Geochemistry and Stratigraphy of Archean Volcanic Rocks from Jessop Township, Timmins Region, Ontario

for:

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-- Ore Systems Consulting, Montreal --

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-- Ore Systems Consulting, Montreal --

Introduction

The Bonhomme claims lie near the shared corner of the four townships of Jessop, Mountjoy, Godfrey, and Jamieson (Figure 1). Claim drilling to date has been carried out in Jessop and Mountjoy townships. The area is underlain by mafic and felsic volcanic rocks of the Archean Blake River Group. All of the samples discussed in the present study are from Jessop township. The sampled drillholes include K2-87-01, K2-87-02, K2-87-03, Jess-12-01, Jess-12-02, K2-92-01, and K2-92-02. In addition, three samples were taken from hole JS-3 (claim 118352) located ≈150m west of the western margin of the Bonhomme claim block in Godfrey township, and two samples from Noranda hole J-92-03, located ≈300m east of the northeastern margin of the Bonhomme claim block in Jessop township.

Previous reports on the Bonhomme claims by Earth Resource Associates in 1991 and 1992 emphasized the results of geophysical surveys, and to an extent the drilling recommendations by Earth Resource Associates were designed to test known EM and magnetic conductors. Little outcrop exists in the area, so geological relations have been inferred over recent years from geophysical surveys, or from examination of existing drillhole logs; lithogeochemical data were limited. As a complementary approach, the present report emphasizes stratigraphy and lithogeochemistry as applied to evaluation of the property.

Purpose and Scope of Study

The purposes of this preliminary study are: 1) to characterize chemically the main volcanic rock types in several drillholes on the Bonhomme claims, which are located mainly in southwestern Jessop township and northwestern Mountjoy township; 2) to establish chemostratigraphic units that might be used for correlation purposes; 3) to assess the extent of hydrothermal alteration; 4) to reconstruct the original volcanic environments from variations in stratigraphic sequence and volcanic facies as recorded in existing drill logs; and 5) to compare the chemistry of the volcanic rocks with those hosting massive sulfide deposits in the Timmins area and elsewhere in the Abitibi greenstone belt.

JAMIESON TOWNSHIP   JESSOP TOWNSHIP

P.986663

Nor 92-3

Concession 1

P.986668   P.986667   P.986664

K2 87-1   *Jess 12-1*   *K2 92-1*

P.986670   P.986669

K2 92-2

P.723296   P.723283   *K2 87-3*   *K2 87-2*   *Jess 12-2*

P.986666   P.986665

Concession 6

BM 85-1

P.723297   P.732132   *BM 86-1*   P.732128

P.723129   *BM 90-1*

JS-3

P.723298   P.732131   P.732130   P.732127

1984-1,2

P.732125

P.732126

GODREY TOWNSHIP   MOUNTJOY TOWNSHIP

0   0.25   0.50

Miles
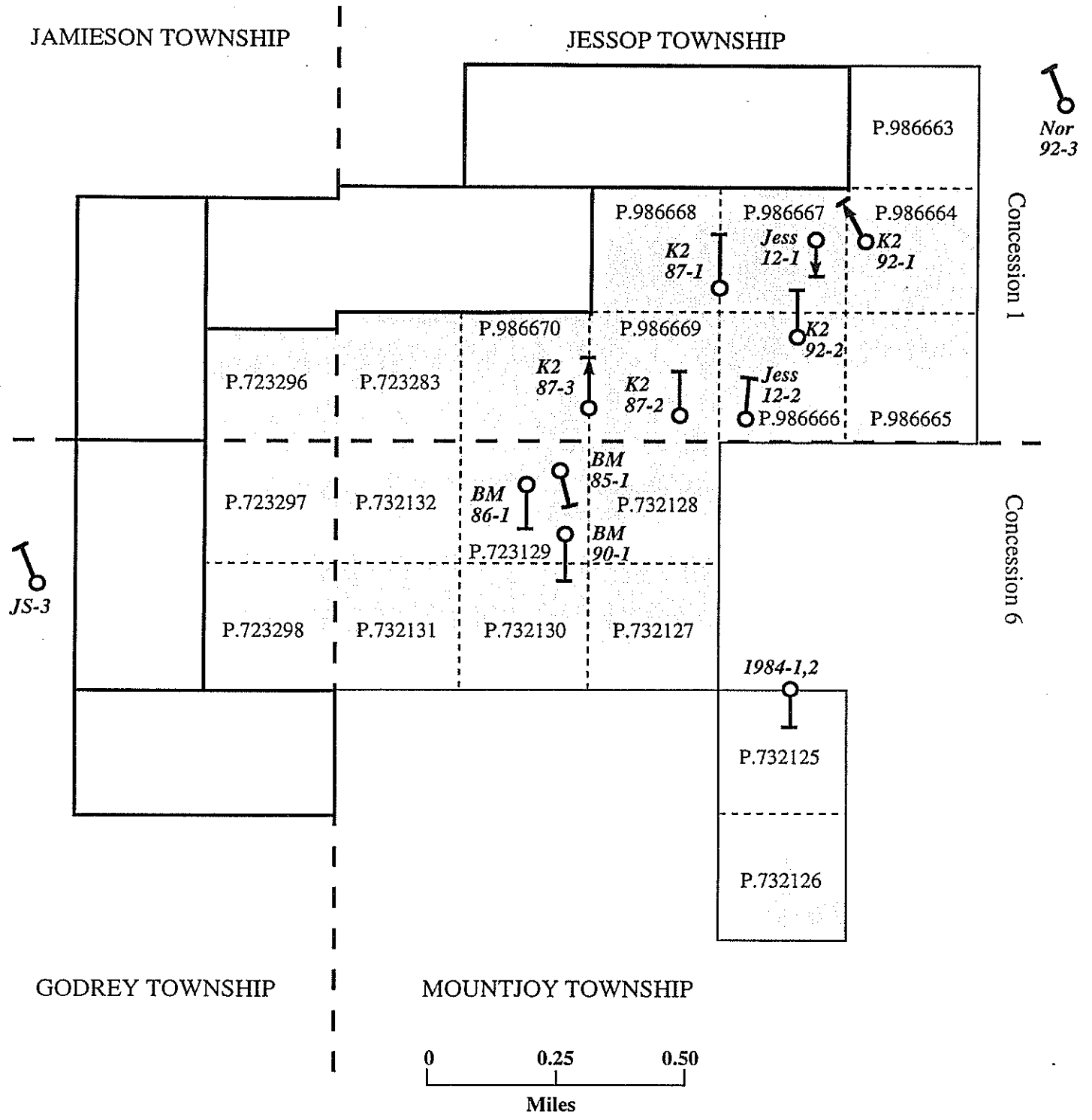
Location of initial Bonhomme 20-claim block (grey),
new claims (white), and known diamond drillholes
(from J.L. Kirwan report dated April 27, 1992)

Fig. 1

No petrographic data were available for this study, which places limits on interpretations. Furthermore, with the exception of JESS 12-01, only 2-5 samples were analyzed per hole, in drillholes ranging from 150-250 metres in length. As a result, only a few of the stratigraphic units in each hole were sampled, thus correlation of all units from hole to hole generally is not possible. Also, samples were taken by different individuals, and therefore analyzed core lengths are variable. A final caveat is that since a majority of the samples were taken to chemically identify primary volcanic units, the chemical analyses probably are not representative of the alteration zones described in the core logs.

Geochemistry

Methods

The overall sample set consists of 35 samples that were analyzed for major elements and the trace elements Zr, Y, and Sr (Table 1). For some samples, Ba, Rb, Nb and Sc were also determined. Samples were analyzed by:

i) XRF glass beads at the XRAL lab in Toronto, at the Chemex lab in Vancouver, and at an unknown lab; ii) I.C.A.P. following lithium metaborate fusion at the Swastika lab (holes K2-92-01, K2-92-2, JS-3 and two samples from K2-83-03). The fusion step prior to acid dissolution ensures that the immobile elements are taken into solution.

The use of two different analytical methods, and various labs for the XRF method, introduces unknown errors into the results. For major elements, the problem may not be serious. However, for trace elements, precision and accuracy can vary depending on the method and lab used. Unfortunately, no inter-laboratory standards were measured since the analyses were collected by different groups over several years, so it is difficult to assess errors. In the future, trace elements should be measured by one technique such as the XRF pressed-pellet method. Trace elements analyzed using XRF glass beads are less than satisfactory for Zr and Sr in most rocks, but for Y and Nb are not sufficiently accurate for confident lithogeochemical treatment, particularly at the lower concentrations of Y and Nb typical of mafic to intermediate volcanic rocks. The Y and Nb analyses in Table 1 therefore should be viewed as approximate, as are classifications based on Zr/Y ratios.

A standard part of our lithogeochemical treatment involves normalization of all data, including trace elements, to 100% on a volatile-free basis. Analytical data are given on this basis in Table 1, which also lists the original loss on ignition (LOI), and gives total iron as FeO. This basis facilitates comparison of initially nearly anhydrous rocks that were subsequently affected by variable additions of volatiles such as water, sulphur, and carbon dioxide. The volatile-free data are used in all chemical plots.

The precursor compositions of altered volcanic rocks, and thus the degree of alteration, can be accurately determined using incompatible and immobile element methods, as outlined in MacLean and Kranidiotis (1987), MacLean (1990), Barrett and MacLean (1991), and Barrett et al. (1991a, 1991b, 1991c, 1992). This approach requires that a suite of least altered lithologies also is sampled as part of the overall data set. Primary fractionation trends are established, using least altered samples, by plotting an immobile compatible element such as TiO_2 (or Al_2O_3) against an immobile incompatible element such as Zr. If the behavior of Zr is erratic, a plot of Al_2O_3 versus TiO_2 can be used to monitor fractionation and alteration.

Schematic fractionation curves resulting from ideal fractionation of a magmatic reservoir to produce liquids of basaltic to rhyolitic composition are shown in Fig. 2a for the TiO_2-Zr pair, and in Fig. 2b for the Al_2O_3-TiO_2 pair. In reality, many altered rocks do not lie on primary fractionation trends because hydrothermal alteration processes have affected the mobile elements in the rock, introducing mass from hydrothermal solutions, or removing mass from the rock. Schematic alteration lines are shown in Figures 2a and 2b for precursor compositions corresponding to andesite, dacite, and rhyolite.

Alteration lines result from the immobility of elements such as Ti, Al, Zr, Y and Nb, at least under alteration conditions typically associated with greenstone belts. Mass gain, such as occurs during addition of silica, metal sulfides or carbonates, will move a point towards the origin as a result of dilution of the immobile element pair. Mass loss, such as occurs during strong chloritization or sericitization through loss of silica, calcium and sodium, will move a point away from the origin through residual concentration of the immobile element pair.
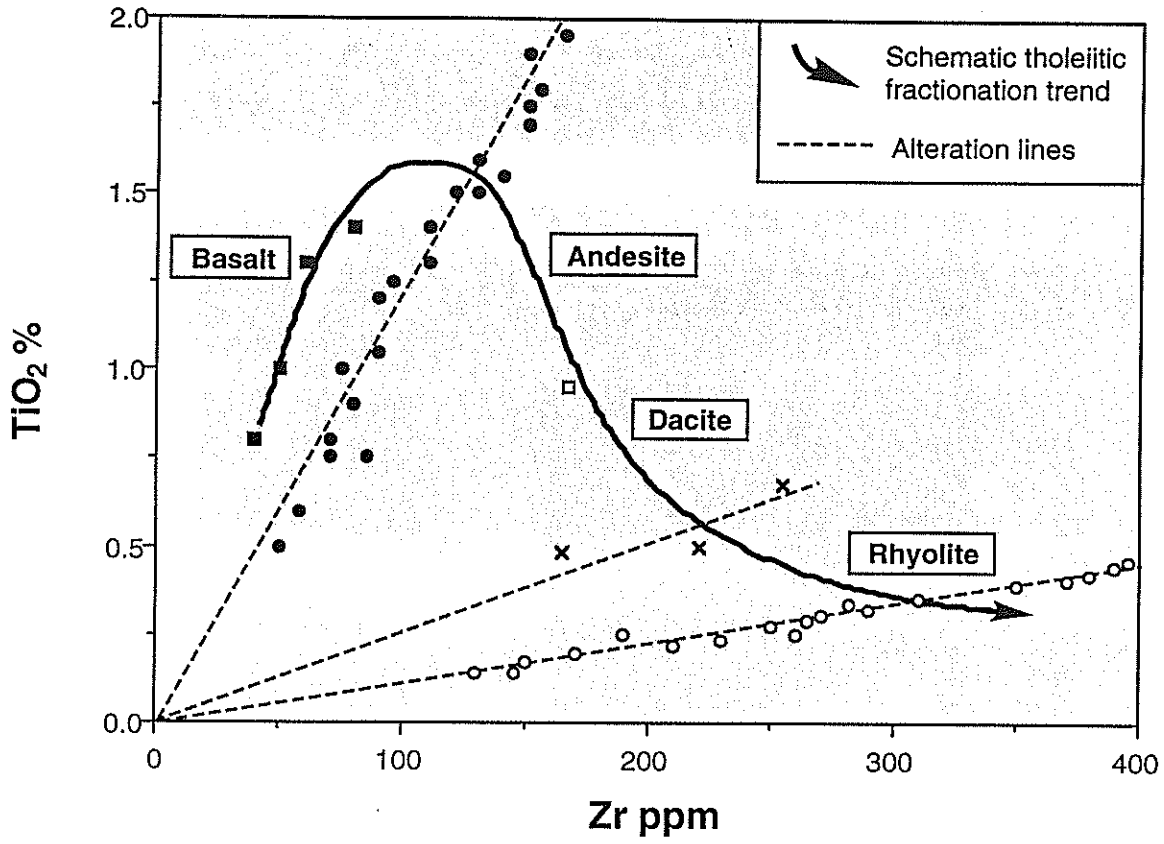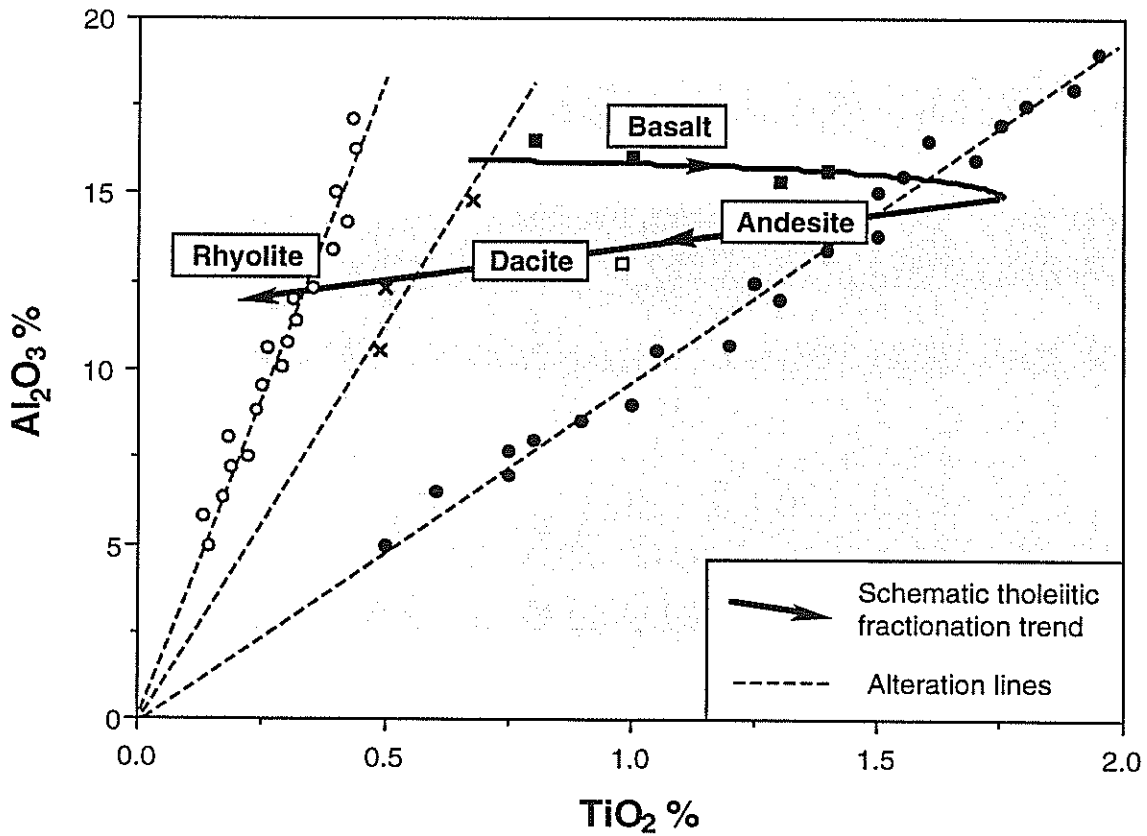
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Even if least altered samples cannot be obtained in a particular alteration zone, the existence of several discrete alteration lines with different slopes is a very useful feature that allows one to identify and correlate volcanic units. In fact, since alteration emphasizes primary compositional differences in immobile element plots, even slight differences within volcanic sequences can be detected in alteration zones, which allows chemostratigraphic correlation.

Alteration can be assessed on an element-by-element basis using the displacement of altered samples from the primary fractionation curves; the results are expressed as mass changes (MacLean, 1990). However, the present data set contains only a few least altered samples, which is not sufficient in size to confidently obtain primary fractionation trends. With future drilling and further sampling of existing drillcore, these trends can be defined and mass changes can be calculated in order to quantify hydrothermal alteration on an element-by-element basis.

Least altered samples are selected on the basis of their chemical analyses where no petrographic data are available. The term 'least altered' in this case refers only to the anhydrous chemical composition, not to the mineralogical composition. Alteration minerals in these 'least altered rocks' probably formed during reactions that were near-isochemical with respect to the anhydrous components. For example, carbonate alteration can form if added CO_2 combines with Ca-Mg-Fe already in the rock; the rock experiences no mass gain or loss in Ca-Mg-Fe components. Similarly, chlorite can form in mafic rock through hydration with no mass change in Mg-Fe-Al components.

Primary Geochemistry

Plots of TiO_2 versus Zr (Fig. 3a) and Al_2O_3 versus Zr (Fig. 3b) for all data indicates that most volcanic rocks sampled in the southeastern part of Jessop township are either: i) basalt to basaltic-andesite; or ii) rhyodacite to rhyolite. The mafic rocks show progressive Zr enrichment (from 100 to 250 ppm) as TiO_2 increases from 2.1 to 3.4% during fractionation from basalt to basaltic-andesite composition. The mafic rocks clearly belong to a tholeiitic fractionation trend, as corroborated by corresponding Fe and P enrichments that accompany the Ti enrichment trend (see below).
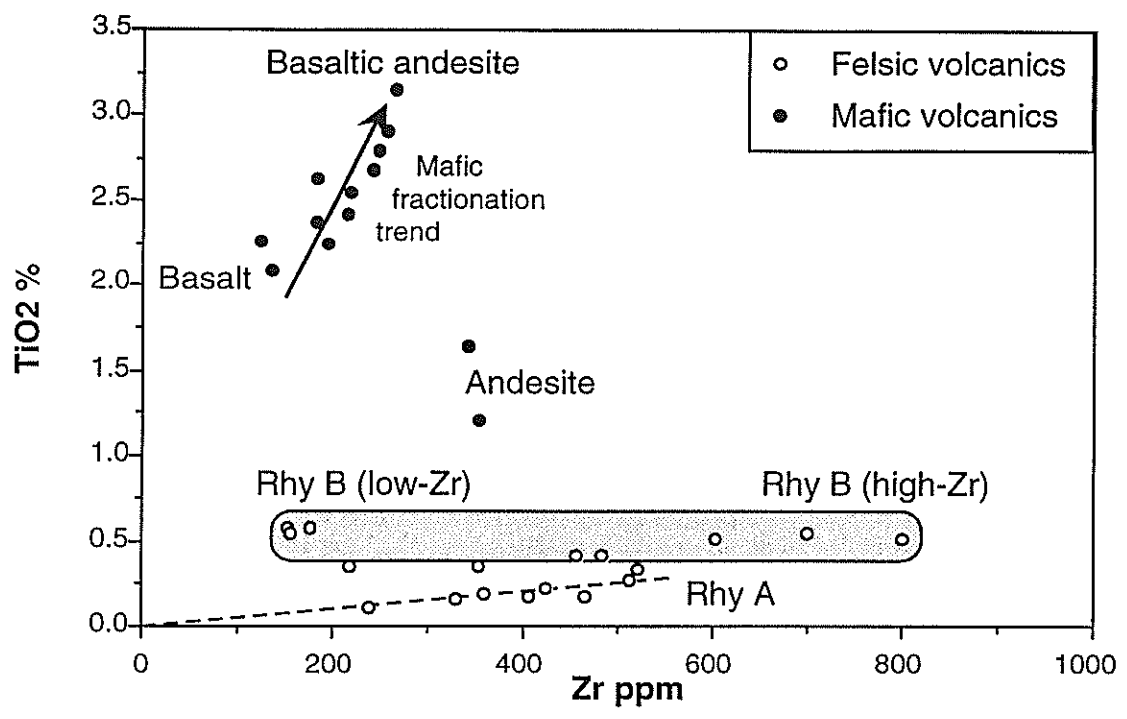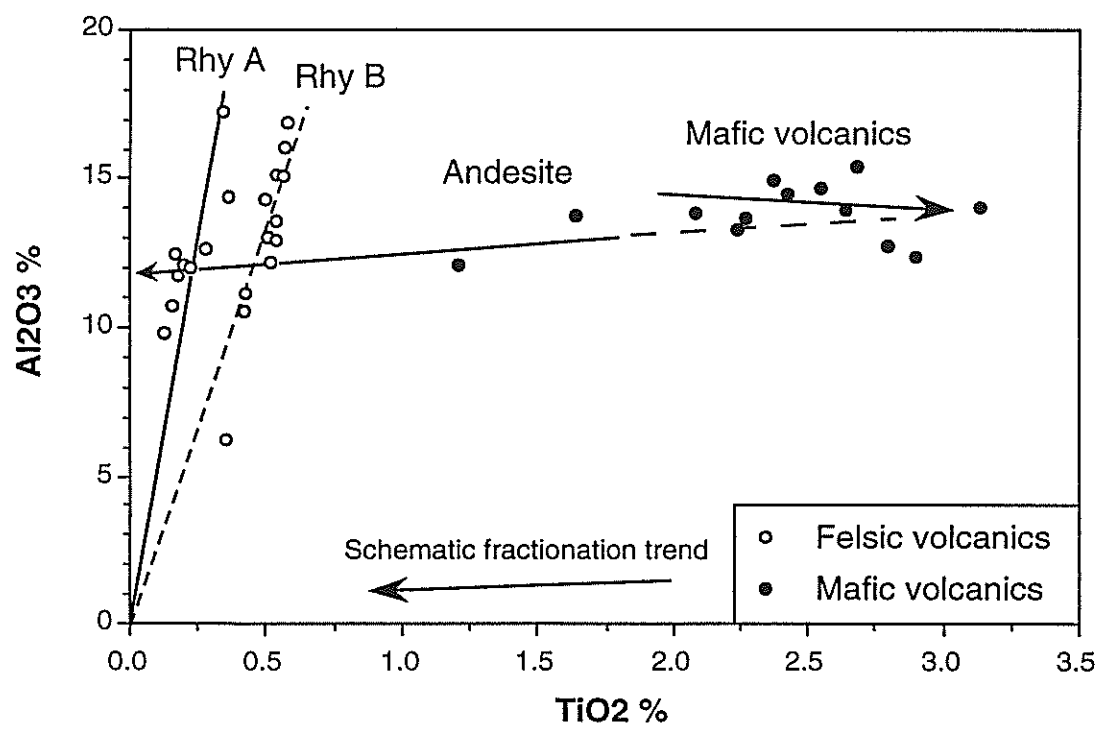
Fig. 3a

Fig. 3b

There are two main groups of felsic rocks. One type, termed rhyolite A, is a strongly fractionated, low-Ti, low-Al, high-Zr, tholeiitic rhyolite. This type has an Al_2O_3/TiO_2 ratio of about 50-60. The Zr content of rhyolite A (least altered samples) is about 400-500 ppm, which is similar to the Zr contents of rhyolites associated with the Kamiskotia and Kidd Creek VMS deposits.

The other felsic rock type, termed rhyolite B, has higher Ti and Al contents (this rock is close to rhyodacite in composition). This type has an Al_2O_3/TiO_2 ratio consistently of about 20-30, which distinguishes it from rhyolite A (Fig. 3b). The Zr content of rhyolite B is variable, indicating that unusual enrichment or precipitation of Zr has occurred relative to the normal TiO_2-Zr fractionation trend (compare Figures 2a and 3a). Some rhyolite B rocks have Zr contents similar to those of rhyolite A, but others range from much lower (200 ppm Zr) to much higher (2000 ppm Zr) contents.

A plot of Al_2O_3 versus TiO_2 (Fig. 3b) is useful to identify samples that show erratic Zr behavior in the TiO_2-Zr plot, but which still may constitute one rhyolite type (e.g. rhyolite B). Note that rhyolites A and B are clearly defined in this plot. The Al_2O_3 versus TiO_2 plot can also be used to make an initial assessment of alteration. Rhyolites with mass gain plot along alteration lines that extend towards the origin, relative to the estimated fractionation line (based on several least altered samples). Rhyolites with mass loss normally plot on the opposite side of the fractionation line. In the case of rhyolite B samples that plot above the fractionation line, there is ambiguity about the degree of net mass loss because some samples initially may have had unusually high Al_2O_3 contents (about 13-14% relative to the 12% typical of rhyolite A).

A plot of TiO_2 versus P_2O_5 (Fig. 4a) clearly separates the felsic and mafic rocks, separates rhyolites A and B, and outlines the fractionation trend in the basalt to basaltic-andesite series. Mafic rocks also can be distinguished by their consistently higher Sc contents relative to felsic rocks; this results from the fact that Sc shows a strong correlation with TiO_2 due to the geochemical similarity of these elements.
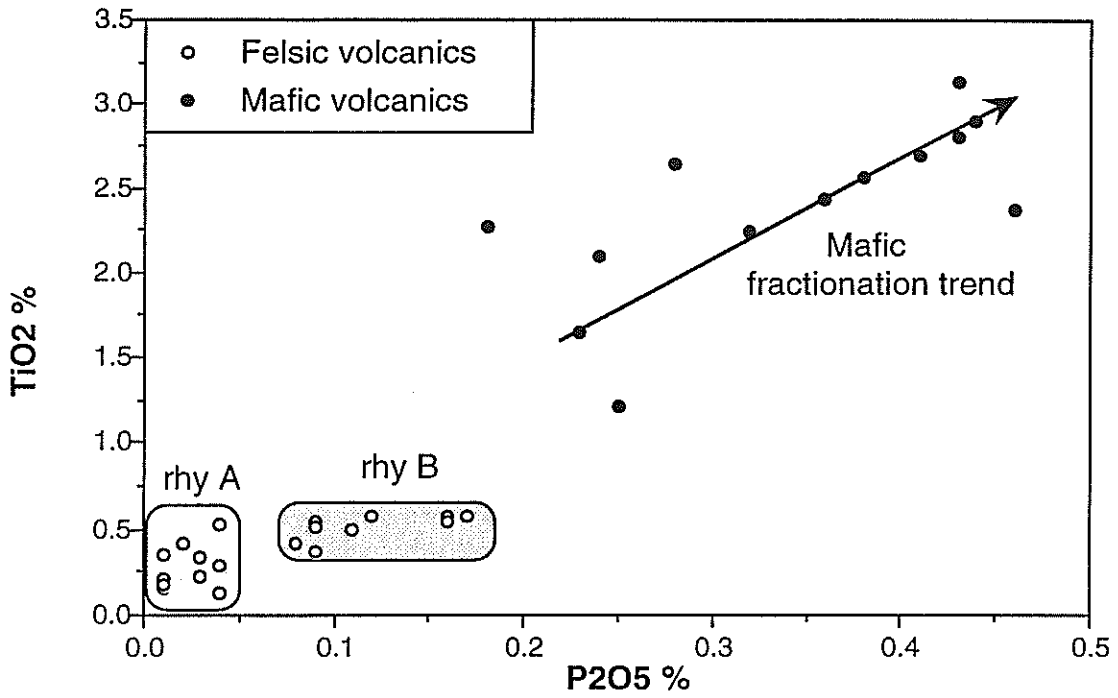
Fig. 4a

Fig. 4b

-- Ore Systems Consulting, Montreal --
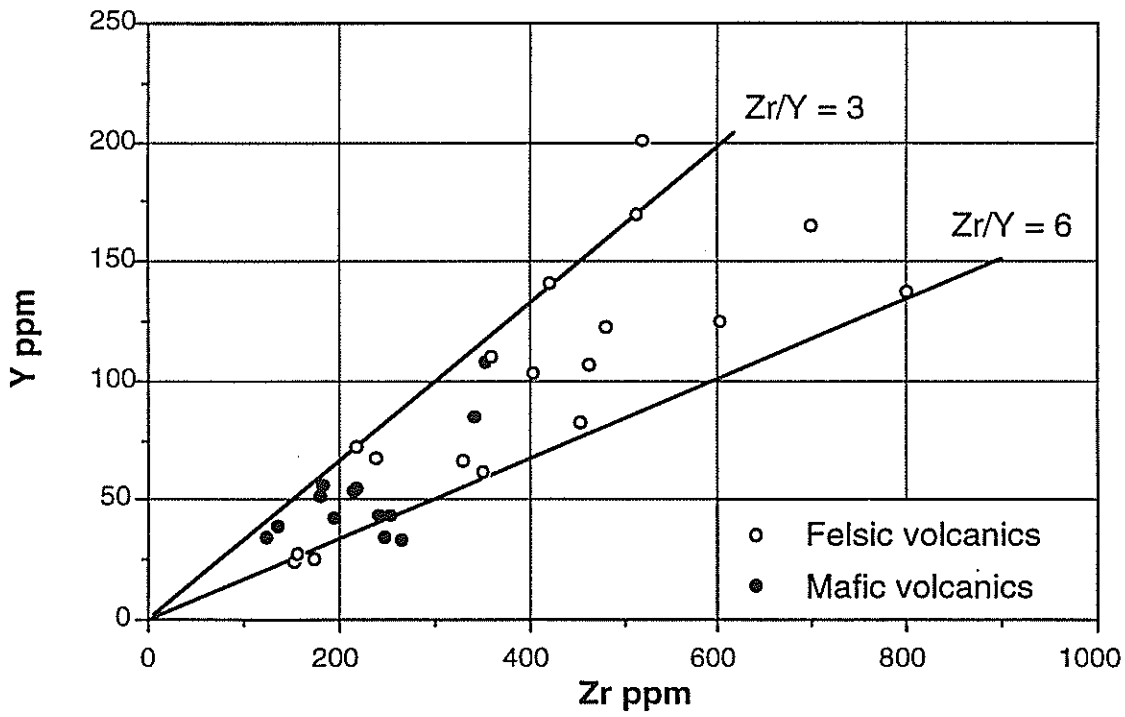
Basic identifications of the analyzed samples based solely on their geochemistry is given is Table 1. It should be noted that in several instances the lithologies differ from those given in the core logs, due to the fact that correct identification of strongly altered and sheared volcanic rocks in drill core is a difficult task. Discrimination of different chemical types of rhyolite tuff would be impossible, as would the realization that some apparently mixed fragmental rocks are actually of near-uniform rhyolite B composition.

Plots involving incompatible and immobile elements, such as Y-Zr, yield information on magmatic affinity of volcanic rocks. In these and related plots (Nb-Zr, Y-Nb) progressively more fractionated rocks will have progressively higher contents of incompatible elements, as these become concentrated in the residual liquid. The existence of a linear trend passing through the origin in a given plot indicates that rocks are co-magmatic. Volcanic rock suites with Zr/Y ratios in the 3-5 range are of tholeiitic affinity, those in the 5-7 range are of transitional affinity, and those in the 7-20 range are of calc-alkaline affinity. Since alteration lines for any sample lying initially on the fractionation trend also pass through the origin, alteration does not affect the primary slopes of data in Y-Zr and Nb-Zr plots. In these plots, altered samples can be used along with unaltered samples to determine magmatic affinity of the rocks.

A plot of Y versus Zr (Fig. 4b) for the Jessop rocks indicates that most mafic and felsic samples have Zr/Y ratios of 3-6, consistent with tholeiitic to transitional magmatic affinities. Limited data on Nb/Zr ratios (Table 1) also are consistent with a tholeiitic to transitional affinity (Barrett et al., 1992). However, these ratios may not be very reliable in rhyolite B rocks with unusual primary Zr enrichments and depletions (unless Y and Nb continued to covary with Zr). The magmatic affinity of rhyolite B could be confirmed with rare-earth element data.

Alteration Geochemistry

Net mass gain has affected several rhyolite samples, whereas net mass loss has affected several other samples (Fig. 3b). These samples are tagged on the plots of Al_2O_3-TiO_2 and SiO_2-Al_2O_3 shown in Appendix I. Mass gain has occurred in rhyolites JESS 12-1-86m, 92-1-141', 92-2-570', JS-3-411a and NOR92-3-99m. Silica addition was the dominant alteration in these samples (particularly in

-11-

the latter three). Rhyolites with net mass loss include 87-2-376', 87-3-421', 87-3-464', 87-3-489', 87-1-341' and JS-3-411b. Of these rocks, 87-2-386' has been affected by a large silica loss.

Volcanic rocks showing net mass gain commonly occur on the cooler fringes of synvolcanic hydrothermal systems, where precipitation of silica and low-temperature sulfides occurs, whereas rocks with net mass loss are associated with the hotter portions associated with feeder zones, where leaching of silica and alkalis is important and chlorite-sericite alteration is dominant. It is of interest that the rhyolites with net mass gain occur in the apparently more distal (fine tuff) portion of the felsic complex, whereas rhyolites with net mass loss occur in 87-3 in the more proximal part of the felsic complex. This suggests that hydrothermal leaching effects are more important in the vicinity of 87-3 on the flank on an inferred rhyolite edifice, than in holes such as 12-1 and 92-1 located in an distal, deeper water setting.

The effects of K_2O and FeO addition to the composition of the volcanic rocks during alteration is shown in Figure 5a and 5b, respectively. In these plots, we have used TiO_2 as a monitor of fractionation, because Zr behavior in rhyolite B is erratic. The amount of mass addition suggested by the plots is approximate only, as mass changes in other mobile elements will have a small effect on both the K_2O and TiO_2 values. Nevertheless, it is clear that some sericitization (K_2O addition) has occurred in rhyolites of holes 87-1 and 87-2, and significant sericitization in rhyolites of 87-3 (Fig. 5a). This plot also shows that three rhyolites are apparently depleted in K_2O relative to least altered rhyolites. However, this is due to the effect of mass addition of silica in these samples (92-2-570', JS-3-411a and NOR92-3-99m).

Moderate addition of FeO has occurred in rhyolites 12-1-81m, 12-1-96m and 87-2-386'. Despite this addition, the corresponding rocks show no net gain of mass, but rather a loss in net mass (as shown by the immobile element plots). Such features are characteristic of rocks affected by chloritization, which causes net mass loss (rocks affected only by iron sulfide addition show net mass gain). Chloritization is supported by the fact that rocks with addition of FeO also show addition of MgO (plot not shown, but analogous to Fig. 5b).

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Fig. 5a

Fig. 5b

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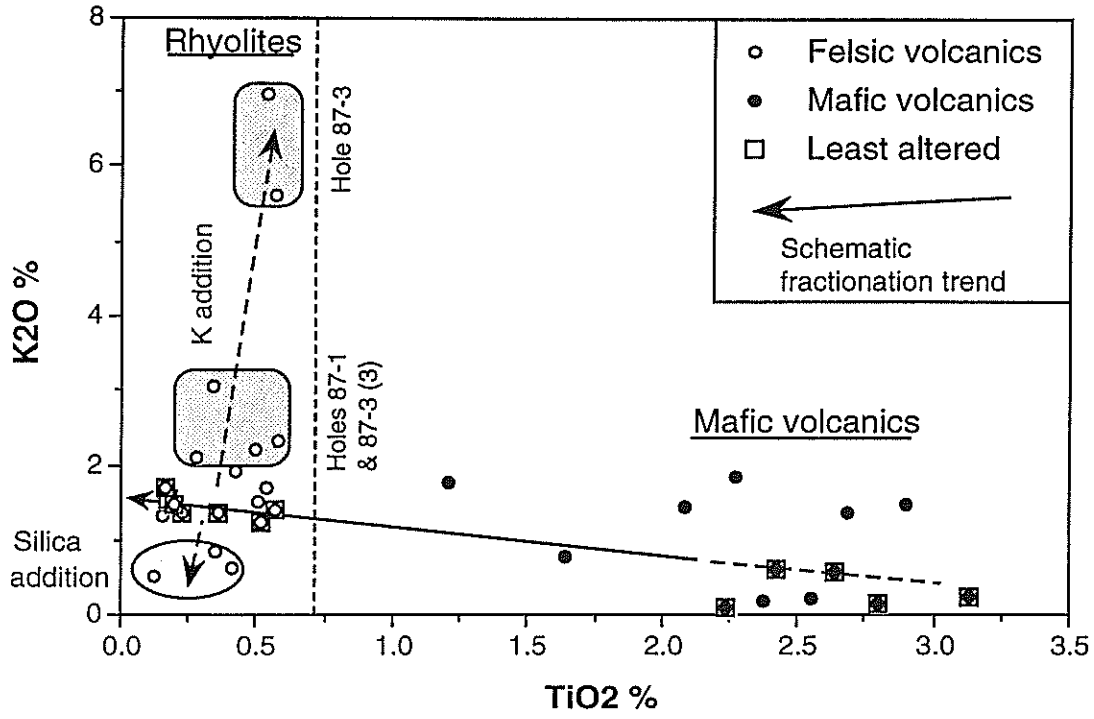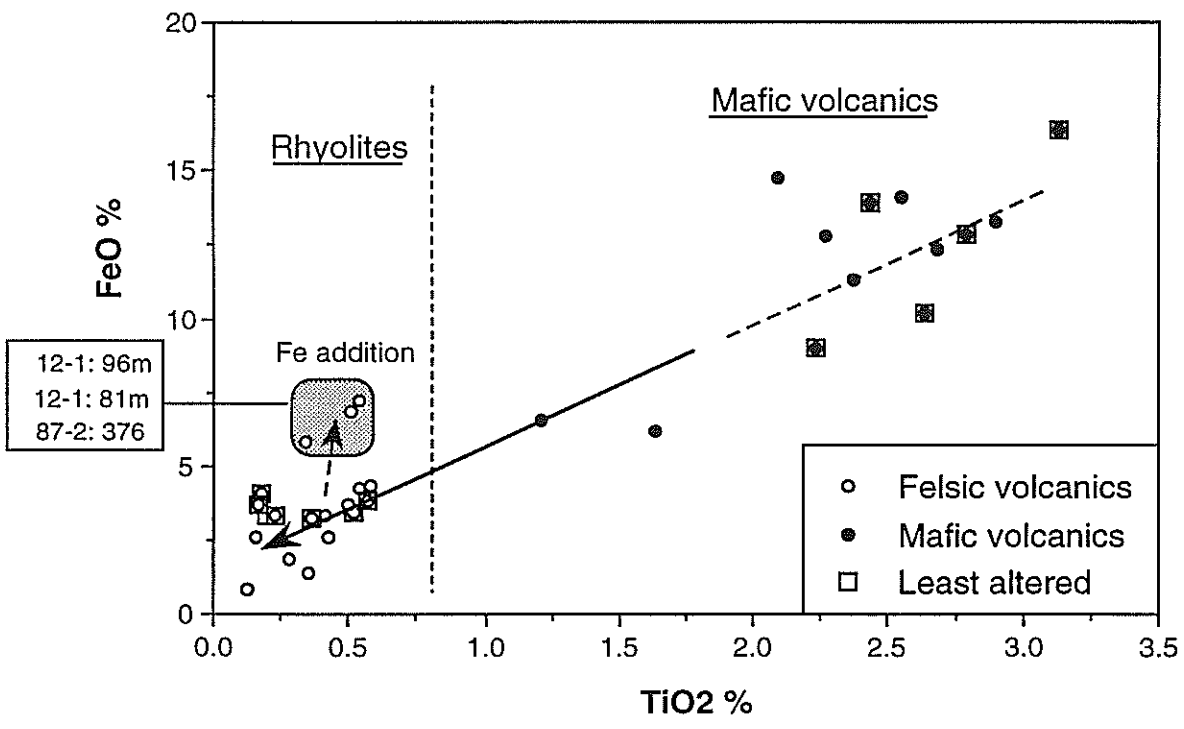
A plot of Ba versus K$_2$O shows that the most sericitized rhyolites are generally the most Ba-enriched (Fig. 6a). This relationship has been noted in sericitized rhyolites around Horne VMS deposit at Noranda, where it results from substitution in sericite due to the chemical similarity of Ba and K (MacLean and Hoy, 1991). Mass changes calculations show that both Ba and K were added to Horne sericitized rhyolites by hydrothermal solutions (Barrett et al., 1991a).

A plot of Sr versus CaO shows that the most sericitized and Ba-enriched rhyolites are generally also the most Sr-enriched (Fig. 6b). However, there is not a 1:1 relationship between Sr addition and Ba addition when individual rhyolites are compared. The Sr enrichment contrasts with the common Sr depletion that accompanies plagioclase destruction during alteration (Barrett et al., 1992), and may reflect retention together with Ba in a minor sulfate phase that formed during the sericitization phase. It does not appear that Sr was introduced with Ca during formation of minor carbonate, as there is no correlation between Sr and CaO. [Only sample JS-3-360 is notably CaO-enriched.]

Discussion and Conclusions

Volcanic Composition

The volcanic sequence in the southwestern corner of Jessop township is essentially bimodal, with one main mafic fractionation trend (basalt to basaltic-andesite), and two felsic rock types termed rhyolites A and B. There are two samples with an essentially andesitic composition (92-2-629' and 92-2-679') in the Jessop stratigraphy, although they have quite high Zr contents.

The magmatic affinity of the whole volcanic sequence ranges from tholeiitic to transitional based on Zr/Y ratios. In addition, the basalt to basaltic-andesite part of the sequence displays Fe-Ti-P enrichment trends with increasing Zr content that are typical of tholeiitic fractionation (McGeehan and MacLean, 1980). The overall composition of the Jessop mafic and felsic rocks is very similar to the bimodal tholeiitic volcanic sequence in the Kamiskotia area west of Timmins, with distinctly high contents of immobile incompatible elements (Hart, 1984; Barrie, 1990; Barrie et al., in press).

Fig. 6a

All volcanic rocks:
y = 308x - 0.62; r^2 = 0.85

87-3

Increasing sericitization

87-1, 2

○ Felsic volcanics
● Mafic volcanics
□ Least altered

Ba ppm

K2O %

Fig. 6b

○ Felsic volcanics
● Mafic volcanics
□ Least altered

Holes 87-1, 87-2, 87-3

Sr (and Ba) enrichment

Schematic fractionation trend

Sr ppm

CaO %

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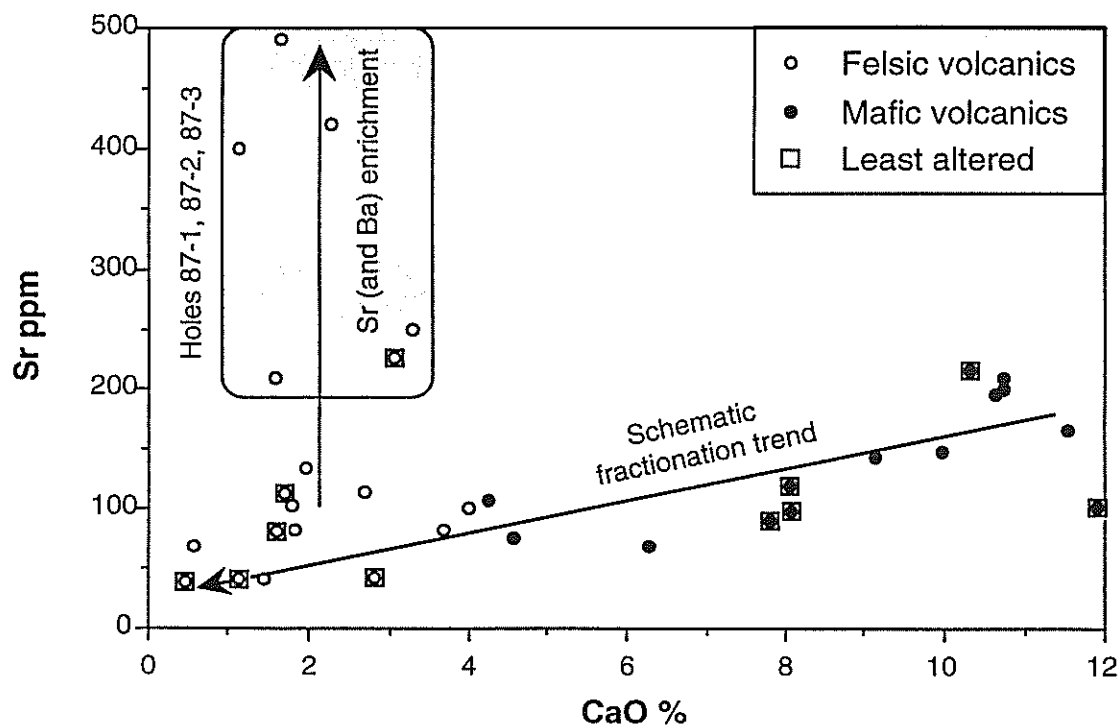
Zr contents in Jessop mafic rocks is 200-250 ppm; normal Jessop rhyolites have about 400-600 ppm Zr and 100-200 ppm Y. These characteristics are 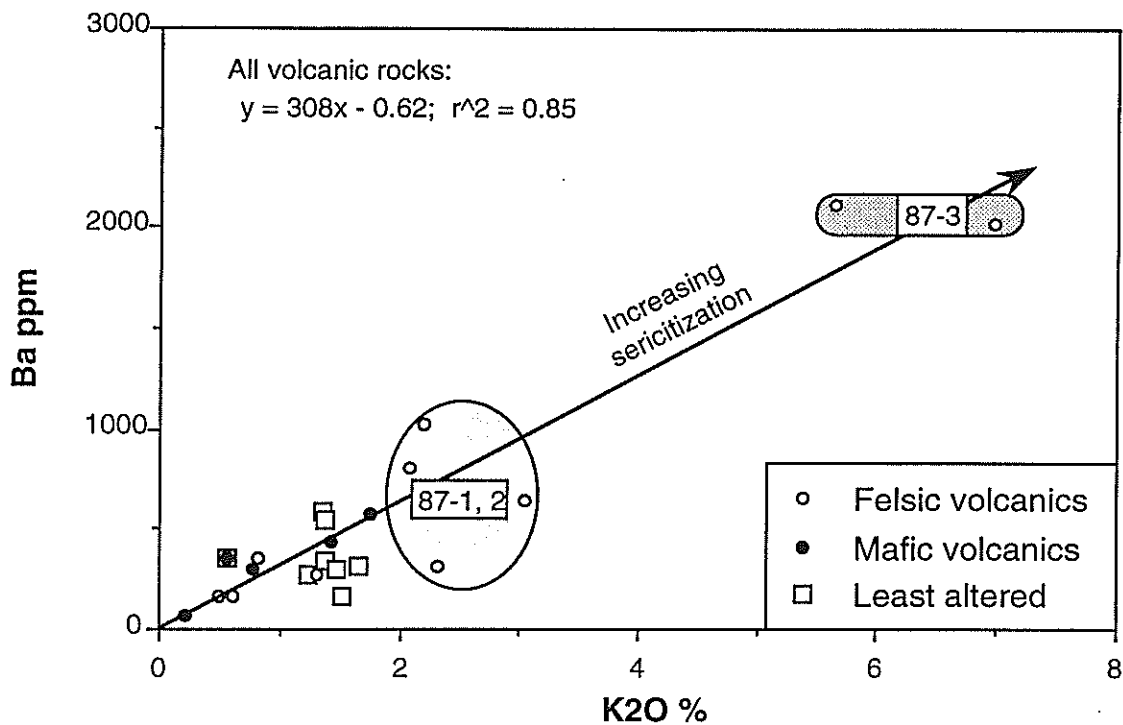typical of Barrie's Group I felsic-bearing volcanic sequences in the Abitibi greenstone belt (Lesher et al., 1986; Ujike and Goodwin, 1987). Ore-hosting volcanic sequences in the Matagami camp (McGeehan and MacLean, 1980; MacLean and Kranidiotis, 1987) and the Chibougamau area (Ludden et al., 1984; Barrett and MacLean, 1991) also show Group I geochemistry, as do the Kidd Creek felsic volcanics (Lesher et al., 1986; Barrie et al., in press). Thus, the overall composition of the volcanic sequence in southwest Jessop township reflects a very favorable tectonic setting for ore deposition, given that at least half of the total tonnage of VMS deposits in the Abitibi are included in Group I volcanic rocks.

The Jessop volcanics differ somewhat in composition from the Noranda mining camp, where volcanic rocks classified as Group II by Barrie et al. (in press) have magmatic affinities transitional between tholeiitic and calc-alkaline, and the common mafic rocks are andesitic rather than basaltic (Ujike and Goodwin, 1987; Barrett et al., 1991a,b,c; 1992). The Jessop volcanics differ markedly from calc-alkaline volcanics, which in the Archean Blake River group are host to very few VMS deposits.

An interesting feature of the Jessop mafic volcanic rocks is their high TiO_2 content of 2-3%, which suggests that titanomagnetite is an important minor phase, especially if the mafic rocks are not strongly altered (as appears to be the case). The abundance of titanomagnetite-rich mafic stratigraphy could account for magnetic anomalies in the northeastern portion of the claim block, where much of the drilling to date has been concentrated (Fig. 1). The common occurrence of graphitic argillites interbedded with mafic volcanics (and in overlying argillite-greywacke sediments) could account for the EM conductors associated with this part of the property.

It is also important that the geochemistry of rhyolite B indicates a near-constant Al_2O_3/TiO_2 ratio that is lower than that of rhyolite A, but much higher than that of the mafic volcanics (Fig. 3b). This precludes a significant component of mafic fragmental material in the rhyolite B rocks. This is of interest because drill core samples from 87-3 (463' and 419') show intermixed light and dark fragments up to 1 cm across. This colour variation must result from variations in alteration prior to formation of rhyolite B fragments. The available analyses

indicate that rhyolite B fragments are dominantly derived from one felsic magma type, whereas rhyolite A tuffs are derived from a separate felsic magma type.

Stratigraphy

Figure 7 shows a restored geological section for the northeastern portion of the claim block, as interpreted from core logs made available to the present authors, together with lithogeochemical data from the present study. The direction of younging was not recorded apart from holes 87-3 (north), 92-1 (north) and JESS 12-1 (south). These holes are based in mafic volcanics, pass through variable thicknesses of fragmental rhyolite (either agglomerate, lapilli tuff or tuff), and end in argillites. Based on an intersection of this succession, hole 87-1 is inferred to young to the north.

The stratigraphically lower part of 87-3 contains a thick unit of quartz-eye felsic tuff, which appears to correlate with a similar unit in 87-2 which has rhyolite A composition. To confirm this correlation, the quartz-eye felsic tuff in 87-3 should be sampled. The locations of holes 12-2, 92-2, 85-1 and 86-1 are based on field locations, and fact that they intersected mostly mafic volcanics and minor felsic tuff of rhyolite A composition (although sampling of felsic units is limited).

Facies relations in the restored stratigraphic sequence suggest that there is an overall gradation from west to east in the upper felsic unit (rhyolite B) from rhyolite agglomerate to lapilli tuff to tuff. This gradation is interpreted as representing a proximal to distal, lateral facies change on the flank of a subaqueous felsic volcanic edifice (cf. Roobol and Hackett, 1987). This facies change, when taken together with the decreased thickness of felsic fragmental rocks to the east and the increased proportion of argillite to the east, suggests that the original marine basin deepened in this direction. An examination of sedimentary structures in various drillcores (e.g. the distribution of turbidite facies, and directions of slump structures) would help to document these relations and strengthen the interpretation.

SSW

ENE

Basin deepens and stagnates to ENE, accumulating thick greywacke and carbonaceous slate

Eroding edifice of rhyolite B: yields proximal to distal fragmental volcanic facies with po-rich disseminations and clasts throughout

Target drilling area

Hole 12-1 drilled to south and youngs to south - this sequence is interpreted as a folded over portion of an otherwise north-younging sequence.

92-1

12-1

+Fe

Ash tuff

+Fe
+Si

Greywacke & graphitic argillite-slate

92-2

Lapilli tuff

87-1

+K
+Mg

12-2

Lapilli tuff

87-2

+K,
+Fe

+K

+K+Mg

++K+Mg

Agglomerate

Net mass loss

87-3

Rhyolite Tuff with quartz eyes

Agglomerate

Agglomerate

85-1

Massive rhyolite?

Massive rhyolite?

Rhyolite Tuff with quartz eyes

86-1

QP

QP

Rhyolite Tuff (massive)

Rhyolite B composition

Rhyolite A composition

Schematic Restored Geological Section

-- from SW corner of claim P. 986670 to NE corner of claim P. 986667 --

Younging direction is N in 87-3 and 92-1, and S in 12-1. Assumed to be to north in other holes.

0m   400m

Approximate hor. scale

-- Ore Systems Consulting, Montreal --

Fig. 7

As noted earlier, rhyolite B has a consistently higher P_2O_5 content than rhyolite A. Nevertheless, there is a recognizable decrease in the P_2O_5 content of rhyolite B from west to east (holes 87-3, 87-1, 12-1 and 92-1). This could be the effect of gravitational separation of a heavier, apatite-bearing phase during transport of rhyolite fragments (either by air or by downslope mass flow). If so, this would be consistent with the proximal to distal relations suggested above. A final feature worth noting is that the two extremely Zr-enriched rhyolites (1390 and 2370 ppm) occur near the middle of the rhyolite B sequence intersected in 87-3 and 87-1, suggesting the possible existence of a Zr-rich marker unit.

Alteration

Increasingly strong alteration effects occur towards the west, although Na depletions are only modest. Both K_2O and MgO have been added to rhyolite B in drillholes 87-1 and 87-3, an alteration feature suggestive of the moderate temperature, recharge portions of seafloor hydrothermal systems (Barrett and MacLean, in review). In addition, rhyolite B in drillhole 87-3 shows some net loss, implying that alteration was stronger in this hole than to the east. As noted earlier, strong sericitization with net mass loss may occur on the flanks of hydrothermal alteration systems, lateral to and within a few hundred metres of strongly chloritized zones associated with feeder pipes.

Drilling to date does not appear to have intersected such proximal, high-temperature alteration, where pervasive chloritizition is accompanied by major Fe-Mg addition and strong Si loss. Such alteration may lie to the west of drillhole 87-3.

Pyrrhotite-pyrite mineralization is commonly reported in the drill logs in rocks corresponding to rhyolite B, where it occurs as clots, flattened lenses and disseminations within fragmental rhyolites (clots are up to 1 cm across). It is possible that some of this mineralization represents resedimented sulfide clasts, whereas some may represent in-situ precipitation. In either case, the mineralization can be interpreted as occurring on the margins of a hydrothermal system. In this model, more massive base metal sulfides and the felsic volcanic centre are inferred to lie to the west. At the Horne mine in Noranda, pyrite-rich sulfide fragments are associated with mass-flow rhyolitic breccias in the No. 5

Zone; these accumulations appear to have formed lateral to and downslope from a felsic volcanic edifice that hosted the cupriferous orebodies (Fisher, 1970).

Paleoenvironment

The rhyolitic volcanic fragmental sequence that thins and fines to the east (holes 87-3 to 87-1 to 12-1) is interpreted as representing lateral and downslope variations along the flank of a subaqueous felsic volcanic centre. In the deeper part of the basin, bedded argillite-tuff and argillite-greywacke and intercalated with, and then overlie a thick sequence of basalt and basaltic-andesite. In holes JESS12-1 and 92-1, mafic volcanics occur above distal rhyolite B tuffs, but below the argillites. This suggests a that some mafic flows were derived from the east.

We infer that holes such as 85-1, 86-1, 87-2 and 12-2 intersected deeper levels of a primarily mafic stratigraphy that initially floored both the basin and the future site of the felsic complex. Within this older stratigraphy, some felsic tuffs are intercalated, but they appear to be of rhyolite A type and do not show a significant coarsening to the west (as does rhyolite B). Nevertheless, the quartz-eye rhyolite tuff intersected in hole 87-2 does show notable K_2O addition, and strong net mass loss near its top. It would be interesting to test if hydrothermal alteration in rhyolite A also intensifies towards the west, as would be expected if a central hydrothermal alteration system penetrated relatively deep into the rhyolite edifice. Unfortunately, we have no analyses from the stratigraphically deeper part of 87-3 and the shallower part of 12-2 (Fig. 7) to test this idea.

Thin intervals of massive to semi-massive sulfide mineralization do occur in holes JESS 12-1 and to a lesser extent in 92-1, but the overall setting in this area suggests that the mineralization may be a product of the reduced bottom waters that apparently existed during basalt-graphitic argillite accumulation, together with low temperature hydrothermal discharge on the seafloor (possibly a distal manifestation of hydrothermal activity to the west). If so, the Fe sulfides would be more closely related to SEDEX or sulfide-facies iron-formation environments than to a typical VMS felsic-associated environment. Although this interpretation is but one of several possibilities, it is supported by the low-temperature alteration in the associated felsic rocks of JESS 12-1 and 92-1, where only silica and iron addition has occurred (in contrast to the K and Mg addition in 87-1).

Recommendations

Locating and tracing a base metal-rich zone within basinal basalt-argillite stratigraphy may be more difficult than in a rhyolite complex, due to the likely similarity of host volcanic units and relatively low intensity of alteration over wide lateral areas. In addition, a considerable amount of this stratigraphy has already been tested by drilling to date. Although some felsic tuffs occur, they probably represent distal accumulations derived from a felsic volcanic centre.

The strategy now, in our opinion, is to locate the massive central area of the inferred rhyolite complex to the west. In such settings, surficial and high-level massive domes, flows, plugs and sills are expected to occur together with proximal breccias in spatial association with synvolcanic faults in caldera or related tensional graben settings (cf. Gibson and Watkinson, 1990; Barrett et al., 1991a). Such settings provide major near-surface sources of heat to drive hydrothermal circulation, as well as fault-related conduits along which fluids can circulate through the volcanic pile, and confined topographic depressions in which sulfide precipitates can accumulate. Lithologically, VMS deposits in felsic volcanic rocks tend to occur either at the transition from mafic to felsic episodes of volcanism (Gibson and Watkinson, 1990), or at contacts between different felsic volcanic units (Barrett et al., 1992, in press).

Certain VMS deposits in the eastern Abitibi occur in graben-type settings within felsic complexes (e.g. the Horne mine), whereas other occur at the contact between chemically contrasting rhyolite types. Examples of the latter are the Mobrun 1100 lens and Delbridge deposit near Noranda (Barrett et al., 1992, in press) and the Lemoine mine at Chibougamau (Barrett and MacLean, 1991b). These deposits occur at, or near the contact between highly fractionated rhyolite in the footwall and less fractionated rhyolite in the hangingwall. In this regard, it should be emphasized that Jessop rhyolite A is chemically more fractionated than rhyolite B.

All the evidence cited above for the Jessop volcanic rocks suggests that the massive part of an inferred felsic complex, as well as an area of important hydrothermal alteration, may lie immediately to the west or southwest of hole 87-3, depending on structural complexities (Fig. 8).

Possible areas of massive sulfide deposition within such a felsic complex include: (1) synvolcanic grabens within the massive to proximal-breccia portions of the inferred complex; and (2) any contact between rhyolites A and B, both of which appear to thicken westwards at the expense of intervening basalts (Fig. 8). These rhyolites conceivably may come into contact in the core of the inferred felsic complex.

In terms of exploration in southwestern Jessop township, the recognition of distinctive chemical volcanic units using immobile element methods has the potential for correlating units between drillholes, even where rocks are strongly altered. Chemically distinctive felsic units (e.g. those with favorable primary chemistry, or those displaying increasing alteration intensity, or those flanking known mineralization) should be traced laterally, especially in conjunction with any changes in volcanic lithofacies that would indicate the felsic volcanic vent region is being approached.

Acknowledgements

JAMIESON TOWNSHIP

JESSOP TOWNSHIP

Concession 1

Concession 6

Nor 92-3

P.986663

P.986668   P.986667   P.986664

K2 87-1   *Jess 12-1*   *K2 92-1*

P.723283   *K2 87-3*   P.986669   *K2 92-2*

P.723296   *Jess 12-2*

P.986670   *K2 87-2*   P.986666   P.986665

BM 85-1

P.723297   *BM 86-1*   P.732128

BM 90-1

P.732132   P.723129

P.723298   P.732131   P.732130   P.732127

1984-1,2

P.732125

JS-3

------------- Greywacke-slate

— — — Rhyolite B

— — — — Rhyolite A

P.732126

GODREY TOWNSHIP

MOUNTJOY TOWNSHIP

0   0.25   0.50

Miles
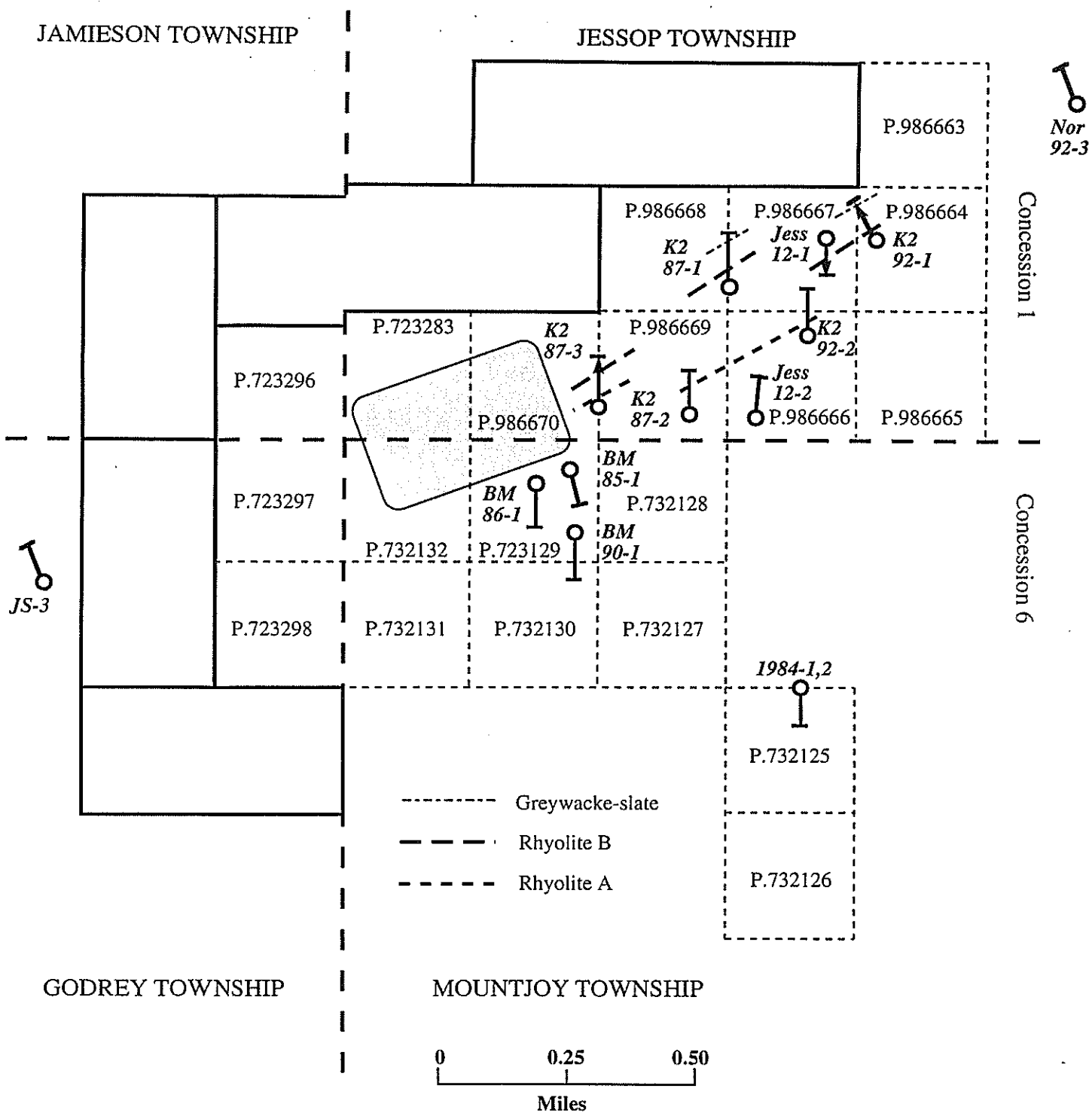
**Location of initial Bonhomme 20-claim block (dashed),
new claims (solid), and known diamond drillholes
(from J.L. Kirwan report dated April 27, 1992)**

Drilling area recommended by Ore Systems Consulting

Fig. 8

-- Ore Systems Consulting, Montreal --

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Table 1. Chemical Analyses of Volcanic Rocks from Jessop Township, Ontario.

LOI-CORRECTED

Hole	Depth	Rock	Co.	Number	SiO2	Al2O3	TiO2	FeO	MnO	CaO	MgO	K2O
90-01*	150 ft	fault rubble	JK	7545	66.53	18.75	0.58	3.38	0.04	2.14	1.52	3.39
92-01	141 ft	rhyolite	Nor	16723	75.43	10.62	0.41	3.35	0.09	4.01	0.31	0.61
92-01	170 ft	mafic	JK	7547	55.60	13.89	2.09	14.73	0.32	6.28	3.77	1.42
92-01	181 ft	mafic	JK	7546	51.07	14.94	2.37	11.32	0.27	11.54	4.80	0.20
92-01	535 ft	rhyolite tuff	JK	7548	68.96	16.05	0.57	3.66	0.08	3.10	1.84	1.39
92-02	150 ft	rhyolite	JK	7549	76.41	12.14	0.20	3.31	0.05	0.47	0.35	1.48
92-02	161 ft	rhyolite	Nor	16724	74.99	12.46	0.17	3.72	0.08	1.13	0.29	1.67
92-02	381 ft	rhyolite	Nor	16725	75.74	11.77	0.18	4.04	0.10	1.11	0.36	1.53
92-02	513 ft	mafic	JK	7550	55.80	13.91	2.64	10.10	0.32	10.31	3.38	0.56
92-02	570 ft	rhyolite	Nor	16726	84.39	6.25	0.35	1.34	0.07	3.69	0.10	0.83
92-02	629 ft	mafic	JK	7551	64.93	13.75	1.64	6.15	0.16	4.56	2.95	0.77
92-02	679 ft	mafic	JK	7552	67.34	12.15	1.21	6.53	0.14	4.24	1.48	1.76
92-03	99.0-99.35m	rhyolite	Nor	16721	79.18	10.71	0.16	2.62	0.07	1.45	0.37	1.31
92-03	201.0-201.3m	rhyolite	Nor	16722	74.14	12.23	0.52	3.40	0.07	2.85	0.14	1.25
Jess 12-01	20.7-24.7 m	mafic	KC	28351	50.72	14.00	3.14	16.27	0.26	7.83	5.00	0.22
Jess 12-01	33.8-33.9 m	mafic	KC	28352	59.48	13.34	2.24	8.98	0.22	8.06	4.10	0.09
Jess 12-01	36.3-37.5 m	mafic	KC	28353	52.26	14.49	2.43	13.90	0.23	8.06	5.27	0.58
Jess 12-01	45.4-48.5 m	mafic	KC	28354	51.89	14.64	2.55	14.06	0.26	10.75	3.63	0.23
Jess 12-01	68.6-71.3 m	mafic	KC	28355	52.81	13.68	2.27	12.82	0.33	9.96	5.19	1.85
Jess 12-01	79.2-82.5 m	rhyolite	KC	28356	69.85	12.99	0.51	6.79	0.14	2.69	0.53	1.52

Table 1. Chemical Analyses of Volcanic Rocks from Jessop Township, Ontario.

LOI-CORRECTED

Hole	Depth	Na2O	P2O5	Anh. sum	Orig. LOI	Ba	Sr	Y	Zr	Rb	Nb	Sc	Al2O3/ TiO2	Zr/Y	Zr/Nb	Y/Nb
90-01*	150 ft	3.52	0.15		2.43	730	123	23	142		26	11			17.6	3.2
92-01	141 ft	5.14	0.02	100.00	3.29	162	101	83	455	11			25.7	5.5		
92-01	170 ft	1.65	0.24	100.00	4.37	435	69	39	136			47	6.6	3.5		
92-01	181 ft	3.04	0.46	100.00	7.82	71	165	52	181			42	6.3	3.5		
92-01	535 ft	4.19	0.16	100.00	1.82	342	224	24	152			10	28.1	6.2		
92-02	150 ft	5.57	0.01	100.00	0.25	294	39	110	360			3	60.6	3.3		
92-02	161 ft	5.47	0.01	100.00	1.30	319	40	103	405	61	26		71.4	4.0	15.8	4.0
92-02	381 ft	5.16	0.01	100.00	1.30	169	40	107	464	50	31		64.1	4.3	15.2	3.5
92-02	513 ft	2.68	0.28	100.00	5.12	357	217	56	183			46	5.3	3.3		
92-02	570 ft	2.95	0.01	100.00	2.84	348	82	62	352	19	16		17.7	5.7	22.7	4.0
92-02	629 ft	4.86	0.23	100.00	1.85	304	75	85	341			28	8.4	4.0		
92-02	679 ft	4.91	0.25	100.00	2.01	575	106	108	353			20	10.1	3.3		
92-03	99.0-99.35m	4.11	0.01	100.00	2.47	274	41	66	330	42	20		65.9	5.0	16.3	3.3
92-03	201.0-201.3m	5.35	0.04	100.00	2.79	277	41	138	799	27	41		23.4	5.8	19.5	3.4
Jess 12-01	20.7-24.7 m	2.12	0.43	100.00	5.85		88	33	265	6			4.5	8.0		
Jess 12-01	33.8-33.9 m	3.19	0.32	100.00	5.93		97	43	194	5			6.0	4.5		
Jess 12-01	36.3-37.5 m	2.43	0.36	100.00	3.62		118	54	215	21			6.0	4.0		
Jess 12-01	45.4-48.5 m	1.62	0.38	100.00	5.93		208	55	218	11			5.8	4.0		
Jess 12-01	68.6-71.3 m	0.89	0.18	100.00	9.31		147	34	124	45			6.0	3.7		
Jess 12-01	79.2-82.5 m	4.89	0.09	100.00	2.93		114	125	603	62			25.5	4.8		

Table 1. Chemical Analyses of Volcanic Rocks from Jessop Township, Ontario.

LOI-CORRECTED

Hole	Depth	Rock	Co.	Number	SiO2	Al2O3	TiO2	FeO	MnO	CaO	MgO	K2O
Jess 12-01	86.5-86.1 m	rhyolite	KC	28357	77.09	11.25	0.42	2.62	0.06	1.78	0.29	1.90
Jess 12-01	96.0-96.6 m	rhyolite	KC	28358	68.79	13.59	0.54	7.21	0.14	1.82	0.66	1.67
Jess 12-01	104.5-106.4 m	mafic	KC	28368	51.82	12.40	2.90	13.25	0.35	10.74	3.75	1.46
Jess 12-01	115.2-118.3 m	mafic	KC	28369	50.99	15.42	2.68	12.39	0.29	9.12	3.68	1.34
Jess 12-01	149.0-150.3 m	mafic	KC	28370	51.63	12.71	2.80	12.85	0.30	11.92	4.84	0.15
87-01	340-342	rhyolite	Nor	16713	71.09	14.30	0.50	3.67	0.08	2.29	1.53	2.21
87-02	279-281 ft	rhyolite	Nor	16710	75.48	12.70	0.28	1.88	0.07	1.64	0.40	2.09
87-02	316.2-318.2 ft	rhyolite	Nor	16711	75.09	12.08	0.23	3.35	0.11	1.61	0.41	1.36
87-02	374.8-376.8 ft	rhyolite tuff	Nor	16712	65.36	17.28	0.34	5.83	0.17	1.59	0.48	3.04
87-03	419-422 ft	rhyolite	Nor	16714	68.18	15.13	0.57	3.83	0.06	1.14	1.79	5.63
87-03	463.5 ft	rhyolite	LB	K2-87-3	67.01	15.10	0.54	4.21	0.08	1.95	1.90	6.98
87-03	488.5 ft	rhyolite	LB	K2-87-3	66.26	16.89	0.58	4.30	0.08	3.30	1.70	2.32
Jonsmith-3*	360	intermed.	LB	3-360	56.98	12.95	0.54	7.40	0.21	11.53	3.91	1.07
Jonsmith-3	411a	rhyolite	LB	3-411a	82.86	9.78	0.12	0.86	0.01	0.56	0.19	0.50
Jonsmith-3	411b	rhyolite	LB	3-411b	72.16	14.39	0.36	3.21	0.04	1.73	1.02	1.37

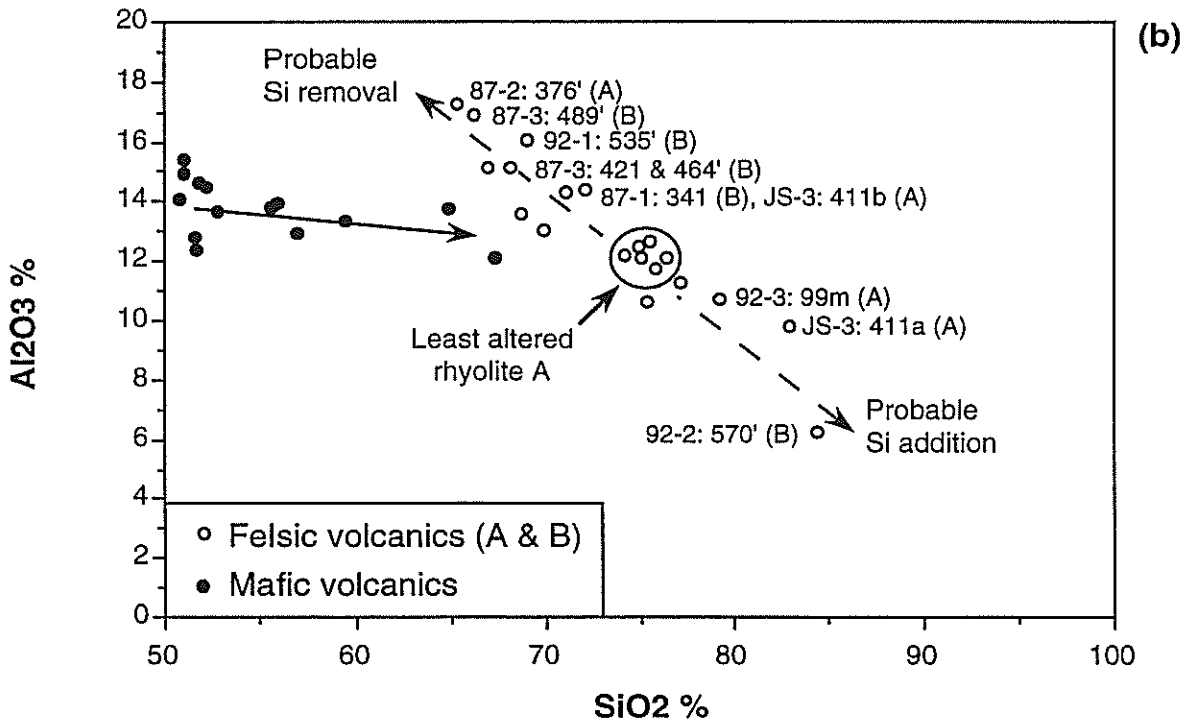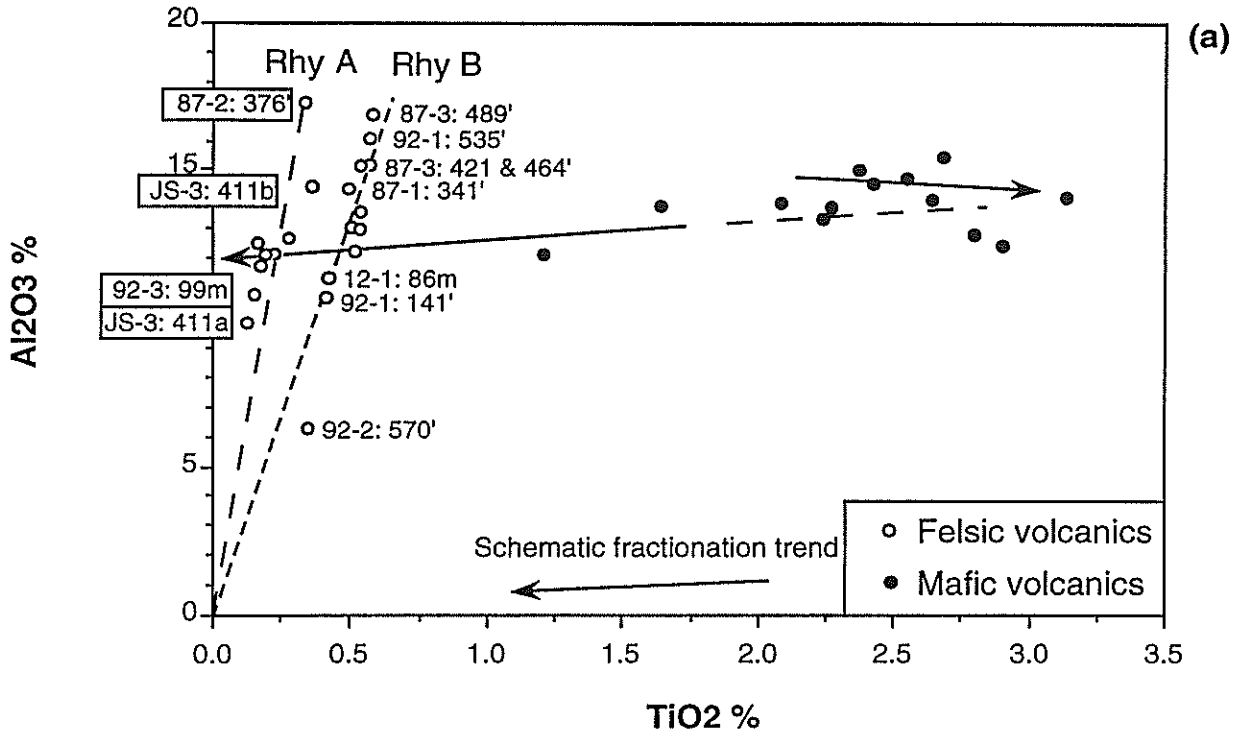JK samples: ICAP lithium metaborate fusion

* not plotted

Table 1. Chemical Analyses of Volcanic Rocks from Jessop Township, Ontario.

page 26b

LOI-CORRECTED

Hole	Depth	Na2O	P2O5	Anh. sum	Orig. LOI	Ba	Sr	Y	Zr	Rb	Nb	Sc	Al2O3/TiO2	Zr/Y	Zr/Nb	Y/Nb
Jess 12-01	86.5-86.1 m	4.51	0.08	100.00	2.00		102	123	481	51			26.8	3.9		
Jess 12-01	96.0-96.6 m	5.49	0.09	100.00	2.08		82	165	700	51			25.4	4.3		
Jess 12-01	104.5-106.4 m	2.88	0.44	100.00	8.08		199	44	255	66			4.3	5.8		
Jess 12-01	115.2-118.3 m	3.69	0.41	100.00	7.54		143	44	242	11			5.8	5.5		
Jess 12-01	149.0-150.3 m	2.37	0.43	100.00	8.77		101	34	247	11			4.5	7.3		
87-01	340-342	4.20	0.11	100.00	2.23	1021	420	98	2370	66	5		28.5	24.1	454	18.8
87-02	279-281 ft	5.42	0.04	100.00	1.93	809	492	170	512	69	40		45.9	3.0	12.8	4.3
87-02	316.2-318.2 ft	5.72	0.03	100.00	2.23	590	79	141	423	68	25		52.7	3.0	16.9	5.6
87-02	374.8-376.8 ft	5.88	0.03	100.00	2.93	638	208	201	520	121	53		50.3	2.6	9.8	3.8
87-03	419-422 ft	3.54	0.12	100.00	1.47	2116	400	5	1390	97			26.4	272		
87-03	463.5 ft	2.06	0.16	100.00	1.57	2024	134	27	157			11	27.8	5.9		
87-03	488.5 ft	4.40	0.17	100.00	2.65	310	250	25	175			13	29.1	6.9		
Jonsmith-3*	360	5.26	0.14	100.00	12.92	589	285	19	39			20	24.2	2.1		
Jonsmith-3	411a	5.07	0.04	100.00	0.39	170	68	68	239			2	81.7	3.5		
Jonsmith-3	411b	5.63	0.09	100.00	2.23	546	112	72	217			5	40.2	3.0		

JK samples: ICAP lithium metaborate fusion

* not plotted

-- Ore Systems Consulting, Montreal --

Appendix Fig. 1