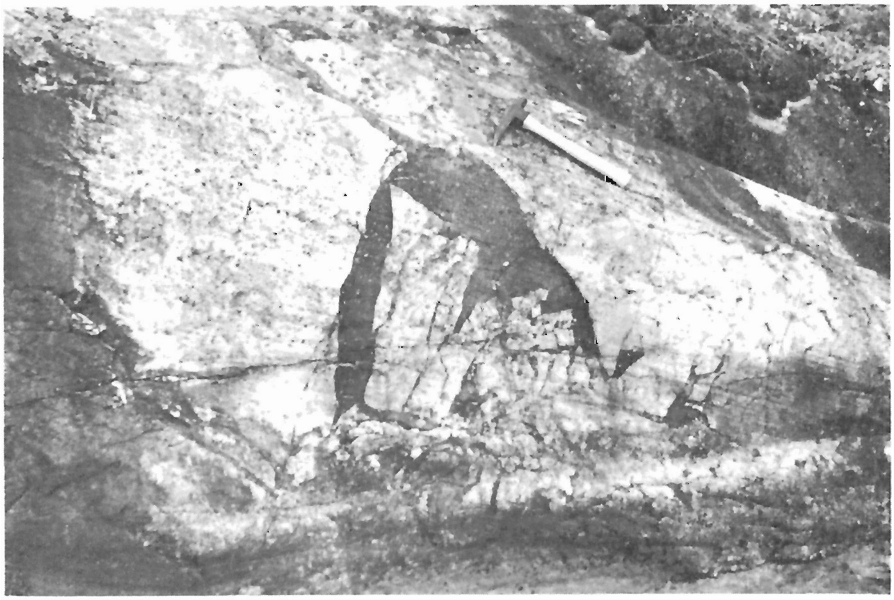

Figure 9. Breccia (dark) infilling shattered Hornby Channel subarkosic sandstone. Note the dilation probably imposed as a result of infilling. GSC photo 149857.

They commonly consist of maroon siltstones and brown stromatolitic dolomite and show bedding. The bedding often has steep dips, and in a few places, the beds are overturned. The blocks likely vary in shape but some are known to be tabular or slab-like parallel to bedding. One of the most spectacular larger blocks of maroon siltstone lies along the north shore about half a mile from the southwest entrance to the narrow channel. This block appears to be lenticular and is enclosed by normal breccia; exposed dimensions suggest a thickness of at least 50 feet and a length in the order of several hundred feet. Elsewhere carbonate blocks with dimensions measurable in tens of feet were observed. Accurate estimates of the proportion of large blocks relative to material containing fragments measurable in inches are not available, but the former appears to be definitely subordinate in overall amount. The only mappable occurrence of breccia on the south side of the narrow channel contains deformed slabs of carbonate and siltstone. Here one can see a few examples of local dismemberment of large slabs into smaller slabs that are separated and 'strung out' in an enclosing breccia matrix of finer material. Such relationships appear to be somewhat exceptional in that most breccia at this location is of a highly mixed nature.

A rough appreciation of the normal size ranges observed can be obtained from field photographs included in this part of the report. The average overall size of fragments is probably in the order of one to two inches. Fragment size is gradational to matrix size in many exposures whereas in others, distinct differences in the size range of fragments relative to matrix are maintained. The proportion of matrix material varies appreciably over several feet in some outcrops and, in places where the matrix is best developed, it is considerably darker than the enclosed fragments. In carbonate breccias the matrix material is often sparse and less obvious. Colour of the finely fragmental matrix varies from place to place with dark greys being prevalent and brown and dark red being less common. In addition to the commonly observed fragmental matrix, there is a nonfragmental 'felsitic matrix' which has more restricted development; the colour of the latter matrix is consistently brick-red. Angular fragments, on the whole, predominate over rounded fragments but a complete gradation between these extremes exists. A very spectacular occurrence of pseudoconglomerate discovered at location "A" will be described following the general account.

A sufficient number of observations were made to conclude that much of the breccia was intruded or injected into its present position within the enclosing Hornby Channel bedded sandstone and quartz-pebble conglomerate. In extreme examples, contact relations are not only indicative of injection but also suggest some concomitant enlargement of fractures (Fig. 9). The majority of well-exposed contacts are steeply dipping and irregular. Host rock strata have often been cut at high angles to bedding, and in many places, the boundary with breccia is flame-like in detail. Many contacts are essentially zones of larger angular fragments of wall-rock set in a breccia made up of smaller foreign material (Fig. 10). This indicates that locally derived larger fragments were late contributions to a more fragmented heterolithic mixture derived from elsewhere in the stratigraphic sequence and fracturing and transport were phases of the same total event. Generally, the size and proportion of locally derived fragments decreases away from contacts. Irregular fracturing of the host Hornby Channel Formation is common adjacent to contacts with breccia and, in some places, evidence of this fracturing can be recognized several hundred feet away from the actual contacts. Nearby fractures are invariably filled with vein quartz and carbonate either together or

Figure 10. Brecciated Hornby Channel subarkosic sandstone (light fragments) at the contact with exotic breccia (dark matrix). Location in the vicinity of "A", Figure 2, sub-area 1. GSC photo 149803.

Figure 11. Contact of Hornby Channel subarkosic sandstone (left) with felsite dyke (right) at location "A" (Figure 2). The attitude of this contact appears to be nearly vertical. GSC photo 149858.

separately. Where fracturing was most intense a quartz-carbonate stockwork prevails. Quartz-carbonate veining and infilling were also observed to a lesser extent within the breccia. The vein material is believed to be derived from hydrothermal activity accompanying breccia formation and transport. Localization of similar quartz-carbonate veins along faults where the presence of exotic breccia is not apparent may represent still later hydrothermal activity.

No identifiable bedding structure was seen in exotic breccias of this or any other sub-area. However, examples of crude foliation were occasionally noted. Cleavage or schistosity is developed in breccia matrix towards the south end of the channel where minor faults lie within or near breccia zones. Similar examples are found on the small island directly on the south boundary of sub-area 1 (Fig. 2). This type of foliation is likely related to fault movement following breccia emplacement. Another locally developed form of foliation appears to be the result of flow of the breccia matrix around large fragments or subparallel to wall-rocks.

Detailed Relationships at Location "A"

Location "A" (see Fig. 2) offered the most interesting geological features found during the brief examination of exotic breccias. Many of the conclusions as to the origin of the breccias are based on observed or interpreted relationships from this locality.

First, the dyke of felsitic rock, shown much exaggerated in size in Figure 2, cuts sedimentary strata of the Hornby Channel Formation. The contact is well exposed in several places along the south side of the dyke which appears to be nearly vertical (Fig. 11). Marginal autobrecciation of the dyke is more pronounced than brecciation of the adjacent subarkosic sandstone. The latter shows progressive reddening towards the contact whereas its colour six feet away is the characteristic buff of the Hornby Channel Formation in this region. The dyke rock at the contact is uniformly brick red, both on fresh and weathered surfaces. The sandstone for a foot or more from the contact has been modified to a vitreous metaquartzite. The average width of the dyke is unknown but near the northeast end it is about 20 feet wide.

No variation in either grain size or colour was noted between the central part of the dyke and its margins. In overall field appearance, the dyke rock closely resembles a massive, fine-grained volcanic rock. Microscopic examination reveals a trachytic texture (more accurately pilotaxitic when applied to plagioclase feldspar) composed of subhedral to euhedral lath-like andesine (0.5 mm x 0.1 mm). The plagioclase makes up over 80 per cent of the rock with the remainder consisting largely of fine-grained white mica, green chlorite, zoisite, carbonate, and opaque minerals. A trace amount of quartz was also seen in one thin section. The white mica is, at least in part, a replacement of an earlier interstitial phase, possibly a feldspathoid. Chlorite is less abundant than white mica and may be a replacement of an earlier mafic phase (biotite?). Not all zoisite is interstitial and an elongate subhedral habit is often well exhibited, and a few grains approach the size of plagioclase. Carbonate may exhibit euhedral forms (rhombs) in addition to irregularly shaped interstitial aggregates of grains. Both phases may represent minerals formed by deuteric action. The brecciated felsite from the dyke walls shows greater proportions of carbonate mainly as a matrix aggregate to rock fragments which are almost wholly composed of andesine exhibiting a trachytic texture. There is a notable increase in the amount of dusty hematitic staining of felsitic rock fragments from the contact compared with unbrecciated felsite from the interior of the dyke. Petrographically, the dyke felsite is not typical of commonly occurring hypabyssal or volcanic rocks, and thus no specific rock name can be conveniently applied. Texturally, it resembles trachyandesite whereas compositionally it approaches andesite (leucodiorite). The term "felsite" is therefore applied with some reservation.

At its northeastern extremity, the felsitic dyke passes rather abruptly along strike into exotic breccia containing some fragments of identical felsite. In general, the breccia at this point is as a pseudoconglomerate and contains abundant clasts in the order of 2 inches in diameter. Figures 6 and 12 show outcrops of this variety of breccia which is composed of well-rounded clasts of orthoquartzite, subarkose, and maroon siltstone all of which closely resemble the lower lithologies of the Hornby Channel Formation. Large clasts of carbonate rock are rare but there is a significant proportion of fragmented granitic rock, clasts of which are pink to salmon in colour. The matrix of the pseudoconglomerate is dark maroonish grey and, on the average, accounts for about half the total rock volume. Thin section examination of the matrix showed a high proportion of crushed and deformed angular quartz and feldspar grains about 0.4 mm across. Both microcline and plagioclase are present, the latter usually is sericitized and bent. Some ragged chlorite, of equivalent grain size, and irregular patches of interstitial secondary carbonate, were also noted. Still finer grained (less than 0.2 mm), angular quartz and feldspar form a submatrix to the material just described. Chlorite and white mica become abundant in only the finest grained matrix material that could be resolved under the microscope and these minerals appear to fill irregular voids formed by the larger fragments of quartz and feldspar. Finely divided opaque minerals are evenly disseminated throughout the matrix and probably rank in equal amounts with chlorite and mica in the finest grained material. It can tentatively be suggested that most of the matrix material could be derived from comminution of granitic rock. Certainly the relative proportions of constituent minerals is about what one would expect from the Archean granitic rocks observed in the general area. In thin section it is seen that large clasts of subarkosic sandstone are neither deformed nor altered and the matrix within these clasts is dominantly very fine grained white mica. The only other significant matrix mineral is finely aggregated quartz.

The pseudoconglomerate, both in outcrops and large specimens, closely resembles sedimentary conglomerate. However, the lack of bedding in the matrix, which is characteristically massive but occasionally shows foliation explainable as flowage, slump, or squeezing, does not support a sedimentary origin. Furthermore, local stratigraphically enclosed lenses of conglomerate in the unbrecciated Hornby Channel Formation are characterized by quartz pebbles rather than sandstone, siltstone or granitic clasts. Probably the most convincing arguments against a sedimentary origin for the pseudoconglomerate is its irregular distribution coupled with apparent cross-cutting and intrusive relations. A high degree of rounding from processes other than sedimentary transport has some precedence (e.g. Farmin, 1934; Bowes and Wright, 1961). In the present case, the rounding is believed to have been accomplished by upsurgent volcanic gases in a near vertical conduit (the conceptual treatment of this mechanism appears later in this report).

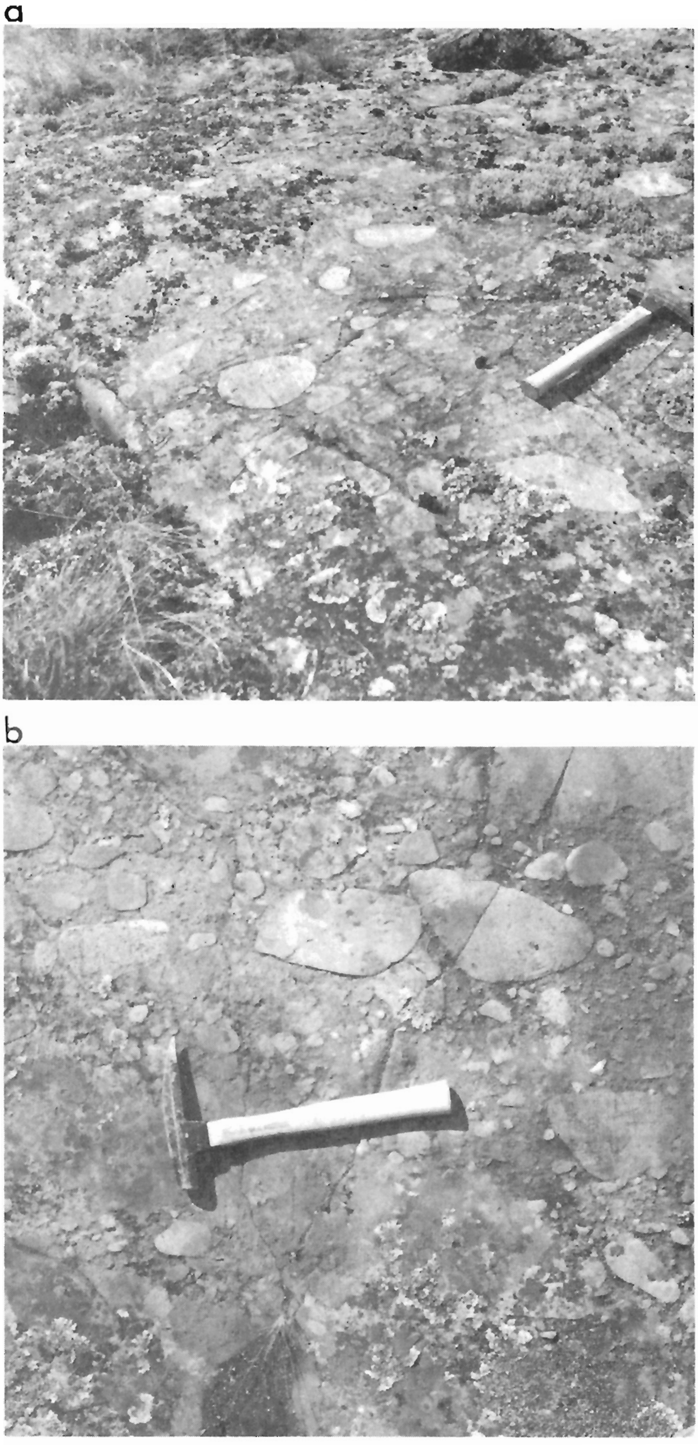

Figure 12a, b. Typical pseudoconglomerate at location "A", Figure 2, subarea 1. Description and fragment lithologies are given in the text. GSC photos 149807 and 149805.

A dyke-like body a few tens of feet wide and composed of heterolithic breccia occurs southwest of the pseudoconglomerate described above. This 'breccia dyke' strikes roughly northwesterly so as to intersect the northeast-striking felsite dyke. The exact relationships at the junction are obscured by overburden. At first sight, the 'breccia dyke' appears to be a right-angled offshoot of the felsite dyke with the breccia matrix being of volcanic derivation directly associated with felsite emplacement. Certain facts negate such a conclusion. Abundant fragments of felsite appear in the breccia at the point of merger. The proportion of these fragments in the 'dyke' decreases sharply to the southeast over a distance of a few feet and felsite is relatively uncommon at the southeastern extension of the 'dyke' where it meets the shoreline of the channel. Near the latter location, a large block of maroonish grey siltstone (accompanied by smaller fragments including carbonate rock) appears to be wedged against the wall-rock which is typical subarkose of the Hornby Channel Formation. The straight, vertical nature of the 'breccia dyke' contact with subarkose is well exhibited right at the shoreline and is shown in Figure 13. Probably the simplest explanation for the observed relations between felsite and breccia is multiple introduction, and this has the further merit, as will be seen later, in accounting for such a wide range of breccia types according to rounding, fragmental material, amount of matrix, etc.

Figure 13. Location "A", Figure 2, sub-area 1. Contact of 'breccia dyke' (right) with the Hornby Channel Formation (left). The pick marks the position of contact. GSC photo 149856.

Origin and Emplacement of Exotic Breccia

The interpreted genesis of exotic breccias in sub-area 1 will be based largely on the foregoing descriptions. Some of the more obvious conclusions have already been included and the remaining discussion is essentially concerned with processes and mechanisms of brecciation and transport. Similar occurrences outside of Canada will be referred to where comparisons are instructive.

The outstanding facts and obvious conclusions that must be explained in an overall interpretation of breccia genesis are summarized below;

1. The Hornby Channel Formation, in sub-area 1, rests unconformably on Archean metamorphic and granitic rocks. In general, the depth to basement along the narrow channel is not likely to be great because: (a) sediments on the south side have shallow regional dips, (b) the possible outcropping of basal Hornby Channel sedimentary strata on the small island at the southern extension of the breccia zone, (c) the known location of the unconformity on south Simpson Island, and (d) the appearance of an inlier of basement granitic rocks surrounded by Hornby Channel sediments near the east boundary of the sub-area. (This latter location requires more careful examination as it is possible that some basal beds of the Hornby Channel Formation may be exposed on the southwest shore of the small lake that separates basement rocks from overlying sediments.)

2. In overall shape, the breccias have a trend pattern that roughly corresponds to that of the northeast-striking faults (note extension shown in Fig. 15). The irregularity of distribution of breccias and other relationships argue against faulting being the cause of the extensive brecciation but support pre-breccia faulting as a controlling factor in localizing breccia emplacement. Post-breccia faulting is also probable but the effects are thought to be minor.

3. The intrusive nature of the breccia is well demonstrated by: (a) its crosscutting relationships to unbrecciated Hornby Channel Formation, and (b) a preponderance of sedimentary fragments that are distinctive of rocks* known to occur at or near the unconformity with Archean basement. Of further significance is the appearance of granitic fragments and the likelihood that a high percentage of the dark matrix is composed of disintegrated granitic rock. Downward transport of fragmented rock from stratigraphically and structurally higher levels cannot be demonstrated (if this had been the case, one would expect a much higher proportion of buff subarkosic sandstone). Some local involvement of wall-rocks, however, in the form of larger fragments adjacent to contacts is strongly suggested, but the extent to which lateral introduction took place at the present level cannot be assessed. Rounding of fragments such as seen in the pseudoconglomerate infers attrition and transport. Emplacement of breccia in gaping fractures projecting into the host rock along contacts indicates extensive shattering and removal of some host material prior to introduction of breccia.

4. The presence of at least one felsite dyke, felsite as a minor fragmental component of breccias, and felsite forming an igneous matrix to sedimentary fragments in a few occurrences suggest an association of volcanic activity with breccia formation and emplacement. The above relations further suggest that introductions of felsite magma and breccia were oscillatory over a short interval of geological time.

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*Some lithologies are also similar to these noted by Hoffman (1968) in descriptions of the upper strata of the Hornby Channel Formation.

The more interpretive and speculative aspects of breccia genesis will be considered in following pages. For the most part, the overall interpretation follows current ideas related to the development of diatremes* and breccia pipes but certain features require special treatment.

The breccia zones outlined in Figure 2 are believed to be composed of a network of irregularly shaped and overlapping breccia 'pipes'. The term 'pipe' is applied for want of a better word but the actual cross-sectional shape of these bodies may be highly irregular (such as the breccia dyke) and reflect certain controlling features such as the northeast-trending fault system. Unfortunately specific observations designed to delineate the shape of breccia masses and the existence of overlapping were neglected but should be part of any future studies. At least some of the breccia pipes (if the assumption of a network is valid) are assumed to have had surface venting, although examples in other areas having terminations below their contemporaneous landsurface are known (e.g. Perry, 1961; Bowes and Wright, 1961). If the structures in the Petitot and Wilson Islands areas had surface venting, volcanogenic deposits at higher stratigraphic levels would be expected and in fact pyroclastic ejecta occurs near the top of the Hornby Channel Formation, according to Hoffman (1968; 1969). Flows and pyroclastic debris form a major part of the Seton Formation (Kahochella Group) as also noted by Hoffman (1969, p. 447). The previously described volcanic-like felsite in association with exotic breccia supports the contention that a mobile melt phase was available even though the actual proportion of felsite in comparison to lithic fragments of other rocks is relatively small. Perhaps one explanation is that substantial amounts of this phase were removed by subsequent upward discharges of brecciated rock. In addition, one might assume that the present level of exposure represents the lower part of the conduit and that crystallization of igneous material would be more common in the higher, cooler parts of the vent. If the pyroclastic rocks near the top of the Hornby Channel Formation are related to the same activity, the present level of exposure may lie in the order of a mile below the contemporaneous land surface using Hoffman's (1969) estimates of stratigraphic thickness. Similar speculative estimates for the Seton Formation would give a value of approximately 2 miles. In brief, the level of examination may be deeper than that exposed for similar structures in geologically younger rocks from other places.

According to the descriptions from the literature many breccia pipes are crudely circular in cross-section and have near vertical orientation. The mechanism for drilling or boring such a pipe-shaped cavity has attracted considerable interest. Most authorities derive the energy for diatreme propagation from upwelling of magma and a magma reservoir is a prerequisite for most interpretations. McBirney (1959, p. 436) gave three processes for emplacement of volcanic necks: (1) explosive boring, (2) forceful intrusion of magma, and (3) churning through oscillation of a magma column. In effect, these processes can be divided into those employing magma directly as a stoping or brecciating agent and those processes employing a gaseous agent. Successive advance and retreat of a magma column might result in spalling and release fracturing at the uppermost point with probable assistance

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*Specific definition of the term "diatreme" in current literature is uncommon; it is often used interchangeably with volcanic "vent" or "pipe". Diatremes presumably originate through the drilling or coring action of high energy gas release accompanying upward movement of magma. <u>See</u> also Bryner (1961, p. 490) for discussion of related terminology.

of some gaseous emanations. The apparent shortage of crystallized magmatic material found with the breccias suggests that both the second and third of McBirney's processes are of limited application in the present study. The most realistic approach, following McBirney's categories, would be one involving a gaseous explosion. Advocates of "gas coring" invariably make reference to some form of explosive activity. This is somewhat justified by many known instances of explosive volcanism but the exact manner in which volcanogenic explosions originate in the substratum is a matter of conjecture. The effectiveness of explosive action in producing a column of fragmented rock is realized by analogous experiments involving underground nuclear explosions as a possible mining technique. According to Coates (1967), the average height of a fragmental chimney above the centre of such an explosion is about five times the radius of the chimney.

Johnston and Lowell (1961, p. 931-933) provided a brief review of existing theories relevant to the origin of columnar or tabular bodies of fractured or brecciated rock. Five of the seven theories listed can be ignored for purposes of the present problem. The remaining two include (1) explosion and (2) fluid intrusion both of which are considered relevant in the present context. Explosive action has already been mentioned but fluid intrusion requires some amplification. The fluid may be either gas or liquid and the process is closely allied to that of explosion so that certain aspects of each can be treated jointly. Gaseous processes may originate by rapid fluid expansion in at least two ways: (1) thermal expansion and (2) 'pressure release' expansion. The first could result from the interaction of hot magma with entrapped formation fluids or groundwater. Large amounts of steam could be generated if the magnitude of intermingling was significant. In the case of rather rapid contact, explosive action could ensue. The second method of expansion could arise from rapid release of gases from a volatile-charged magma when the confining pressure is reduced to a critical level during upward migration of magma. This unmixing would be essentially a 'boiling off' of volatiles from the magma. The probable source of gas, whether magmatic or extra-magmatic, has been a topic of debate between McBirney (1963) and Kerr and Barrington (1963). No serious attempt is made in this report to identify which gas-generating mechanism might have been the most effective but it is interesting to note that the Simpson Islands breccias occur above an unconformity that separates crystalline basement rocks and relatively permeable sedimentary strata. The implications of this configuration will be treated subsequently in this paper.

Shoemaker _et al._ (1962), in outlining diatreme activity in the Hopi Buttes region of Arizona, propose a mechanism of hydraulic fracturing to account for initial fracture propagation. This concept has a realistic foundation because hydraulic fracturing is widely used to improve oil production from petroliferous strata. The hydraulic medium envisioned by Shoemaker _et al._ (op. cit.) was magmatic gases released by lowering of lithostatic pressure. It is also plausible that the gaseous medium could have originated through thermal expansion. Irrespective of the gas source the idea of hydraulic fracturing is tentatively accepted as a likely process for creating a myriad of fractures outlining elongate vertical pipe-like or dyke-like forms. This does not eliminate the possibility of similar results being produced by explosive activity and, as already mentioned, the two types of processes are hardly separable. In addition, hydraulic fracturing could result from a pressurized liquid or "thick mud" as advocated by Farmin (1934, p. 370). Upward advance of fracturing need not be accomplished in a single step and penetration to the land surface need not be anticipated in all cases.

Undoubtedly, the network pattern of fracturing in the overlying strata will be governed by their strength and attitude as well as pre-existing zones of weakness such as fault planes. The writer is of the opinion that northeast-striking faults localized gas-driven brecciation and/or magma upwelling in the granitic and metamorphic rocks below the unconformity. This same control may have been established in strata of the Hornby Channel Formation if post-depositional fault movement occurred. The only obvious

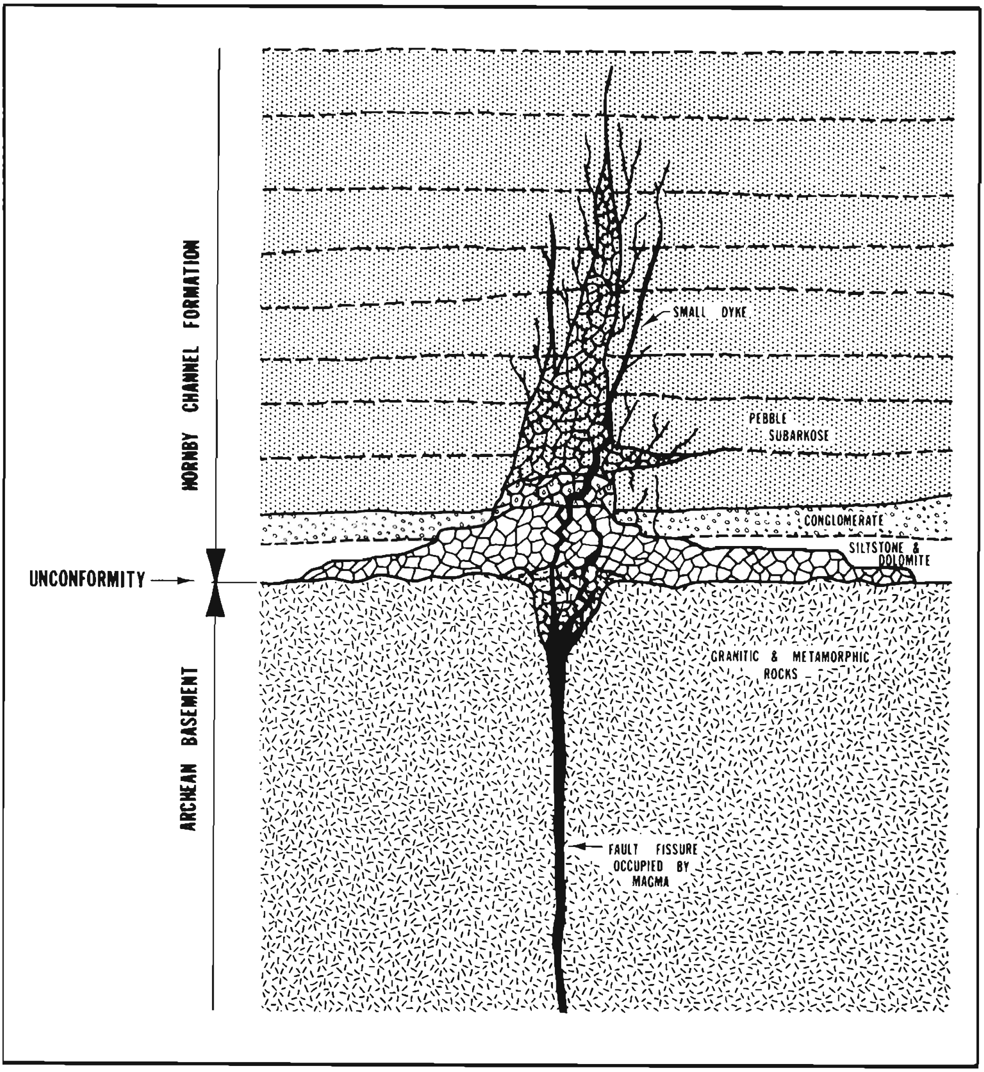


Figure 14. Schematic vertical cross-section showing a postulated breccia pipe in the brecciation stage of development. Plane of section is oriented roughly northwest-southeast.

feature recommending such a proposal is the elongate distribution of the breccia zones. The writer's interpretation of brecciation stage of development prior to significant transport is embodied in the schematic cross-section (Fig. 14). The possibility of pre-breccia faulting of the Hornby Channel Formation has been ignored and strong emphasis has been given to the controlling elements of the unconformity separating widely dissimilar rocks. The unconformity itself is regarded as a horizontal zone of inherent weakness in which hydraulic fracturing would have lateral advance before and during vertical propagation. Brecciation of the Archean rocks is thought to be confined to the zone of faulting whereas brecciation of the overlying sediments is envisioned as having an irregular configuration. Factors contributing to changes in pattern and magnitude of brecciation on approaching the unconformity are: (1) differences in rock competence and porosity, (2) existence of significant amounts of meteoric or formation water in the sediments, and (3) lack of, or weak pre-fracturing above the Archean rocks. According to the model, magma would work its way up the fault (which may also have been a wet zone) either by magmatic stoping or hydraulic fracturing. Upon reaching the unconformity, the fracturing would be caused mainly by gas action (hydraulic or explosive) and the breccia configuration would mushroom until a vertical passage was found along zones of weakness. Small upward injections of magma into the brecciated rock above the unconformity would congeal as matrix or form dykes as offshoots into the wall-rock. Fracturing mainly by gas action would continue until surface venting occurred marking the beginning of the next postulated process.

Decompression would accompany surface venting and gas-streaming would ensue. A more comprehensive evaluation of this phenomena has been presented by Shoemaker et al. (1962). The violent uprushing of gas would promote 'fluidization', a process whereby a rapidly moving gas stream can suspend and transport solid particles. The nature and applications of this process is well described by Reynolds (1954) and it is a popular explanation for pipe-like bodies of breccia. Gas-streaming and resulting fluidization would produce attrition and reduction in size of entrained particles along with upward movement. The comminuted granite from near the unconformity would form the finer material in which larger fragments of sediments would be entrained. Previous discussions in the literature refer to fragments normally of a few inches in diameter as those that experienced upward transit and little mention is made of fragments of more than a few feet in diameter. Certainly spalling of conduit walls producing large blocks would seem natural upon decompression but upward elutriation of large blocks from beneath, as appears to be the case in this area, may exceed even the most extreme capabilities of fluidization. Also gas-streaming cannot be thought of as an extended event. Several cycles are likely to have occurred. During fluidization considerable material could be ejected through vents and upon cessation suspended fragmental material would fall back down the conduit and the collapse of the decompressed chamber might be assumed. This action can be regarded as a further stage of the process.

The occurrence of purely brecciated material from below and large blocks (some in the order of several hundred feet in length) suggest upwelling of breccia in a relatively quiet manner. One could account for this in two ways: (1) failure, collapse, and slump of the walls following decompression; and (2) 'piston effect' of uprising, volatile-poor magma. The observed relations may be a consequence of both but the former is favoured. Although faulting has undoubtedly affected the attitude of sedimentary beds, some of the steep dips in the vicinity of the breccia zones may indicate collapse. In the present interpretation, the flaring of the breccia mass at the unconformity would influence the collapse configuration with the excavated lateral volume along the unconformity accommodating slump. Choking of the column by fragmented rock may prevent immediate collapse of wall-rock under dry conditions and temporary support for the superincumbent load would be provided as in backfilling during mining operations. Addition of water either from above or by percolation through enclosing rock is suggested as a means of reducing intergranular friction. The result would be formation of a 'mud' or slurry of fine material capable of moving large blocks. Under these conditions the supporting strength would be reduced and the undermined host rock would fail and squeeze the lubricated breccia and enclosed blocks up the pipe, especially near the unconformity. Not only would this lead to intrusion of finer grained breccia into open fractures, but also cause extension of these fractures through further hydraulic action. Local separation of spalled wall-rocks could also be expected. Some support for collapse as being an important mechanism is offered by Williams' (1936) discussion of calderas in which he points out that depressions surrounding calderas are effectively a result of subsidence rather than decapitation by violent explosion. The present hypothesis could be evaluated more critically if those parts of the unconformity where both breccia and felsite exist, were exposed. The relations expected would include a crude bed-like mass of breccia subparallel to the unconformity and overlying strata, in other words a lateral zone of breccia. A similar arrangement for felsite might be expected with local offshoots in a more or less vertical direction. All upwelling of lubricated breccia need not be attributed to caving or collapse of host rocks strata; some may be a result of preferential sinking of denser material or, as already noted, the piston effect of uprising magma.

The foregoing interpretation is not final but satisfies most of the problems arising from the limited field work.

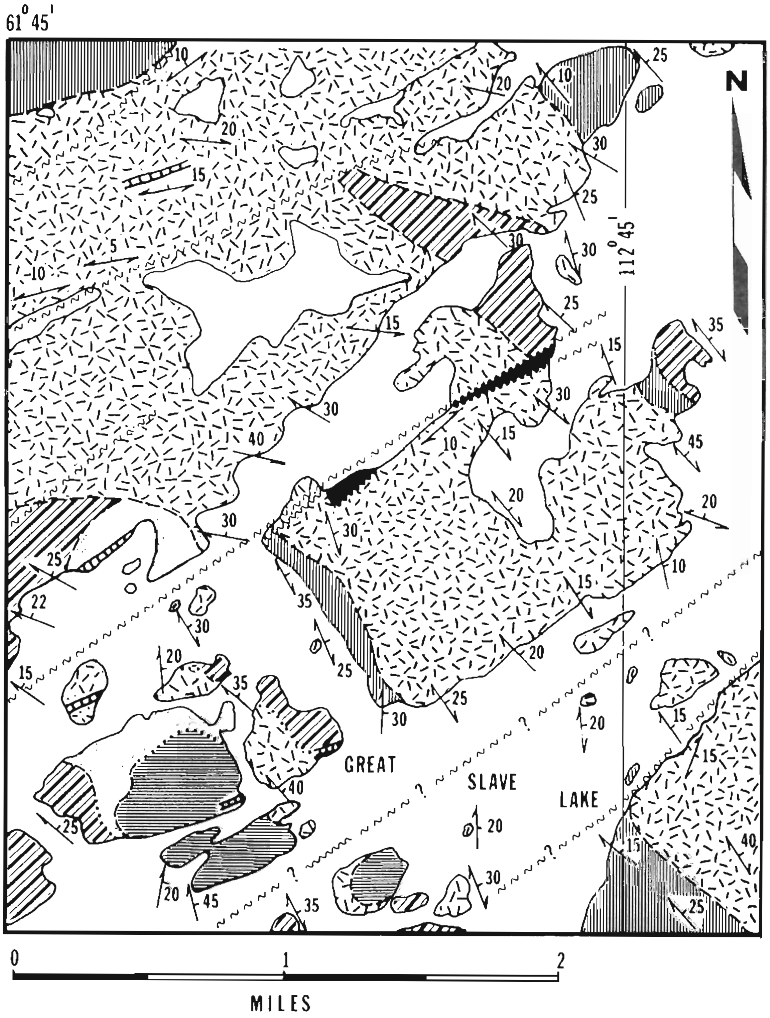
SUB-AREA 2

General Remarks

The breccia in sub-area 2 appears to be an extension of the zone outlined in sub-area 1 and lies along the same set of faults. Information on the breccia in sub-area 2 is limited, being based on a few brief observations made during routine mapping. An independent interpretation of the genesis will not be attempted in view of the scarcity of data and probable association with comparable breccia to the northeast (in sub-area 1).

Description and Field Relations of Breccia

The breccia zone is bounded by northeast-striking faults (Fig. 15) and some of the brecciation may have been formed through fault movement. The configuration of the zone suggests a period of fault movement subsequent to breccia emplacement and the distribution and preservation of breccia appear to be fault controlled.



■ Exotic breccia

▯ Diabase dykes (possibly of more than one age)

░ Mainly leucocratic quartz monzonite and granodiorite, typically buff and garnetiferous; contains assimilated pelitic gneiss in places

▨ Granitic migmatite containing biotite and hornblende schlieren and layers

▤ Meta-gabbro, meta-diorite

▥ Mainly layered, garnetiferous pelitic gneiss; includes some minor granitic rock

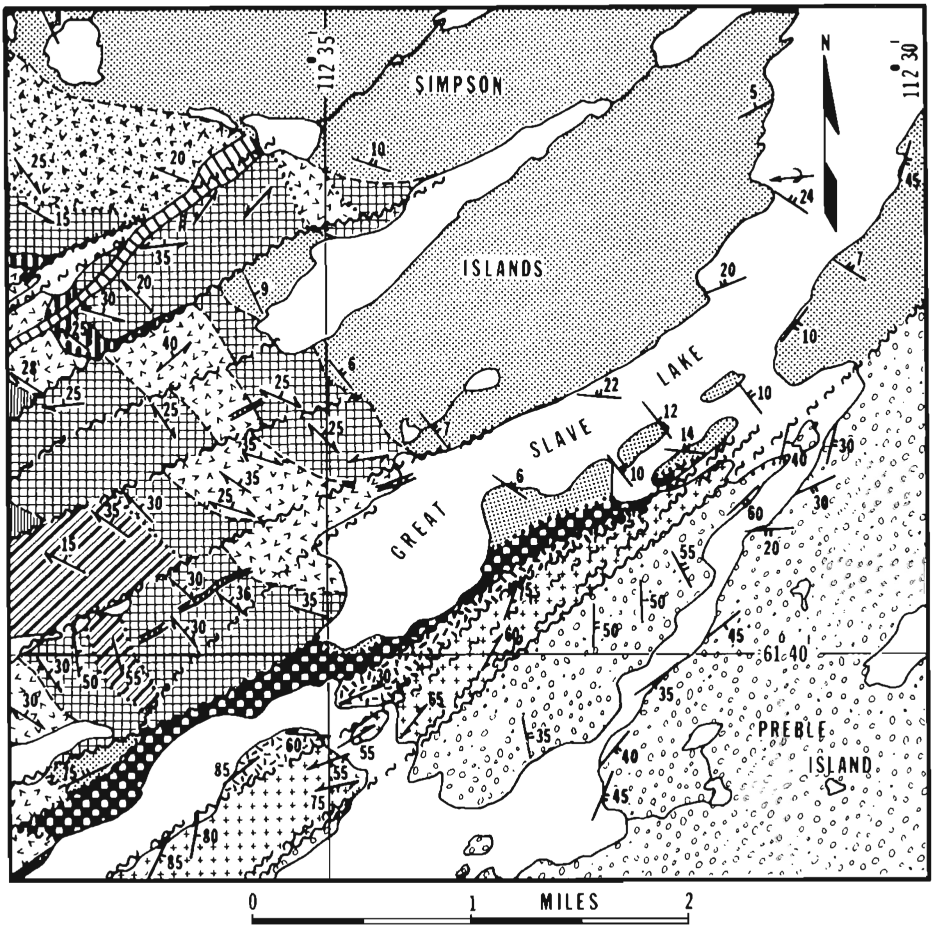
□ Amphibolite

For explanation of symbols, see Fig. 2.

Figure 15. Sketch map showing the general geology of sub-area 2.

In the southwestern part of the zone, the breccia fragments are mainly pink to buff, massive to gneissic granitic rocks. Some fragments of brown, laminated dolomite similar to that in the basal Hornby Channel Formation are mixed with the granitic fragments. Blocks of granitic rock up to several feet in maximum dimension are common. Occasionally carbonate strata are found as blocks up to six feet across. The largest blocks noted were several tens of feet in diameter and were composed of pink granite similar to the unbrecciated granitic country rock nearby. Siltstone, felsite, and layered dark gneiss were tentatively identified as minor fragmental components. The matrix varies from grey to pink and is presumably composed of comminuted granitic material. The granitic host rock near the contact is traversed by a network of fractures which are filled by vein carbonate. A few seams filled with breccia occur outside the main zone and these may represent fault breccia rather than exotic breccia.

Towards the northeastern limit of the breccia zone there is a 'band' of brown weathering algal-bedded carbonate (probably Hornby Channel Formation) which appears to be enclosed, as well as locally cut, by breccia which contains fragments of vein quartz and sedimentary carbonate. Elsewhere in this vicinity the breccia fragments are mainly fine grained, greenish black rock, probably of sedimentary origin, enclosed in a matrix that consists in large part of white quartz with lesser amounts of pinkish felsite.



SUB-AREAS 3 AND 4

General Remarks

The breccias occurring in these two sub-areas (Figs. 16 and 17) belong to the same northeast-trending zone which is delineated by faults of the same trend. In general, the nature and origin of this breccia zone is more obscure than the zone passing through sub-areas 1 and 2. One complicating factor is the existence of extensive post-breccia faulting. The size of individual fragments, although highly variable, is characteristically large with huge blocks presumably making up the greater part of the total area mapped as breccia. In addition, evidence for diatreme or related magmatic activity is not at all obvious at any particular location and further work is needed in order fully to appreciate the mechanisms responsible for brecciation. An initial explanation conceived during the course of field work was that the large deranged blocks that comprise much of the zone were derived through crushing action along a narrow fault slice during transcurrent displacement. The majority of blocks in the fault-bounded breccia zone appear to belong to the basal part of the Hornby Channel Formation. Fault derivation may account for some of the breccia but certain features suggest a genetic connection of the large-scale breccias with the exotic breccias found in sub-area 1.

LEGEND

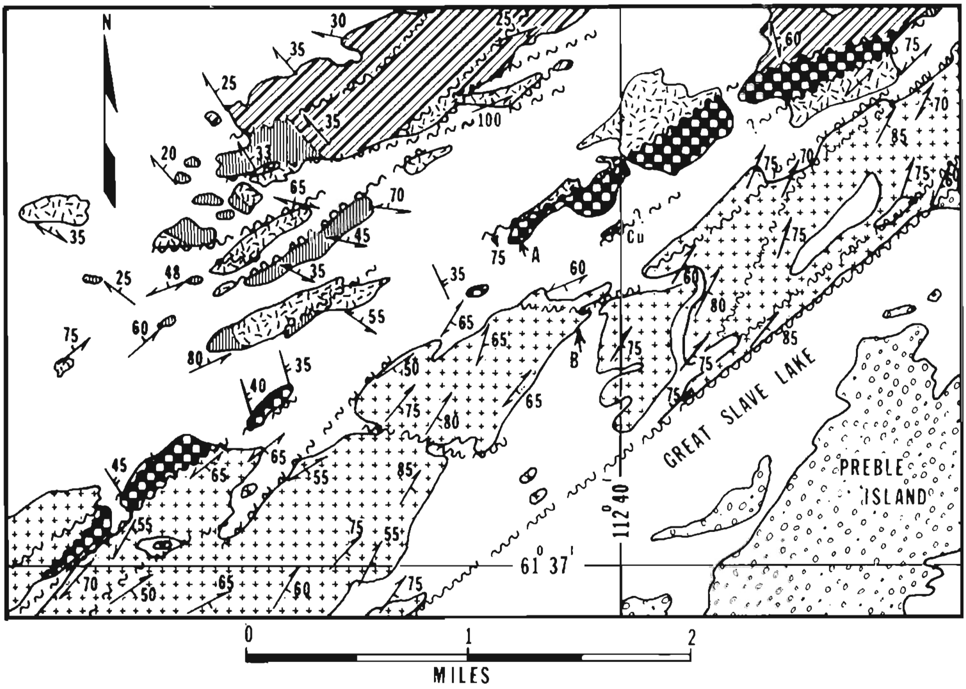
○	PREBLE FORMATION (ET-THEN GROUP)
■	'Breccia' consisting mainly of basal Hornby Channel Formation sediments
░	HORNBY CHANNEL FORMATION
▯	Diabase Dykes (possible of more than one age)
+	Layered granitic migmatite; mafic component dominantly amphibolite; commonly mylonitized
▵	Predominantly leucocratic, medium-grained quartz monzonite; pink, massive to gneissic
▒	Biotite and biotite-hornblende quartz monzonite to quartz diorite; typically porphyritic
▦	Biotite and biotite-hornblende quartz diorite gneiss and *augen* gneiss; minor related granodiorite and quartz diorite
⁝	Mainly leucocratic quartz monzonite and granodiorite; contains minor assimilated pelitic gneiss
▨	Granitic migmatite containing biotite and hornblende *schlieren* and layers
▥	Biotite paragneiss
▮	Mainly layered, garnetiferous pelitic gneiss

For explanation of symbols, *see* Fig. 2.

Figure 16. Sketch map showing the general geology of sub-area 3.

Faulting

The precise sequence of fault movements along the prominent northeast-striking breaks is indeterminate without more detailed work along this zone. Nevertheless, a relatively long history of movement is proposed as already mentioned (p. 5).



▨ PREBLE FORMATION (ET-THEN GROUP)

▦ 'Breccia' consisting mainly of basal Hornby Channel Formation sediments

▯ Diabase dykes (possibly of more than one age)

⊞ Layered granitic migmatite; mafic component dominantly amphibolite; commonly mylonitized parallel to layering

▩ Mainly leucocratic quartz monzonite and granodiorite; contains minor assimilated pelitic gneiss

▧ Granitic migmatite containing biotite and hornblende schlieren and layers

▥ Mainly layered, garnetiferous pelitic gneiss

For explanation of symbols, see Fig. 2.

Figure 17. Sketch map showing the general geology of sub-area 4.

The earlier faulting in the sub-areas is thought to be represented by transcurrent movement involving mylonitization. Much of the layered granitic migmatite is mylonitized parallel to steeply dipping compositional layering which in turn is oriented at low angles to northeast-striking faults. The layering represents a consistent set of parallel planes of inherent weakness almost in the direction of the dominant shear separation so that movement could be transmitted along the layering if a discrete fault was not available. The layered granitic migmatite is the only lithologic unit represented in Figures 16 and 17 that displays cataclastic deformation in positions away from localized zones of recognizable faulting. Previous experience with similar migmatites in the Thubun Lakes area (Reinhardt, 1969b) prompted the writer to submit hornblendes from amphibolite bands within the layered granitic migmatite for K-Ar age determination. The dates obtained* were 1,815 ± 65 m.y. and 1,812 ± 62 m.y. which are consistent with dates previously determined for penetratively deformed layered rocks south of Hornby Channel. The values, however, are at variance with Kenoran ages found in plutonic rocks to the north and of similar aspect but lacking cataclastic deformation. Further discussion of this inconsistency exceeds the scope of this report but it is regarded as a characteristic distinction between plutonic rocks having a high degree of cataclasis and those having virtually none at all; this also serves as further justification for assuming a major fault separating these structurally distinctive units.

Some appreciation of the magnitude of the earlier transcurrent displacement is further suggested by offsetting of strata tentatively assigned to the Wilson Island Group. Such an occurrence of quartzite and metasediments has been mapped as a fault-bounded block southwest of sub-area 4 (see Reinhardt, 1969a, Fig. 1). The nearest other occurrence of Wilson Island Group rocks along the strike of the faulting, according to earlier mapping of Stockwell (1936a,b), is on Union Island, about 30 miles to the northeast. In addition, one might reasonably project the southwesterly extension of the McDonald fault-line scarp through the zone marked by most intense faulting within the present sub-areas. Taking into account the possibility of numerous splays (see Reinhardt, 1966, Fig. 1; 1969b, Fig. 2) which result in local departures from a linear trend, this line of demarcation follows the boundary between areas of considerably different deformational histories.

Lake fault movement took place either along pre-existing breaks or initiated new fractures with the same trend. This movement is especially emphasized by the single fault separating the Hornby Channel Formation from the Preble Formation in the eastern part of sub-area 3. As the Preble Formation belongs to the youngest group of rocks (Et - Then Group) in the East Arm, the movement must post-date its deposition. Relative ages would also require that the south side be the downthrow side. A dextral component of movement can be inferred from offsetting of the unconformity separating the Hornby Channel Formation from underlying rocks. The scheme of late movement is thus south side down and to the southwest.

Description and Field Relations of Breccia

The zones of breccia outlined in Figures 16 and 17 show only localities in which the brecciated rocks consist of recognizable Hornby Channel

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*Determination by the Geochronology Section, Geological Survey of Canada.

Formation. Other localities which may contain breccias of similar derivation but involving different lithologies could not be distinguished because of the widespread effects of faulting. Cataclasis resulting from fault movement has been superimposed on pre-existing structures such that the origin of some brecciation within the present sub-areas is uncertain.

The contacts of mappable breccia zones with adjacent map-units are shown as faults (Figs. 16 and 17) except towards the central part of sub-area 3 (shown as a dotted line, Fig. 16) where relationships are uncertain. Strata above the contact consist of typical buff subarkosic sandstone and quartz-pebble conglomerate of the Hornby Channel Formation. Except in the immediate vicinity of the contact, these rocks are little brecciated and sheared and in general, the bedding attitudes roughly correspond to the orientation of bedding higher in the sequence. Lithologies below the contact closely resemble basal Hornby Channel Formation strata and include stromatolitic dolomite, red siltstone, and occasionally light grey, subarkosic sandstone or orthoquartzite. Brecciation and local mylonitization are common and measurement of bedding attitudes adjacent to the contact suggest either chaotic folding or brecciation that produced huge blocks. Although some small-scale brecciation was evident in the vicinity of the contact, the specific recognition of mega-breccias was confined to locations elsewhere within the zone and away from the contact. The relationships at the contact can only be inferred but the impression held is that the breccia boundaries are not necessarily parallel to the lithologic boundaries and these relationships would be comparable to those schematically illustrated in Figure 14.

Further documentation is required to demonstrate the consistent presence of mega-breccia everywhere throughout the zone outlined in Figures 16 and 17. In many places the critical relationships are obscured by silicification and carbonate veining. Large blocks of sedimentary carbonate having dimensions in the order of several hundred feet could be individually recognized in the southwestern part of the zone, but in many places the evidence of large-scale brecciation consists of anomalous or chaotic disposition of bedding attitudes as already mentioned. Some small-scale folding within large breccia blocks is suggested at location "A" (Fig. 16) and other shoreline localities. Small-scale breccias containing fragments ranging from a fraction of an inch to several feet were observed in several places along the length of the zone, but on the whole are not nearly as obvious as comparable breccias in sub-areas 1 and 2. Certain other general differences exist. First of all, recognizable breccia fragments are more widely separated by fine-grained matrix. Secondly, the matrix and fragments are sufficiently similar in colour and overall aspect so as to blend together in outcrops. Thirdly the matrix is not always distinguishable from other known rock-types in the region. Recognition of small-scale breccia is thus more difficult than in sub-areas 1 and 2 but nevertheless small-scale fragments set in a fine-grained matrix can be readily identified in certain outcrops such as indicated on Figures 18 and 19.

In some outcrops the breccia matrix closely resembles fine-grained sedimentary or tuffaceous rocks, whereas in others it is similar to fine-grained cataclasite that occurs near faults both in neighbouring rocks and farther to the south in the Thubun Lakes map-area. Much of the matrix rock was tentatively identified as 'felsite' in the field but undoubtedly a large part consists of finely fragmented material which may also include fragments of felsite. This matrix varies in colour being light to dark grey, dark green,

Figure 18. Carbonate fragment in fine-grained felsitic-looking matrix at location "A", Figure 16, sub-area 3. GSC photo 149780.

Figure 19.

Large carbonate fragment (dark) enclosed by felsitic-looking matrix (light). Note the irregular patches of matrix that appear to be isolated within the carbonate. The location is approximately the same as that of Figure 18. GSC photo 149781.

salmon, and buff. Positive identification of felsitic matrix material is extremely important in interpreting the nature and origin of the zone and fifteen thin sections of 'field felsite' were examined for this purpose. A well-developed felsitic matrix was found in only one section which came from a specimen containing an undisputed inclusion of dark siltstone. Megascopically, the felsite was light grey and resembled quartzite. Microscopically, the matrix consisted of albitic plagioclase with lesser amounts of quartz and carbonate. The feldspar is subhedral and lath-like with an average grain size of 0.05 mm and the resulting texture could be described as microfelsitic. Quartz is well distributed throughout the feldspar intergrowth and some forms elongate euhedral phenocrysts of about 1 mm in length. These show sharp growth haloes that are defined by extremely fine-grained inclusions suggesting one or more periods of arrested crystallization. Carbonate grains are irregularly scattered throughout the felsite and show growth haloes and euhedralism similar to that in the quartz phenocrysts. The quality of the development of microfelsitic texture in the remaining specimens is substantially poorer and in some its presence is uncertain. Its recognition is further confused by the coexistence of fine-grained fragmental matrix material which also contains major proportions of feldspar, quartz, and carbonate. Carbonate was not always suspected in hand specimens but was found in amounts up to 80 per cent in respective thin sections. Some of this carbonate is a replacement mineral related to veins of brown-weathering carbonate common in certain parts of the breccia zone. Chlorite was noted in significant concentrations in a few sections made up largely of the fragmental-type matrix and this could represent comminuted amphibolite. In general, the composition of fragmental matrix material is more akin to known plutonic rocks in this region than to sediments of the Hornby Channel Formation. The overall conclusion as to the nature of fine-grained breccia matrix is that it may consist of either or both the fragmental type and the felsitic type and positive field delineation is unrealistic.

The only other significant feature of the breccia zone is the extensive veining. Carbonate is the dominant vein material. The orientation of these veins is haphazard and the widths are normally only a fraction of an inch. Where fracturing has been most intense, the veins form a stockwork and often single fracture fillings indicate dilation. Little evidence of replacement was observed adjacent to the veins and the carbonate appears to be mainly an infilling of previously fractured rock.

The overall mode of vein occurrence is similar to that described from sub-area 1 in that the veins are late with respect to breccia, and are more or less confined to zones of breccia. Hematite and chlorite are sometimes associated with vein carbonate and traces of chalcopyrite, bornite, and pyrite were found in highly brecciated rock occurring on the small island in sub-area 4 (position indicated by "Cu" Fig. 17).

A few reddish veinlets, tentatively regarded as felsite, were sometimes seen cutting both matrix and fragments.

Origin of the Breccia

Perhaps the most compelling evidence favouring a similar origin for this zone and that of sub-areas 1 and 2 is the presence of felsite in certain parts of the breccia matrix. This rock was not found outside breccia zones within the Petitot Islands map-area so that its consistent association with the breccia can be interpreted as evidence of diatreme activity. Other similarities include: the lithologies of brecciated strata, type of matrix material, consistent distribution along zones of northeasterly faulting, and presence of carbonate veining. Taken collectively, these similarities point to a common origin.

SUB-AREA 5

General Remarks

Most of the field information is based on routine descriptions of outcrops and a somewhat more sophisticated approach is needed to fully document the relationships implicit in Figure 20. The relative age of the Wilson Island Group with respect to the Sosan Group is uncertain but the Et-Then Group definitely overlies both groups unconformably.

Faulting

The breccias occur along a zone of major faulting that effectively separates rocks of the Wilson Island, Sosan, and Et-Then Groups from basement Archean plutonic rocks to the south. The exact times at which movements occurred within the fault zone cannot be ascertained until more is known about the ages of the major rock groups affected by the displacements. It is conceivable that the earliest faulting predates all the above mentioned groups. Of particular concern with respect to later faulting is the age of the Sosan Group, represented in the sub-area by the Hornby Channel Formation. Hoffman (1969, p. 444) considered this group to be Aphebian. The oldest radiometric dates from rocks that have intruded this group is 1, 845 m.y. (GSC- 61-78) and the mean is about 1, 760 m.y. A recent K-Ar determination* on muscovite from the unmetamorphosed Hornby Channel Formation on Wilson Island gave an age of 1, 855 ± 55 m.y. Similar K-Ar values have been obtained from metamorphic micas from the Wilson Island Group suggesting that the age of 1, 855 m.y. cited above corresponds to the Wilson Island Group metamorphism. Apart from other obvious implications of these dates, they serve as an upper limit for the age of fault movement that displaced the Sosan Group. Considering all groups shown in Figure 20 along with the Archean plutonic complex it would appear that faulting must have been active prior to the deposition of the Sosan Group and following deposition of the Et-Then Group.

Evidence of late faulting is less problematic in that rocks of the Murky Formation are displaced. The late movement is believed to involve a significant component of vertical displacement probably guided to some degree by the earlier fracture pattern.

Description and Field Relations of Breccia

Two zones of breccia have been outlined in Figure 20. The contact between the southwestern zone and the granitic migmatite to the southeast is steep and abrupt and may be a fault. Granite, maroon siltstone, subarkosic sandstone, white quartz, jasper (?), and reddish felsitic rock occur as breccia fragments. The matrix is typically a hard, fine-grained, reddish rock resembling rhyolite. Locally a vague colour lamination is visible but this is usually

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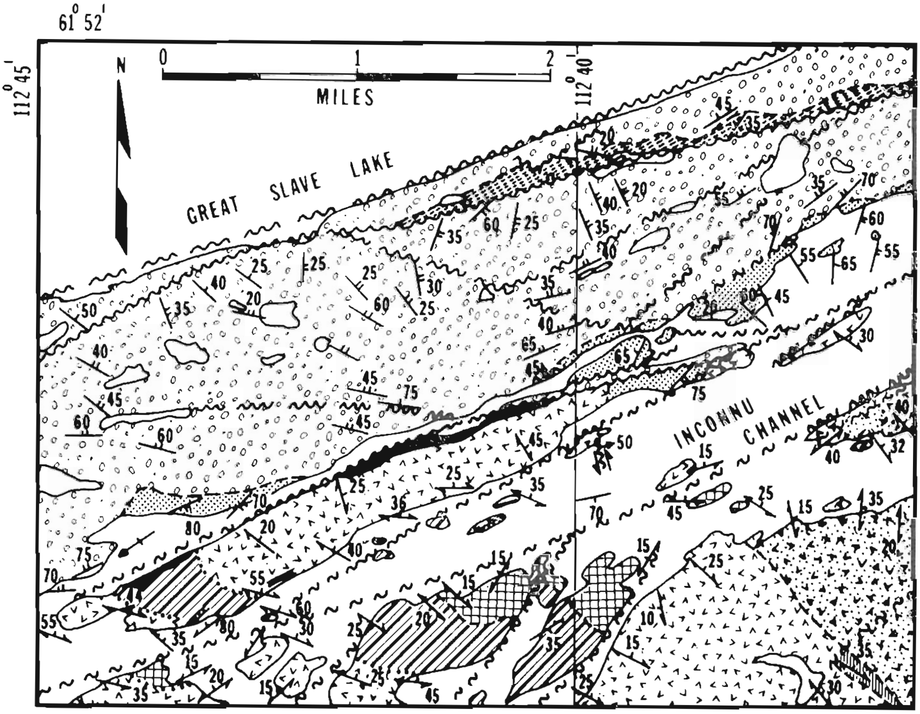
*Determination by the Geochronology Section, Geological Survey of Canada.

lacking. In places the matrix is arkosic in aspect and towards the northeastern extension of the zone, carbonate, probably related to veining, forms the matrix to granitic fragments that measure up to one foot in diameter. Generally, the fragment size is in the order of a few inches or fractions of inches. The



░ MURKY FORMATION (ET-THEN GROUP)

■ Exotic Breccia

▒ HORNBY CHANNEL FORMATION**(SOSAN GROUP)

▯ Diabase dykes (possibly of more than one age)

▨ WILSON ISLAND GROUP*: sedimentary rocks

☐ Predominantly leucocratic, medium-grained quartz monzonite; pink, massive to gneissic

▦ Biotite and biotite-hornblende quartz monzonite to quartz diorite; typically porphyritic

▦ Biotite and biotite-hornblende quartz diorite gneiss; minor related granodiorite and quartz diorite

▧ Granitic migmatite containing biotite and hornblende <u>schlieren</u> and layers

▥ Layered pelitic gneiss For explanation of symbols, <u>see</u> Fig. 2.

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*Age relative to Sosan Group unknown; exposed contact on Wilson Island is a fault rather than an unconformity.

**According to Hoffman (1968, p. 10) this should be Hornby Channel Formation

Figure 20. Sketch map showing the general geology of sub-area 5.

degree of rounding is variable and some pseudoconglomerates were tentatively recognized. The mapped breccia zone is characterized by carbonate veins having random orientations and with variable widths and populations. Such veins are decidedly less abundant in surrounding rocks. A fine lattice-work of carbonate veinlets can often be seen upon close examination of rock specimens that from a distance appear to be unbrecciated. This is especially true of the maroon siltstones which undoubtedly belong to the Hornby Channel Formation.

The nature of the northeastern breccia zone (Fig. 20) is more obscure than the zone just described because many outcrops show a preponderence of finer grained fragments or fragmental-type matrix. Felsitic-looking rock is also present in several places but in general, the finer grained rock appears to be a product of comminution and is characteristically maroonish or reddish and rich in quartz. Outcrop surfaces are often rough or 'crackled' due to the presence of closely spaced, randomly oriented fractures which are partially filled with carbonate. Larger veins and irregularly shaped patches of brownish carbonate are common and at one locality carbonate makes up over 50 per cent of the rock. A thin section of typical fine-grained maroonish rock that showed numerous hair-like carbonate veinlets was examined. The dominant mineral is quartz which ranges in grain size from 2 mm to less than 0.05 mm. Finer grained quartz forms the matrix to coarser quartz. Except for vein carbonate, the only other significant mineral components are microcline and well-disseminated iron ore. Microscopically, the texture is cataclastic and in the field the rock was called a fine-grained breccia.

Origin of the Breccia

The breccias are regarded as having been derived by the same process as proposed for those of sub-area 1 although the documentation is less compelling. The origin, and to some extent, the distribution of these 'exotic breccias' must be considered tentative in view of the following factors: (i) possible presence of fault breccia produced during either early or late displacements, (ii) possible confusion in distinguishing pseudoconglomerates (such as also occur in sub-area 1) from true sedimentary conglomerates of the Murky Formation (Et-Then Group), and (iii) lack of precise stratigraphic control for rocks in this vicinity that have been assigned to the Hornby Channel Formation.

POSSIBLE ECONOMIC SIGNIFICANCE OF ZONES OF EXOTIC BRECCIA

Occurrences of mineralized breccia pipes outside of Canada are well known and have been widely reported from the United States, particularly from the porphyry copper districts (see Lowell and Guilbert, 1970, p. 403). By contrast, documented Canadian examples of breccia pipes, breccia dykes, and diatremes are comparatively few and the number of these structures with associated mineralization are even fewer. Precambrian occurrences are exceptionally rare and perhaps, as suggested by Perry (1961), the explanation lies in the inherent difficulty of recognizing these structures in rocks which have experienced complex geological evolution. No doubt many of the identifying characteristics of diatreme activity have been removed through the effect of erosion reaching deeper crustal levels. In addition, the bulk of the geological mapping in the Canadian Shield has been largely reconnaissance surveys so that many zones of exotic breccia or diatremes may have been overlooked.

The various aspects of ore control attributed to breccia pipes or similarly derived structures are many. An excellent review of pipe-like structures and their association with epigenetic ore deposits was given by Bryner (1961) who emphasized the apparent lack of systematic consideration devoted to these structures in relationship to ore deposits. Moreover, a wide variety in type of deposits can be expected and Bryner (op. cit., p. 505) considered two broad categories - pre-hydrothermal and co-hydrothermal; the latter are presumably more favourable for economic ore deposition.

In considering economic possibilities related to the breccias described in this paper, the approach is to review a very simple model that would seem to account for the reported and observed mineralization. Most of the observed mineralization consists of insignificant scattered showings of copper and iron sulphides that have been indicated on the accompanying sketch-maps for the five sub-areas. The reported mineralization is the uranium showings investigated by Vestors Explorations Limited and occurring on Simpson Islands as noted in the Northern Miner (September 24, 1970) and by Bottrill (1971, p. 83).

Following the model proposed for development of the breccias, the most obvious function with respect to localization of subsequent mineralization is that of a 'ground breaker' so as to permit passage of fluids. Presumably, brecciation, especially that of pipe-like configuration, would provide a porous, permeable, vertical access route for ore-bearing solutions. If access to the landsurface were achieved, significant volume losses in the form of ejecta could be an additional means of producing voids along the conduit. As previously explained, a body of magma is generally conceded to be the motivating energy driving the brecciation so the presence of a magma chamber at depth can be assumed. Eventual crystallization of this magma, in part, if not completely, can be expected and this could produce hydrothermal end-product solutions that may be enriched in elements of economic significance. Both Perry (1961) and Bryner (1961) have considered the possible genetic association between magmatic activity and ore-forming solutions in the context of breccia pipes.

Further consideration of features that might be conducive to mineralization in the Great Slave Lake area will be made in a somewhat more specific sense. Consider the reported radioactive occurrences from sub-area 1 and suppose that upward migration of ore-bearing solutions took place roughly along the pipe-like form. What favourable mechanisms for localization and entrapment may have been operative? The basement rocks because of their low porosity would provide a poor host unless highly fractured. On the other hand, the unconformity separating the Hornby Channel Formation from the basement complex may have been a zone offering considerable lateral space for deposition, especially if the configuration of this zone actually bears any resemblance to that postulated in Figure 14. Another significant factor could be the presence of carbonate and siltstone beds alternating with conglomerate beds so as to produce differential porosity and traps for migrant solutions. This same argument can be applied to conglomerate lenses higher in the Hornby Channel Formation. The direction of dip in strata collaring the conduit could also be important. Inward-dipping strata would create divergent channelways that traverse porous layers until well removed from the conduit mainstream.

As already mentioned, inward-dipping strata would be a natural outcome of slump in the column. Last of all, if the breccia conduit is the main channel, it too might be mineralized.

In considering localization of uranium or thorium mineralization, it is conventional to assume some redistribution through secondary agencies such as groundwater. Secondary solutions thus may also be expected to frequent the same channelways travelled by primary solutions. One then might consider preferential depletion along main conduits compared to branching access ways.

If the actual processes involved in mineralization were those suggested above, favourable prospecting ground should be the Hornby Channel Formation adjacent to the breccia zones, the unconformity where invaded by breccia, and the breccia itself. Undoubtedly, further work is needed to eliminate the possibility of other forms of deposition such as sedimentary concentrations.

The rather erratic distribution of trace amounts of copper sulphides provides little in the way of interpretable information. These sulphides are associated with quartz and carbonate veins and presumably represent late hydrothermal concentrations that were guided by the breccia conduit and adjacent fractured rock. Only one showing was found in the Hornby Channel Formation. One might contemplate a mode of emplacement similar to that postulated for the radioactive mineralization with the exception that leaching or secondary redistribution is likely to be less important.

A brief examination of mineralization associated with breccia pipes and diatremes from elsewhere is instructive for predicting the mineralization potential in the East Arm of Great Slave Lake. Only a few occurrences will be reviewed here, but a systematic topical analysis could prove to be invaluable in searching for certain types of mineral deposits.

According to Shoemaker et al. (1962), the Pliocene diatremes of the Hopi Buttes, Arizona, contain low-grade deposits of uranium. Mineralization is mostly confined to diatremes containing bedded carbonate rock. The highest concentrations of uranium in the area are in fine-grained clastic sedimentary rocks and lapilli tuff occurring: (1) at unconformities within diatremes, (2) at vent walls of diatremes, and (3) enclosing beds of coarse breccia. The authors suggested a syngenetic origin for the uranium deposition that resulted from evaporation of carbonated waters and an eqigenetic origin for the uranium deposited in the clastic rocks through structural control of solution flow.

Gabelman et al. (1962), in a brief study of the Cachimayoc breccia pipe of Cuzco, Peru, indicated a consistent zonal pattern of radioactivity associated with breccia pipes in this region. In general, margins of pipes showed greater radioactivity than interiors and highest anomalies occurred coincidental with strongest deformation and mineralization. Zones of "calcitization" were more radioactive than zones of "pyritization". The authors assumed that original radioactive mineralization was highest in pipe interiors but that this arrangement had been subsequently modified by surficial oxidation and leaching. The radioactivity is tentatively ascribed to uranium. The breccia pipes cut middle Cretaceous strata and are arranged in broad linear zones enclosing major faults.

Johnston and Lowell (1961) in describing mineralized breccia pipes of Copper Basin, Arizona, noted copper-molybdenum mineralization in and peripheral to breccia pipes as well as in shear zones and faults. The mineralized pipes are enclosed by aureoles of alteration that overlap adjacent aureoles. Quartz is the main cementing material of the fragments and preceded emplacement of pyrite and copper sulphides which were deposited in voids and fractures mainly within the quartz. The molybdenite was later than other sulphides but again was deposited in fractures. The authors contend that there was a close association between the mineralized pipes and porphyry copper deposits. The breccia pipes are thought to be Laramide in age and are commonly located near the contact of one or more igneous rock-units although this may be of doubtful significance.

Llambías and Malvicini (1969) reported bismuth-copper mineralization from the San Francisco de los Andes breccia pipe, San Juan, Argentina. The proposed mineral paragenesis comprises three main stages: (1) alteration, (2) filling, and (3) replacement. Zoning of hypogene sulphides in the breccia pipe is roughly concentric with a barren core and a sulphide-rich rim. Tourmaline, the major gangue, along with quartz and pyrite characterize the core and increased amounts of pyrite occur towards the rim. Bi-Cu deposition in the rim zone is thought to represent a second mineralization. Bismuthenite, the chief ore mineral, is commonly associated with earlier arsenopyrite. The principal copper mineral, chalcopyrite, is found in both rim and core zones. The Bi-As-Cu mineralization probably originated from magmatically derived, water- and boron-rich fluids residual from the crystallization of nearby granodiorite. The pipe breccias were probably emplaced during late Paleozoic time and no major structurally controlling factor was mentioned by the authors.

Blecha (1965) briefly described the breccia-pipe copper deposits of the Tribag Mine in the Batchawana area, near Sault Ste. Marie, Ontario. Breccia fragments in the pipe-like "Breton Zone" are separated by quartz-carbonate matrix. Ore mineralization consists mainly of chalcopyrite and pyrite with minor molybdenite, sphalerite, and galena. Giblin (1966) discussed this deposit and attributed the mineralization to post-breccia introduction of carbonate, quartz, fluorite, and sulphides in open spaces between fragments. He also mentioned possible porphyry copper deposits in the Batchawana area and suggested a genetic connection with breccia-pipe mineralization. Ambrust (1969), in a study of hydrothermal alteration of the Breton breccia indicated a possible genetic relationship between the copper deposits and neighbouring Keweenawan basaltic extrusives. Alteration in the breccia zone gave a K-Ar age of 1,055 m.y. (Roscoe, 1965) and this can be taken as roughly the time of mineralization (Armbrust, 1969, p. 562). The structural control of the breccia is apparently uncertain; Giblin (1966) suggested that there may be some relationship with lineaments that commonly represent faults in this area.

Barrington and Kerr (1961) reported significant introduction of quartz and lesser amounts of carbonate, alunite, gold, silver, and manganese in association with a breccia pipe near Cameron, Arizona. Other related mineralization is inferred from radioactive anomalies and copper minerals in the Navajo Sandstone through which the pipe passes. Metallic mineralization was thought to be related to processes involved in pipe formation. The breccia pipe is attributed to the turbulent penetration of steam originating from crystallization of underlying magma. Evidence of hydrothermal activity implies the same source for ascending solutions that resulted in mineralization.

Certain breccias occurring in the Sudbury area of Ontario deserve passing mention. The first detailed examination of these was undertaken by Speers (1957) although they had received attention from earlier workers

(Coleman, 1905; Fairbairn and Robson, 1941, 1942; and Cooke, 1946). Although various "breccias" are referred to in the Sudbury area, those of appropriate interest were termed "common Sudbury breccia" by Speers (1957, p. 497) and are composed of fragments derived predominantly from the host rock. Speers related the formation of these breccias to a major episode of tectonism and igneous activity culminating in the emplacement of the Sudbury nickel irruptive. This overall interpretation involves explosive volcanism, generation of steam, fracturing and crushing, extrusion and intrusion. In spite of this initial attempt to provide a coherent, all inclusive explanation there is much current controversy surrounding the origin of the breccias. Any further discussion of problems relevant to the Sudbury occurrences would soon exceed the scope of this paper.

The few examples of mineralized breccia pipes cited above not only serve to justify the interpretation applied to the East Arm occurrences but also illustrate some common attributes. Several of these are listed below:

1. concentric mineralogical zoning with highest values often in the peripheral regions either in the rims of the pipes or the adjacent wall-rock;
2. common association of "co-hydrothermal" uranium or copper mineralization;
3. a preponderance of quartz and carbonate as matrix or vein material separating fragments or healing fractures;
4. arrangement of breccia zones along linear trends that either represent known or suspected pre-breccia faults;
5. alleged genetic association of ore mineralization with prior crystallization of magma at depth.

From the preceding summary and from the generalizations submitted by Perry (1961) and Bryner (1961), as well as a host of other workers, the need for more careful assessment of breccia pipes with a view to mineral exploration is apparent. Walker (1928) estimated that only about one per cent of known breccia and pebble columns were mineralized, but in view of more recent findings and experience in porphyry copper districts this estimate is judged to be too low. In addition, breccia pipes are more easily recognized than their accompanying mineralization, and genetically associated mineralization, which has been guided away from the pipes by intersecting structures such as faults and unconformities, is even more difficult to connect with the brecciation process. This second possibility calls for critical appraisal of all likely channel-forming structures in the vicinity of breccia pipes or similarly derived structures. For instance, some of the scattered showings along northeastward-striking faults reported from the Thubun Lakes map-area (Reinhardt, 1969b) could belong to the same main period of mineralization that affected the zones of brecciation in the sub-areas herein described. Certainly, faulting in the East Arm of Great Slave Lake has been an important guide to mineralizing solutions. However, the possibility that pipe formation and accompanying mineralization may have been repeated at widely separated times must not be ignored.

In terms of large-scale exploration guides, one might first consider linear fault zones having evidence of major movement throughout a long period of time. Evidence of volcanism or high-level intrusion might prove useful in making a further selection. Finally, the presence and type of mineralization associated with diatremes or related structures might suggest the character of mineralization that could be expected in a prospective area. It should also be stressed that mineralization of different ages could be expected at different points along a linear fault zone which has been active over a considerable period of time. Presumably a major fault would act as a zone of weakness to accommodate subsequent crustal adjustments in the form of fault movements which in turn might act as potential feeders for magmatic and hydrothermal fluids.

As also mentioned elsewhere, many of the discussions presented in this paper are highly speculative and genetic interpretations must be held as tentative. Re-examination of critical parts of the zones would provide enough additional information to conclude whether the breccias were emplaced in a diatreme-like fashion. A careful sampling for radiometric age dating would also be desirous. Establishment of an accurate age for breccia emplacement would also assist in establishing the age of the Great Slave Supergroup which, in the opinion of the writer, is not well documented at present.

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