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Preliminary report

on

STRATIGRAPHIC AND TECTONIC WORK ON THE ROUYN-NORANDA AREA

COUNTIES OF ROUYN-NORANDA, ABITIBI-WEST AND TEMISCAMINGUE

by

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PREFACE

This report resumes the preliminary results of a detailed re-study of the Rouyn-Noranda areas. A first report, resuming the preliminary results obtained in 1972 has already been published (Dimroth et al., 1973) and material contained in the 1973-report is not repeated here.

Work done in 1973 has been concentrated in three districts:

(1) The work along the Duparquet-Destor break in Duparquet, Hébécourt and parts of Destor, Aiguebelle, Manneville, Dufresnoy and Cléricy townships has been completed.

(2) Work in Joannès, Rouyn and Beauchastel townships has started.

(3) The contacts of granitic rocks and the Pontiac metasediments have been mapped in detail in order to obtain data relevant to the intrusive mechanism of these granites.

Material obtained will be worked out in from of the following thesis: Pierre Boivin (Dr. IIIè cycle, Université de Clermont-Ferrand, France), Marc Larouche (M. Sc.,Université Laval, Québec), Michel Rocheleau (Ph. D., Université de Montréal), Richard Côté (M. Sc., Ecole Polytechnique). This report has been prepared by E. Dimroth, partly on the basis of written or oral contributions of the other participants; however the senior author has to accept responsibility for conclusion and for eventual errors in this report.

GENERAL GEOLOGY

The general geology and stratigraphy of the area covered so far has been discussed in the 1973 report (Dimroth et al., 1973). Therefore only a stratigraphic table (table 1) is given here for reference in the following pages.

LITHOLOGY

General

The lithology of mafic and acidic flow, breccias and aquagene tuffs has been described in the 1973 report. Work in 1973 confirmed the preliminary conclusions published. A few new data are available but are not important enough to warrant discussion here. Petrographic work, particularly on the morphology of fragments in various types of fragmental rocks is in progress and will be published when complete. Significant new data have been obtained on the emplacement of the pyroclastie rocks and on the sediments.

Pyroclastie rocks

Sub-aqueous ash-flow tuffs and sub-aqueous avalanche deposits in Rouyn-Noranda area received some attention during the 1973 field season.

Sub-aqueous ash-flow tuffs: Tertiary and Pleistocene sub-aqueous ash-flow tuffs have been described by Fiske (1973), Fiske and Matsuda (1974) and Yamada (1973). Following Yamada we distinguish flow-units, defined as the rock body emplaced by a single moving ash-flow and eruption units, the rock body emplaced during an eruption.

The sequence of sedimentary structures in flow units is comparable to conglomeratic turbidites containing the massive graded A-division and the lower division of parallel laminae. Dune cross-beds occur in recent ash-flows (Yamada, 1973) but have not been observed at Rouyn-Noranda.

Table I Stratigraphic framework of the Rouyn-Noranda area.

Rouyn-Beauchastel townships	Joannès township.	Northern area
Temiskaming Group (several formations) Pontiac Group (1)	Cadillac Group Unit 3 Unit 2 Unit 4 Unit 1	Duparquet Group 2)
Blake River Group	Blake River, Group	Blake River Group
		Kewagama Group
		Malartic upper salic unit upper mafic unit lower salic unit lower mafic unit
		Lac Caste Group 3)
		Kinojévis Group 4) Ruisseau Paré Fm. Ruisseau Deguisier Fm. Hunter's Mine Fm.

Notes: (1) relations to Blake River Gp unknown. (2) Relations to Blake River Gp unknown, younger than Kinojévis Gp. (3) May correlate with Kewagama Group. (4) May correlate with Blake River Group. Sequence of formations in Kinojévis Gp. not known with certainly.

The massive graded division A is commonly subdivided in a lower zone of reversed graded bedding and an upper zone of normal graded bedding. In the lower zone, the grain size of pumice and accidental (non-pumiceous) fragments increases upwards and the pumice/accidental ratio increases; therefore the lower part of the ash-flow generally has reversed size grading but normal density grading. In the upper zone grain size of pumice and accidental fragments decreases upwards and the pumice/accidental ratio increases; thus the upper zone has normal density and size grading. A pronounced break of grain size is generally present either at the top of the A-division or within the B-division.

Parallel laminae in the B-division are vague in coarse-grained material (below the grain size break). They are sharp, in fine grained (sand-size) tuffs. Multiple graded bedding is present. In some cases the base of graded beds of the B-division have erosional bases. Load casts and convoluted bedding occur.

Cannonball bombs and floating pumice lumps have been observed at Dalembert Mountain (locality 17) where a proximal facies is present. Cannonball bombs (Francis 1973) are large bombs (30-130 cm across) of non-vesicular accidental material, nearly spherical, and well rounded.

Cannonball bombs are emplaced at the top of the A-division or within the B-division. Floating pumice has reversed size grading in the A-division of thin flows, and also occurs in the B-division.

A more detailed study of ash-flow tuffs is projected for 1974; therefore extensive comments on their organization and emplacement process are not warranted at this time.

Avalanche deposits:

Non-graded pyroclastic rocks at Dalembert Mountain and at Reneault are interpreted as avalanche deposits. The organization of these deposits is not basically different from the ash-flow tuffs, except for the absence of graded bedding in the A-division. Thus the flows units are subdivided in a basal division of massive of coarse tuff breccia; reversed grading is common at the base of this division but normal grading at the top is absent. The B-division shows parallel lamination with or without multiple graded bedding. Petrographically, the avalanche deposits are of two types: at Dalembert Mountain,avalanche deposits contain much pumice in the massive coarse-grained and in the laminated fine-grained divisions; at Reneault pumice is absent and fragments are derived from poorly to moderately vesiculated lava. We interprete these deposits as sub-aqueous debris flows. Pumiceous avalanche deposits probably are a proximal facies of ash-flow tuffs described above and correspond to a facies of massive chaotic tuff described by Yamada (1973). The deposits devoid of pumice at Reneault, on the other hand, appear to be avalanche deposits formed by the phreatic shattering of lava domes and spines and, therefore, lack, pumice.

Sedimentary rocks

The sedimentary structures and the depositional environment of certain sedimentary units in Rouyn-Noranda area are presently under investigation by Michel Rocheleau (Université de Montréal); a study of the composition and source of sediments is projected. The following brief account is based on work done by Michel Rocheleau on the Duparquet Group and on a conglomeratic sandstone in northern Joannès township and on preliminary work by the senior author. At present we have tentatively defined four facies: (1) Alluvial fan facies; (2) Alluvial-marine transition facies; (3) Turbidite facies which can be subdivided according to the geometry of the turbidite formations; (4) jasper-chert-argillite facies. The sediments occur in two setting: (a) as background sediment within the volcanic group and (b) in dominantly or entirely sedimentary groups.

Facies of sediments

Facies are defined as in Turner and Walker (1973) on the basis of their sedimentary structures and textures, and of their internal organization, disregarding composition. We regard composition as essentially an expression of provenance, thus do not consider it in the definition of facies.

Alluvial fan facies:

The alluvial fan facies studied by M. Rocheleau duplicates properties of the Archean alluvial fans described by Turner and Walker (1973). In the Rouyn-Noranda area, this facies is represented by alternation of conglomerate and sandstone beds with the following properties (see fig. 1).

1. Conglomerate beds: The conglomerate beds are generally continuous across an outcrop, thus are tabular or long-lenticular. They have erosional bases but without deep channels. They are massive, without internal structure; graded bedding is absent, or extremely rare. Conglomerates are framework supported; intergranular space between pebbles is filled by coarse sand.

2. Sandstone beds: The sandstone beds are lenticular, not uncommonly quite short lenticular. They grade downward into the sand matrix of the conglomerate below, whereas the contact against the overlying conglomerate bed is sharp, even where its erosional nature is not evident. Erosional contacts within sandstone beds occur, commonly paved with lag gravels. Most sandstone beds are massive, some show parallel lamination and a few have dune cross-bedding (trough-type, larger than ca. 10cm). Isolated pebbles are common in the sandstone.

Some sandstone and conglomerate beds are cemented by carbonate, which indicates absence of a depositional clay matrix. Most are now greywackes containly a finely comminuted matrix; we think that this matrix formed largely during dianegenis.

Following Turner and Walker (1973) we interpret this facies as flood-surge deposits on alluvial fans. Deposition occurred during short-lasting floods from swiftly moving sediment-water suspensions of high density. A few outcrops NW of McWatters commonly have cross-bedding in sandstone interbeds. We suspect that some of these cross-bedded sandstone might be flood-surge deposits reworked by braided streams.

The conglomerates and arkoses os the Duparquet Group and a small unit of conglomerate and arkose between volcanic rock NW of McWatters belong with certainty to the alluvial fan facies. Some of the conglomerate-arkose units of the Temiskaming Group of Wilson (1972), west of Kinojevis River might belong to the alluvial fan facies, but this is not certain. However turbidite-associated conglomerates do occur in the Cadillac and Temiscamingue Groups.

Alluvial-marine transition facies:

Alluvial-marine transition has been recognized in the Temiskaming Group. The unit is represented by the greywacke unit with few conglomerate lenses mapped by Wilson (1972) and extending from Granada to McWatters. A facies that we tentatively interpret as deltaïc represents these strata halfway between Granada and McWatters and grades laterally into turbidites.

The "deltaïc" facies (see fig. 1) has a crude cyclical organization. Upwards coarsening cycles begin ideally with conglomerate-arkose units ca 10m thick identical to the alluvial facies described above. Massive sandstone, ca. 10m thick follows. The sandstone bed has the following properties: erosion channels with lag gravels are common, particularly in its lower part. Most of the bed is massive but dune cross-bedding (trough-type, 10-50cm high) is not uncommon. Isolated pebbles are common. Grain size generally decreases to the top.

Thin-bedded argillite, siltstone and fine-grained sandstone are at the top of the cycle. These beds show planar lamination and not uncommonly graded bedding. Bouma-cycled graded beds (with a regular sequence of A-D divisions) have not been observed.

Cycles are crude; the sandstone unit may directly overlie the thin-bedded argillite stage, without intervening conglomerate. The "deltaïc" facies overlies laminated argillites and fine-grained graded graywackes (in part apparently with Bouma-cycles). Some pebbly sandstone and open-fabric conglomerates occur in the transitional zone. Thus the base of the "deltaïc" facies appears to form an upwards coarsening sequence, whereas the deltaïc facies itself contains upwards fining cycles.

We tentatively interpret the conglomerate-sandstone division of the "deltaïc" facies as the filling of the main alluvial channels, the sandstone division as wide "levées" at the margin of the main alluvial channels, and the laminated argillite division as overbank deposits, laid down during flooding in ponds, lagons and bays between the alluvial channels. The upwards coarsening sequence at the base of the deltaïc facies may be interpreted by progradation of the deltaïc sediments over the marginal marine deposits. Relation in the zone between McWatters and Granada suggest that the "deltaïc" facies grades laterally into marine turbidites. Details of the transition are unknown at present. The "deltaïc" facies is typically exposed in large outcrops south of lac Bouzan. Turbidites which appear to be stratigraphically equivalent are exposed at the McWatters - Lac Bruyère road, at the McWatters dump, and west of the cemetery of Granada.

Turbidite facies:

Most greywackes and a substantial volume of conglomerate in the area belong to the turbidite facies. Turbidite sandstones ideally show the Bouma-cycle of sedimentary divisions (Bouma, 1964), from base to top: A = massive graded division; B = lower division of parallel lamination; C = division of ripple cross-lamination; D = upper division of parallel lamination; E = pelitic background sediment of the basin. The ideal sequence may show base cut-outs (lower divisions lacking), top cut-outs (upper divisions lacking) and base and top cut-outs (upper and lower divisions lacking).

Within the Rouyn-Noranda area cross-laminations are comparatively rare. On the other hand, beds beginning with division A and grading perfectly into pelitic material (apparently division E), without a division of cross-laminae appear to be common. Most of these beds are medium to coarse-grained sandstone and are 10-30cm thick, thus cannot be interpreted as distal turbidites of Walker's (1967, 1970) type A → E. We call these beds (AE) sequence, and point out that they are much thicker and coarse grained than Walker's (1970) A → E sequence.

The reasons for the relative common occurence of the (AE) sequence in Rouyn-Noranda are not presently known. However, the following observations are, perhaps, relevant. The thickness of the cross-laminated C-division in turbidites of the Rouyn-Noranda area varies greatly. For example, turbidites exposed in large outcrops west of the cemetary of Granada have a thick C-division of climbing ripples. In other turbidites, for example at the north shore of Lac Beauchastel, the C-division is very thin (1-3cm), and is poorly visible because of the intense metamorphic and tectonic overprint. This observed variation in the thickness of the rippled division and the degree to which they are tectonically obscured, suggests two alternate hypotheses that could explain absence of the C-division:(1) thin ripple-division might generally have been obscured by metamorphism, (2) in some turbidites ripples may have formed only a transient bed form and have not been preserved.

Several conglomerate suites, in particular the conglomerates in the Kewagama Group at Destor, the basal conglomerates of the Cadillac Group in northern Joannès township, and two conglomerates units in the uppermost Pontiac Group (shown us by N. Goulet) are probably turbidite-associated. Only the granule and small-pebble conglomerates (largest grain size below 1cm) are well graded and show the typical properties of conglomeratic turbidites described by Walker and Pettijohn (1969) and by Hubert et al (1970). There exist, at least, two types of turbidite-associated conglomerates with different internal organization. The details of their internal organization have not been worked out, at this time, so that comments on their emplacement mechanism are not warranted.

Analysis of the depositional environment of turbidites and turbidite-associated conglomerates is one of the most complex sedimentological tasks in the area. A first step to such an analysis is the definition and mapping of lithologically defined assemblages; the relations between the assemblages and their geometry are established by mapping. Assemblages so defined are of two types: (1) assemblages defined by granulometry (mainly conglomerates and conglomeratic sandstones). These are facies units, laterally grading into other assemblages. Their geometry is established by mapping; so far fan-shaped geometries and channel-fill geometries have been recognized. (2) Other assemblages are defined by compositional properties, for example participation of tuff interbeds or absence of quartz. Such assemblages are derived from a common source and are, to degree, time-stratigraphic units.

Further analysis is possible by study of the sedimentary structures in turbidite-associated conglomerates and by measurements of the P_1-indices (Walker, 1967, Henderson, 1972) of the turbidite sandstones. It is not yet known to which degree slope indicators other than channels (for example slump structures) may be usefully applied. Work on these aspects of the sedimentary sequence in the Rouyn-Noranda area is in progress, but will take considerable time for completion.

Jasper-chert-argillite facies:

A fourth facies is characterized by the presence of jasper iron-formation with parallel laminations, of black, graphitic chert, either massive or with parallel laminations, of black, graphitic shale, commonly rich in pyrite, with parallel laminations and of silt-laminated argillite, also with parallel lamination.

Not all of these constituents need be present. Greywackes, where present are thin-bedded (less than 10 cm), fine-grained or very fine-grained, and show only parallel lamination. This facies is common as interflow-sediment in the volcanic assemblages, but also occurs in the sedimentary units. Its relations to the other facies are presently unknown, and this precludes unambiguous interpretation of the sedimentary environment. However there can be little doubt that these sediment are marine.

Cherty iron-formation, where associated with thin, graded siltstone, occupies the upper, pelitic interval. Thus the cherty iron-formation is part of the pelitic background sediment of the basin. Contents of carbonaceous matter in the argillites and silt-laminated shales are inversely proportional to grain size. This suggests that carbonaceous matter accumulated as biogenic detritus and has been diluted by terrigeneous detrital material. Large pyrite contents are consistently associated with high carbon contents. The fine grain size of the terrigeneous material in this facies proves deposition either far from terrigeneous source areas, or more likely, in areas that have been bypassed by terrigeneous material. Considerably more work on its relation to other sedimentary is required before an unambiguous interpretation of its depositional environment is possible.

BASIN ANALYSIS

General outline

Large stratigraphic ensembles of the Rouyn-Noranda area are either predominantly (95%) volcanic (Kinojévis, Malartic and Blake River Groups) or are predominantly (95%) epiclastic-sedimentary (Lac Caste, Kewagama, Duparquet, Cadillac Group). Thus basin analysis of the Archean ensembles of this area comprises three parts: (1) Analysis of the volcanic ensembles; (2) Analysis of the sedimentary ensembles; (3) Analysis of the relations between the volcanic and sedimentary ensembles.

Analysis of the volcanic assemblages proceeds through five steps: (1) mapping of characteristic flows, flow groups or tuff beds, that can serve as marker beds. Very few marker beds can be followed across the whole area. Most have only limited extent. However they do interfinger and thus form a loose and wide-meshed screen that permits lateral correlation. Marker beds have been emplaced within very short periods of time; thus the stratigraphy so obtained is a time-rock stratigraphy.

(2) The second step consists in mapping local rock associations defined by their composition; porphyritic and glomero-porphyritic flows are particularly useful. Time-correlative rock associations of different composition necessarily have different sources. Thus in this step correlative rock associations with different provenance are recognized.

(3) The third step consists of mapping, within the associations defined by composition, of volcanogenic facies related to the

distance from source and to water depth. Vesicularity of flows, proportion of massive, pillowed and brecciated parts of flows, distribution of aquagene tuffs, bed thickness, grain size and grain shape in pyroclastic units, among others, are useful to define volcanogenic facies. Work on Recent volcanoes, to be discussed below, has established variation of these properties with distance from the volcanic source or with water depth, and therefore permits interpretation.

(4) Finally the emplacement of the volcanic center is more clearly defined by analysis of the relations between intrusive and extrusive rocks. Intrusive rocks co-genetic with the lavas generally are present close to the center of eruption; in favorable cases feeder dykes can be identified; however many lava flows and of course all pyroclastic rocks have lost all original continuity to the feeders. Finally step (5), the determination of flow direction may further confirm the results so obtained. However, indications of flow direction are rare.

Analysis of the sedimentary assemblages also proceeds in several steps: formations defined by their sedimentary facies discussed on p. 5-12 and on compositional characters are mapped; their mutual relationships and geometry are established. Lateral correlation is established by lateral transitions and (where present) by means of tuff markers. The emplacement mechanism of these units is determined by means of sedimentary structures. Finally paleocurrent data (mainly cross-bedding) permit integration of these data.

The relations between the sedimentary and volcanic assemblages are established by mapping and detailed examination of their contact zones.

Analysis of volcanic assemblages

Rock assemblages of three types have been recognized in Rouyn-Noranda area: (1) association of regional extent of sheet-like geometry, virtually without thickness and facies variation. We interpret these assemblages as basalt plateaux. (2) associations of local extent (ca. 200 square miles or less), generally with considerable facies variation. Thickness variations are not sufficiently known, because the available tectonic data have not yet been synthesized. Evidently the thickness of a shield volcanic associations decreases from the eruption center, but the relations may be complicated by the presence of calderas, parasitic cones and similar structures. Comparison of the facies variation in these associations with facies variation of Recent volcanoes suggests that they are shield volcanoes ranging in complexity from simple domes to extremely complex groups of volcanoes. (3) the last association comprises distinct flows of small extent aligned along regional faults. We interpret these associations as relatively young fissure eruptions.

We will discuss the characteristics and recognition of the volcanic associations and their interpretation at hand of map and Fig. 2 and 3.

Plateau basalt associations:

The plateau basalt associations are best discussed at hand of the basal variolitic marker of the Blake River Group. The marker has been followed form the interprovincial boundary to the Clēricy-La Pause township line at the northern limit of the group: Van de Walle (1971) traced it across La Pause township. It extends from the inter-provincial boundary to the east of Rouyn township in the south. Thus the unit extends presently at least 70 km in east-west direction, and at least 35 km in a northerly direction. The north-south extent before folding was approximately 70 km, if we assume shortening of the belt to ½ of its original size. Present limits are erosional (north and south) or map-limits (east and west).

The unit shows very small thickness variation in an east-west direction, but it thickens considerably from north to south. Thus the basal variolitic marker of the Blake River Group appears to have the geometry of a sheet thickening from north to south, underlying an area larger than 70 X 70 km. The unit is only a few hundred meters thick.

The larger part of the Ruisseau Deguisier Basalts of the Kinojévis Group also may represent a basalt sheet. However we are not able to distinguish the basalts belonging to this sheet from basalts of the Destor complex, discussed in the 1973 report.

Shield volcanic associations:

Three major associations recognized in the area studied, so far appear to represent remnants of shield volcanoes. They are: (1) an association of basalt and andesite (Lac Montsabrais association) extending from Duparquet Lake to the interprovincial boundary. (2) an association of ash-flow tuffs and of pyroclastic avalanche deposits (Dalembert Mountain association) extending from Duparquet Lake to Reneault. (3) a mixed basalt-rhyolite association (Destor association) north of Destor. The first two associations belong to the Blake River Group, the last one to the Kinojévis Group. Finally there are number of rhyolite domes which represent the simplest possible type of shield volcano.

Lac Montsabrais association:

This association is defined by alternation of aphanitic and finely feldspar-porphyritic or glomero-porphyritic (3mm) flows, flow breccias, aquagene tuffs, and pyroclastic rocks of mafic to intermediate composition. The association overlies the basal variolitic marker of the Blake River Group; its base is defined by the lowermost finely feldspar-porphyritic flows and follows little above the variolitic marker.

The finely feldspar-porphyritic and glomero-porphyritic flows stop abruptly at about the east shore of Duparquet Lake. Farther east an association of aphanitic basalt and andesite flows overlies the variolitic marker and is overlain by coarsely feldspar-porphyritic (5mm and more) pyroclastic rocks. These ash-flows interfinger with finely porphyritic mafic flows in the center of Duparquet Lake.

Therefore it is evident that the Lac Montsabrais association is younger than the variolitic marker. It is equivalent in age to the aphanitic andesite and basalts of Reneault, and to the coarsely feldspar-porphyritic pyroclastic rocks of Dalembert Mountain. Its top may be somewhat younger than the exposed top of the Dalembert Mountain association. A stratigraphic cross-section is presented as Fig. 2.

The Lac Montsabrais association shows considerable thickness variation. The exposed sequence is ca. 5000 meters thick west of Hébécourt Lake, whereas the exposed thickness at Duparquet Lake appears to vary between 1500 (in the east) and 3000 meters (in the west). These values are approximate, because the large tectonic material available has not yet been evaluated. It is not known with certainty whether the highest strata exposed in the east of Duparquet Lake are stratigraphically equivalent to the uppermost strata exposed west of Hébécourt Lake.

The Lac Montsabrais association shows major facies differentiation. The vesicularity of flows and the proportion of pillow breccia and aquagene tuffs, and of pumice-bearing fragmental rocks closely associated with pillow breccias increase toward the top of the association, and laterally toward the area south of Montsabrais Lake. From Duparquet Lake westward, north of Magusi River, a major unit of flows alternating with fragmental rocks is present. This unit is composed of pillow basalt, pillow breccia, hyaloclastic tuffs and "ash-flow tuffs" (that is pumice tuffs with graded bedding), which are closely associated.

Following Moore (1965) and Jones (1969) we consider vesicularity of basalts an indicator of their depth of deposition. Therefore the upper part of the association, at Montsabrais Lake extruded at water depth probably less than 500 meters, whereas its lateral equivalents at Duparquet Lake were deposited in water probably deeper than 1000 meters. Facies and thickness relationships are not unlike those noted at Hawaii by Moore and Fiske (1969) and suggest the presence of a shallow submarine volcanic center south of Lac Montsabrais (see fig. 3).

This hypothesis is confirmed by the presence, south of Lac Montsabrais, of dykes co-genetic with, and apparently feeding the basalt flows (fig. 4). Care should be taken to distinguish these basaltic dykes cogenetic with flows from the numerous mafic and acidic dykes related to the diorite-granite intrusions northeast of Lac Montsabrais.

Dalembert Mountain association:

The Dalembert mountain association consists of ash-flow tuff, non-graded pyroclastic avalanche deposits, and minor flows of a coarsely (5mm or more) feldspar-porphyritic andesite. The association extends from the center of Duparquet Lake to Lac Dufresnoy. The total thickness is unknown, because the association is at the top of the exposed stratigraphy in the area between Duparquet Lake and the Macamic road. It is nevertheless visible that its greatest thickness is found in the stip between Reneault and Dalembert Mountain and that its thickness decreases rapidly to the west and east.

The facies relations of the association are shown in fig. 2. The following changes are visible: (1) the average thickness of ash-flows, the total thickness of the association, and the grain size of the pyroclastic rocks increase toward Dalembert Mountain and Reneault; (2) pillowed flows, characterized by their coarsely feldspar-porphyritic petrography, belonging to the suite are present in the sub-proximal facies zone west and woutheast of Dalembert Mountain; (3) the association consists mainly of ash-flow tuff in the area around and west of Dalembert Mountain, whereas pyroclastic avalanche deposits predominate at Reneault; (4) the association interfingers with basalt flows of the Lac Montsabrais association on islands of Duparquet Lake; (5) intrusive rocks, petrographically similar to the ash-flow tuff are present at Reneault.

We interpret these facies and thickness variations according to the scheme of Yamada (1973) as follows; graded ash-flows probably have not been deposited on the slopes of the volcanoes, but at its foot; avalanche deposits, on the other hand, may well mantle the eruptive centers. The thickening and coarsening of the flow from west and south toward Dalembert Mountain probably indicates proximity to the source. The avalanche deposits at Reneault, very coarse grained (1m largest fragment size) likely are very proximal deposits; intrusive dykes of petrographically similar material are in foct exposed. The coarse-grained (1m largest fragment size) ash-flow tuffs of Dalembert Mountain likely also are proximal. Therefore we locate the eruptive centers somewhere between Dalembert Mountain and Reneault.

Destor association

The Destor-association consists of a complex of rhyolite and basalt-flows centered north of Destor. Its main properties have been described in the 1973 report, and need not be repeated here. An intrusive complex, composing a stockwerk of many generations of gabbro, and of porphyries, probably co-genetic with the basalts and rhyolites, occupies the center of the complex. We mention the presence, in the Destor complex, of highly vesicular basalt flows, whereas the correlative flows of the Ruisseau Deguisier Formation show low vesicularity. This feature, in addition to criteria mentioned in our 1973-report, suggest that water depth increased away from Destor complex.

Fissure eruptive associations

Small flows of Komatiite and small rhyolite domes occur along the Duparquet-Destor Break (see map). Probably co-magmatic dykes of pyroxinite and porphyries are numerous in the same zone. The stratigraphic relations northwest of Destor suggest that this association formed at the end of the activity of the Destor complex. We suspect that these flows are related and indicate the presence of a regional fissure along the Duparquet-Destor-Manneville break.

Generalizations

In general it appears that the plateau basalt associations form the base of the volcanic groups and the Shield volcanic associations their top. This is perhaps most clearly exemplified by the Blake River Group, where the basal plateau basalt sequence is clearly overlain by several independent shield volcanic associations.

The relations within the Kinojévis Group may be move complex. Basalts of the Kinojévis Group north of the Lepine Lake syncline, and in Manneville townships also south of the syncline seem to have many characteristics of the plateau type associations. On the other hand there can be little doubt that these basalts are to a large part equivalent in age to the Destor complex. In this case there may exist a correlation between time-equivalent shield and plateau-basalt associations.

The single fissure-type association, at the Duparquet Destor break, belongs to the Kinojévis Group of which it appears to form the youngest part.

Analysis of sedimentary assemblages

The facies of the sedimentary assemblages have already been described above. Therefore we can restrict us to discussion of the relations between the different facies in this area.

Duparquet Group

The Duparquet Group contains many fragments of local derivation (particularly porphyries), and fragments of pebbles characteristic of the Kinojévis Group (notably spinifex-bearing ultramafic rocks). Not a single rock fragment derived with certainty from the Blake River Group has been recognized, although many rock types are typical of the Blake River and are completely absent from the Kinojévis Group. For this reason we suspect that the clastic rocks were derived from the Kinojévis Group, and that the area underlain by the Blake River Group now, formed part of the depositional basin during Duparquet deposition.

The grain size of conglomerates, and the ratio conglomerate/sandstone decreases from east to west in the Duparquet Group. This decrease of grain size suggests derivation of the clastic rocks from the east or northeast. Unfortunately, three-dimensional outcrops of crossbeds are absent and, therefore, we cannot present additional paleocurrent evidence.

North of Duparquet Lake transition into a marine turbidite facies is present. The basal conglomerate at the bridge crossing Duparquet River is overlain by alternation of conglomerate with greywacke and shale grading into greywacke toward the top of the exposed sequence. This suggests transition, laterally (to the SW) and vertically into a turbidite sequence. That the transition takes places at the Duparquet-Destor break may not be accidental. We have noted before (Dimroth et al., 1973) that the Duparquet-Destor fault probably began to form late during the eruptive history of the Kinojévis Group. It is conceivable that the fault remained active during sedimentation of the Duparquet Group, and that it separated a marine basin (in the south) from a domain of sub-aerial deposition (in the north).

Kewagama Group

Not more than preliminary work has so far been done on the sedimentology of the Kewagama Group. Conglomerates of the Kewagama Group at Destor are turbidite - associated, and are related to proximal turbidites (in the sense of Walker, 1967, 1970). Conglomeratic sandstones south of Montbrun, mapped by MacIntosh (1972) are of uncertain, probably turbidite - related, origin. The geometry of both bodies has not been clarified, but provisional we consider it to have fan-shaped geometry. The sandstones of the Kewagama Group appear to be turbidites, without exception.

Cadillac Group, area east of Kinojévis River

So far only the sediments in the northern ranges VI to X of the northwestern quarter of Joannès twp, and the adjoining part of Rouyn twp have been studied. In this area four formations have been distinguished. Unit 1 is a conglomeratic sandstone, overlain by Unit 2 (greywacke) and by Unit (3) greywacke and arkose with conglomerate lenses. A white-weathering fine-grained rhyolite (Unit 4) is present in the Rouyn Lake basin.

Unit 1 consists of open-fabric conglomerate alternating with Bouma-cycled sandstone and micro-conglomerate beds. It overlies and interfingers with andesite flows and flow breccias, and with a few beds of tuff breccia. The unit appears to have a fan-shaped geometry. The terrigeneous fragments in the conglomerate are mainly feldspathic andesites; rhyolite fragments are rare and fragments of acidic intrusive rocks are absent.

The conglomerate and the accompanying sandstones contain little quartz. Many fragments of fine-grained sediments are present and prove intense intra-basin erosion. The coarse fragments are angular, therefore have not been rounded by fluvial transport of beach processes. Tentatively we interpret the unit I as a turbidite fan derived from emerging volcanic islands located farther to the north. The fragments have been transported into deep water directly after their breakage, without undergoing rounding in a fluvial or beach environment. Part of the transport, particularly of the coarse clastics took place in submarine erosional valleys; angular sediment fragments in the conglomerates were produced by lateral erosion of these valleys. However the presently exposed sequence has a fan-shaped geometry, without deeper erosional depressions.

Unit 2 is a normal medium-grained turbidite, quartz-bearing, derived from a mixed volcanic-plutonic terrain. Unit 3 has been little studied. The tuff-turbidites (Unit 4) are in proximal facies in the center of Lac Rouyn, where Bouma-cycles are complete (except perhaps for top cut-out sequences), and where little shale is intercalated. Farther east a distal facies (many beds beginning with the B and C division of the Bouma-cycle, much intercalated shale) is present. Thin-bedded tuff-turbidites with perfect graded bedding, but devoid of parallel or cross-lamination occur in units 1 and 2 farther east. They are probably distal turbidites of Walker's (1967, 1970) type A→E. They may correlate with the tuff turbidites of Unit 4.

Tentative conclusions on the evolution of the lower part of the Cadillac Group in Lac Rouyn Basin and east of Kinojévis River are as follows: Evolution proceeded in more than three steps. (1) Emergence of a chain of andesite volcanoes in the area south of Cléricy; erosion and deposition of a fan of conglomerate and greywacke around the islands. (2) Overlapping with (1) and (3) minor explosive rhyolite eruptions (sub-aerial?) in Rouyn area and deposition of tuff turbidites.

(3) Submergence of the volcanic islands, uncovering of granodioritic intrusions in the hinterland farther north and spreading of quartz-bearing greywackes on top of the fan (1). Conglomerates overlying unit (3) prove renewed emergence, but too little is known about the stratigraphy of the upper part of the Cadillac Group east of Kinojévis River to permit more detailed statements.

Relations between volcanic and sedimentary assemblages

Outcrops exposing the undisturbed contacts between volcanic and sedimentary assemblages are rare. Therefore, our knowledge on the interrelations between both are still unsatisfactory.

An outcrop exposing the unconformity between komatiites of the Kinojévis Group intruded by quartz-porphyry, and the alluvial conglomerate of the Duparquet Group is exposed south of the Duparquet-Reneault road, at the Duparquet-Destor township line. Outcrops exposing the contacts of the Kewagama Group do not exist, but several outcrops show not more than a few feet of cover between strata of the Kewagama Group and the overlying and underlying units. Tentatively one can consider the relations assumed by MacIntosh (1972) to be likely correct: MacIntosh (1972) assumes a more or less conformable contact between the Kewagama Group and the underlying Malartic Group, and interfingering relations with the Blake River Group above.

The relations between the Blake River and Cadillac Groups are complex. Unit 1 of the Cadillac Group conformably overlies and interfingers with the volcanic rocks of the Blake River Group. Unit 4, at Rouyn Lake, also appears to overlie volcanic rocks of the Blake River Group with conformity. Wilson (1962), on the other hand, described an unconformity between a conglomerate unit and the Blake River Group at McWatters. Relations between the Blake River, Temiskaming and Pontiac Groups south of Rouyn are presently being re-investigated by Goulet.

In general our observations suggest that the alluvial conglomerates overlie volcanic rocks with a strong angular unconformity, caused by tectonic movement and erosion. The turbidites overlie volcanic rocks without unconformity and, in a few cases, interfinger with volcanic rocks. In brief our tentative interpretation is that the proximal sedimentary facies overlie volcanic suites discordantly, whereas distal facies interfinger with volcanic rocks and/or overlie the latter concordantly.

General results

No regional synthesis of the sedimentologic and volcanologic relations can be attempted at the present time, because of the lack of regional stratigraphic correlation. Nevertheless the facies relation within the groups permit certain generalizations.

If we consider the Blake River and Kinojévis Groups as the type examples of the volcanic evolution: basaltic sheets, laterally extensive, are the base of the volcanic sequence. Shield volcanoes, many of which contain considerable andesite and rhyolite, are set on this basal volcanic plateau. They range in complexity from simple rhyolite domes to extremely complex groups of volcanoes. Deep faulting, and eruption of minor flows along the faults, appear to be late stage of volcanic evolution.

The sedimentation is characterized by rapid transition from sub-aerial into marine turbidite deposition. A domain of shelf sedimentation does not exist. Alluvial suites grade laterally into turbidites without transition. The textural immaturity of the turbidites leaves no doubt that beach processes, which normally cause rapid rounding and elimination of unstable fragments, were not active. These features of sedimentation suggest: (1) the sedimentary basins were steep-sloped; pro-deltaic platforms and similar transitional zones between sub-aerial and submarine domains were small or absent; (2) sedimentation rates were high, in particular sediment was rapidly transported through the beach zones, so that processes of normal beach abrasion were inactive.

Sedimentation and submarine volcanism overlap in time, at least in part. Proximal sediments are discordantly on top of sub-marine volcanics, whereas distal sediments interfinger with sub-marine volcanics. Thus we get the impression that the Archean depocenter consisted of volcanic chains alternating with sedimentary basins.

Tectonics

The general structural relationships in the Rouyn-Noranda area have been discussed in the 1973 - report, and need not been repeated here. Considerable new work has been done on the microstructures, particularly in the area north of the Blake River Group in Destor, Cléricy, and Dufresnoy townships, and in the area south of the Horne Creek fault.

In Destor, Cléricy, Dufresnoy and Aiguebelle townships north of the Blake River Group, four tectonic phases have been outlined. The oldest folds are essentially flexure folds. The Lepine Lake syncline, trending east, several folds north of Lac Caste, and the anticline of the Malartic Group, trending east-southeast, belong to this generation. Schistosity does not accompany this fold generation, except here and there in the Malartic and Kewagama Groups.

This fold generation is overprinted by an older schistosity trending southeast and a younger schistosity trending east-northeast.

Kink-bands, trending north to north-northeast are the youngest fold generation. A sub-horizontal schistosity, of unknown age relation, has been recognized locally.

South of the Horne Creek fault four fold phases have been recognized, isoclinal folds trending east-southeast (older) and east to northeast (younger), and a north to north-northeast trending generation of kinkbands. A sub-horizontal schistosity, younger than the ESE trending and older than the NE trending schistosities, is present in the zone of the Cadillac fault. All schistosities are axial planes to flexure-shear folds.

Granite tectonics

The sequence of intrusion of the granitic rocks in the Bellecombe-Rémigny area, south of Rouyn-Noranda, and the general aspects of their intrusive mechanism, have been discussed in our previous report. A wide zone, extending from Bellecombe nearly to Angliers and Ville-Marie in a N-S direction, and from the Ontario boundary to Louvicourt in an E-W direction is underlain by a huge granite batholith. In the area between Bellecombe and Angliers (Chagnon 1968) the batholith consists of two principal phases: (1) a hornblende tonalite, diorite and syenodiorite, occupies the core of the batholith; (2) heterogeneous granodiorite forms an irregular sheet capping the tonalite - syenodiorite masses and separating it from the Pontiac schist. At the present level of erosion the heterogeneous granodiorite underlies by far the largest part of the granitic region. From the structure of the heterogeneous granodiorite "massif" and from dyke relationships we concluded that this "batholith" is composed in reality of innumerable dykes, and that it formed by slow infilling of many successive generations of gradually widening dykes.

This concept has been confirmed by detailed mapping, at a scale of 5 and 2½ feet equals 1 inch, at two locations: (1) dyke systems composing the roof facies of the batholith and intruding the overlying Pontiac Schist have been mapped at the shore-line of Lac Caron, southeast of Bellecombe; (2) dyke systems cutting the floor of the "batholith", and probably constituting is feeders have been mapped north of Rémigny.

Texture and structure of dykes

The texture and structure of the dykes of heterogeneous granodiorite, their layering and zonation, symetry of filling and internal and external structures, give evidence on the history of dyke filling.

Layering and zonation

A noted by the name, homogeneous dykes are rare in the heterogeneous granodiorite. Most dykes show one or several types of zonation. We have observed: (1) Comb layering, (2) Screen layering, (3) Mineral and grain size zonation. Comb layering is defined by shape orientation of minerals perpendicular to the dyke walls. It is best developed at the margin of dykes. Comb layering is nearly always related to grain size zonation and commonly to mineral zonation. The grain size of comb layered crystals generally increases toward the interior of the dyke, and from a certain maximum, may decrease again. The texture of comb layers is typical of open pore-space filling (Schmidegg, 1928; Folk, 1965) and is thought to be produced by nucleation of the growing crystals at the vein walls, and selection of the crystals growing fastest in the direction perpendicular to vein walls.

Screen layering is defined by continuous biotite screens a fraction of a mm thick. Comb layers, where associated with biotite screens, have their origin in the biotite screens. Transitions between biotite screens and thin, long inclusions of Pontiac schist are very common. Both observations prove that biotite screens represent in fact paper-thin fragments of the dyke walls.

Mineral and grain-size zonation is present in virtually all dykes. The zonation can take the form of layering, where thin laminae of strongly contrasting composition are present, for example mm-thin laminae containing garnet in a granodiorite from which garnet otherwise is absent. Tectonic structures, in the first line schistosity, intersect here and there the textures and structures described above and destroy the primary features of the dykes.

Symetry of dyke filling

The dyke filling may be symetrical or asymetrical. Symetrical filling exists only in thin dykes, and forms, where the filling crystallizes from both vein walls. All thick dykes show asymetrical filling, due to multiple acts of filling, asymetrical to the vein walls. Very commonly a vein appears to reopen at the vein wall.

Conclusions

Several stages of opening and of filling can be distinguished in nearly all dykes. This proves that dykes formed and were filled slowly, over an extended period of time.

Dyke systems

The dyke systems above the roof of the batholith show narrow zonation and commonly are layered. Up to seven generations of dykes have been mapped in outcrops a few tens of feet square, and each dyke generation is the product of several acts of filling. Thus it is clear that the dyke systems formed slowly by the slow opening and filling of complicated fissure systems. The structure of the roof part of the batholith is identical, except that fewer inclusions of the Pontiac schist are present. In other words the batholith formed in the same way as the dyke systems in its roof, except that the total volume expansion is larger. In contrast, the dyke systems of the floor of the batholith have a more homogeneous structure, but show, in principle, the same phenomena. We interpret this as due to infilling of dykes by a more homogeneous and continuous filling process, by a fluid of more constant composition.

METAMORPHISM

Petrographic and tectonic studies permitted to distinguish the following five metamorphic phases within the Rouyn-Noranda area (see map 2): (1) Propylitization; (2) Pre-Kinematic load metamorphism; (3) Pre-Kinematic thermal metamorphism; (4) Syn-Kinematic dynamo-thermal metamorphism and (5) Post-Kinematic thermal metamorphism. Map 2 shows the metamorphic grades so far recognized. Mapping of isograds however is hampered by the fact that index minerals (pumpellyite, prehnite, biotite, garnet, alumosilicates) occur only in rocks of specific chemical composition. For this reason isograds are necessarily approximate.

Propylitization is indicated by the presence of chloritic and sericitic alteration haloes below the massive sulphide ore bodies. The alteration has been described in detail by Riddell (1952) and their origin has been discussed by Roscoe (1965) and Sharpe (1965). De Rosen-Spence (1969) discussed the later, thermal overprint (phase 5) on the propylitization.

Relicts of a pre-kinematic load metamorphism are clearly exemplified in rocks of the pumpellyite-prehnite facies. These rocks contain two generations of pumpellyite and prehnite. The older generation form encrustation in amygdules and thus formed at a time at which the amygdules were still voids. On the other hand, eye-structures around amygdules prove that the amygdules had been filled at the time of orogenic deformation; consequently we must assume that the amygdule-filling pumpellyite and prehnite formed during a pre-kinematic metamorphic phase.

On the other hand the same rocks contain tectonic fractures filled by pumpellyite and prehnite; thus they also underwent a synkinematic metamorphism in the same mineral facies. Relicts of pre-kinematic minerals have never been observed in rocks affected by a synkinematic metamorphism in the greenschist facies.

A haloe of pre-kinematic contact metamorphism is well exemplified around the granite massive north of Lac Montsabrais. Pillow basalts, and pillow breccias of this contact haloe have been transformed to coarse-grained amphibolites. The amphibolites as well as the granite itself have been deformed, and contain locally a schistosity defined by chlorite and sericite. Thus the thermal haloe is defined by amphibolite-facies rocks, with granoblastic to nematoblastic hornfels texture, that underwent a retrograde dynamo-thermal metamorphism in the greenschist facies and, in part, in the pumpellyite-prehnite facies. A second haloe of pre-kinematic contact metamorphism is present around the Cléricy granodiorite. This haloe is less well identified, because the basalts affected by it were largely massive before the metamorphism and because the granodiorite and its contact aureole suffered intense deformation and retrograde metamorphism. Graham (1954) described the aureole around the Lac Montsabrais granite, but ascribed it to metasomatic changes related to the intrusion of diorites ("dioritization").

Little need be said about the dynamo-thermal metamorphism, which constitutes the major metamorphic episode affecting all rocks of the area, except for a few post-kinematic intrusive rocks. Generally the metamorphic grade increases southward; however a zone of greenschist and amphibolite facies metamorphism along the Duparquet-Destor break subdivides the northern area of pumpellyite-prehnite metamorphism.

The dynamo-thermal metamorphism of the Pontiac Group is more complicated. Two generations of biotite, both oriented parallel to the schistosity are present; the first generation is small (0.1-0.3mm), the second consists of large (1mm or larger) tablets. Staurolite and muscovitized pseudomorphs after a primatic alumo-silicate (kyanite?) appear to be unoriented, thus are later than the schistosity. However growth of the muscovitized alumo-silicate is probably correlated with the growth of partly muscovitized sillimanite in the heterogeneous granodiorite (see Dimroth et al., 1973) which intruded during the latest part of the deformation. Thus the amphibolite-facies metamorphism of the southern part of the Pontiac Group likely is very late tectonic, and is related to the intrusion of large granodiorite and trondhjemite-tonalite massifs. Finally the Pontiac Group underwent a post-kinematic retrograde metamorphism that caused muscovitization and sericitization of the alumo-silicates and of straurolite.

A haloe of post-kinematic cross-biotite has been observed in rocks of north-western Joannès township. De Rosen-Spence (1969) described a post-kinematic thermal aureole around the Lac Dufault granite, indicated by the presence of biotite-bearing rocks and by the presence of cordierite-anthophyllite hornfels, that formed at the expense of chloritized and sericitized volcanic rocks.

Corrections of the 1973-report

Two errors in the 1973-report (Dimroth et al., 1973) are substantial enough to warrant correction. Both concern the layered gabbro complex east of Duparquet Lake (p. 29-30), of which thin sections were not available at the time of writing.

On page 29 (1st paragraph) we mention that "the uppermost part of the complex, at the western part of the mountain (locality 17) contains globules of granophyr about 2cm across". This is not the case; the rock containing these spots is an ash-flow tuff, strongly metamorphosed in contact to the gabbro and consequently difficult to recognize in outcrop. No granophyr globules occur at the locality.

In the second paragraph of p. 29 we describe "ellipsoidal bodies, 1-5cm long, an about 4-12mm thick" exposed at a promontory of Duparquet Lake (locality 19).

The bodies are said to be composed "of pyroxene at the base, crowned by plagioclase". In fact the bodies are ellipsoidal patches of chlorite, surrounded by the ophitic plagioclase-pyroxene fabric of the gabbro. Plagioclase laths penetrate the upper part of the chlorite-ellipsoids, making up the crowns at their top. As noted in our previous report the objects are aligned parallel to stratification, and are perfect top indicators. It is very well possible that they formed by liquid unmixing, as we suggested, but they do not contain "a cumulate phase" at the base, (p. 30, 1st paragraph). Rather they contain a floating phase (plagioclase) at the top.

Preliminary map

There are no substantial changes in the preliminary map, published 1973, except for the part west of the Rouyn-Macamic road. Only this part is re-published with the present report. A map of the re-mapped part of Joannès township has not yet been complilied.

ECONOMIC GEOLOGY

Two main types of ore deposits are present in the Rouyn-Noranda area: (1) massive heavy metal (Cu-Zn) sulfide deposits and (2) native gold in quartz-carbonate lenses.

(1) Heavy metal sulfide (Cu-Zn) deposits: Sangster (1972) described the general features of the massive heavy metal sulfide deposits of the Canadian Shield. Some deposits of the Rouyn-Noranda area are described in the C.I.M.M. Centennial field excursion guidebook. The best detailed descriptions available are those of the Delbridge deposit by Boldy, 1968, and particularly the work on the Millenbach Mine by Simmons et al., 1973.

Ideally, the ore bodies consist of two parts: A lens-shaped mass of stratiform sulfides, with massive, banded or brecciated structure overlies rhyolite and grades laterally into pyritic chert and, in some cases, into pyritic shale. It is underlain by a stockwork of Cu-Zn veins and a pipe of intense alteration. The underlying rhyolite bodies need not be large. On the contrary, the ore bodies of the Millenbach Mine, for example, overlie a relatively small dome of rhyolite. Rhyolite underlying the ore bodies generally is brecciated. Very little petrographic work has been done on these breccias, so that the nature of brecciation is poorly known. Most are throught to be pyroclastic, but the mechanism of the pyroclastic eruption responsible for brecciation (steam explosion or magmatic explosion) is unknown, in the absence of petrographic work. Some brecciated rocks may have formed as flow breccia.

Most ore bodies are more complex than the simplest type described above. For example three bodies of massive sulfide are present at the Millenbach Mine (Simmons et al) the oldest at the top of an extensive rhyolite flow (Amulet rhyolite) and two overlying two successive domical rhyolite extrusions of very small extent (lower and upper quartz porphyry). Alteration pipes affected not only the rocks below the lower orebodies, but all rocks underlying the highest ore bodies, as well as a number of dykes intersecting the ore bodies. Thus in some cases repeated extrusion of rhyolite accompanied by repetition of the ore-forming processes took place at the same locality.

One may suspect that ore bodies formed close to the place of extrusion of small to medium-sized rhyolite domes during a period in which volcanic activity was otherwise relatively quiet. Under this assumption one could recommend several steps in prospecting: (1) Recognition and mapping of horizons of pyritic chert and pyritic shale, indicating temporary interruption of volcanic activity, at stratigraphic levels where rhyolites are present. (2) Search for rhyolite domes underlying the sediments (1) and search for the place of extrusion of larger rhyolite flows underlying the sediments. Alteration, thickness changes of rhyolite between adjacent drill holes, and the aspect of flow breccias may give indications on their place of extrusion.

The Noranda-type massive sulfide deposits are necessarily restricted to shield volcanic associations with mixed chemistry. It is not recommended to prospect for this type of deposit in the sheet-type volcanic associations of mafic chemistry defined in the earlier part of this report.

(2) Native gold: A modern description of the gold mines of the Rouyn-Noranda area is not available. Most old gold mines are located in the strongly deformed zone south of the Cadillac fault. A more detailed study of the relations between gold mineralisation and microtectonics in this zone is recommended.

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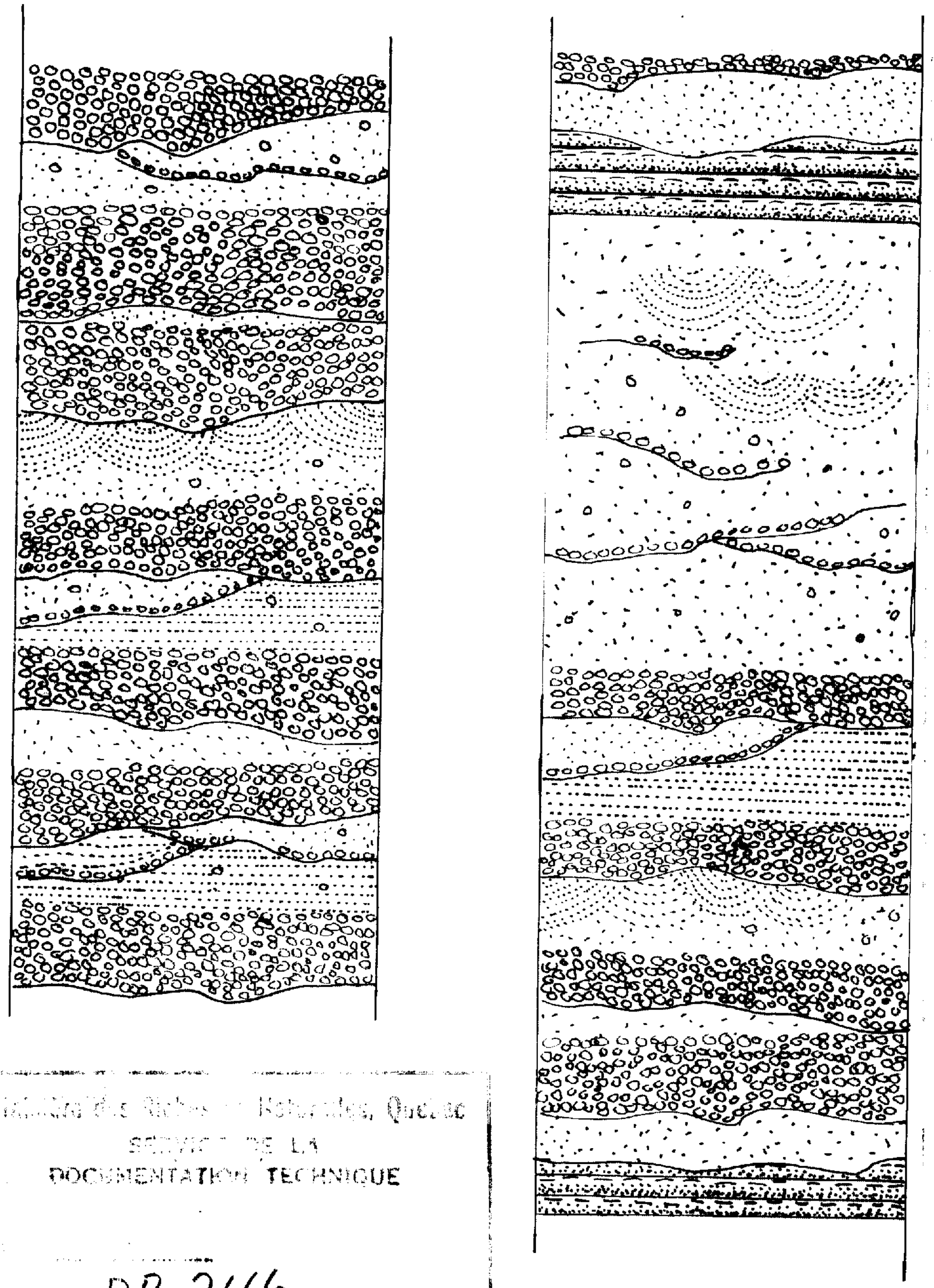
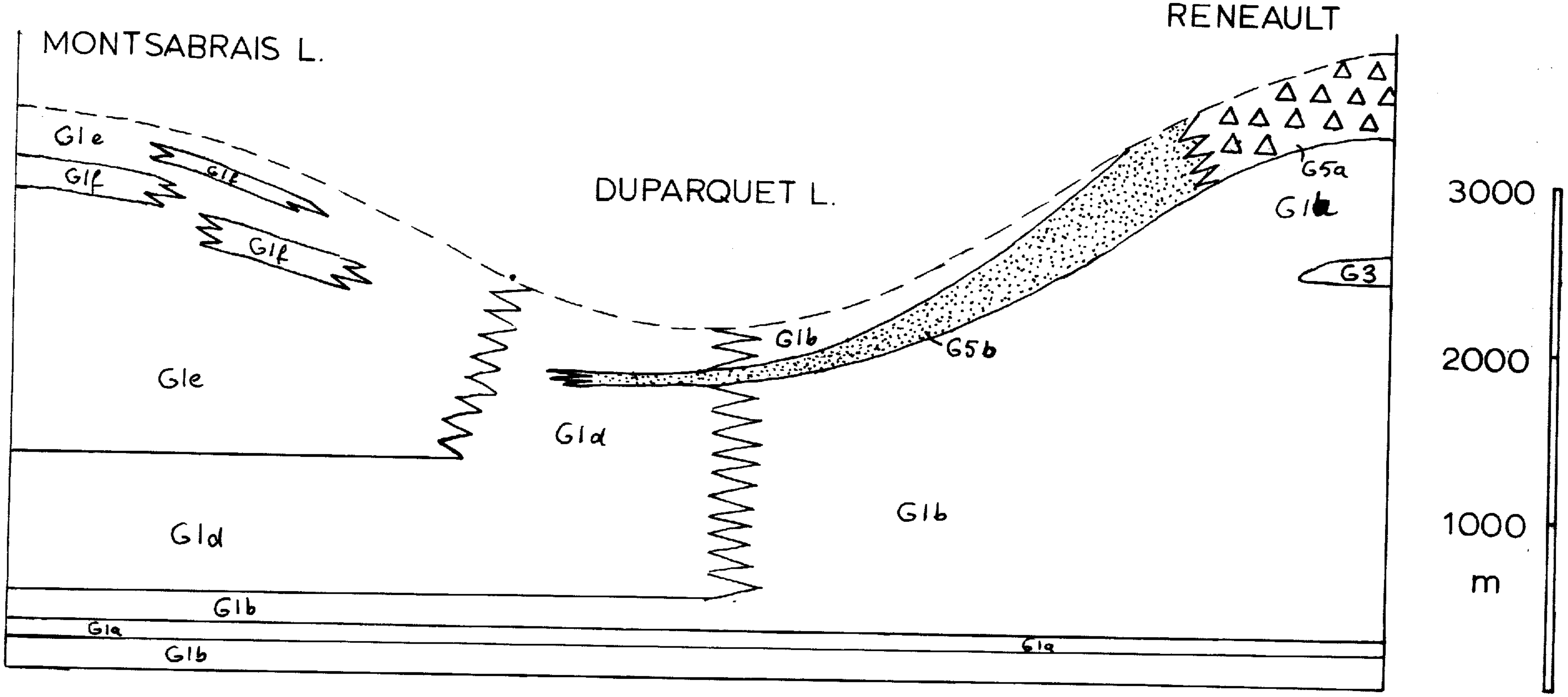


ALLUVIAL FAN
(TURNER AND
WALKER 1973)

"DELTA"

FIG 1


MONTSABRAIS L.
DUPARQUET L.
RENEAULT
G1e
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G1b
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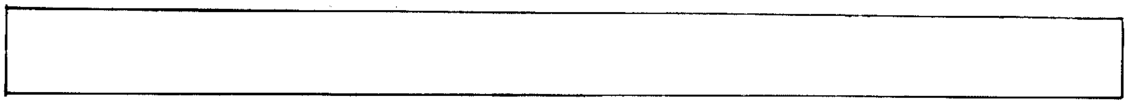
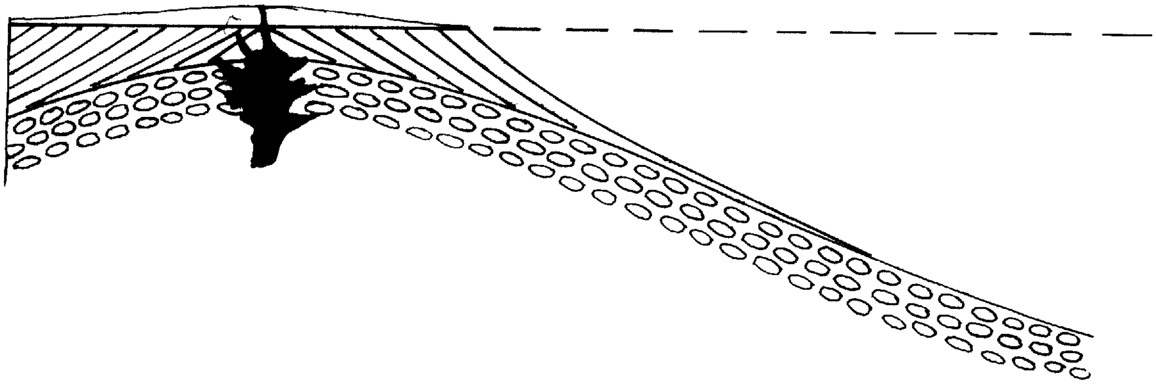
G3
3000
2000
1000
m

FIG. 2

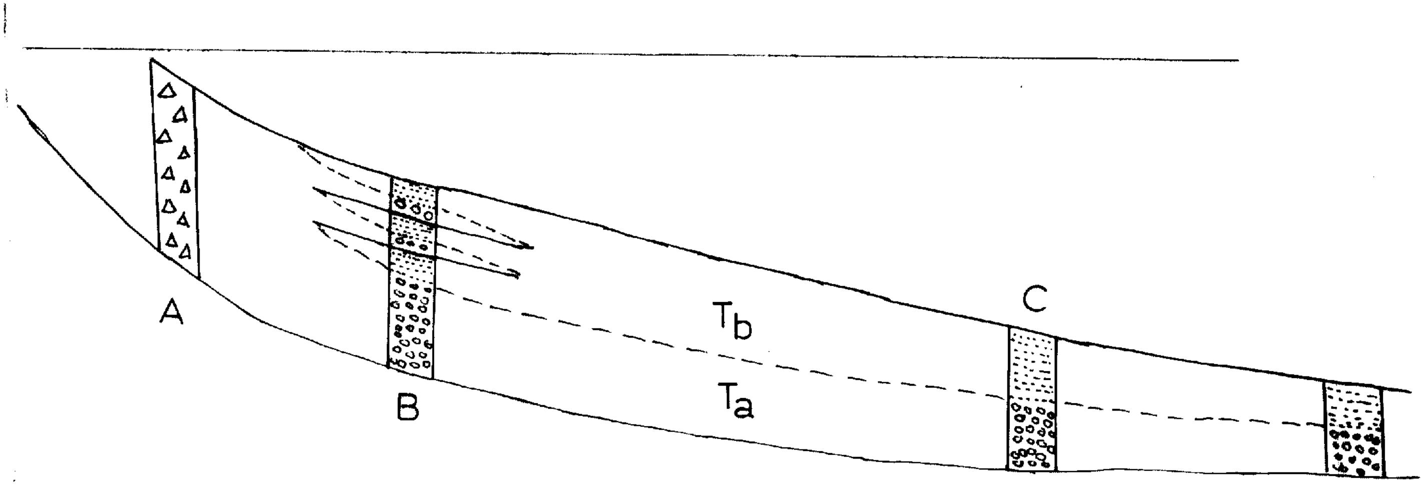
Basalt sheet



Submarine mafic cone (Moore and Fiske 1969)



Ash-flow tuff (Yamada 1973)



Fissure (Rittman 1960)

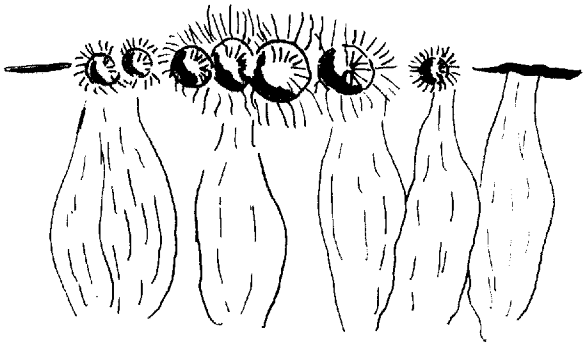


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FIG 3