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NEW MINERAL-EXPLORATION TARGETS IN THE PINWARE TERRANE, GRENVILLE PROVINCE, SOUTHEAST LABRADOR

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ABSTRACT

The Pinware terrane is a distinct region in the eastern Grenville Province characterized by alkali-rich granitoid rocks, volcanogenic? supracrustal rocks and a host of syn- to post-Grenvillian plutons. A large layered mafic intrusion, the Kyfanan Lake body, borders much of the presently mapped northern margin of the Pinware terrane. Using information from recent reconnaissance-mapping projects, in conjunction with lake-sediment geochemical data and/or mineral occurrences, two major potential mineralization targets are: i) Ni−Co−V mineralization associated with ultramafic rocks in layered mafic intrusions, especially the Kyfanan Lake body, ii) Cu−Mo−U−Ag mineralization associated with Proterozoic felsic volcanic rocks, but localized by early Phanerozoic faults and/or an unconformity. Minor targets are: i) amazonite−Mo−F mineralization in pegmatites, and ii) nepheline in syenite.

INTRODUCTION

Although lake-sediment geochemical data are available for all of Labrador, interpretation of the information, from a mineral-exploration viewpoint, is hampered in many areas for want of either adequate geological information, or sufficient familiarity with that which is available. This communication seeks to bridge this gap for a small part of the Grenville Province in southeast Labrador, where some previously unidentified mineral-exploration targets are suggested.

Attention here is directed toward the Pinware terrane, recently mapped for the first time at 1:100 000 scale (Gower *et al.*, 1988, 1993, 1994). In emphasizing the Pinware terrane, it is not implied that the mineral potential of other parts of the Grenville Province in Labrador is lower, but because the Pinware terrane differs geologically in several respects to terranes farther north in the Grenville Province in Labrador (Gower *et al.*, 1993), it is considered to be different.

The approach followed here has been to examine a subset of the lake-sediment geochemical data specific to the Pinware terrane and offer explanations for anomalous values based on available geological information concerning the bedrock and known mineral occurrences. No attempt has been made to be exhaustive in the assessment, and the identification of additional targets may reward a more detailed evaluation of the same dataset. A preliminary version of this report has been released in Open File (Gower and van Nostrand, 1994) and presented in poster form (Gower and McConnell, 1994).

GEOLOGICAL REVIEW

The Pinware terrane, defined by Gower *et al.* (1988), is the most southerly terrane in eastern Labrador and forms part of the Interior Magmatic Belt of Gower *et al.* (1991) (Figure 1).

Rocks in the terrane are subdivided into 6 major groups as follows: i) supracrustal units, ii) recrystallized, foliated to gneissic alkali-rich granitoid rocks, iii) mafic rocks, including both layered mafic intrusions and mafic dykes, iv) syn- to late-Grenvillian(?) granitoid rocks, v) late- to post-Grenvillian granitoid rocks, and vi) Neoproterozoic to Early Cambrian rocks (Figure 2).

Units interpreted to be of supracrustal origin are dominated by fine-grained, recrystallized, commonly banded quartzofeldspathic rocks, locally showing inhomogeneous texture in detail. These rocks are suspected to be of felsic volcanic origin, although features sufficiently obvious to support this suspicion are only rarely seen in outcrop (Gower *et al.*, 1994). Associated banded mafic rocks are interpreted as having a mafic volcanic protolith, but a similar identification caveat applies. The assertion that either is supracrustal rests upon its occurrence with rocks of obvious supracrustal parentage, such as quartzite, calc-silicate units and sillimanite- or muscovite-bearing pelitic schists and

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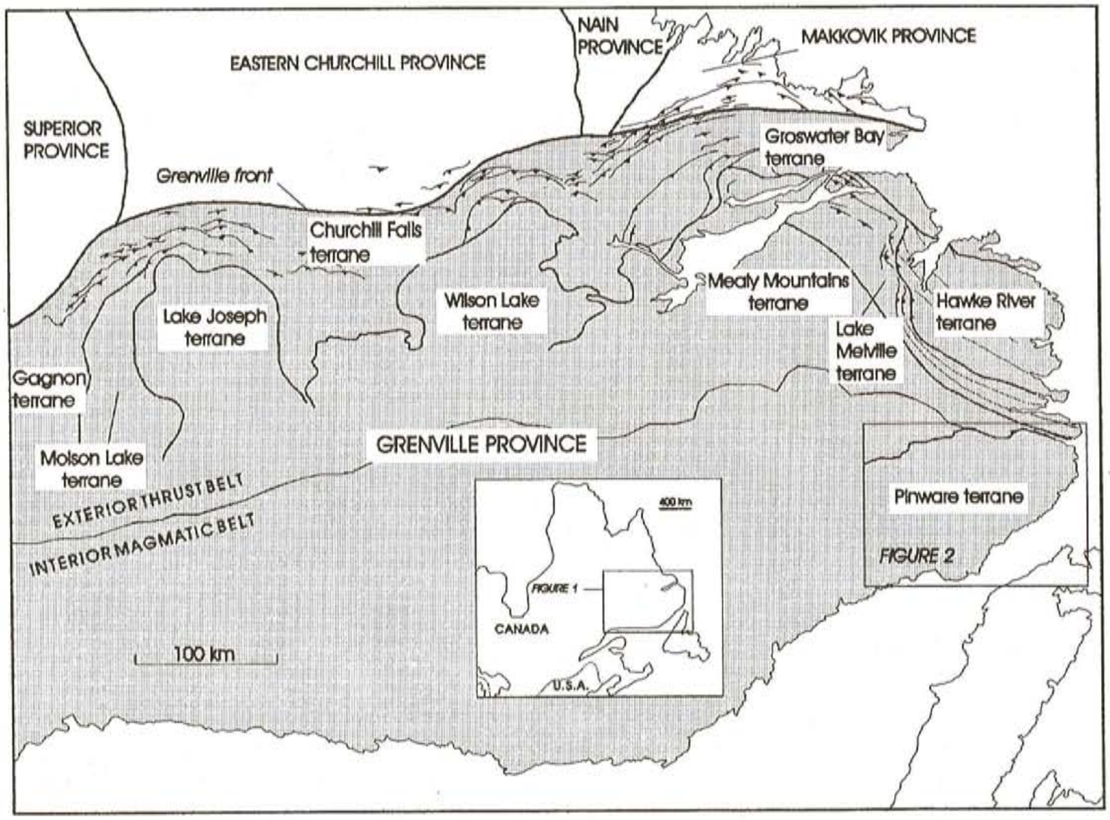

Figure 1. *Geological framework for the eastern Grenville Province; area addressed in this report is shown as Figure 2.*

gneisses. A point emphasized by Gower *et al.* (1993) is the dearth of pelitic rocks in the Pinware terrane, especially when compared to the Labradorian (1710 to 1620 Ma; Gower *et al.*, 1992) terranes farther north. Of particular interest are those rocks suspected to be of volcanic origin, as extrusive rocks are rare in Labradorian terranes, except along the north flank of the Trans-Labrador batholith. The age of the supracrustal rocks in the Pinware terrane is uncertain; preliminary, unpublished U–Pb geochronological data (Royal Ontario Museum) indicate that at least some are Labradorian and the current hypothesis is that all are coeval and pre-1500 Ma (cf. Gower *et al.*, 1994).

U–Pb dating of recrystallized granitoid rocks in the Pinware terrane has provided ages of 1490 $\pm$ 5 Ma, 1479 $\pm$ 2 Ma, and 1472 $\pm$ 3 Ma from three coastal localities (Tucker and Gower, 1994). Inheritance in an inland Grenvillian granite of 1530 $\pm$ 30 Ma (Gower *et al.*, 1991), an age of 1509 $^{+11}_{-12}$ Ma from a granitoid vein at the Pinware–Mealy Mountains terrane boundary (Scott *et al.*, 1993), high-grade metamorphism in the Harte Jaune terrane (west of that part of the Grenville Province shown in Figure 1) at 1469 $\pm$ 5 Ma (Scott and Hynes, 1994) and metamorphism in the basement to the Wakeham Supergroup (slightly below the central part of the southern boundary of Figure 1) at 1495 $\pm$ 2 Ma (Clark and Machado, 1994) suggest that Pinwarian ages (1510 to 1470 Ma) are widespread (see also Gower and Tucker, 1994). Not all strongly deformed granitoid rocks in the Pinware terrane have this age range, and preliminary, unpublished U–Pb geochronological data (Royal Ontario Museum) indicate that some Labradorian orthogneisses are present. Alkali-rich granitoid rocks dominate (granite, alkali-feldspar granite, syenite, alkali-feldspar syenite), grading into monzonite locally. Aegerine- and nepheline-bearing alkali-feldspar syenite also occur. Amphibolite, thought to represent remnants of extremely deformed mafic dykes, is common throughout the unit. Gower *et al.* (1993) noted that, whereas K-feldspar megacrystic rocks associated with pelitic gneisses are characteristic of the Lake Melville terrane, this association is not seen in the Pinware terrane. The small areas of megacrystic rocks that do exist in the Pinware region show neither obvious association with pelitic rocks nor close textural resemblance to those farther north.

Mafic rocks in the Pinware terrane fall broadly into two groups, namely layered mafic intrusions and mafic dykes. The largest mafic plutonic body (110 km long and up to 12 km wide) is located at the boundary between the Mealy Mountains and Pinware terranes and is termed the Kyfanan Lake layered mafic intrusion. That such a large body remained unmapped until 1992 (Gower *et al.*, 1993) illustrates how poorly known some parts of the eastern Grenville Province still remain. The intrusion comprises ultramafic rocks (websterite and clinopyroxenite), gabbronorite, gabbro, leucogabbronorite, anorthositic gabbro and anorthosite. Layering is evident in several places and coronitic textures

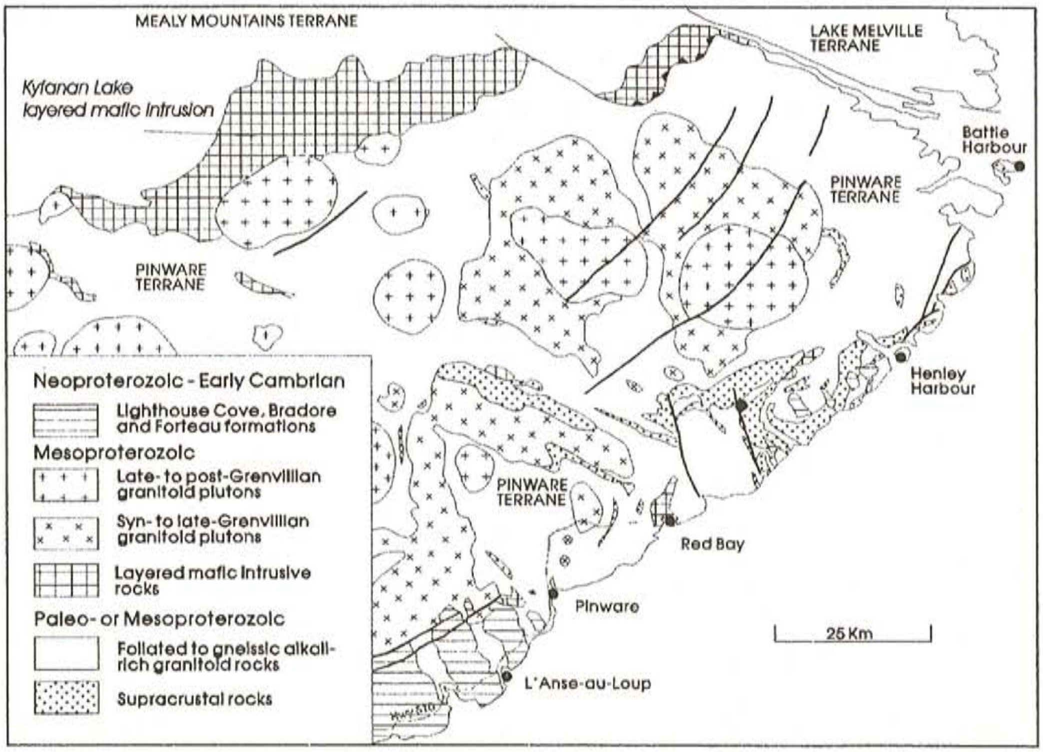

Figure 2. *Simplified geological map of the Pinware terrane, based on Gower* et al. *(1988, 1993, 1994).*

around olivine are common. Several smaller mafic bodies exist in other parts of the Pinware terrane and a wide range of discordant mafic dykes are also present (Gower *et al.*, 1994). The mafic dykes clearly postdate deformation and metamorphism that affected the foliated to gneissic granitoid rocks. It is not established whether or not the mafic dykes and layered mafic intrusions have similar ages, but such a hypothesis is compatible with present data. The rocks are inferred to have been emplaced between ca. 1450 and 1150 Ma. Note that, overall, mafic intrusive rocks are not an important component of the Pinware terrane, in contrast to terranes farther north. The large Kyfanan Lake layered mafic intrusion described by Gower *et al.* (1993) is an exception, but so is its tectonic position (at the probable interface between the Pinware and Mealy Mountains terranes).

A separate group of strongly to weakly foliated granitoid rocks are assumed younger because they apparently lack mafic dykes. It must be kept in mind, however, that these rocks have only been mapped in inland areas, where outcrop is inadequate to be sure that the lack-of-mafic-dykes criterion is valid. The only indication of the age of these rocks comes from a unit dated to be ca. 1145 Ma, but this age is open to interpretation (Tucker and Gower, 1994) and, in any case, need not be representative of the whole group. Granitoid rock types include monzonite, syenite, alkali-feldspar syenite (quartz-bearing varieties), and granites. Some of the deformation shown by these rocks could have occurred during metamorphism at 1000 ± 2 Ma (zircon in amphibolite), dated elsewhere in the Pinware terrane (Tucker and Gower, 1994).

Late- to posttectonic granitoid rocks form discrete monzonite, syenite and granite plutons that are generally circular in plan, are homogeneous and are undeformed. Some show mantled feldspar textures. Their dated emplacement age is between 966 and 956 Ma (Gower and Loveridge, 1987; Gower *et al.*, 1991; Tucker and Gower, 1994). It is clear that this package of rocks also includes earlier plutons (emplaced between 1000 and 960 Ma?). These have undergone some deformation, but escaped the high-grade metamorphic event responsible for the recrystallization, migmatization and strong fabric development in the alkali-rich granitoid rocks. Collectively, the plutons are relatively weakly deformed, but there are differences in fabric between adjacent plutons, which suggest that they were not all emplaced at the same time.

The boundary between the Pinware and Mealy Mountains terranes, excluding that part associated with the Kyfanan Lake layered mafic intrusion, is marked by well-banded gneiss and mylonite (Gower *et al.*, 1988). Along northwest-trending segments of the boundary, foliations are steep (50 to 80° northeast) and lineations plunge moderately to the northwest. Where the boundary is oriented northeast (correlating with particularly well-developed mylonite) foliations dip moderately (20 to 50° northwest) and lineations plunge down dip. No unequivocal kinematic indicators were recorded during reconnaissance mapping, but if mafic plutonic rocks on the northern side of the boundary link up with similar mafic rocks on the south side, 20 km apparent dextral movement and southeast-directed overthrusting of the Pinware terrane by the Mealy Mountains terrane, is implied.

GEOCHEMICAL INTERPRETATION PROCEDURES

The accompanying geochemical figures (Figures 3, 4, 5 and 6) are derived from an interpretation of geochemical analysis of 537 lake-sediment samples collected over the Pinware terrane. For areal completeness, data from some additional sites in the Mealy Mountains and Lake Melville terranes were then included in constructing the actual contour figures.

Cumulative frequency plots and histograms of Ag, Co, Cu, Mo, Ni, Pb, Mo and Zn were prepared and inflection points on the plots, or in some cases, gaps in the histogram distributions, were used to separate the geochemical populations. Inflection points toward the upper end of the population curves were preferentially selected in order to emphasize the distribution of the high-end of the analytical spectra. These points were then used to define the intervals on the accompanying contour maps (Figures 3 and 5). The contour maps themselves were prepared using a computer contouring and map-plotting program (GEOSOFT, 1991). The program uses the raw data to prepare a grid file whereby an orthogonal grid is overlaid on the area. Analytical values are assigned to the grid nodes using an algorithm, which derived the values from the surrounding raw data and places primary emphasis on site proximity. The influence of more remote sample sites falls off exponentially with distance. The final contouring is done on the gridded rather than raw data. This results in a somewhat smoother and different shaped image than that obtained by hand contouring. Partly to illustrate the difference, Figures 4 and 6, prepared by hand contouring prior to obtaining computer-generated contour maps, were retained rather than redrawn. Any hand-drawn contoured map also embodies subtle interpretational bias, an advantage to the user under many circumstances.

NEWLY IDENTIFIED MINERAL-EXPLORATION TARGETS

Four mineral-exploration targets have been newly identified in the Pinware terrane. These are suggested on the basis of geological setting, lake-sediment geochemical data (Geological Survey of Canada, 1984; Friske *et al.*, 1994), and mineral occurrences. The first two targets listed below are considered to be of primary potential significance. The four targets are:

(i) Ni–Co–(V)–(Ag) mineral potential, especially associated with the Kyfanan Lake layered mafic intrusion but possibly including other mafic bodies,

(ii) Cu–Mo–U–Ag mineralization, which may be linked to Mesoproterozoic felsic volcanic rocks, but having Neoproterozoic structural and/or stratigraphic control,

(iii) Amazonite–Mo–F mineralization associated with late- to post-Grenvillian granite and pegmatite, and

(iv) Nepheline in alkali-feldspar syenite.

POTENTIAL Ni–Co–(V)–(Ag) MINERALIZATION

Examination of the regional lake-sediment geochemical data (Figure 3a) shows several small localized Ni anomalies close to the coast and some broader anomalies along the northwest margin of the Pinware terrane. Lake-sediment anomalies for Co (Figure 3b) and V (not illustrated) show a comparable pattern. The Co anomalies appear to be more localized than those for Ni, but this is simply an artifact of the contour intervals used. Interestingly, although there are some significant Cu anomalies (Figure 3c) they do not correlate with those of Ni except along portions of the southeast coast, where, however, they correspond more closely to U, Pb, Mo and Ag (see below). Most of the coastal Ni–Co anomalies can be directly correlated with mafic intrusive bodies; two clear examples are the Red Bay layered mafic intrusion and a small body west of Pinware. Bostock (1983) reported that samples containing chalcopyrite and ilmenite that were shown to him by local people were claimed to have been found in the drift near Red Bay.

There seems little doubt that the large inland lake-sediment Ni and Co anomalies are related to the Kyfanan Lake layered mafic intrusion. In detail, the pattern is suggested to be dependant on two factors: i) the major source of the anomalies is interpreted to be at the northwest side of the body, where the highest values occur; glacial dispersion eastward from this point may have given rise to regionally elevated Ni values, and ii) secondary sources for both Ni and Co anomalies are suggested to exist at the northeastern end of the Kyfanan Lake layered mafic intrusion (where there are also anomalous Ag values; Figure 3d), and along the southern side of part of the body.

That the major source is at the western end of the body is justified further in Figure 4, in which an outline geological map of part of the Kyfanan Lake layered mafic intrusion is superimposed on contoured lake-sediment data for Ni, Co and V. The region is either heavily forested or swamp and the distribution of rock types is only known approximately. Sparse observations of layering attitudes suggest that the body is complexly folded, but the overall distribution of rock types may indicate that it has a broadly synformal shape. Of particular interest are ultramafic rocks located at the borders of the intrusion. Although only shown as sporadic on the northwest side of the body (reflecting where ultramafic rocks were actually observed), they could form a continuous layer along this margin. Conversely, the extent of ultramafic rocks on the southern side may be exaggerated.

The most anomalous Ni lake-sediment samples come from a small lake just to the northwest of the inferred boundary of the layered mafic intrusion. This area forms the ill-defined watershed between the Alexis River and St. Lewis River drainage basins, hence it is likely that the source is local. An abrupt cutoff on the western side of the peak Ni value, but systematically decreasing values to the east, is consistent with eastward glacial dispersion. The peak Ni lake sediment analyzed has somewhat elevated Mn values but this is not the case for the remainder of the samples defining the

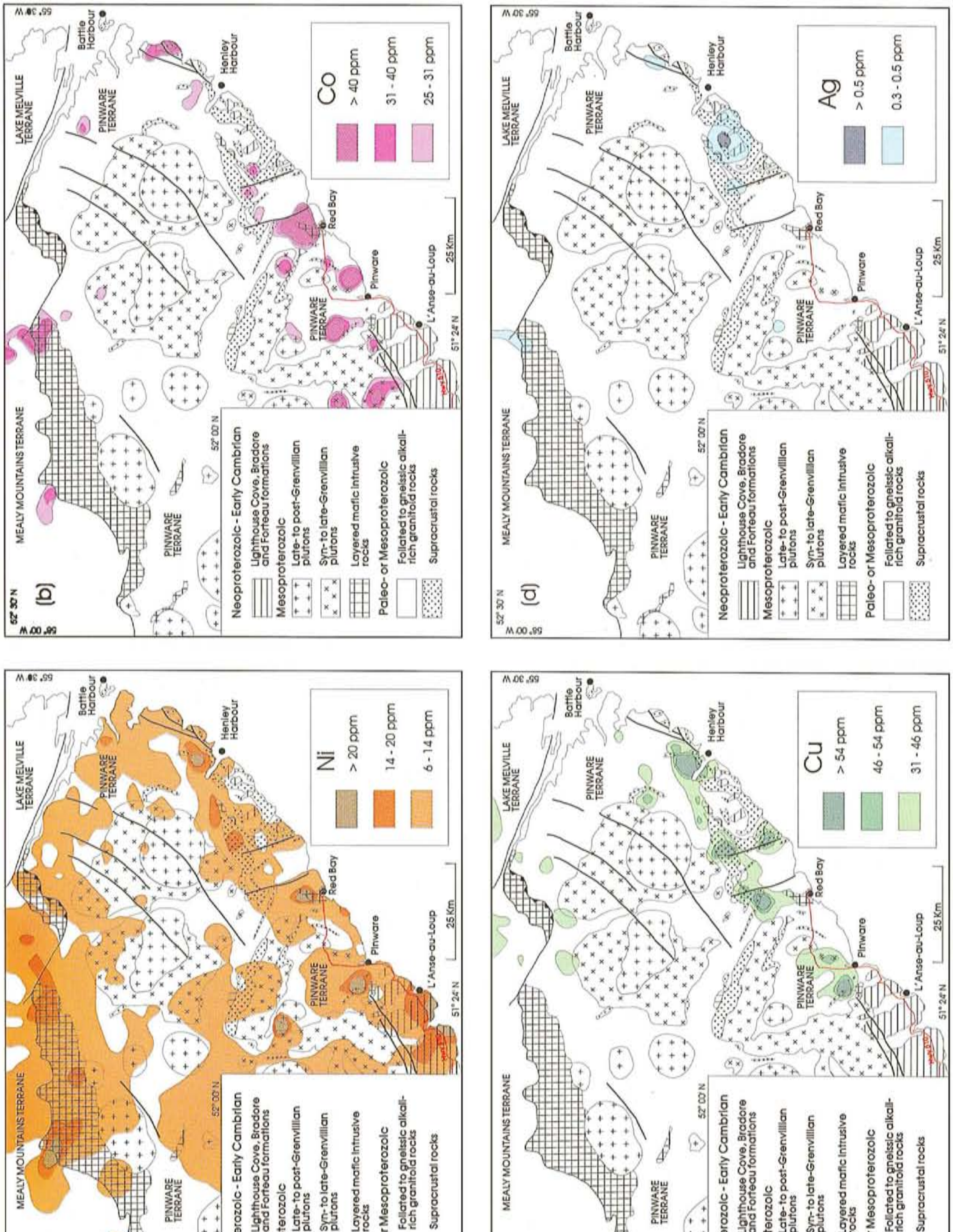

Figure 3. *Distribution of Ni, Co, Cu and Ag in lake sediment in the Pinware terrane, illustrating a correlation between Ni and Co values and layered mafic intrusions. Although the correlation does not extend to Cu, it may include Ag in part.*

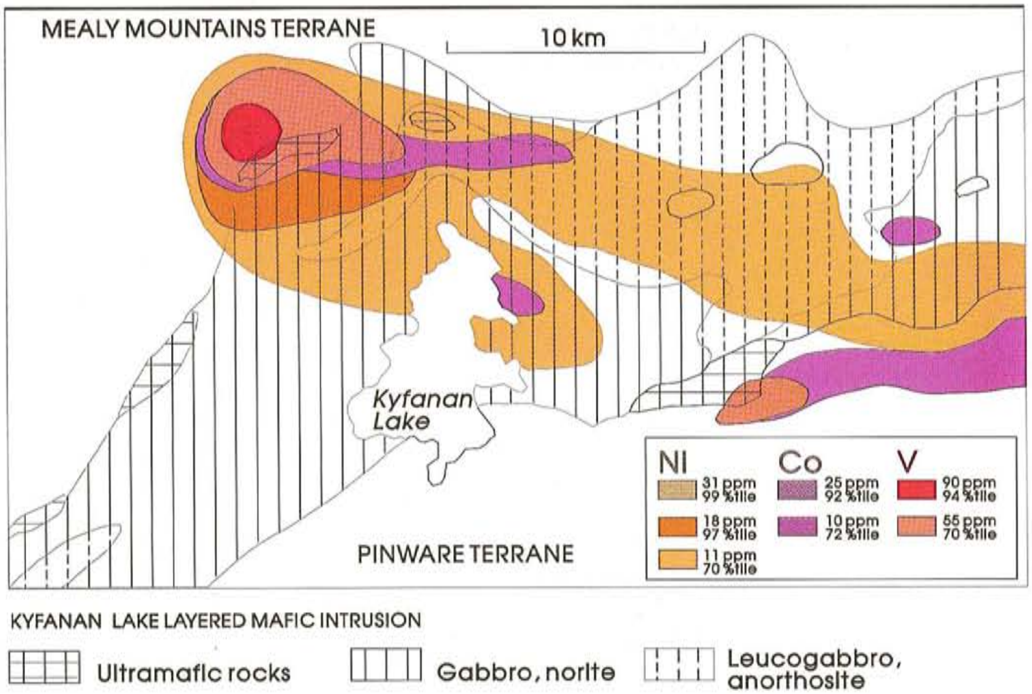

Figure 4. *Part of the Kyfanan Lake layered mafic intrusion showing main Ni–Co–V target on northwest side of body and subsidiary Co–V target on south side. The east-trending 'tails' of the anomalies are interpreted to be due to glacial dispersion.*

dispersion train. Lake-sediment values for Co and V confirm the anomalous primary source, and suggest a secondary source on the southern side of the Kyfanan Lake layered mafic intrusion (Figure 4). As Ni, Co and V are typically concentrated in ultramafic rocks it could be argued that the anomalies are simply due to weathering of the bedrock. If this is so, then similar lake-sediment values should have been obtained from lakes adjacent to the other occurrences of ultramafic rocks, but this does not appear to be the case.

POTENTIAL Cu–Mo–U–Ag MINERALIZATION

Regional lake-sediment Cu geochemical data (Figure 3c), coupled with that for Ag (Figure 3d), U (Figure 5a), Mo (Figure 5b) and Pb (Figure 5c) show well-defined anomalies close to the coast between Red Bay and Henley Harbour. This observation is most applicable to U, but is almost equally valid for Cu and Ag. Note that the pattern does not include Zn (Figure 5d), which, together with Hg (not illustrated), shows a spatial affinity with the posttectonic Grenvillian granites.

Geological features in the Henley Harbour area are overlain on contoured maps showing composite U–Cu lake-sediment anomalies in Figure 6a and Mo–Ag–As anomalies in Figure 6b. Significant in this area are fine-grained, recrystallized quartzofeldspathic rocks thought to be derived in part from felsic volcanic rocks. These are associated with medium- to coarse-grained recrystallized granitoid rocks, commonly so similar to the supracrustal rocks that the distinction between the two units has to be made on a somewhat arbitrary basis in places. The megacrystic granitoid rocks in the southwest part of this area are most likely part of the same package, but the body on the coast southwest of Henley Harbour may be a younger intrusion. The structural configuration is very poorly known. Foliations are consistent in a given area, but may be at right angles from each other in adjacent areas. Whether this is due to superimposed folding or some other cause has not been determined. Mineral occurrences for pyrite, malachite and molybdenite are also shown. The inland molybdenite locality is based on one speck of the mineral seen in hand sample. In all cases, the host rocks are interpreted to have been derived from supracrustal protoliths (Gower *et al.*, 1994).

The U and Cu anomalies (Figure 6a, and Pb–Figure 5c) cover relatively large areas; in contrast those for Mo, Ag and As, which are very localized (Figure 6b). These data are interpreted to mean that there is a regionally high background source for the anomalous metals, coupled with more specific controls that have resulted in a localized concentration. The geologically distinct feature about this region is the high proportion of metamorphosed supracrustal rocks; it seems likely that these are the source for the regionally anomalous metals. The localized control is probably a north-northwest-trending fault passing through the area and which is very obvious on aerial photographs. Note from Figure 6a that another Cu anomaly occurs farther south along the same fault and a larger Cu anomaly correlates with a northeast-trending fault west of Henley Harbour. These faults probably postdate Grenvillian deformation, most likely being related to the opening of Iapetus Ocean. It should be added that, although

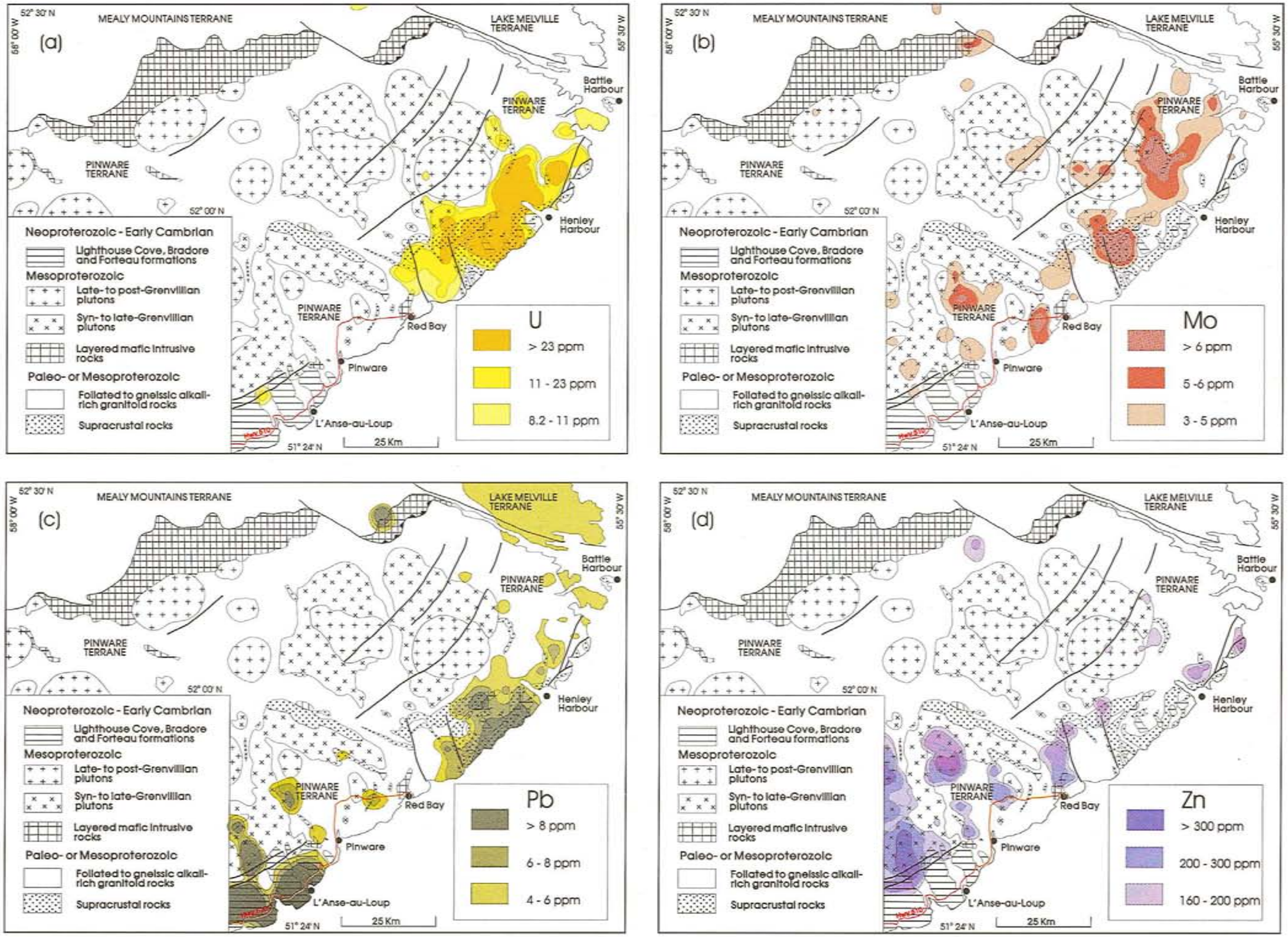

Figure 5. *Distribution of U, Mo, Pb, and Zn in lake sediment in the Pinware terrane. High U, Mo, Pb, Cu (see Figure 3c) and Ag (see Figure 3d) values are concentrated along a coastal strip between Red Bay and Henley Harbour and appear to be regionally correlated with rocks interpreted to have been derived from a supracrustal (possibly felsic volcanic) protolith.*

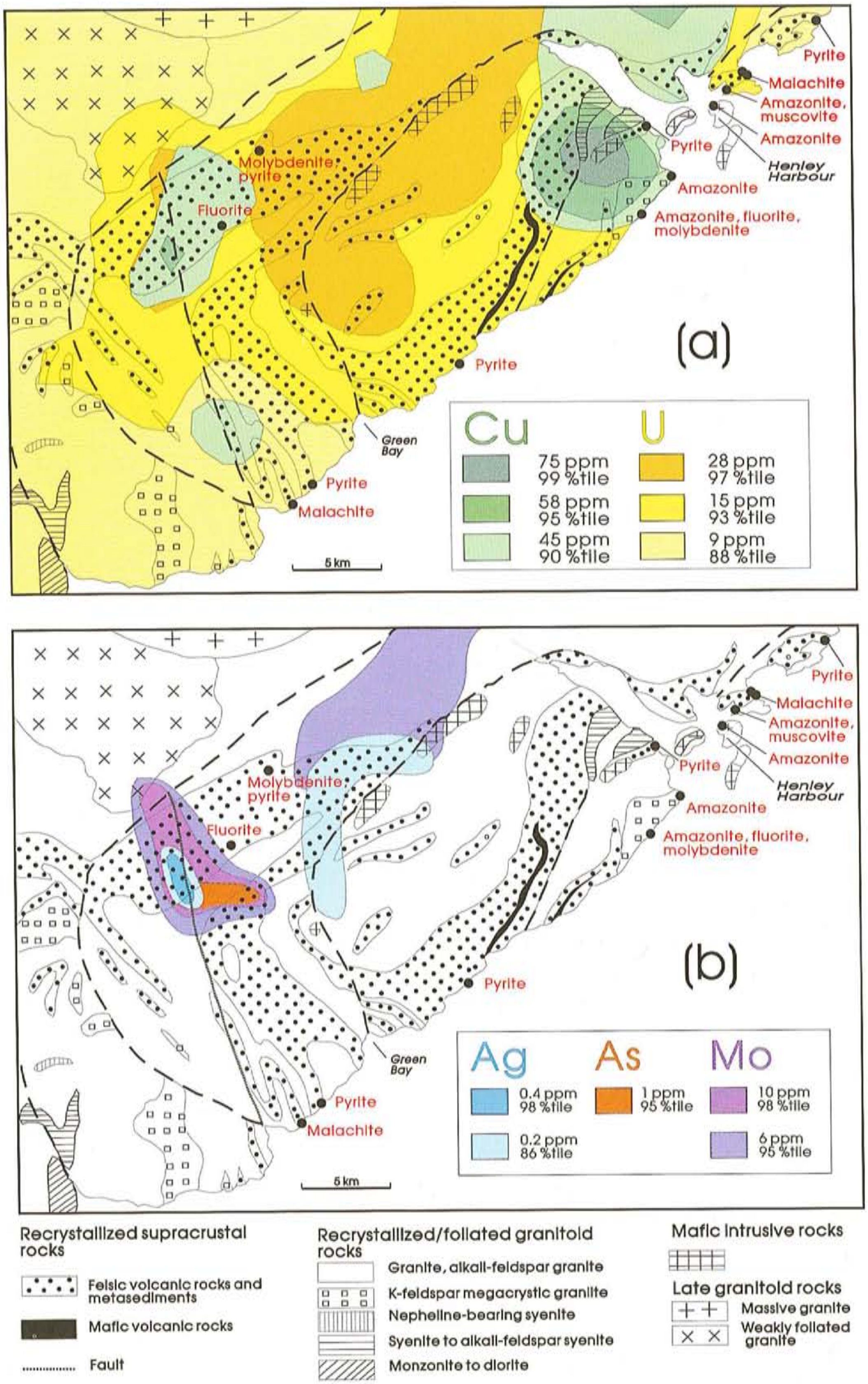

Figure 6. *Enlargement of part of the area near Henley Harbour showing superimposed U and Cu anomalies (6a) and superimposed Mo, Ag and As anomalies (6b). The most obvious target is a multi-element anomaly coinciding with a north-northwest-trending fault intersecting probable supracrustal rocks in the west-central part of the area, but two other Cu anomalies coinciding with faults suggest additional potential.*

not shown on the geological map, Late Neoproterozoic to Early Cambrian arenaceous sediments unconformably overlie parts of the area and some of the high metal values appear to show spatial correlation with these rocks.

As the age of the metamorphosed supracrustal rocks is unknown, it is probably unwise to speculate on their tectonic setting, beyond observing that formation in either an anorogenic rift-related environment or inboard of a continental-margin arc is consistent with present data. The rock types and the association of anomalous metals perhaps suggest either an Olympic-Dam or porphyry-Cu environment.

In contrast, the tectonic setting in the Late Neoproterozoic is much better understood, the rocks and faults being related to the opening of Iapetus Ocean. Three points are pertinent to evaluating fault-related mineralization in the region. First, huge quartz veins in the Pinware terrane (Meyer and Dean, 1986; Gower *et al.*, 1988) provide ample evidence for fluid migration along Iapetus-related faults in the region. Second, it has been suggested that Au mineralization in Newfoundland is fault controlled (Tuach, 1987)—a thesis that could be used to argue that there may be Au mineralization in southeast Labrador, also. Third, although not illustrated in this report, there are other As anomalies in southeasternmost Labrador that correlate with late faults, hence offering additional targets to the one emphasized here.

AMAZONITE–MOLYBDENITE–FLUORITE MINERALIZATION IN PEGMATITE

This target differs from the previous two in that all three minerals have all been observed in the Pinware terrane, occurring in pegmatite dykes, some of which are several metres across.

Amazonite, a green alkali feldspar, is most abundant on the coast in the vicinity of Henley Harbour (Figure 6), but occurrences are known on the coast as far north as Battle Harbour (cf. Gower *et al.*, 1988). The largest known amazonite crystal occurs on the mainland north of Henley Harbour and is at least 50 cm across. The deepest-coloured amazonite found occurs in a coast-parallel pegmatite located halfway between Barge Bay and Wreck Cove. The green colour is attributed to high Pb; it is noteworthy that, excluding areas underlain by carbonate rocks of the Forteau Formation, there is a close correlation between Pb lake-sediment anomalies and the distribution of amazonite (compare Figure 5c and 6).

Both molybdenite and fluorite have been seen as trace minerals associated with amazonite, but it is doubtful whether either is a viable mineral-exploration target, alone. The inland fluorite locality shown in Figure 6 is taken from Bostock (1983), who observed it in thin section. Many of the pegmatites in the Pinware terrane are also extremely rich in magnetite (Hawley, 1944; Gower *et al.*, 1994) and some also have unusually abundant allanite, but genetic relationships to the amazonite-bearing intrusions have not been established.

NEPHELINE

Nepheline- and aegerine-bearing syenitic rocks have recently been discovered in the Pinware terrane, where they are presently known in two areas. One occurrence, southwest of Kyfanan Lake, is quite small, but the other (18 km west of Green Bay cf. Figure 6) is sizable. The Red Bay occurrence was previously reported to be about 1 km long (Gower *et al.*, 1994), but the body is now known to be much larger, following re-examination (by Gower) of thin sections prepared for H. Bostock during his earlier investigation. One thin section from a locality 3.5 km southwest of Gower *et al.* (1994) discovery locality, contains an altered mineral that Bostock, at the time, listed as an 'unknown'. Given the characteristic alteration of the mineral, the fact that the hand sample is essentially identical to the nepheline syenite recorded by Gower *et al.* (1994), and the fact that the two localities are on strike, the 'unknown' can now be confidently identified as nepheline. Other considerations aside, this discovery is an interesting example of the value of retaining samples from previous surveys.

The minimum strike length of the nepheline syenite is now inferred to be 4.5 km, trending in a northeast direction; aerial photographs suggest that it could be longer. Apart from its potential economic significance, the body, when fully mapped out, will form a valuable marker unit. No mineralization is known to be associated with the nepheline syenite (or at any of the aegerine-bearing syenite occurrences) and scintillometer readings were low at all localities. Gower *et al.* (1994) suggested that these rocks might have rare-earth-element potential, but R. Miller (personal communication, 1994) considers this unlikely, based on his previous experience with similar rocks. The economic potential of these rocks may lie in the nepheline itself. The proximity of the body to existing infrastructure (less than 10 km from a paved road and an excellent harbour), and the distinct possibility that presently unmapped extensions are even closer to Red Bay, make this a target worth considering.

SUMMARY

Examination of lake-sediment geochemical data coupled with recently acquired geological information has resulted in the recognition of new mineral-exploration targets in the Pinware terrane. Two specific targets are Ni–Co–V mineralization associated with ultramafic rocks in layered mafic intrusions and Cu–Mo–U–Ag mineralization associated with Proterozoic felsic volcanic rocks (but localized by early Phanerozoic faults and/or an unconformity). Other targets are amazonite–Mo–F mineralization in pegmatites, and nepheline in syenite.

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