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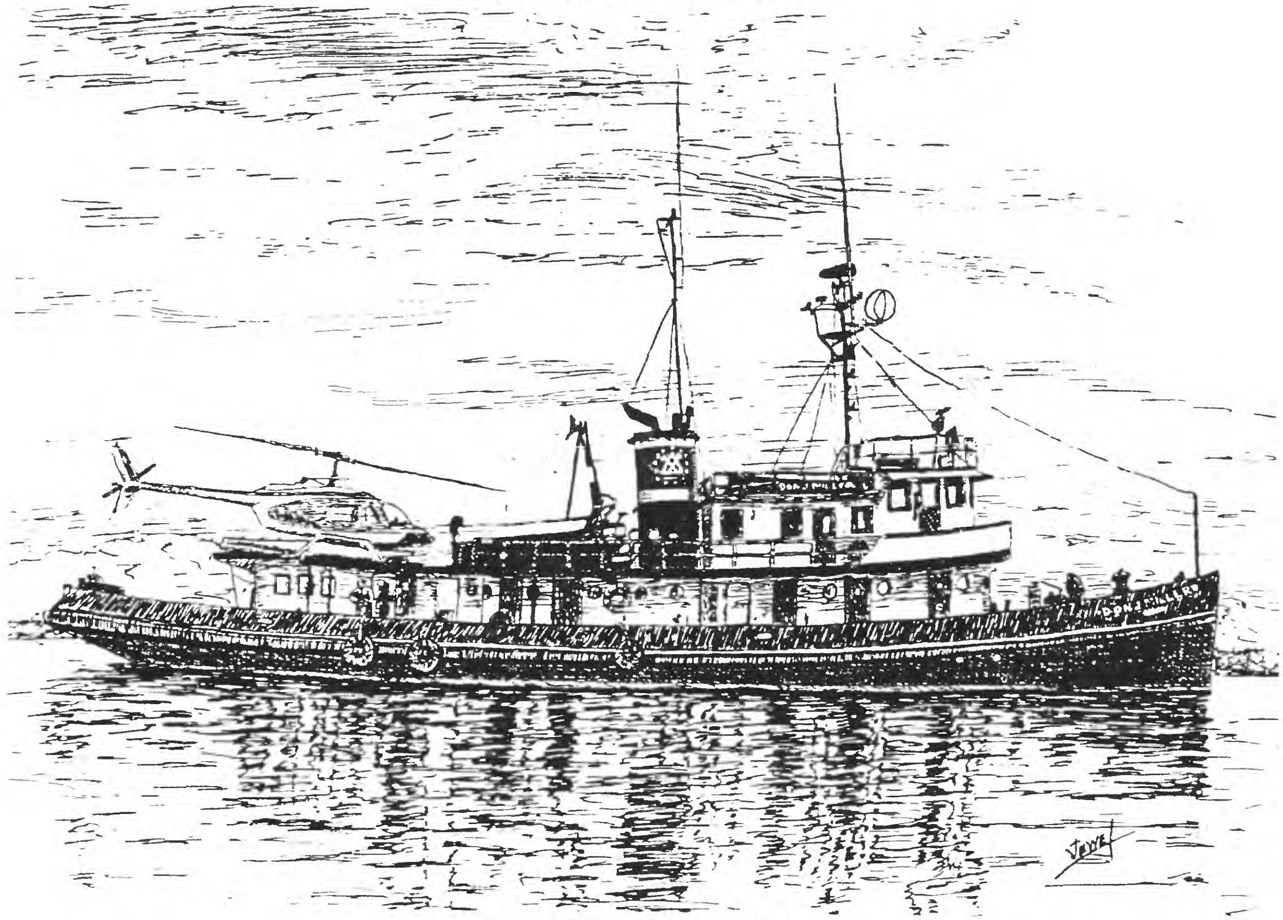

[U.S.G.S. R/V Don J. Miller II]

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By Rainer J. Newberry and David A. Brew

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ABSTRACT

Chemical and isotopic data from samples of drill core and underground exposures at the volcanogenic massive sulfide (VMS) deposit at the Greens Creek mine on Admiralty Island and from VMS prospects on Woewodski Island in the Duncan Canal area about 200 km to the south indicate that both the ores and host rocks have similar compositions. These two localities are within a regional VMS belt of Late Triassic age that extends from the Windy-Craggy deposit to the northwest in British Columbia to Zarembo Island, about 20 km southeast of Woewodski Island. Although there are some felsic volcanic rocks near the Woewodski Island prospects, this VMS belt is distinguished by their absence and by the dominance of metabasalts; as well as by sparse but consistent fossil evidence for their Late Triassic age. Specifically, the major- and trace-element chemical data indicate basaltic compositions for Greens Creek stratigraphic footwall rocks and sedimentary compositions for the stratigraphic hangingwall rocks. The near-absence of bimodal volcanism and the rare-earth-element data indicate that the tectonic environment was not extensional, but are instead arc-related. The corresponding data for the Woewodski Island rocks give similar results. Although the Woewodski Island metavolcanic rocks are not as deformed or altered as those at Greens Creek, they can be confidently grouped together.

INTRODUCTION

The Greens Creek mine contains the largest one known of many volcanogenic massive sulfide (VMS) deposits in southeastern Alaska (Figs. 1, 2). It and the other Late Triassic deposits shown on figure 1 are part of a regional belt that extends to the northwest into British Columbia, where it includes the Windy-Craggy deposit. This belt occurs in rocks assigned to the Alexander terrane by Berg and others (1978), but Brew and Ford (1994) and Brew (1996) interpret them instead to be equivalent to the Wrangellia terrane rocks exposed adjacent to the Alexander terrane. The Devonian(?) VMS deposits shown on figure 1 are in what Brew and Ford (1994) and Brew (1996) call the Behm Canal structural zone and their protoliths may actually be as old as Late Proterozoic and as young as Late Paleozoic. The Late Proterozoic-Early Paleozoic VMS deposits shown on figure 1 are all in the Alexander terrane.

World-wide, VMS deposits of a given age, like the Late Triassic deposits that are the focus of this report, invariably occur in clusters within larger belts. Thus, the presence of one major deposit invariably signals the likelihood for others. Evaluations of undiscovered mineral resources and strategies for exploration and development of Greens Creek-like deposits in southeastern Alaska depend on understanding the origin of the Greens Creek deposit.

Published models for the Greens Creek deposit include: (a) proximal VMS, ores related to felsic volcanics and phreatoclasitic breccias (MacIntyre, 1986); (b) distal VMS, ores related to buildup in felsic tuff-like rocks (Dunbier and others, 1979); (c) sediment-hosted sulfide, with ores related to syn-sedimentary breccias and feeder veins (Dreschler and Dunbier, 1981); and (d) proximal VMS, with ores related to extremely altered and deformed mafic volcanic rocks (Crafford, 1989). Given the degree of chemical and mineralogical alteration typically associated with VMS formation (see Date and others, 1983), and the highly sheared and foliated character of the rocks at Greens Creek, macroscopic and microscopic observations of color, texture, and mineralogy are insufficient to identify the rock protoliths.

These contrasting interpretations and uncertainties regarding the origin of the deposit prompted this study of the major and minor element compositions of the rocks. We also studied the composition of the rocks that enclose VMS prospects on Woewodski Island, in the Duncan Canal area (Fig. 1); these prospects have been interpreted to be of the same Late Triassic age as the Greens Creek deposit (Berg, 1981; Berg and Grybeck, 1980). Finally, we studied the lead isotopes of ores from both locations and from several other VMS prospects in southeastern Alaska in order to further clarify the ages of the deposits.

GENERAL GEOLOGY OF THE GREENS CREEK DEPOSIT

Massive sulfide at the Greens Creek deposit is discontinuously distributed along the contact between a structural hanging wall of thinly laminated quartz-mica-carbonate phyllite and a structural footwall of black graphitic meta-argillite (Fig. 2). *Halobia* present in carbonate-rich black argillite clasts contained within pyritic massive sulfide ore indicate a Late Triassic age for the deposit (N.J. Silberling, U.S. Geological Survey, written communs., 1988, 1989, 1990; Crafford, 1989). Regional structural relationships and locally preserved graded bedding suggest that the stratigraphy at the mine is inverted and that the structural hanging wall rocks originally underlay the VMS deposit. Accepting this suggestion, the stratigraphic footwall rocks are very fine grained (<0.2 mm typically), are very strongly foliated, and have been described both as "mudstones","tuffites", and "exhalites" with an upward-increasing felsic volcanic component (Dunbier and others, 1979) and as sedimentary rocks (Nokelberg et al., 1987). At least four folding events are documented at the mine, however (Crafford, 1979), and their cumulative effect has been to largely obliterate original stratigraphic footwall rock textures.

Given the inverted stratigraphic interpretation, the overall stratigraphy of the Greens Creek Mine is an upward progression from >100 meters of chloritic phyllite (chlorite > carbonate> quartz > sericite), to 0-70 meters of seriticic phyllite (sericite > quartz > carbonate), to 0-20 meters of breccia, to massive sulfide, to (overlying) graphitic calc-argillite and limestone (Newberry and others, 1990). The thickness and silica content of sericitic phyllite increases dramatically in areas proximal to ore. The thicknesses of the breccia unit that is stratigraphically just below the ore horizon are greatest approximately 50-300 m laterally away from major sulfide thicknesses (Crafford, 1979). Carbonated-quartz-mariposite rocks are variably present near the ore horizon, but are distal to massive sulfide ore.

Mafic rocks with recognizable igneous textures are found approximately 2 km north and 1 km west of the Greens Creek mine (Fig. 1). These rocks include massive porphyritic basalt, hornblende clinopyroxenite, and serpentinite. The structural relationship between these rocks and the rocks of the Greens Creek mine is unclear. It is also unclear whether the ultramafic rocks are cumulates related to basaltic volcanism or are unrelated, structurally emplaced bodies.

The structural hangingwall (i.e., stratigraphic footwall) quartz-carbonate-mica phyllite contains variable amounts of ankerite, dolomite, calcite, white mica, chlorite, mariposite, pyrite, and titanium oxides. These rocks are referred to as "footwall phyllite" (Newberry and others, 1997). The carbonate content of these phyllosilicate-rich rocks often exceeds 10% by volume and the rocks typically become progressively more silicic and pyritic with increasing proximity to massive sulfide mineralization (Newberry and others, 1990). Stratigraphically beneath the most Cu-rich part of the orebody is a rock which consists of quartz, pyrite, sericite, and minor chalcopyrite referred to as "siliceous pyritic phyllite". A rare rock type in the stratigraphic footwall package contains visible graphite and is referred to as "graphitic phyllite"; we interpret the organic carbon in this rock to indicate a sedimentary origin. Reflected light petrography indicates that most of the black color in the stratigraphic footwall rocks is, however, due instead to very fine-grained sulfide minerals.

Stratigraphic hangingwall graphitic argillite , referred to as "black argillite", is graphite-rich quartz-mica-carbonate-graphite rock, that is commonly transitional to argillaceous limestone (Newberry and others, 1990). Within about 3 to 6 m of massive sulfide, the black argillite is hard and siliceous. Black argillite is in places (structurally?) interleaved with massive sulfide and footwall phyllite.

GENERAL GEOLOGY OF WOEWODSKI ISLAND

Rock exposures on Woewodski Island, 30 km south of Petersburg, Alaska (Figs. 1, 3), are limited almost exclusively to beaches and stream cuts. Based on similarities to known fossiliferous Triassic rocks to the northwest, most of the metavolcanic rocks on Woewodski Island are interpreted to be of Late Triassic age (Berg, 1981; Berg and Grybeck, 1980; Brew, 1997a, b). However, Cretaceous rocks of the Gravina assemblage are present just east of Woewodski Island, and it is not clear where the contact between Triassic and Cretaceous rocks is located. Lithologies on Woewodski Island include black slate, greenstone of probable basaltic composition, basaltic tuff, limestone, and cherty sulfide-bearing rocks. VMS prospects have been identified at the Helen S. prospect and have been drilled near the center of the island (Fig. 3). Due to the limited exposures, the ages and character of the ores and host rocks are not well-constrained.

ANALYTICAL METHODS

Seventy-one (71) samples were selected for major and minor element analysis during detailed diamond drill core logging and underground and surface mapping in the Greens Creek deposit area. Ten (10) samples from drill core of VMS prospects on central Woewodski Island were also analyzed. Outcrop samples were clean, fresh, 0.5-2.0 kg, composite chip samples. Drill core was sampled by sawing complete 0.2-3.0 m sections lengthwise; and the entire half of the core was ground for analysis. All samples were analyzed for major elements using standard fused-pellet XRF techniques, for FeO by titration, and for minor elements by energy-dispersive XRF. CIPW norms were calculated from the major element analyses using the "Petcal" program (R.D. Koch, U.S. Geological Survey, written commun., 1980). In addition, twenty-three (23) samples from Greens Creek were analyzed for rare earth and additional trace elements by standard Neutron Activation techniques. Galena-rich samples were analyzed for Pb isotopic ratios by Richard Hurst at Chempet laboratories, Moorpark, California.

RESULTS

Locations for, and brief descriptions of, rocks from the Greens Creek Mine area analyzed for this study are given in Table 1. This table also contains (in the column marked by an "*") the rock type symbols which are employed in plotting both the compositional diagrams (Figs. 4-13) and the interpreted protoliths, as based on the major and minor element compositions (Figs. 4-13). Major oxide analyses (Table 2), CIPW normative analyses (Table 3), and minor element analyses (Tables 4-6) are given for selected samples. Location information and major and minor element analyses for rocks of Woewodski Island are given in Tables 7 and 8. Lead isotopic analyses for selected VMS deposits of southeastern Alaska are given in Table 9.

INTERPRETATION

Compositional Characteristics and Protoliths of Rocks from the Greens Creek Deposit and Vicinity

Major element analyses of rocks from the Greens Creek mine area indicate broadly basaltic compositions (Table 2) for the bulk of stratigraphic footwall rocks. However, very high LOI (Loss On Ignition = sum of H_2O + CO_2 + S) values (Table 2) and variably high normative corundum (Table 3) indicate that these rocks are either sedimentary or very strongly altered. MnO, an oxide component commonly associated with hydrothermal alteration, is also present at very anomalous concentrations (Table 2). Because LOI and MnO are roughly proportional (Fig. 4a) for a variety of lithologies, it is likely that the two were introduced together, and the rocks have experienced hydrothermal alteration. Because the rocks have such high LOI's, it is best to compare oxide concentrations normalized to an anhydrous basis.

Of the various major oxides, SiO_2 and TiO_2 are among the most immobile during chemical alteration and it is notable that that bulk of stratigraphic footwall rocks have SiO_2 and TiO_2 contents compatible with mafic and ultramafic protoliths (Fig. 4b). Clearly sedimentary rocks, i.e., hangingwall argillites ("h") and graphitic phyllites ("r") have much higher SiO_2 contents but TiO_2 concentrations elevated relative to rhyolite (Fig. 4b). Only a few of the samples have SiO_2 and TiO_2 contents appropriate for felsic igneous rocks (Fig. 4b).

MgO contents of the greenstones and chloritic phyllites ("c") , serpentinites ("p"), gabbros ("g"), and mariposite-bearing phyllites ("m") are similarly appropriate for mafic and ultramafic rocks (Fig. 5a). Many of the muscovite phyllites ("s") also show SiO_2, TiO_2, and MgO contents appropriate for basaltic rocks (Figs. 4b, 5a). Na_2O concentrations, however, are extremely erratic (Fig. 5b) and reflect the extreme mobility of Na^+ during hydrothermal alteration. Most of the samples are strongly depleted in Na_2O relative to normal igneous and sedimentary rocks (Fig. 5b); two samples from a felsic sill (?) from the mine area ("k") have extremely high Na_2O and keratophyric compositions. Similarly, all of the samples have < 3.0% K_2O, and, despite the apparent abundance of fine grained white mica, are significantly depleted in K_2O relative to felsic igneous rocks (Table 2). Depletion in alkalis, especially Na_2O, is characteristic of alteration developed under VMS deposits (e.g., Date and Watanabe, 1979; Date and others, 1983; Hashiguchi and others, 1983).

CIPW Norms for the samples (Table 3) show variably high corundum and quartz (Fig. 6a). The greenstones and chloritic phyllites have near-zero values for normative corundum and quartz; other footwall phyllites have variably high corundum and low normative quartz, whereas the clearly sedimentary rocks have high normative quartz and variable corundum (Fig. 6a). High normative corundum values in altered igneous rocks result from removal of Na_2O, K_2O, and CaO; the classification of such rocks based on the abundance of alkali elements is consequently dangerous. The normative compositions, however, are consistent with mafic-ultramafic protoliths for the less-altered greenstones, chloritic phyllites, and gabbros; with non-igenous protoliths for the clearly sedimentary rocks, and with a variety of apparent protoliths for the muscovite phyllites (Fig. 6b).

Major oxide compositions plotted in terms of A, C, and F components (Fig. 7) help clarify the nature of the rock protoliths. The rocks with clearly sedimentary protoliths (hangingwall argillite and graphitic phyllite) plot with argillaceous and carbonate rocks. Some of the rocks of apparent mafic-ultramafic parentage plot in fields appropriate to basalts and ultramafic rocks (Fig. 7); however, the bulk do not. If the phyllites were sedimentary rocks, then they would be most likely graywacke. However, less than a third of the analyses plot in the field of typical graywackes (Fig. 7). Given that, a more likely explanation is that the phyllites were mafic rocks (including possibly mafic tuffs) which experienced various degrees of Na_2O (Fig. 5) and especially CaO loss during hydrothermal alteration.

Trace element compositions most clearly indicate the mafic-ultramafic parentage for most of the Greens Creek stratigraphic footwall phyllites. Notably, all these rocks, (except the graphitic and siliceous-pyritic phyllites) contain substantial concentrations of Cr and Ni, whereas the rocks of clearly sedimentary parentage are low in these elements (Fig. 8). We interpret the low abundance of Cr and Ni in the graphic phyllites and siliceous-pyritic phyllites as due to non-igneous parentage and extreme degree of hydrothermal leaching, respectively. Mariposite-bearing phyllites, serpentinites, and gabbroic-appearing rocks show concentrations appropriate to ultramafic rocks; chloritic phyllites, greenstones, and muscovite phyllites (i.e., non-graphitic stratigraphic footwall rocks) have Cr-Ni appropriate to basaltic rocks (Fig. 8). The proportionality in Ni-Cr abundances for the bulk of stratigraphic footwall rocks contrasts sharply with the lack of proportionality in the meta-sedimentary rocks; we interpret both the absolute abundances and elemental proportionalities to indicate that the bulk of footwall rocks were mafic volcanic rocks and not sediments derived from such rocks.

Because standard igenous rock chemical classification schemes are based on the mobile elements Na_2O, K_2O, and CaO, and because these elements are tremendously mobile in VMS environments (Date and others, 1983), chemical classification is more reliably based on "immobile" elements (Winchester and Floyd, 1977). These elements, including Ti, Zr, Y, Nb, and the rare earth elements, are much less susceptible to chemical transport during hydrothermal alteration than most major elements. Further, we consider elemental ratios more reliable than elemental abundances in most cases, because immobile-ellement ratios remain constant despite loss of mobile components or addition of new components (e.g., water, carbonate, sulfide). A SiO_2 vs. Zr/TiO_2 diagram (Fig. 9) shows that with the exception of graphitic and siliceous phyllites, all the stratigraphic footwall rocks at Greens Creek have compositions consistent with basalt and andesite. The bulk of the footwall phyllites are classified as sub-alkalic basalt (Fig. 9).

Concentration of SiO_2 is used in most igenous rock classification schemes, but silica is clearly a mobile constituent in VMS deposits in general and at Greens Creek in particular. Abundant quartz veining in stratigraphic footwall rocks indicates that silica concentrations which suggest andesite to rhyolite composition (Fig. 9) could be of secondary origin. Classification based entirely on immobile element ratios (Fig. 10) indicates that by such a scheme none of the stratigraphic footwall rocks have protoliths more felsic than andesite or trachyandesite. Unfortunately, several of the samples of footwall phyllite conained Y or Nb below detection (Table 4), so that they could not be plotted. However, all these samples contained Zr/TiO_2 ratios below 0.03 (Fig. 9) indicating non-rhyolitic parentage. That most of the samples have immobile element ratios compatible with basalt implies that their protoliths were basaltic or sediments derived from basaltic rocks (e.g., graphitic phyllite, black argillite). The quartzose phyllites are most problematic--they have experienced such intense hydrothermal alteration that it is unclear whether they represent silicified mafic rocks or silicified sediments--but they definately lack the immobile trace element characteristics of felsic volcanic rocks (Figs. 9, 10).

Immobile trace elements are also employed in characterization of the tectonic environment of basaltic rocks. Employing the Zr-Ti-Y diagram (Fig. 11) of Pearce and Cann (1973) yields ambiguous results: least-altered mafic rocks (greenstone and chloritic phyllite) plot in a field ("B") compatible with calc-alkalic arc, tholeiitic arc, or mid-ocean ridge basalt (MORB). Notably, the bulk of the least-altered rocks plot outside of the field of "within plate" (extensional setting) basalt. A non-extensional setting is also compatible with the absence of felsic volcanic rocks. Compositionally bi-modal felsic plus mafic suites are characteristic of extensional settings, as in the Ambler VMS district of the central Brooks Range and the Bonnifield VMS district of the central Alaska Range (Gilbert and Bundtzen, 1979; Schmidt, 1988; Newberry and others, 1997). Sericitic phyllites have compositions (Fig. 11) which plot with and around the field defined by least altered mafic rocks. Such a scatter is consistent with greater degree of hydrothermal alteration of these rocks (e.g., Figs. 5, 6) and the fact that even the most immobile elements exhibit some mobility during extreme hydrothermal alteration (Winchester and Floyd, 1977).

Rare earth element (REE) concentrations are also employed to assess basalt tectonic environments. Existing REE data (Davis and Plafker, 1980; MacIntyre, 1986; McClelland and others, 1991; Gehrels and Barker, 1993) for well-characterized mafic meta-volcanic rocks of northern southeastern Alaska show that units of different ages have contrasting patterns (Fig. 12). In particular, clearly Triassic basalts are different from MORB in that they lack light REE depletion (Fig. 12) but are different from older and younger basalts in lacking light REE enrichment. Within-plate (extensional) basalts invariably display light REE enrichment and arc-related basalts commonly exhibit relatively flat patterns (Henderson, 1984), like those exhibited by the Triassic basalts of southeastern Alaska.

REE abundance data for Greens Creek deposit area rocks most closely resembles that of typical southeastern Alaska Triassic basalts (Figs. 13, 14). Rocks identified by other trace and major elements as having mafic protoliths exhibit relatively flat to slightly light REE-enriched patterns (Fig. 13a). Rocks identified as gabbroic parentage and mariposite-rich phyllites (altered ultramafic rocks?) also exhibit flat patterns but with low REE abundances or positive Eu anomalies (Figs. 13b, 14a) which are characteristic of mafic-ultramafic cumulate rocks (Henderson, 1984). The two breccia samples analyzed for REE's exhibit flat patterns similar to Triassic basalt (Fig. 13), suggesting that these two samples are also of basaltic parentage. Finally, all the other rocks analyzed--including graphitic (sedimentary protolith) rocks from both hangingwall and footwall--have patterns almost identical to the mafic or ultramafic protolith rocks, except that they display distinctly low relative Eu concentrations (Figs. 13, 14). In igneous rocks Eu is present largely in feldspar, whereas the other (smaller) REE's are present largely in minor minerals (e.g., apatite). Feldspars are destroyed--and their Eu released--during both extreme hydrothermal alteration and normal weathering. Consequently, an interpretation of the REE patterns compatible with other trace and major element data is that the rocks surrounding the Greens Creek deposit have mafic/ultramafic protoliths. Further, the graphitic rocks are metasedimentary rocks derived from weathering of mafic rocks, and silica-pyrite-rich rocks are extremely altered mafic or sedimentary rocks. Most notably, all the rocks sampled lack the heavy REE enrichment characteristic of felsic igenous rocks.

Woewodski Island Metavolcanic Rocks--Character and Contrast with other Triassic rocks, including those of the Greens Creek Deposit

Metavolcanic rocks sampled from the vicinity of VMS prospects on Woewodski island were identified in the field as massive greenstone/diabase and as andesitic(?) tuff (Table 8). Major element compositions (Fig. 15) are compatible with basaltic protoliths for the greenstones and indicate that the tuffaceous rocks are either not andesitic or are hydrothermally altered. In particular, the tuffaceous rocks exhibit very high LOI's (Fig. 15a) and very low Na_2O (Fig. 15d). The SiO_2 and MgO contents are compatible with andesitic protoliths but the TiO2 contents are more typical of basaltic rocks (Fig. 15).

Despite significant major element compositional differences, immobile element ratios (Fig. 16a) for the massive and tuffaceous rocks are essentially identical and indicate basaltic protoliths. Classification based on silica and Zr/TiO_2 suggests that the tuffaceous rocks are andesitic (Fig. 16b). These apparently contradictory classifications can be reconciled if the tuffaceous rocks are recognized as strongly altered basaltic tuffs, with addition of silica, losses in MgO and Na_2O, and large LOI.

Abundances of the relatively immobile oxides P_2O_5 and TiO_2 suggests that the Woewodski Island metavolcanic rocks are both basaltic and of Triassic age (Fig. 17). Newberry and others (1995) showed that metavolcanic rocks in northern southeastern Alaska could be distinguished based on concentrations these elements; our data for Woewodski Island metavolcanic rocks plots with the well-characterized field of southeastern Alaskan Triassic basalts (Fig. 17). Although Woewodski Island lies near the contact between Alexander Terrane and the Gravina belt (Fig. 1), and although the Woewodski metavolcanic rocks are not as deformed or altered as those at Greens Creek, they can be confidently grouped together.

Trace element data also suggest similarities between the rocks of the Greens Creek area and those on Woewodski Island (Fig. 18). Permian metabasalts and volcanic rocks of the dominantly Cretaceous Gravina belt plot as "within-plate" and calc-alkalic, respectively, whereas those of Woewodski island plot in field "B", as do the least-altered metabasaltic rocks from Greens Creek (Fig. 11). However, other Triassic basalts from the Juneau-Haines area (Ford and Brew, 1993) contain relatively lower Y concentrations and do not plot with Woewodski Island data. It is unclear whether this apparent difference is statistically significant. The Juneau-Haines area basalts are from what is clearly Wrangellia terrane (Ford and Brew, 1994) that has oceanic or transitional crust as substrate to the Triassic basalts, whereas the volcanic rocks on Woewodski and at Greens Creek are from what Brew and Ford (1994) have interpreted to be Wrangellia-terrane-equivalent rocks that were erupted through a significant thickness of Alexander terrane crust.

Age of VMS Deposits in the Greens Creek-Zarembo Island Belt

Berg and Grybeck (1980) and Berg (1981) inferred that the VMS occurrences on Woewodski and Zarembo Islands were Late Triassic, based on Late Triassic fossils associated with VMS prospects on nearby Kupreanof Island. However, given the absence of radiometric or fossil evidence and the presence of VMS prospects of other ages in southeastern Alaska (Fig.1), this inference remains untested.

Our compositional data for metavolcanic rocks of Woewodski island show them to be indistinguishable from Triassic basaltic rocks of the Greens Creek mine area. In addition, Pb isotopic data (Table 9; Fig. 19) from VMS ores indicates that the Woewodski Island VMS is most likely of Greens Creek age. Newberry and others (1997) have shown that Alaskan VMS deposits exhibit common Pb isotopic ratios which vary with age of the deposit. Our data (Table 9) indicate that Woewodski Island and Greens Creek possess nearly identical common Pb isotopic ratios, both of which fall into the range of data for Triassic-Jurassic deposits of southeastern Alaska and nearby Canada. Additionally, prospects in Cretaceous Gravina group rocks of the Juneau area exhibit common Pb isotopic ratios that are significantly different from those of the Triassic-Jurassic deposits. Thus, it is almost certain that the VMS prospects on Woewodski Island and elsewhere in the Duncan Canal area are of the same age and origin as the Greens Creek deposit.

CONCLUSIONS

Major and trace element data for rocks at Greens Creek and on Woewodski Island indicate the stratigraphic footwall rocks have primarily basaltic and altered basaltic protoliths. There is no evidence for significant associated felsic volcanism at either area. Immobile trace element and rare earth element data suggest that the basaltic rocks are of immature arc affinity and do not represent an extensional environment. At Greens Creek, most of the phyllitic rocks originally stratigraphically beneath the ore are not of sedimentary parentage, and the geologic environment was not likely to have been a spreading center. Major-minor element and Pb isotopic similarities between rocks at Woewodski Island and at Greens Creek confirm previous suggestions that they are part of the same geologic/metallogenic belt.

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Table 1: Descriptions of and Locations for Greens Creek Samples

smpl #	description	*	location	Latitude			Longitude			likely protolith
gc78b	siliceous breccia	x	920 Adit, 1st x-cut	58	4	55	134	38	0	silicified breccia
gc80d	pyrite dolomite musc quartz phyllite	q	1350 Adit: x-cut to ore	58	4	47	134	37	47	altered sediment?
gc80i	pyrite dolomite musc quartz phyllite	q	1350 Adit: x-cut to ore	58	4	47	134	37	47	altered rock
gc80k	pyritic qtz muscovite phyllite	s	1350 Adit: x-cut to ore	58	4	47	134	37	47	altered basalt
gc80m	pyrite dolomite musc quartz phyllite	q	1350 Adit: x-cut to ore	58	4	47	134	37	47	altered basalt?
gc80pq	pyritic quartz muscovite phyllite	s	1350 Adit: x-cut to ore	58	4	47	134	37	47	altered basalt
gc81a	graphitic phyllite	r	1350 Adit	58	4	47	134	37	47	C-rich mudstone
gc82a	chlorite-dolo phyllite	c	Greens Creek Road	58	4	54	134	38	37	basalt
gc82c	dolomite muscovite quartz phyllite	q	Greens Creek Road	58	4	54	134	38	37	altered sediment?
gc83b	dark grey qtz phyllite	q	Greens Creek Road	58	4	49	134	38	50	silicified sediment
gc83c	typical musc phyllite	s	Greens Creek Road	58	4	49	134	38	50	altered basalt
gc84b	metagabbro	g	Greens Creek Road	58	4	44	134	39	32	gabbro
gc84c	mariposite rock	m	Greens Creek Road	58	4	44	134	39	32	altered mafic rock
gc85b	greenstone	c	Greens Creek Road	58	4	35	134	41	50	basalt
gc89a	black argillite	h	Greens Creek Road	58	5	13	134	43	40	carbonaceous mudstone
gc90a	black, siliceous argillite	h	Greens Creek Road	58	5	33	134	44	0	siliceous mudstone
gc93a	siliceous breccia	x	Greens Creek Road	58	5	54	134	44	21	conglomerate?
gc94a	mariposite muscovite dolomite phyllite	m	Greens Creek Road	58	5	58	134	44	24	altered ultramafic rock
gc94b	mariposite muscovite dolomite phyllite	m	Greens Creek Road	58	5	58	134	44	24	altered mafic rock
gc95a	graphitic phyllite	r	Greens Creek Road	58	6	5	134	44	22	C-rich mudstone
gc101a	metagabbro	g	Mariposite Ridge	58	6	12	134	40	40	gabbro
gc102a	metagabbro	g	Mariposite Ridge	58	6	16	134	40	36	gabbro
gc103a	metagabbro	g	Mariposite Ridge	58	6	28	134	41	9	gabbro
gc121b	grey musc phyllite	s	920 Adit "serp"	58	4	55	134	37	55	alt'd basalt
gc122a	greenstone	c	GC 511 90-91'	58	4	30	134	38	0	basalt
gc122b	quartz albite rock	k	GC 511 129.5'	58	4	30	134	38	0	keratophyre
gc122d	quartz albite rock	k	GC 511 169.5'	58	4	30	134	38	0	keratophyre
gc122e	meta-diabase	g	GC 511 203'	58	4	30	134	38	0	altered diabase
gc122f	greenstone	c	GC 511 273'	58	4	30	134	38	0	basalt
gc284b	calcareous argillite	h	920 Adit	58	4	55	134	38	0	calc mudstone
gc284c	tan muscovite dolomite phyllite	s	920 Adit	58	4	55	134	38	0	altered basalt
gc284d	tan muscovite dolomite phyllite	s	920 Adit	58	4	55	134	38	0	altered basalt
gc284e	chlorite cal phyllite	c	920 Adit	58	4	55	134	38	0	basalt
gc284f	siliceous argillite	h	920 Adit	58	4	55	134	38	0	siliceous shale
gc285a	mariposite phyllite	m	1350 Adit	58	4	47	134	37	47	altered mafic rock
gc285b	siliceous argillite	h	1350 Adit	58	4	47	134	37	47	siliceous shale

Table 1: Descriptions of and Locations for Greens Creek Samples, cont.

smpl #	description	*	location	Latitude			Longitude			likely protolith
gc285g	mariposite phyllite	m	1350 Adit	58	4	47	134	37	47	altered mafic rock
gc286a	meta hbl gabbro	g	Mariposite Ridge	58	6	10	134	39	40	hbl gabbro
gc286b	greenstone	c	Mariposite Ridge	58	6	10	134	39	40	basalt
gc286c	metagabbro	g	Mariposite Ridge	58	6	10	134	39	40	gabbro
gc286d	greenstone	c	Mariposite Ridge	58	6	10	134	39	40	basalt
gc286e	serpentinite	p	Mariposite Ridge	58	6	10	134	39	40	ultramafic rock
gc286f	greenstone	c	Mariposite Ridge	58	6	10	134	39	40	basalt
gc287a	mariposite dolomite phyllite	m	MPR-1 258-261'	58	6	3	134	39	21	altered mafic rock
gc287b	greenish-grey muscovite phyllite	s	MPR-1 40-41'	58	6	3	134	39	21	altered basalt
gc287c	tan muscovite dolomite phyllite	s	MPR-1 166-168'	58	6	3	134	39	21	altered basalt
gc288a	grey-tan muscovite dolomite phyllite	s	PS 25 198-199'	58	4	42	134	37	13	altered basalt
gc288b	grey-tan muscovite dolomite phyllite	s	PS 25 223-224'	58	4	42	134	37	13	altered basalt
gc288c	grey musc phyllite	s	PS-25 46-47'	58	4	42	134	37	13	altered basalt
gc288d	grey musc phyllite	s	PS 25 129-130'	58	4	42	134	37	13	altered basalt
gc288e	grey-tan phyllite	s	PS 25 274-275'	58	4	42	134	37	13	altered basalt
gc288f	pyrite musc phyllite	q	PS 25 372-374'	58	4	42	134	37	13	silicified rock
gc289a	tan musc phyllite	s	PS-5 20-25'	58	4	42	134	37	13	altered basalt
gc289b	muscovite phyllite	s	PS-5 135-139'	58	4	42	134	37	13	altered basalt
gc289c	grey-tan phyllite	s	PS-5 295-300'	58	4	42	134	37	13	altered basalt
gc289d	graphitic phyllite	r	PS-5 80-81'	58	4	42	134	37	13	C-rich sediment
gc289e	grey-tan phyllite	s	PS-5 85-86'	58	4	42	134	37	13	altered basalt
gc289f	grey-tan phyllite	s	PS-5 558-560'	58	4	42	134	37	13	altered basalt
gc289g	breccia	x	PS-5 440-442'	58	4	42	134	37	13	silicified breccia
gc289h	greenish-grey muscovite phyllite	s	PS-5 631-635'	58	4	42	134	37	13	altered basalt
gc289i	breccia	x	PS-5 366-369'	58	4	42	134	37	13	silicified breccia
gc289j	grey siliceous phyllite	q	PS-5 696-698'	58	4	42	134	37	13	silicified rock
gc290a	grey musc phyllite	s	GC-139 955-957'	58	4	27	134	37	2	altered basalt
gc291a	serpentinite	p	PS-83 978-980'	58	4	23	134	38	51	ultramafic rock
gc293a	greenish-tan phyllite	s	GC-11 32-34'	58	4	48	134	37	23	altered basalt
gc293b	chlorite phyllite	c	GC-11 89-90'	58	4	48	134	37	23	basalt
gc293d	grey-tan phyllite	s	GC-11 240-242'	58	4	48	134	37	23	altered basalt
gc294a	greenish-tan phyllite	s	GC-67 8-10'	58	4	36	134	37	9	altered basalt
gc294b	grey musc phyllite	s	GC-67 78-80'	58	4	36	134	37	9	altered basalt
gc294c	tan-grey phyllite	s	GC-67 101-102'	58	4	36	134	37	9	altered basalt
gc294d	dark grey phyllite	s	GC-67 156-157'	58	4	36	134	37	9	altered basalt

* = symbol used on figures

Table 2: Major Oxide compositions for Greens Creek Samples

smpl #	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	tot[1]	LOI[2]	S	H_2O	CO_2	sum[3]
gc78b	85.7	4.12	2.70	0.16	0.60	0.80	0.20	1.00	0.22	0.08	0.02	95.6	2.49	2.76	0.63	1.76	100.8
gc80d	57.1	8.74	3.60	4.76	4.90	2.32	0.65	1.64	0.32	0.16	0.17	84.4	10.60	4.7	1.03	10.6	100.7
gc80i	60.4	6.41	0.10	9.10	5.40	0.46	0.65	0.74	0.24	0.08	0.19	83.8	12.17	5.68	1.08	9.74	100.3
gc80k	37.8	7.73	0.20	13.65	9.40	1.08	1.40	0.18	0.92	0.16	0.44	73.0	19.91	10.2	1.2	16	100.4
gc80m	51.7	8.04	0.40	9.33	7.60	0.26	0.95	0.72	0.36	0.14	0.37	79.9	15.23	7.44	1.47	11.4	100.2
gc80pq	22.0	11.1	0.22	12.72	11.30	7.50	0.65	1.48	0.90	0.16	0.81	68.8	16.39	10.6	2.2	18.9	100.5
gc81a	63.6	12.8	0.60	4.11	2.50	1.24	1.10	2.36	0.50	0.20	0.08	89.1	7.05	4.26	1.79	5.25	100.4
gc82a	47.4	14.0	3.20	7.39	10.90	8.08	2.30	0.92	1.22	0.12	0.26	95.8	3.14	0.01	3.64	0.08	99.5
gc82c	69.3	10.7	1.30	5.26	5.80	0.22	0.70	1.74	0.44	0.16	0.18	95.8	3.55	0.32	3.68	0.1	99.9
gc83b	76.3	5.60	0.80	4.00	4.90	1.50	0.20	0.44	0.28	0.32	0.19	94.5	3.50	1.35	2.6	1.91	100.4
gc83c	45.6	13.8	2.80	11.70	11.50	0.76	1.24	0.24	1.40	0.44	0.36	89.8	7.32	3.76	6.45	0.26	100.3
gc84b	51.2	13.4	1.50	7.55	9.80	7.40	4.30	0.12	0.86	0.12	0.26	96.5	2.47	0.01	3.35	0.01	99.9
gc84c	44.8	19.6	0.86	7.23	13.90	0.46	5.20	0.70	0.10	0.04	0.25	93.1	6.24	0.32	5.91	0.21	99.6
gc85b	47.8	17.4	2.40	8.06	8.00	3.30	5.00	0.84	0.94	0.44	0.13	94.3	4.00	0.01	4.36	0.51	99.2
gc89a	56.2	14.8	1.90	4.40	3.40	2.54	1.90	3.04	0.82	0.34	0.14	89.5	5.50	2.2	2.9	5.83	100.4
gc90a	82.9	6.08	0.25	2.11	2.60	0.48	0.55	1.14	0.22	0.06	1.80	98.2	1.65	0.01	1.7	0.65	100.6
gc93a	63.9	8.91	0.06	3.15	0.55	5.24	0.20	2.36	0.39	3.76	0.03	88.6	6.25	5.35	1.25	4.9	100.1
gc94a	39.1	2.09	0.15	4.69	27.60	5.60	0.20	0.03	0.06	0.01	0.08	79.6	15.88	0.44	3.91	17.4	101.4
gc94b	44.8	20.3	0.26	6.00	13.60	1.88	2.60	1.40	0.24	0.02	0.08	91.2	7.67	0.01	6.96	1.86	100.0
gc95a	68.0	14.1	1.50	3.73	2.10	0.44	4.50	1.08	0.60	0.30	0.10	96.5	2.49	0.17	1.78	2.4	100.8
gc101a	45.4	21.6	1.02	2.21	8.60	11.5	3.80	0.03	0.08	0.01	0.05	94.3	5.46	0.01	5.18	0.2	99.7
gc102a	44.5	21.1	0.50	3.72	10.10	10.3	3.10	0.60	0.10	0.01	0.07	94.1	5.68	0.01	5.51	0.17	99.8
gc103a	44.5	19.4	0.70	3.03	9.70	14.9	2.50	0.03	0.14	0.01	0.09	95.0	5.12	0.01	4.71	0.14	99.9
gc121b	53.2	11.0	1.55	7.62	16.6	0.56	0.10	0.01	0.56	0.03	0.22	91.5	7.35	-	6.76	0.94	99.2
gc122a	48.9	10.1	1.92	6.98	12.9	9.7	0.69	2.86	1.28	0.25	0.19	95.8	2.91	-	3.25	0.84	99.9
gc122b	66.3	17.7	0.53	2.07	1.02	1.1	7.57	1.68	0.13	0.03	0.09	98.2	1.57	-	0.89	0.74	99.9
gc122d	67	17.9	0.84	1.34	0.54	1.7	7.00	1.81	0.13	0.02	0.06	98.3	1.16	-	0.71	0.6	99.7
gc122e	44.4	8.59	1.95	7.02	13.5	16.4	0.43	0.44	1.24	0.06	0.19	94.2	4.75	-	2.84	3.05	100.1
gc122f	43.5	10.6	2.08	8.49	10.7	12.9	1.14	1.58	1.49	0.2	0.2	92.9	5.98	-	3.06	3.34	99.3

Notes: [1]tot = total of anhydrous oxide components; [2] LOI = Loss On Ignition to 925° C; [3] sum = oxide total + S + CO_2 + H_2O

Table 2: Major Oxide compositions for Greens Creek Samples, cont

smpl #	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	LOI	SUM
gc284b	51.3	5.35	1.05	0.80	6.10	14.20	0.59	0.61	0.26	0.06	0.08	17.10	97.5
gc284c	48.4	12.5	2.20	13.0	4.29	2.22	1.20	2.14	1.41	0.16	0.16	10.30	97.98
gc284d	39.8	13.0	1.90	9.00	5.80	7.74	1.44	2.11	1.50	0.17	0.16	13.90	96.52
gc284e	40.6	15.6	1.50	11.0	6.21	6.80	1.99	2.74	1.63	0.16	0.13	11.60	99.96
gc284f	69.1	14.0	1.95	2.65	1.43	0.47	2.92	2.41	0.50	0.16	0.06	4.20	99.85
gc285a	24.8	13.0	3.70	3.00	16.90	9.09	0.47	2.11	0.24	0.02	0.54	24.60	98.47
gc285b	83.6	3.65	1.90	1.33	1.47	3.08	0.22	0.52	0.17	0.03	0.01	4.25	100.2
gc285g	41.6	19.6	1.68	3.00	12.90	3.64	0.89	4.48	0.13	0.03	0.33	10.60	98.88
gc286a	32.4	12.4	2.20	20.0	8.89	13.10	0.37	0.18	1.92	2.12	0.29	4.41	99.18
gc286b	45.3	15.3	2.10	8.75	8.41	6.12	0.89	2.54	1.33	0.19	0.20	8.63	99.76
gc286c	45.8	5.97	2.60	4.81	13.30	19.80	0.53	0.97	0.72	0.16	0.14	5.19	99.99
gc286d	48.2	14.5	3.40	10.8	7.97	5.52	2.90	0.01	1.99	0.21	0.22	3.91	99.63
gc286e	41.3	1.80	0.20	6.80	37.20	0.14	0.07	0.01	0.01	0.03	0.13	11.50	99.19
gc286f	44.8	12.3	3.00	7.90	8.79	6.62	2.31	0.78	1.38	0.15	0.49	11.20	99.72
gc287a	37.4	11.7	2.00	5.88	11.70	7.30	0.38	1.64	0.12	0.03	0.94	19.80	98.89
gc287b	47.9	16.1	3.30	8.60	5.74	3.01	2.30	3.06	1.00	0.50	0.52	6.94	98.97
gc287c	47.9	13.0	6.30	5.14	4.05	3.00	1.63	3.12	0.81	0.42	0.45	9.63	95.45
gc288a	43.4	10.5	3.90	9.00	9.23	0.85	0.85	2.72	1.35	0.16	0.61	16.00	98.57
gc288b	47.4	9.94	2	11.2	9	0.26	0.22	2.38	0.43	0.14	0.47	15.2	98.64
gc288c	42.1	15.3	1.70	9.62	7.07	1.09	3.34	2.47	2.14	0.23	0.32	13.90	99.28
gc288d	44.7	8.85	2.75	6.00	9.62	6.86	1.27	1.07	0.34	0.16	0.66	10.20	92.48
gc288e	34.5	8.06	4.00	5.00	9.09	10.50	0.29	2.18	0.51	0.16	1.21	18.20	93.7
gc288f	70.9	7.09	0.10	9.30	1.07	1.19	0.01	2.12	0.29	0.12	0.03	6.22	98.44
gc289a	44.2	12.7	2.00	10.0	6.97	4.11	2.03	0.64	0.76	0.08	0.09	12.80	96.38
gc289b	43.8	5.18	2.70	3.00	7.63	12.70	1.25	0.73	0.29	0.08	0.40	18.50	96.26
gc289c	29.3	10.8	4.00	8.00	14.10	2.80	3.86	0.49	1.34	0.15	0.59	19.50	94.93
gc289d	58.6	4.51	2.40	6.00	4.00	6.40	0.10	1.07	0.26	0.06	0.13	10.10	93.63
gc289e	36.3	12.3	2.00	9.00	8.00	8.40	1.75	1.33	0.60	0.08	0.30	14.80	94.86
gc289f	49.8	15.5	2.60	7.00	8.21	2.51	1.96	2.00	1.63	0.17	0.47	6.98	98.83
gc289g	51.3	4.94	1.40	1.98	11.50	9.83	0.10	0.30	0.33	0.07	0.82	16.00	98.57
gc289h	43.1	12.3	2.20	8.38	8.14	9.53	1.40	0.82	1.48	0.15	0.46	11.00	98.96
gc289i	58.6	6.85	1.40	2.00	7.56	7.13	0.78	0.89	0.48	0.18	0.63	11.00	97.5
gc289j	74.3	10.1	0.20	3.20	3.66	0.52	1.23	2.44	0.26	0.06	0.15	2.93	99.05
gc290a	35.8	16.2	1.00	10.4	16.80	2.15	0.10	0.20	1.45	0.02	0.33	9.16	93.61
gc291a	40.7	0.88	0.20	6.50	36.00	1.83	0.10	0.01	0.01	0.02	0.15	11.90	98.3
gc293a	47.8	13.1	1.30	12.4	10.40	2.22	0.92	1.03	1.68	0.33	0.46	6.76	98.38
gc293b	46.6	12.6	2.30	9.64	9.43	4.25	0.73	1.40	1.69	0.17	0.39	9.63	98.83
gc293d	41.2	8.78	2.00	18.5	5.66	0.97	0.89	2.36	1.08	0.13	0.37	15.70	97.64
gc294a	46.2	14.8	0.60	15.1	9.20	0.37	1.21	1.50	1.28	0.16	0.29	8.54	99.25
gc294b	45.3	10.8	2.00	8.60	10.20	5.94	1.67	0.35	1.28	0.19	0.67	9.08	96.08
gc294c	44.1	12.3	2.50	9.30	10.00	5.00	2.16	0.25	1.57	0.19	0.59	8.45	96.41
gc294d	43.1	13.1	2.70	11.6	15.30	0.71	0.10	0.31	0.98	0.25	0.53	10.70	99.73

TABLE 3: CIPW NORMS FOR GREENS CREEK SAMPLES

Smpl #	Qtz	Co	Or	Ab	An	Le	Ne	Wo	Di	Hy	Ol	Ca Or	Mt	Hm	Ilm	Ap
gc78b	81.9	1.5	6.2	1.8	3.6	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	2.8	0.4	0.2
gc80d	38.8	2.4	11.5	6.5	12.4	0.0	0.0	0.0	0.0	21.1	0.0	0.0	6.2	0.0	0.7	0.4
gc80i	44.7	4.7	5.2	6.6	2.1	0.0	0.0	0.0	0.0	35.9	0.0	0.0	0.2	0.0	0.5	0.2
gc80k	2.9	5.0	1.5	16.2	5.9	0.0	0.0	0.0	0.0	65.3	0.0	0.0	0.4	0.0	2.4	0.5
gc80m	30.3	7.0	5.3	10.1	0.5	0.0	0.0	0.0	0.0	44.9	0.0	0.0	0.7	0.0	0.9	0.4
gc80pq	0.0	0.0	0.0	0.0	33.4	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
gc81a	44.3	7.5	15.7	10.5	5.4	0.0	0.0	0.0	0.0	14.1	0.0	0.0	1.0	0.0	1.1	0.5
gc82a	0.0	0.0	5.7	20.3	26.3	0.0	0.0	0.0	11.8	17.8	10.5	0.0	4.8	0.0	2.4	0.3
gc82c	48.2	8.0	10.7	6.2	0.1	0.0	0.0	0.0	0.0	23.6	0.0	0.0	2.0	0.0	0.9	0.4
gc83b	64.4	3.0	2.8	1.8	5.7	0.0	0.0	0.0	0.0	19.9	0.0	0.0	1.2	0.0	0.6	0.8
gc83c	13.3	12.4	1.6	11.7	1.0	0.0	0.0	0.0	0.0	51.4	0.0	0.0	4.5	0.0	3.0	1.1
gc84b	0.0	0.0	0.7	37.7	17.5	0.0	0.0	0.0	15.9	8.7	15.2	0.0	2.3	0.0	1.7	0.3
gc84c	0.0	10.3	4.4	41.9	2.2	0.0	2.9	0.0	0.0	0.0	36.7	0.0	1.3	0.0	0.2	0.1
gc85b	0.0	3.5	5.3	44.9	14.3	0.0	0.0	0.0	0.0	4.3	21.1	0.0	3.7	0.0	1.9	1.1
gc89a	24.0	5.1	20.1	18.0	11.6	0.0	0.0	0.0	0.0	15.5	0.0	0.0	3.1	0.0	1.7	0.9
gc90a	68.8	3.3	6.9	4.7	2.0	0.0	0.0	0.0	0.0	13.4	0.0	0.0	0.4	0.0	0.4	0.1
gc93a	56.4	6.2	15.8	1.9	1.6	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.1	0.0	0.8	9.8
gc94a	0.0	0.0	0.2	2.1	5.9	0.0	0.0	0.0	22.8	25.1	43.4	0.0	0.3	0.0	0.1	0.0
gc94b	0.0	12.2	9.1	24.1	10.1	0.0	0.0	0.0	0.0	30.4	13.2	0.0	0.4	0.0	0.5	0.1
gc95a	33.5	5.7	6.6	39.5	0.2	0.0	0.0	0.0	0.0	10.4	0.0	0.0	2.3	0.0	1.2	0.7
gc101a	0.0	0.0	0.2	18.1	44.3	0.0	8.7	0.0	12.7	0.0	14.3	0.0	1.6	0.0	0.2	0.0
gc102a	0.0	0.0	3.8	14.3	44.5	0.0	7.4	0.0	7.7	0.0	21.3	0.0	0.8	0.0	0.2	0.0
gc103a	0.0	0.0	0.2	6.4	43.8	0.0	8.6	0.0	26.9	0.0	12.7	0.0	1.1	0.0	0.3	0.0
gc121b	23.2	10.8	0.1	0.9	2.8	0.0	0.0	0.0	0.0	58.5	0.0	0.0	2.5	0.0	1.2	0.1
gc122a	0.0	0.0	17.7	6.1	16.7	0.0	0.0	0.0	25.4	19.9	8.2	0.0	2.9	0.0	2.5	0.6
gc122b	10.7	1.5	10.1	65.2	5.4	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.8	0.0	0.3	0.1
gc122d	14.5	1.4	10.9	60.2	8.4	0.0	0.0	0.0	0.0	3.1	0.0	0.0	1.2	0.0	0.3	0.1
gc122e	0.0	0.0	2.8	2.9	21.5	0.0	0.6	0.0	51.5	0.0	15.3	0.0	3.0	0.0	2.5	0.2
gc122f	0.0	0.0	10.1	5.2	20.6	0.0	2.8	0.0	37.8	0.0	16.7	0.0	3.3	0.0	3.1	0.5
gc284b	23.6	0.0	4.5	6.2	12.6	0.0	0.0	8.9	41.5	0.0	0.0	0.0	1.9	0.0	0.6	0.2
gc284c	15.3	5.2	14.4	11.6	11.4	0.0	0.0	0.0	0.0	35.0	0.0	0.0	3.6	0.0	3.1	0.4
gc284d	0.0	0.0	15.1	14.8	27.6	0.0	0.0	0.0	14.5	7.2	13.7	0.0	3.3	0.0	3.5	0.5
gc284e	0.0	0.0	18.3	11.2	28.9	0.0	4.3	0.0	6.7	0.0	24.2	0.0	2.5	0.0	3.5	0.4
gc284f	40.8	6.4	14.9	25.8	1.4	0.0	0.0	0.0	0.0	6.4	0.0	0.0	3.0	0.0	1.0	0.4
gc285a	0.0	0.0	0.0	0.0	36.7	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
gc285b	76.1	0.0	3.2	1.9	7.8	0.0	0.0	0.0	6.3	1.5	0.0	0.0	2.9	0.0	0.3	0.1
gc285g	0.0	7.6	30.0	8.5	20.2	0.0	0.0	0.0	0.0	3.6	26.9	0.0	2.8	0.0	0.3	0.1
gc286a	0.0	0.0	0.0	0.0	33.4	0.9	1.8	0.0	9.7	0.0	39.0	2.8	3.4	0.0	3.9	5.2
gc286b	0.0	0.5	16.5	8.3	32.0	0.0	0.0	0.0	0.0	35.1	1.2	0.0	3.3	0.0	2.8	0.5
gc286c	0.0	0.0	0.0	0.0	11.7	4.7	2.6	0.0	65.8	0.0	7.1	2.4	4.0	0.0	1.4	0.4
gc286d	1.8	0.2	0.1	25.6	27.2	0.0	0.0	0.0	0.0	35.5	0.0	0.0	5.2	0.0	4.0	0.5

TABLE 3: CIPW NORMS FOR GREENS CREEK SAMPLES, CONT.

Smpl #	Qtz	Co	Or	Ab	An	Le	Ne	Wo	Di	Hy	Ol	Ca Or	Mt	Hm	Ilm	Ap
gc286e	0.0	1.7	0.1	0.7	0.6	0.0	0.0	0.0	0.0	39.5	57.1	0.0	0.3	0.0	0.0	0.1
gc286f	0.0	0.0	5.2	22.1	23.6	0.0	0.0	0.0	10.0	28.0	2.9	0.0	4.9	0.0	3.0	0.4
gc287a	0.0	0.0	12.3	4.1	32.1	0.0	0.0	0.0	10.8	15.1	21.6	0.0	3.7	0.0	0.3	0.1
gc287b	3.9	5.1	19.7	21.2	12.7	0.0	0.0	0.0	0.0	29.0	0.0	0.0	5.2	0.0	2.1	1.3
gc287c	15.7	2.9	21.5	16.1	14.2	0.0	0.0	0.0	0.0	16.1	0.0	0.0	10.6	0.0	1.8	1.1
gc288a	8.9	6.1	19.5	8.7	3.8	0.0	0.0	0.0	0.0	42.6	0.0	0.0	6.9	0.0	3.1	0.5
gc288b	17.7	8.2	16.9	2.2	0.5	0.0	0.0	0.0	0.0	49.7	0.0	0.0	3.5	0.0	1.0	0.4
gc288c	0.0	6.7	17.1	33.1	4.6	0.0	0.0	0.0	0.0	14.1	16.2	0.0	2.9	0.0	4.8	0.6
gc288d	5.1	0.0	7.7	13.1	18.6	0.0	0.0	0.0	17.3	32.2	0.0	0.0	4.9	0.0	0.8	0.5
gc288e	0.0	0.0	11.5	0.0	18.9	4.4	1.8	0.0	39.0	0.0	15.1	0.0	7.7	0.0	1.3	0.5
gc288f	55.7	3.2	13.6	0.1	5.6	0.0	0.0	0.0	0.0	20.9	0.0	0.0	0.2	0.0	0.6	0.3
gc289a	4.6	1.7	4.5	20.6	23.8	0.0	0.0	0.0	0.0	39.5	0.0	0.0	3.5	0.0	1.7	0.2
gc289b	7.6	0.0	5.6	13.6	8.2	0.0	0.0	0.0	57.2	1.9	0.0	0.0	5.0	0.0	0.7	0.2
gc289c	0.0	0.0	3.8	5.1	14.2	0.0	20.7	0.0	2.4	0.0	42.3	0.0	7.7	0.0	3.4	0.5
gc289d	42.2	0.0	7.6	1.0	10.4	0.0	0.0	0.0	22.4	11.5	0.0	0.0	4.2	0.0	0.6	0.2
gc289e	0.0	0.0	9.8	7.9	27.2	0.0	5.8	0.0	19.8	0.0	24.3	0.0	3.6	0.0	1.4	0.2
gc289f	10.4	6.5	12.9	18.1	12.4	0.0	0.0	0.0	0.0	31.9	0.0	0.0	4.1	0.0	3.4	0.4
gc289g	21.6	0.0	2.2	1.0	14.7	0.0	0.0	0.0	34.5	22.7	0.0	0.0	2.5	0.0	0.8	0.2
gc289h	0.0	0.0	5.5	13.5	28.3	0.0	0.0	0.0	19.8	22.3	3.4	0.0	3.6	0.0	3.2	0.4
gc289i	32.3	0.0	6.1	7.6	14.5	0.0	0.0	0.0	19.8	15.8	0.0	0.0	2.4	0.0	1.1	0.5
gc289j	50.9	4.8	15.0	10.8	2.3	0.0	0.0	0.0	0.0	15.3	0.0	0.0	0.3	0.0	0.5	0.2
gc290a	0.0	14.2	1.4	1.0	12.5	0.0	0.0	0.0	0.0	57.8	8.1	0.0	1.7	0.0	3.3	0.1
gc291a	0.0	0.0	0.1	1.0	2.2	0.0	0.0	0.0	6.4	29.5	60.4	0.0	0.3	0.0	0.0	0.1
gc293a	11.1	7.9	6.6	8.5	9.7	0.0	0.0	0.0	0.0	49.8	0.0	0.0	2.1	0.0	3.5	0.8
gc293b	9.0	2.9	9.3	6.9	22.4	0.0	0.0	0.0	0.0	41.7	0.0	0.0	3.7	0.0	3.6	0.4
gc293d	3.2	4.0	17.0	9.2	4.8	0.0	0.0	0.0	0.0	55.3	0.0	0.0	3.5	0.0	2.5	0.4
gc294a	8.5	12.0	9.8	11.3	0.9	0.0	0.0	0.0	0.0	53.5	0.0	0.0	1.0	0.0	2.7	0.4
gc294b	2.7	0.0	2.4	16.2	24.1	0.0	0.0	0.0	6.8	41.2	0.0	0.0	3.3	0.0	2.8	0.5
gc294c	0.0	0.0	1.7	20.8	26.3	0.0	0.0	0.0	0.4	41.2	1.7	0.0	4.1	0.0	3.4	0.5
gc294d	10.1	13.4	2.1	1.0	2.1	0.0	0.0	0.0	0.0	64.2	0.0	0.0	4.4	0.0	2.1	0.7

TABLE 4: TRACE ELEMENT ANALYSES (IN PARTS PER MILLION) BY WAVELENGTH DISPERSIVE X-RAY FLUORESCENCE ANALYSIS

smpl #	Nb	Rb	Sr	Zr	Y	Ni	Cr	Ba	Ce	La	Cu	Zn
78b	<10	12	14	34	10	25	48	5000	34	58	10	820
80D	<10	20	46	92	16	12	11	780	28	10	10	90
80I	<10	5	24	44	<10	20	14	560	10	10	10	100
80K	<10	5	74	58	<10	46	91	680	29	10	10	320
80M	<10	5	60	58	10	28	68	2550	46	30	10	120
80PQ	<10	28	215	76	46	50	129	5000	34	82	68	1500
81a	14	34	76	122	24	10	12	3450	48	48	10	40
82a	<10	5	112	68	20	88	355	830	34	24	24	455
82c	<10	20	5	68	12	15	24	1100	44	10	10	100
83b	<10	5	36	38	<10	14	29	435	34	10	10	66
83c	<10	5	16	82	18	46	94	355	30	10	10	196
84b	14	5	285	82	16	234	610	205	22	10	24	100
84c	<10	5	5	16	<10	380	345	840	24	24	130	1500
85b	14	5	325	52	18	63	134	210	54	26	70	98
89a	16	74	60	140	32	22	28	3350	48	44	82	315
90a	<10	14	22	48	<10	30	14	1100	40	24	24	66
93a	14	46	136	62	44	102	355	2850	50	36	26	96
94a	<10	5	78	10	<10	2500	4150	48	26	22	188	36
94b	<10	20	36	14	<10	300	920	1850	20	10	48	36
95a	12	12	16	104	18	12	17	590	42	10	54	90
101a	<10	5	24	12	<10	240	980	118	64	22	10	10
102a	<10	5	24	10	<10	260	620	225	30	10	10	32
103a	<10	5	5	<10	<10	250	1600	68	24	10	10	24
121b	<10	5	42	60	10	410	750	34	<30	<30	5	690
122a	10	68	142	50	18	100	830	1900	<30	<30	5	130
122b	16	56	160	120	12	<10	10	1700	40	<30	34	56
122d	12	62	790	118	10	<105	10	1400	<30	<30	26	52
122e	<10	12	560	68	16	130	500	400	<30	<30	88	70
122f	<10	42	540	66	19	72	330	1600	<30	<30	72	68
284b	10	14	126	74	26	11	124					
284c	<10	22	60	78	16	98	114					
284d	<10	20	86	82	20	72	104					
284e	12	54	90	104	32	90	142					
284f	16	42	30	110	26	10	30					
285a	16	34	166	62	12	600	1650					
285b	12	16	54	50	16	10	54					
285g	12	88	70	28	12	405	530					
286a	<10	5	620	46	10	60	92					
286b	18	56	72	88	30	92	365					
286c	16	30	255	34	14	88	250					

TABLE 4, CONT.

smpl #	Nb	Rb	Sr	Zr	Y	Ni	Cr
286d	22	5	150	126	48	76	140
286e	10	5	12	16	<10	2150	2600
286f	20	20	122	98	24	325	980
287a	14	38	130	24	10	530	1450
287b	10	50	270	92	30	45	132
287c	18	54	265	86	28	50	246
288a	16	42	26	98	32	50	108
288b	16	38	18	40	18	106	330
288c	18	34	34	142	34	44	134
288d	14	16	230	38	18	150	780
288e	20	34	134	58	38	116	650
288f	12	14	42	54	18	11	40
289a	14	18	106	66	28	98	194
289b	14	28	186	82	22	50	66
289c	16	16	128	96	66	38	150
289d	18	40	86	76	30	26	18
289e	15	48	132	52	42	164	850
289f	20	34	46	104	32	54	205
289g	10	5	190	44	34	146	340
289h	18	18	148	100	32	56	205
289i	14	18	160	58	32	46	176
289j	<10	62	24	100	<10	10	24
290a	28	1350	102	280	30	126	176
291a	<10	5	40	12	<10	2100	1350
293a	18	24	38	82	50	50	62
293b	14	24	74	108	32	58	158
293d	12	40	24	80	32	32	64
294a	18	24	20	84	38	64	320
294b	14	5	92	90	34	38	98
294c	20	5	96	106	42	46	146
294d	21	5	20	86	26	240	630

Note: empty space indicates element was not analyzed

TABLE 5: Trace element concentrations (in ppm) for Greens Creek samples by Neutron Activation Analysis

Smpl #	Ba	Sr	Co	Ni	Cr	Cs	Hf	Rb	Sb	Ta	Th	U	Zn	Zr	Sc
78b	4570	43.1	7.37	27.9	48.6	0.93	0.84	26.2	15.2	0.158	1.03	0.97	782	24.3	8.01
80d	707	35	12.8	12.8	11.7	1.2	2.39	31.7	1.31	0.157	2.06	1.35	89.3	85.2	11.6
80i	515	49	18.5	23.7	15.6	0.78	1.09	15.4	1.8	0.126	1.14	0.58	88.8	36.2	9.77
80k	561	95.9	24.2	53.1	90.9	0.59	1.39	4.7	6.94	0.204	0.44	0.7	303	43	21.9
80m	2400	67.6	12.8	44.8	110	1.08	1.49	14.2	1.6	0.258	2.05	0.79	104	66	11.9
80pq	8760	171	21.4	63.1	111	1.9	1.66	33.5	7.34	0.272	1.13	1.13	2260	92.4	26.7
81a	3530	68.4	10.2	6.42	14.5	2.18	3.36	44.5	2.01	0.239	2.69	1.63	39.1	136	14.6
82a	704	213	34	75.3	276	0.29	1.83	16.8	1.08	0.257	0.24	0.09	303	100	40
82c	1060	6	13.1	25.2	25.9	0.69	1.9	35.5	0.69	0.268	2.37	0.87	83.6	82.3	13.9
83b	404	59.2	9.91	26.7	29.1	0.27	0.97	9.08	0.56	0.146	1.32	1.76	105	50.4	8.7
83c	295	7	34.5	40.7	94.1	0.18	2.35	7.29	1.22	0.338	0.85	0.74	180	121	33.9
84b	155	346	38.6	241	550	0.07	2.04	6.57	2.89	0.417	1.04	0.43	107	77.6	35.3
84c	794	3	37.8	379	272	0.45	0.22	15.2	1.16	0.072	0.21	0.08	7350	17	6.92
85b	176	330	24	61.5	109	0.26	3.21	14.5	0.49	0.727	3.41	1.48	71.7	125	26.4
89a	3230	75	8.1	23.5	57.5	4.41	3.14	79.8	1.3	0.613	4.33	4.29	253	132	21.9
90a	1020	22	12.4	37	14.5	1.21	1.39	24.4	0.62	0.255	1.96	0.77	51.8	56.3	7.89
93a	2490	169	15.9	134	235	3.72	1.62	49.8	21.6	0.307	2.49	4.73	112	64.7	16.2
94a	5.9	5	145	3550	2790	0.08	0.06	1.92	1.36	0.01	0.44	0.09	21.2	5.5	7.96
94b	1910	57	41	306	796	2.4	0.24	34.8	0.52	0.009	0.11	0.16	45.2	8.3	42.1
95a	492	10	14	14.4	16.5	1.18	3.04	19.7	0.48	0.369	2.69	1.21	71.8	122	13.2
101a	58	8	25.4	186	1010	0.05	0.07	1.3	0.82	0.004	0.02	0.04	14	8.6	17.7
102a	165	24	36.7	252	767	0.24	0.13	12	0.37	0.014	0.04	0.12	31.4	4.8	12.5
103a	35.2	4	29.9	229	1760	0.1	0.18	2.02	1.29	0.005	0.05	0.02	87.2	7	25

TABLE 6: CONCENTRATIONS (in parts per million) OF RARE EARTH ELEMENTS BY NEUTRON ACTIVATION ANALYSIS

Sample #	La	Ce	Nd	Sm	Eu	Gd	Tb	Tm	Yb	Lu
78b	7.21	14.8	8.65	1.95	0.73	1.77	0.26	0.17	1.08	0.15
80D	9.44	21.1	12	2.98	0.62	3.17	0.52	0.35	2.25	0.35
80I	1.63	3.52	2.27	0.72	0.13	0.92	0.17	0.16	1.02	0.16
80K	1.93	5.8	4	0.99	0.16	0.9	0.12	0.11	0.67	0.14
80M	13	27.5	14.8	2.67	0.37	2.18	0.3	0.21	1.39	0.22
80PQ	8.22	17.4	9.79	2.83	0.79	3.63	0.63	0.41	2.63	0.38
81a	13.6	30.3	17	4.19	0.85	4.7	0.72	0.48	3.03	0.46
82a	6.18	14.6	9.42	3.22	1.19	4.32	0.77	0.48	3.04	0.43
82c	9.4	23.3	11.8	2.98	0.5	3.18	0.49	0.32	2.03	0.31
83b	7.78	16.4	9.56	2.23	0.37	2.26	0.34	0.2	1.3	0.2
83c	7.11	17.2	11.7	3.56	0.69	4.38	0.73	0.43	2.74	0.39
84b	7.38	18.2	12.2	3.38	1.05	3.72	0.58	0.3	1.73	0.26
84c	1.51	3.44	1.81	0.47	0.21	0.49	0.07	0.05	0.23	0.04
85b	19.4	44.2	20.8	4.46	1.2	3.87	0.61	0.37	2.34	0.36
89a	19.5	39.8	22.1	4.86	1.23	4.92	0.8	0.46	2.93	0.42
90a	11.1	19.5	12.3	2.7	0.55	2.64	0.36	0.23	1.5	0.25
93a	15.3	26.8	17.5	4.36	1.53	5.12	0.88	0.61	3.95	0.59
94a	0.15	0.48	0.28	0.09	0.03	0.12	0.02	0.02	0.14	0.02
94b	0.74	1.4	0.96	0.35	0.1	0.52	0.1	0.07	0.43	0.07
95a	9.93	22.3	12.7	3	0.79	3.19	0.56	0.4	2.71	0.41
101a	0.29	0.76	0.61	0.21	0.18	0.29	0.06	0.03	0.19	0.03
102a	0.58	1.4	0.98	0.32	0.23	0.41	0.07	0.04	0.26	0.04
103a	0.5	1.71	1.33	0.45	0.28	0.6	0.1	0.06	0.43	0.06

Table 7: Descriptions, Locations, and trace element compositions (in parts per million) for Woewodski Island Samples

smpl #	description	*	Latitude			Longitude			Nb	Rb	Sr	Zr	Y
RN116a	massive greenstone	g	56	34	32	133	3	19	14	32	144	94	26
RN116d	pyritic greenschist	a	56	34	32	133	3	19	12	46	44	124	33
RN116g	tuffaceous greenschist	t	56	34	32	133	3	19	17	24	73	114	28
RN118a	massive greenstone	g	56	34	25	133	3	10	12	12	225	114	28
RN118b	masssive greenstone	g	56	34	25	133	3	10	8	15	184	52	18
RN118d	cherty ironstone		56	34	25	133	3	10	12	8	15	53	18
RN119c	tuffaceous greenschist	t	56	34	27	133	3	0	13	44	57	88	24
RN120a	diabase (?)	g	56	34	23	133	2	55	12	20	270	87	27
RN121a	amygdaloidal greenstone	g	56	34	25	133	3	30	10	23	180	74	20
RN123a	tuffaceous greenschist	t	56	34	19	133	3	19	14	24	44	88	25

* = symbol used in compositional figures

Table 8: Major Element Analyses of Samples from Woewodski Island

sample number	description	SiO_2	Al_2O_3	Fe_2O_3 tot*	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	LOI	sum
RN116a	massive greenstone	43.6	13.2	11.6	6.1	8.95	2.32	1.83	1.46	0.14	0.22	7.9	97.3
RN116d	pyritic greenschist	47.6	13.7	14.5	2.23	2.64	0.15	2.15	1.91	0.17	0.69	12.9	98.6
RN116g	tuffaceous greenschist	45.3	15.7	10.4	3.32	5.35	0.15	1.22	1.93	0.17	0.23	15.4	99.2
RN118a	massive greenstone	42.7	15.0	13.7	6.85	10.4	1.66	0.57	1.85	0.16	0.21	6.3	99.4
RN118b	masssive greenstone	51.1	14.4	9.38	7.18	7.54	4.04	0.64	0.49	0.09	0.16	4.8	99.8
RN118d	cherty ironstone	33.3	7.33	30.9	1.49	1.39	0.1	0.01	0.89	0.06	5.26	19.2	99.9
RN119c	tuffaceous greenschist	45.4	16.9	14.8	2.33	1.11	0.1	2.61	1.26	0.32	1.13	13.2	99.2
RN120a	diabase (?)	47.4	14.5	11.6	7.26	10.3	3.1	0.65	1.36	0.11	0.19	3.8	100.3
RN121a	amygdaloidal greenstone	44.9	14.3	10.7	6.75	11.1	2.85	1.13	1.25	0.11	0.16	4.9	98.1
RN123a	tuffaceous greenschist	47.7	14.3	13.2	3.0	3.2	0.1	1.39	1.39	0.13	0.46	14.2	99.1

*Total Iron as Fe_2O_3

Table 9: Pb isotopic Data for Triassic and Cretaceous VMS prospects of SE Alaska

Name	Host Age	Location		$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Greens Creek	Triassic	58° 4' N	134° 37' W	18.635	15.5828	38.239
Woewodski	Triassic?	56° 34' N	133° 3' W	18.672	15.559	37.954
Fremming	Cretaceous	58° 52' N	135° 5' W	18.404	15.466	37.708
Ak Treasure	Cretaceous	58° 15' N	134° 43' W	18.425	15.497	37.924
Ak Treasure	Cretaceous	58° 15' N	134° 43' W	18.412	15.475	37.692

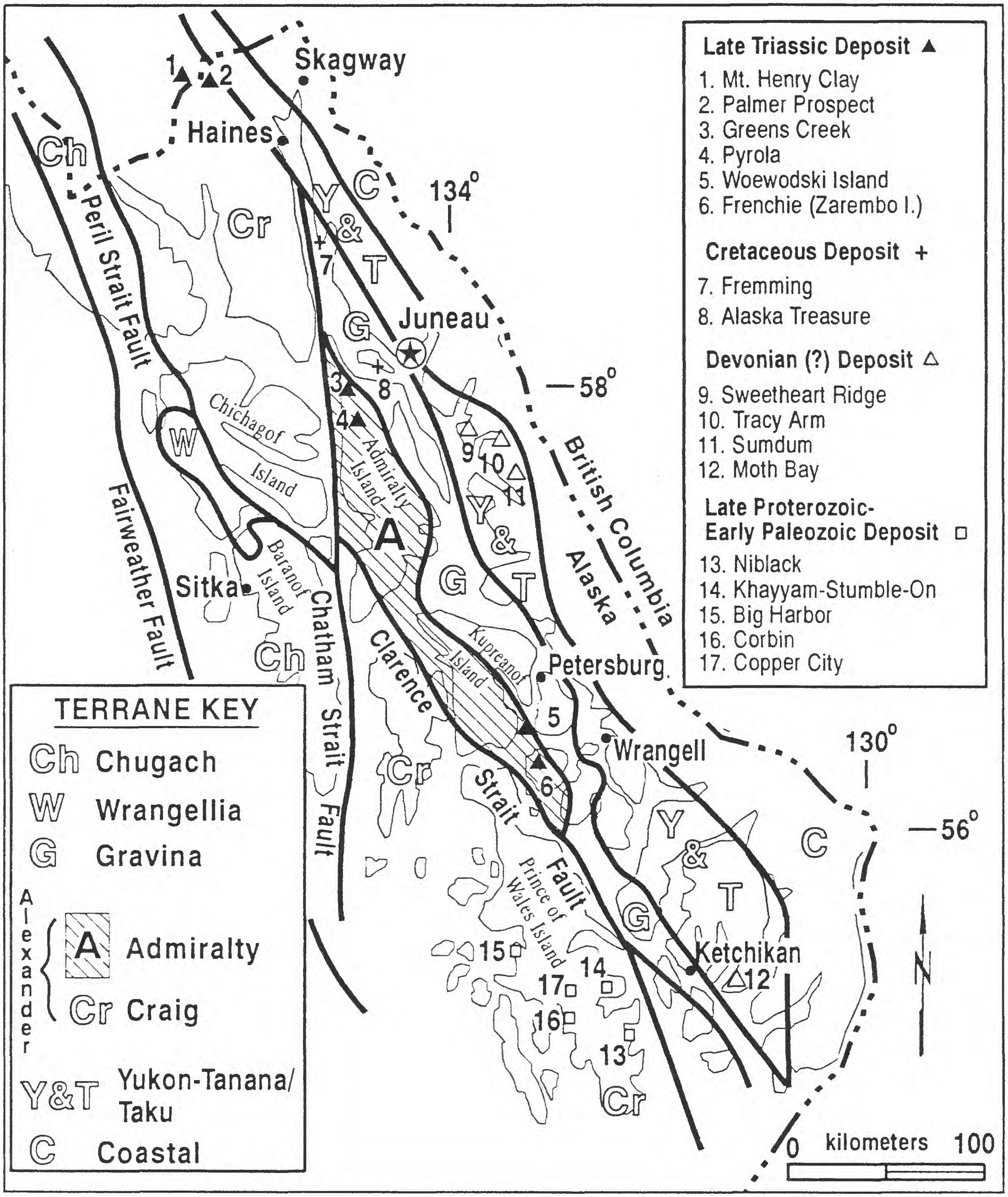

Fig. 1 Location map of major VMS deposits and prospects in SE Alaska with generalized terrane boundaries. Modified from Newberry and others (1997).

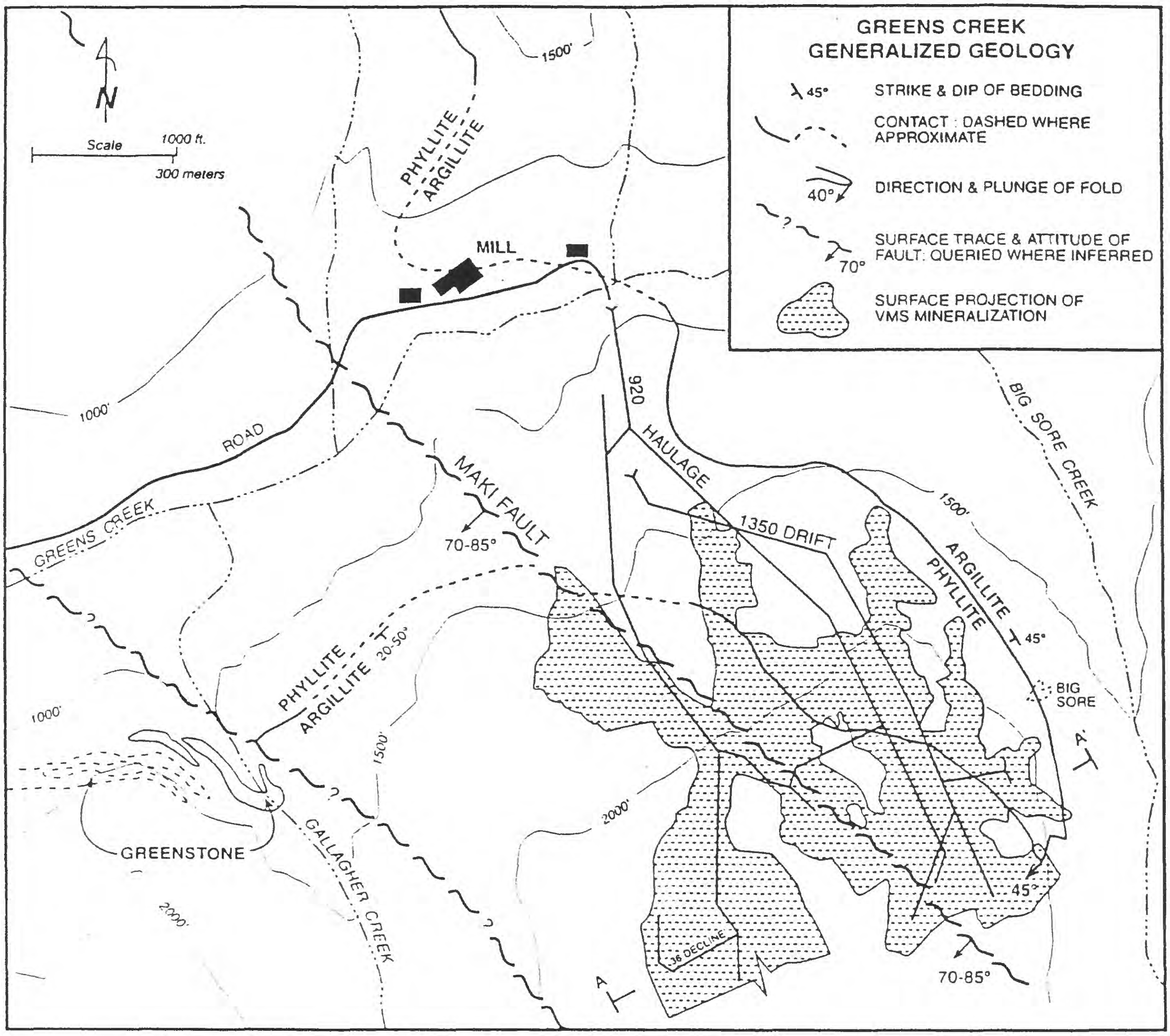

Fig. 2. Generalized surface geology of the Greens Creek Deposit, SE Alaska. Modified from Newberry and others (1997).

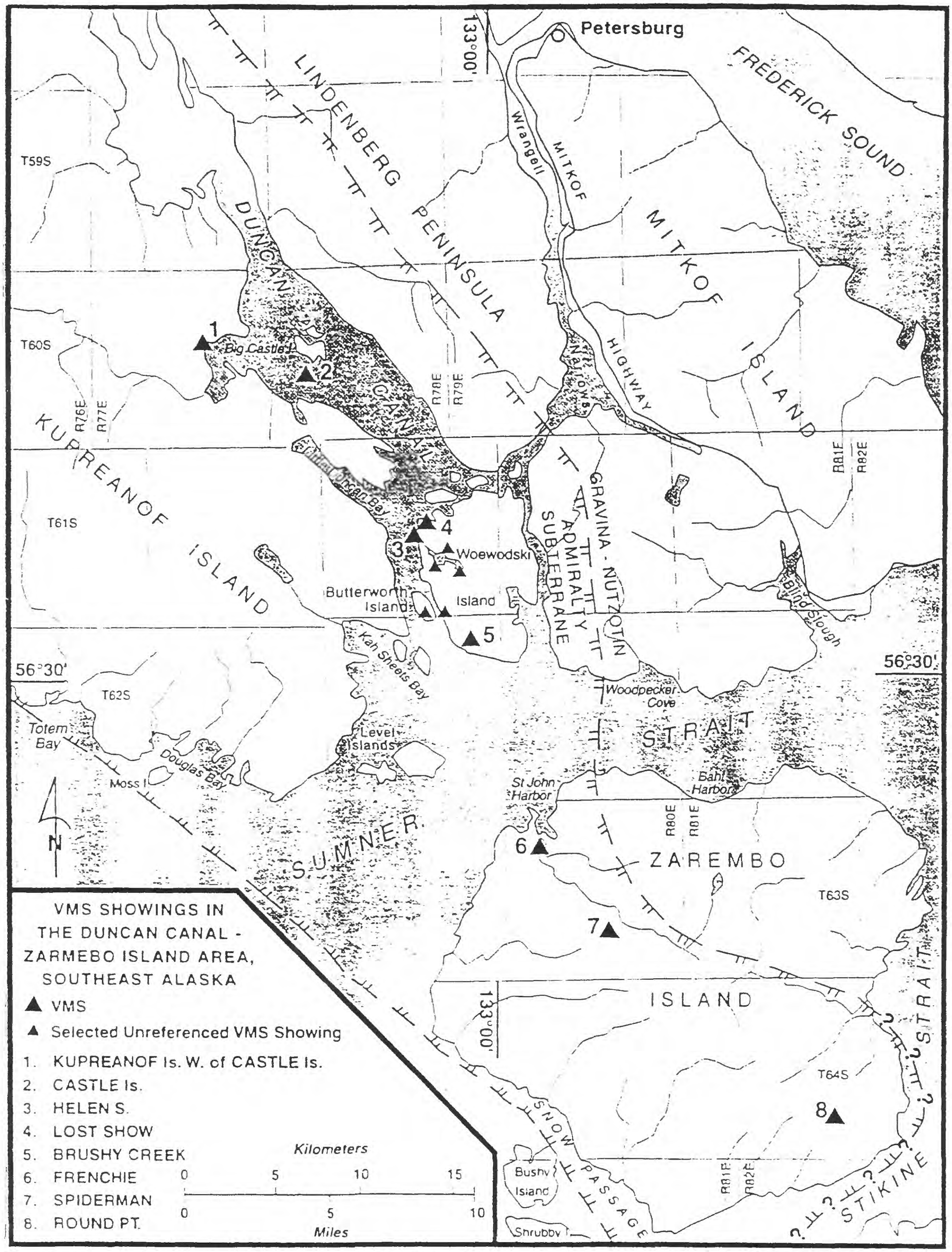

Fig. 3. Locations of VMS showings in the Woewodski Island area, SE Alaska. Modified from Newberry and others (1997).

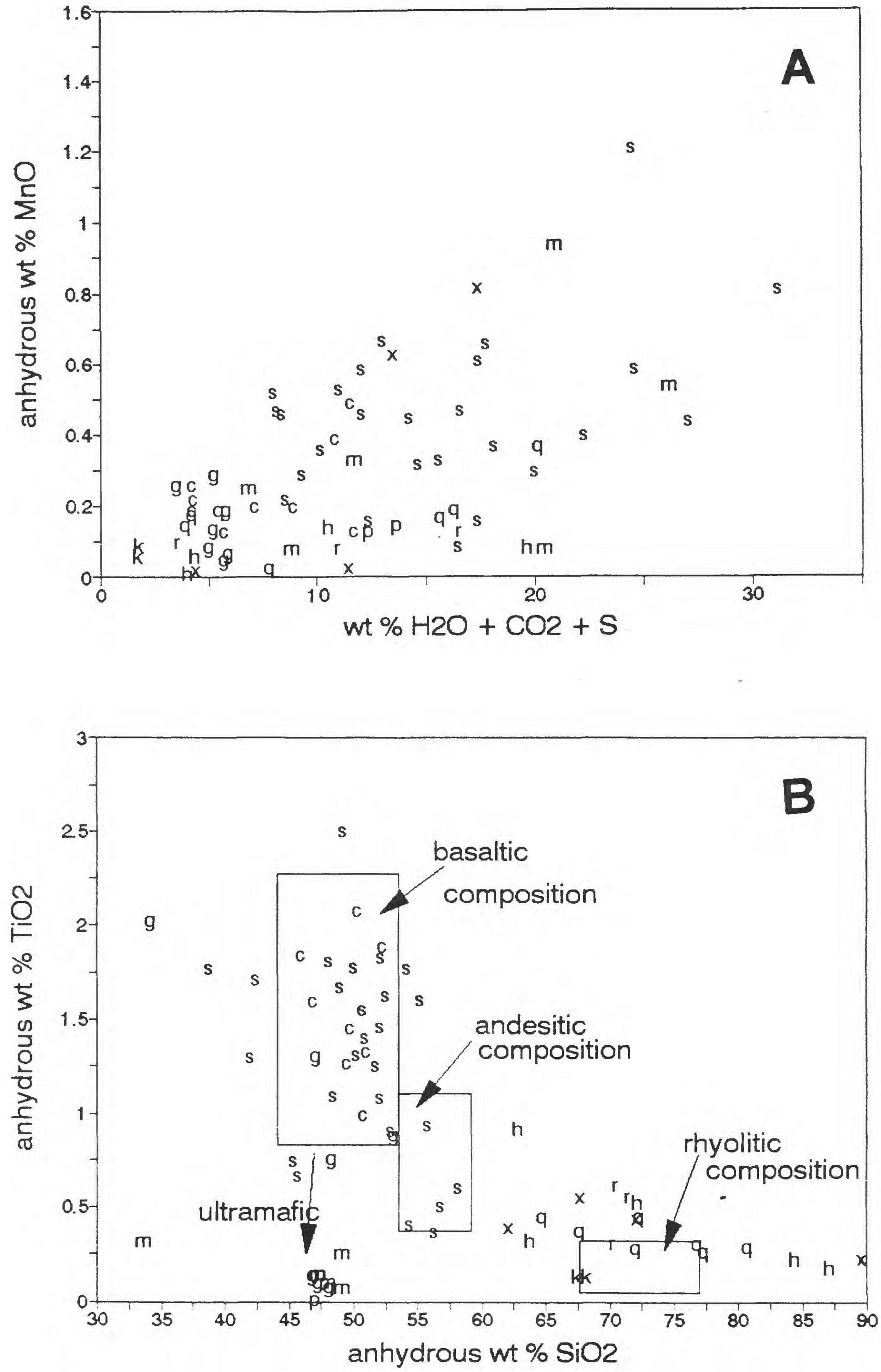

Fig. 4. Major element characteristics of rocks from the Greens Creek deposit and vicinity. Rock type abbreviations are given in Table 1 and data is from this study. 4A. Anhydrous wt % MnO vs. sum of H_2O + CO_2 + S, showing proportionality between the two. 4B. Anhydrous wt % TiO_2 vs. SiO_2, showing that stratigraphic footwall rocks have compositions consistent with mafic and ultramafic igenous rocks.

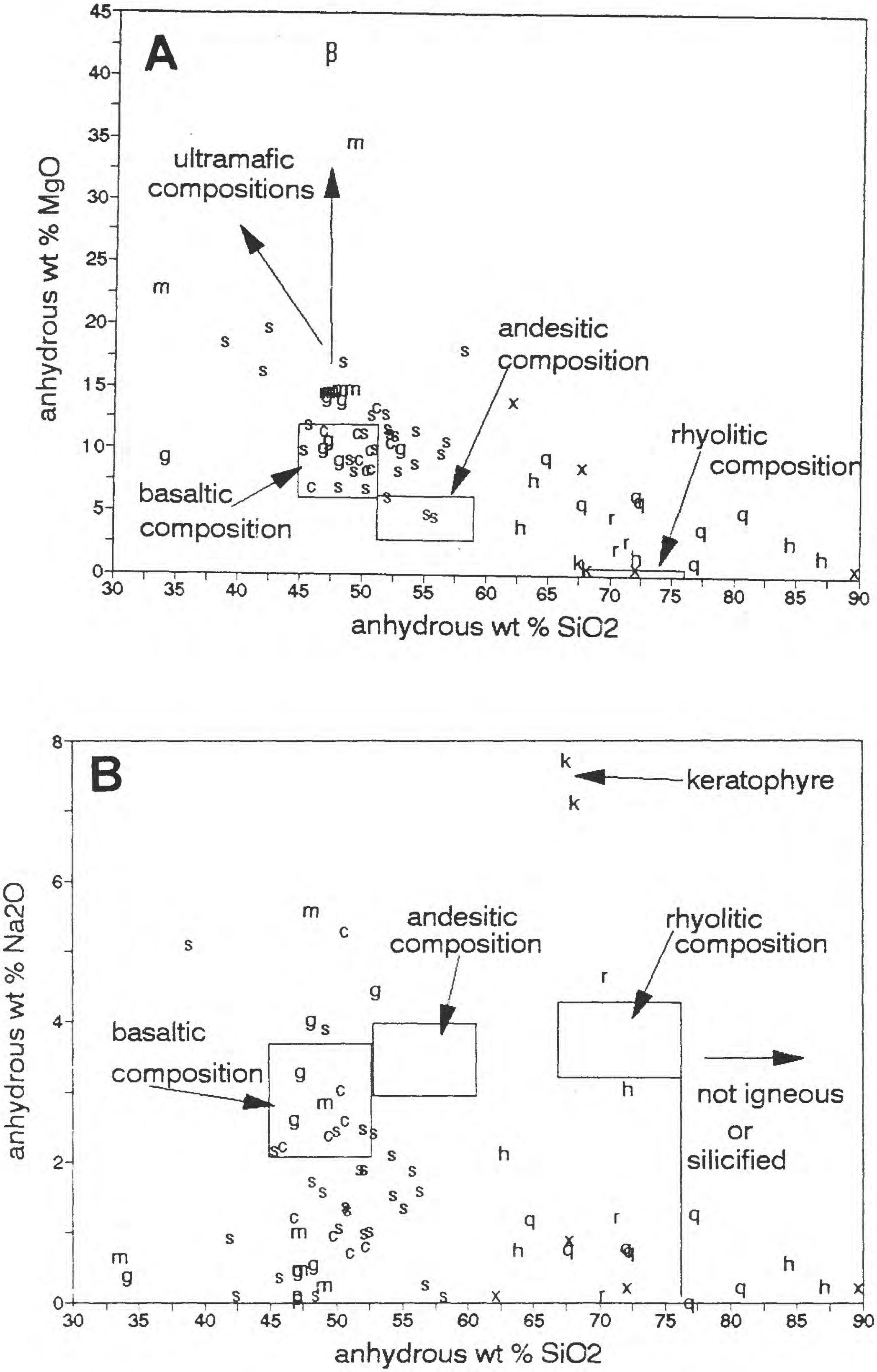

Fig. 5. Major element characteristics of rocks from the Greens Creek deposit and vicinity. Rock type symbols are given in Table 1 and data is from this study. 5A. Anhydrous wt % MgO vs. SiO_2, showing that stratigraphic footwall rocks have compositions consistent with mafic and ultramafic igenous rocks. 5B. Anhydrous wt % Na_2O vs. SiO_2, showing major depletion in Na for most of the stratigraphic footwall rocks relative to normal igenous rocks and extreme enrichment in the sample of keratophyre.

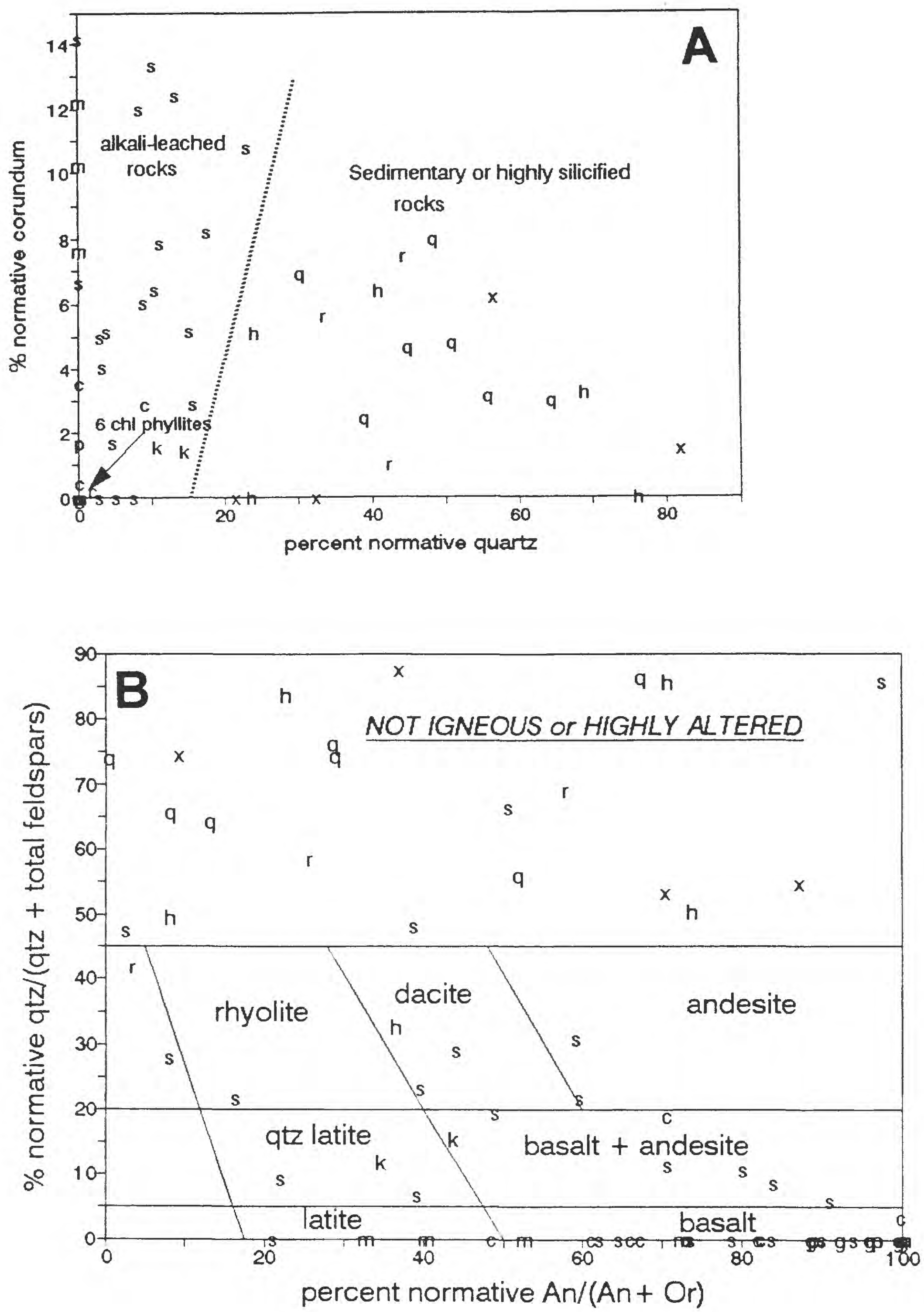

Fig. 6. CIPW Normative characteristics of rocks from the Greens Creek deposit and vicinity. Rock type abbreviations are given in Table 1 and data is from this study. 6A. Percent normative corundum vs. normative quartz, showing extremely high corundum and low quartz in the altered stratigraphic footwall rocks. 6B. Normative classification diagram for igenous rocks (Streckeisen and LeMaitre, 1979), showing that greenstones in the mine area have normative compositions consistent with mafic igneous rocks, whereas other stratigraphic footwall rocks and stratigraphic hangingwall rocks have non-igneous normative compositions.

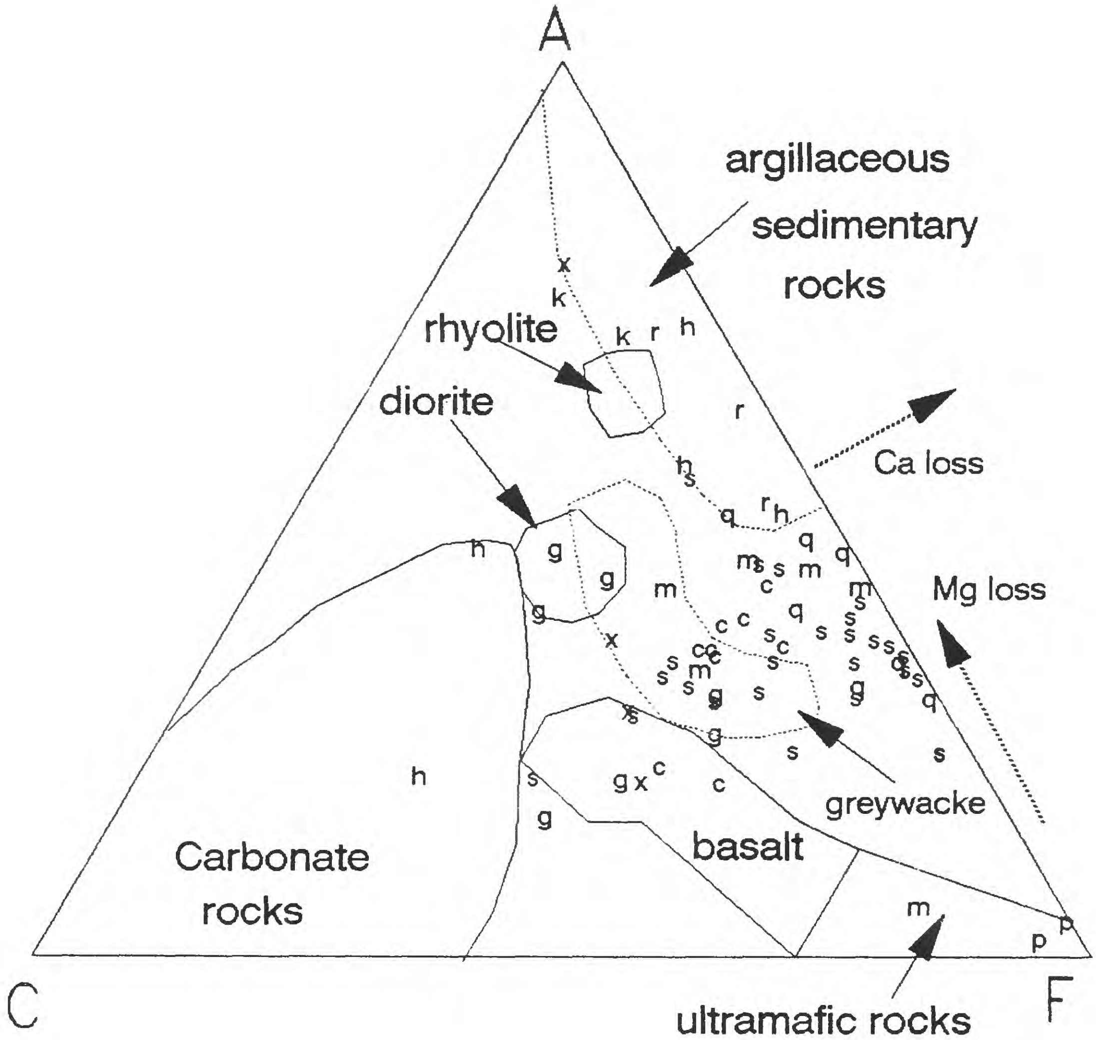

Fig. 7. Major element compositions of Greens Creek and vicinity rocks plotted on ACF diagram (after Winkler, 1979), showing compositional relationships among rock types. Note that stratigraphic hangingwall rocks fall in well-defined fields of sedimentary rocks, whereas stratigraphic footwall rocks do not. Field boundaries from Winkler (1979).

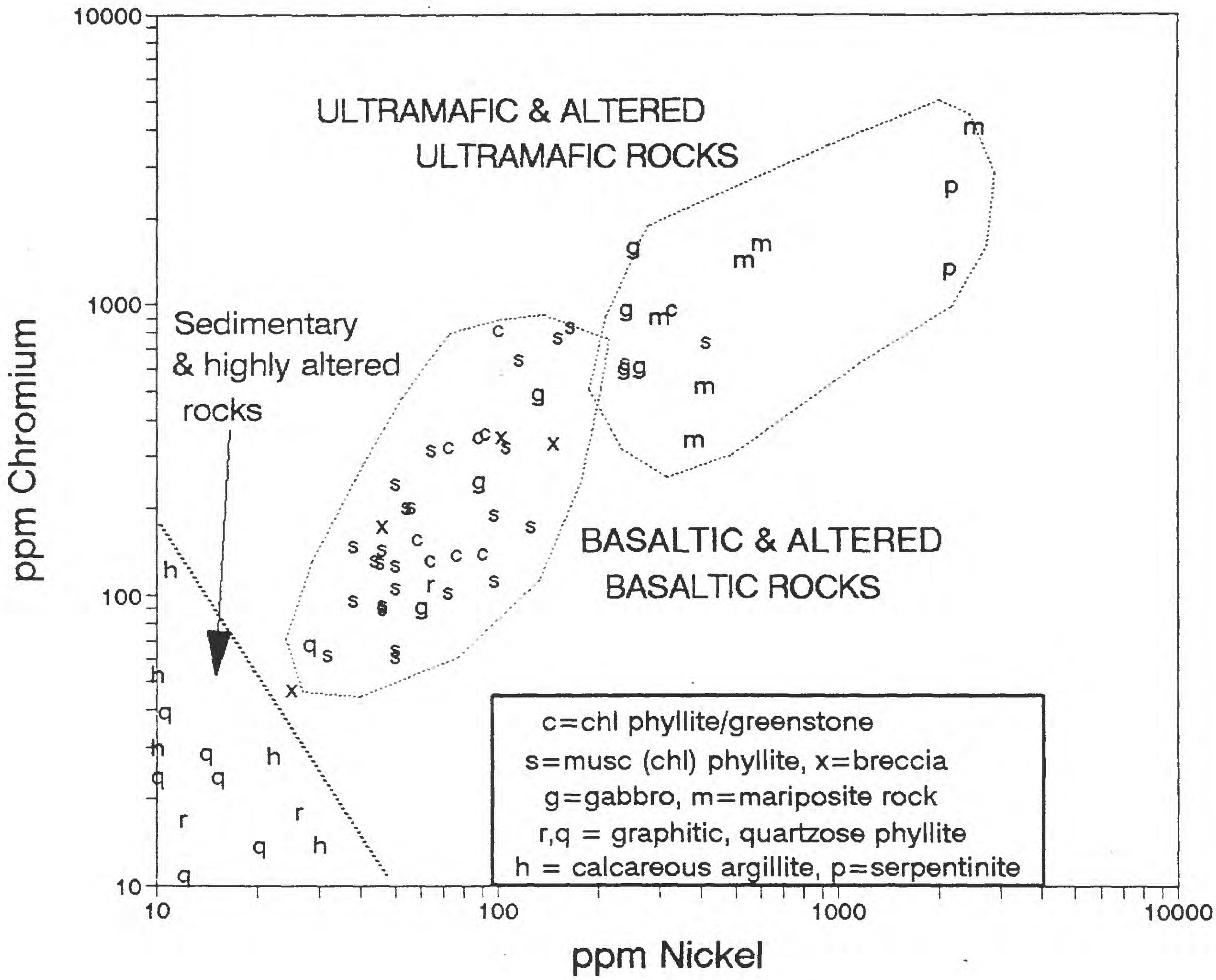

Fig. 8. Ni vs. Cr for rocks of the Greens Creek mine and vicinity, using data from this study. Field boundaries are based on data in BVSP (1981).

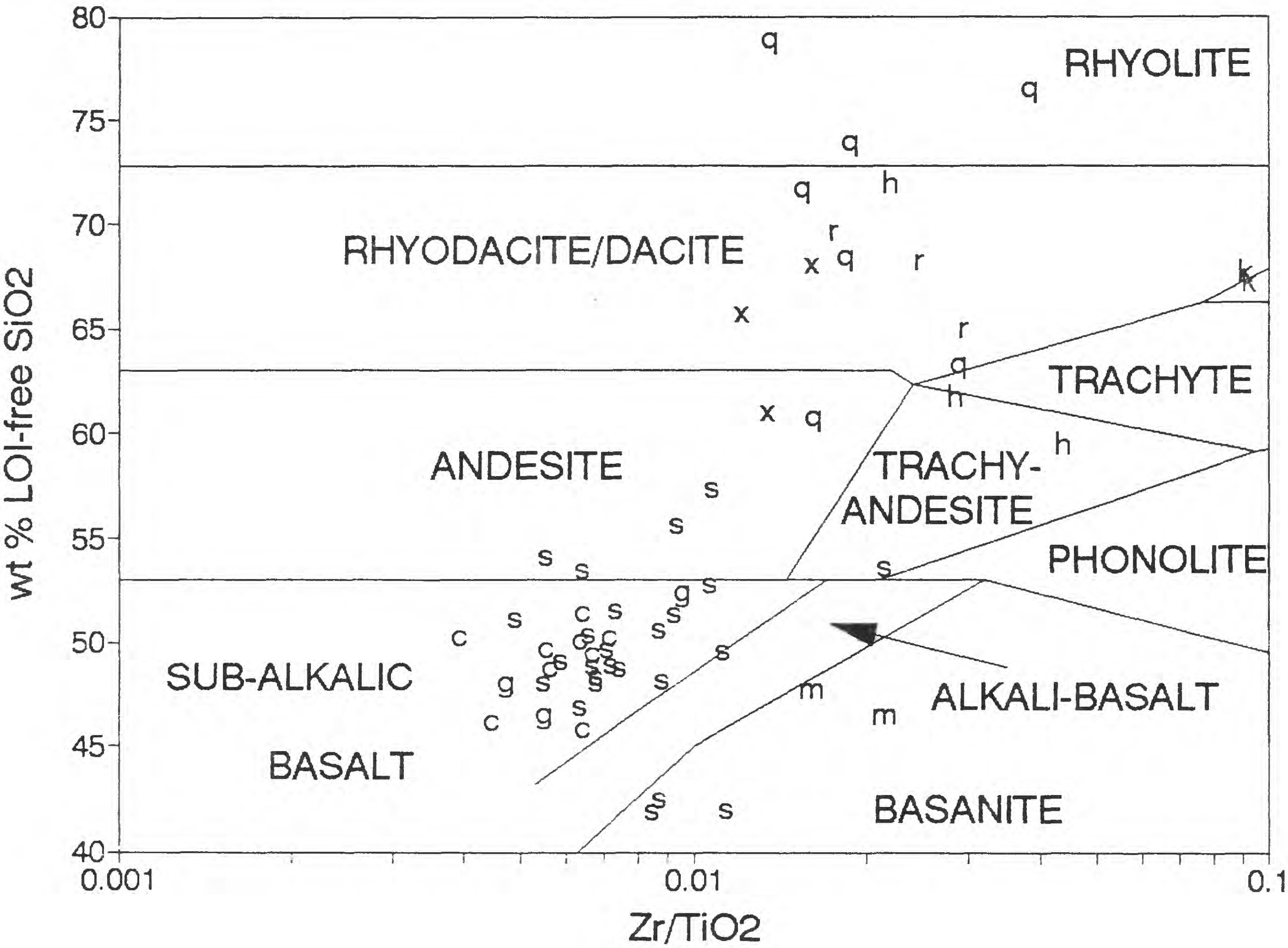

Fig. 9. Classification of rocks from Greens Creek and vicinity employing the SiO_2 vs. Zr/TiO_2 diagram of Winchester. and Floyd (1977). Rock type symbols are given in Table 1 and data is from this study.

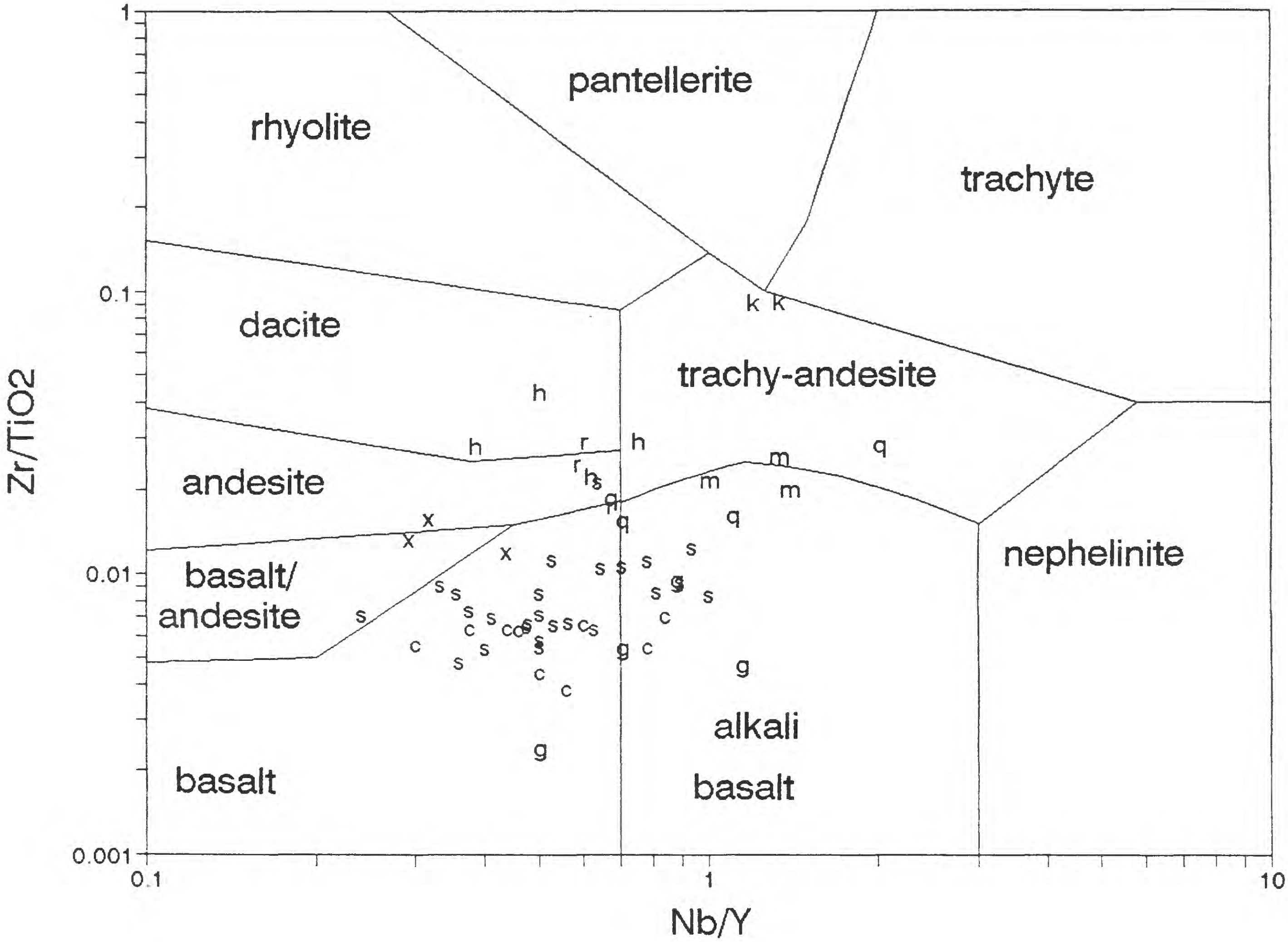

Fig. 10. Classification of rocks from Greens Creek and vicinity employing the Zr/TiO_2 vs. Nb/Y diagram of Winchester. and Floyd (1977). Rock type symbols are given in Table 1 and data is from this study. Note that samples with Nb and Y below detection are not plotted.

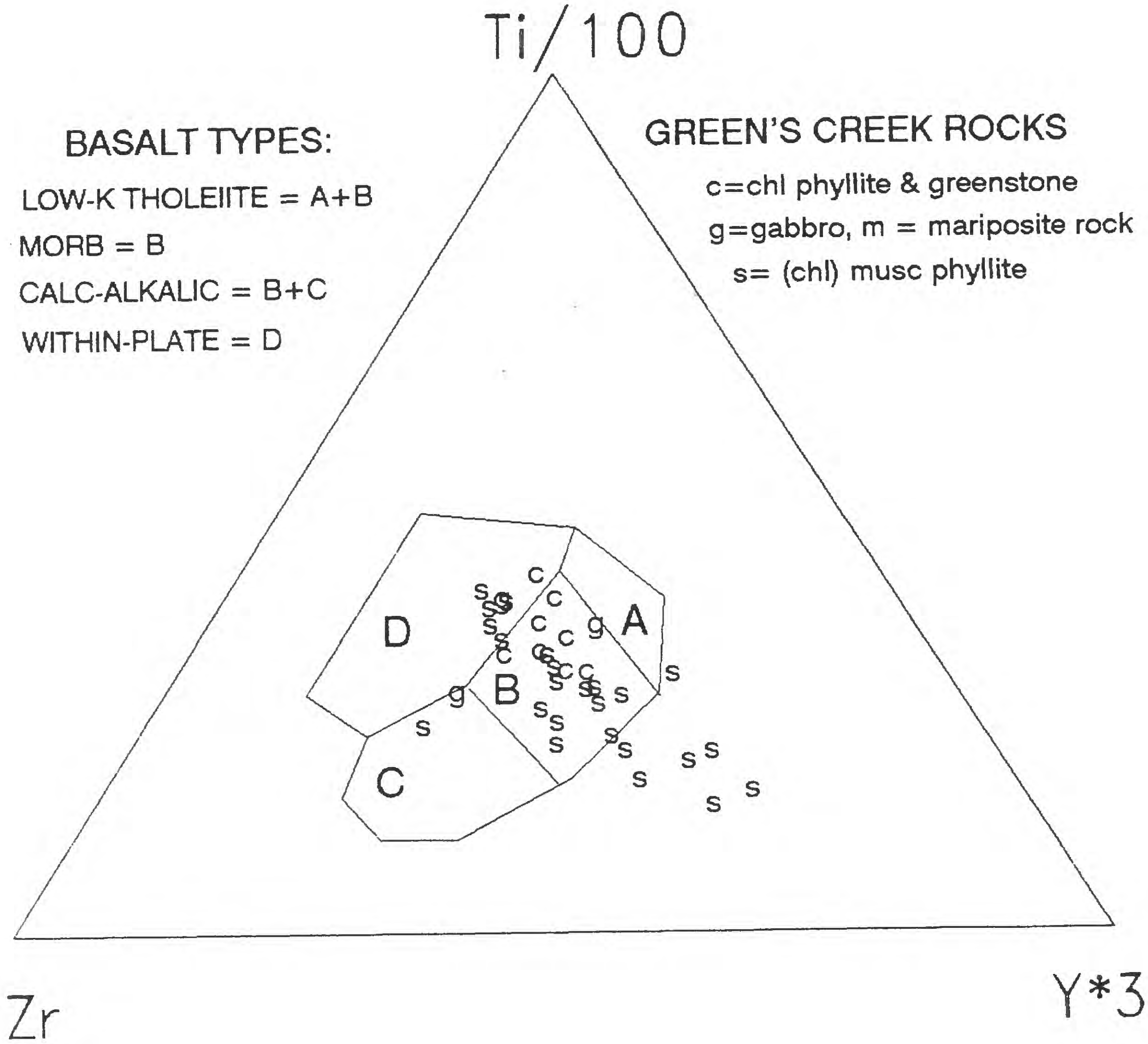

Fig. 11. Basalt tectonic environment diagram of Pearce and Cann (1973) with data from those Greens Creek samples which exhibit Ni-Cr compositional evidence (Fig. 8) for a basaltic protolith. Increased scatter of muscovite phyllite data is most likely due to slight trace-element mobility during hydrothermal alteration.

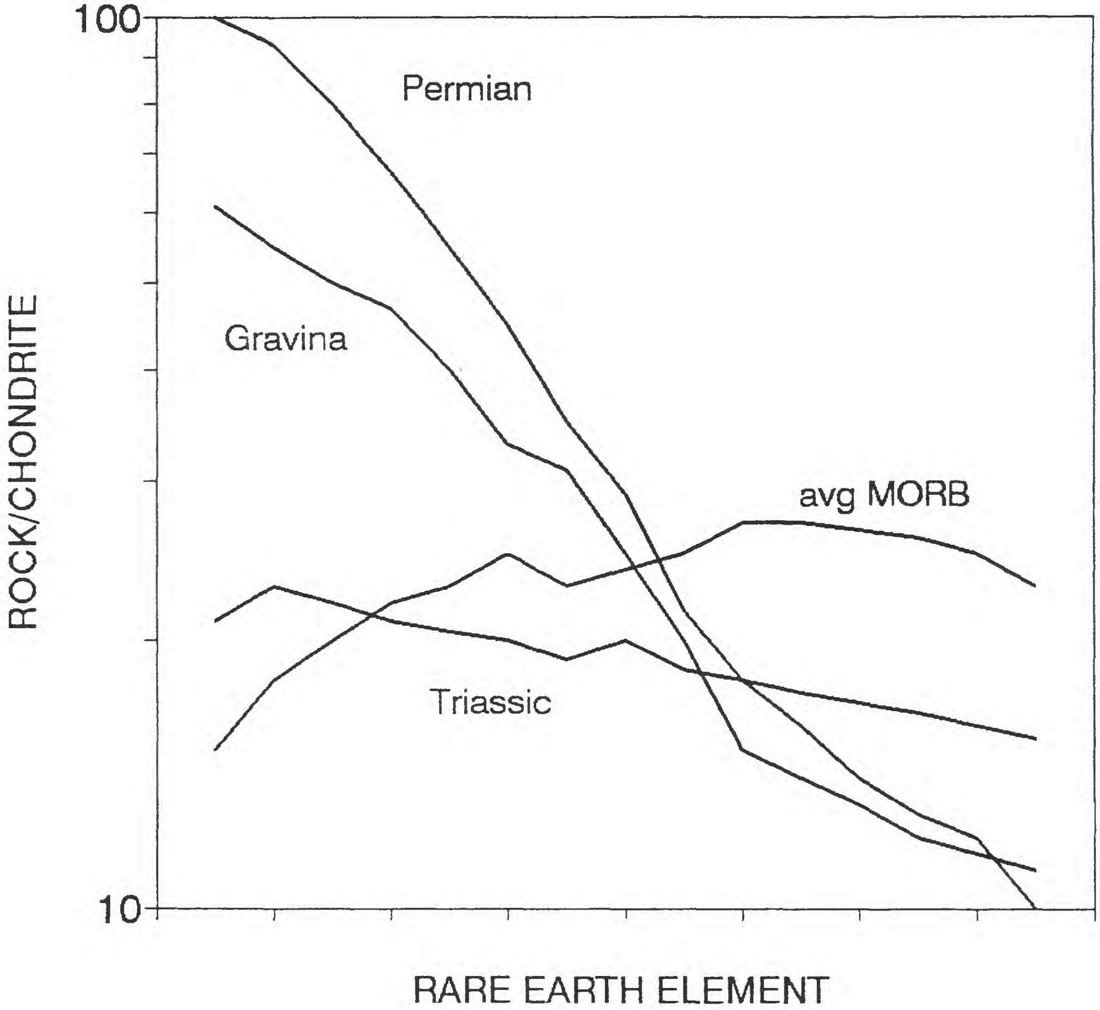

Fig. 12. Chondrite-normalized average REE plots for basaltic rocks of northern SE Alaska compared to typical mid-ocean basalt (MORB). Data for Alaskan rocks from Davis and Plafker (1980), MacIntyre (1986), McClelland and others (1991), and Gehrels and Barker (1993). Average MORB from BVSP (1981).

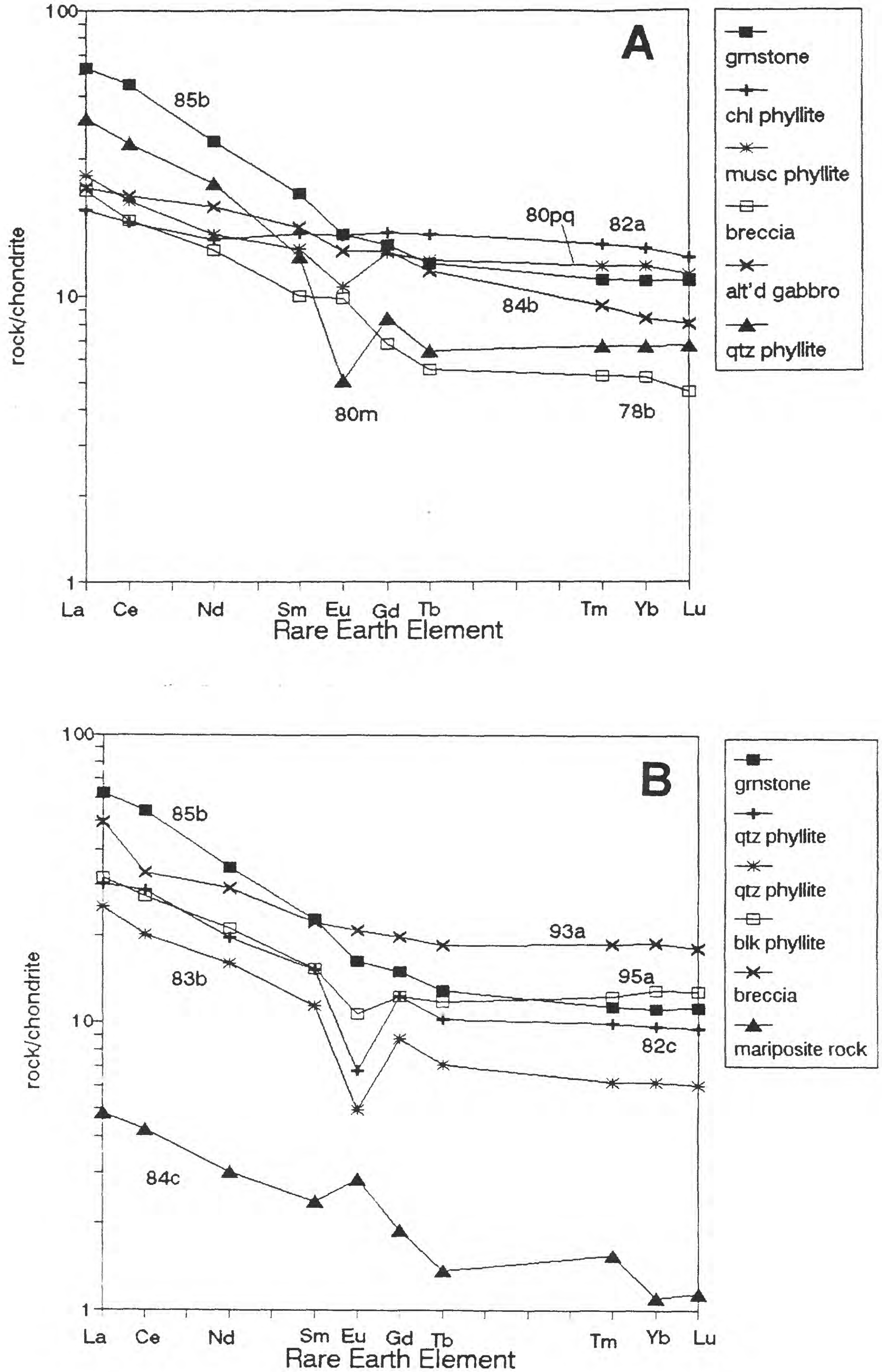

Fig. 13. Chondrite-normalized REE plots for rocks from the Greens Creek mine and vicinity. Data from this study.

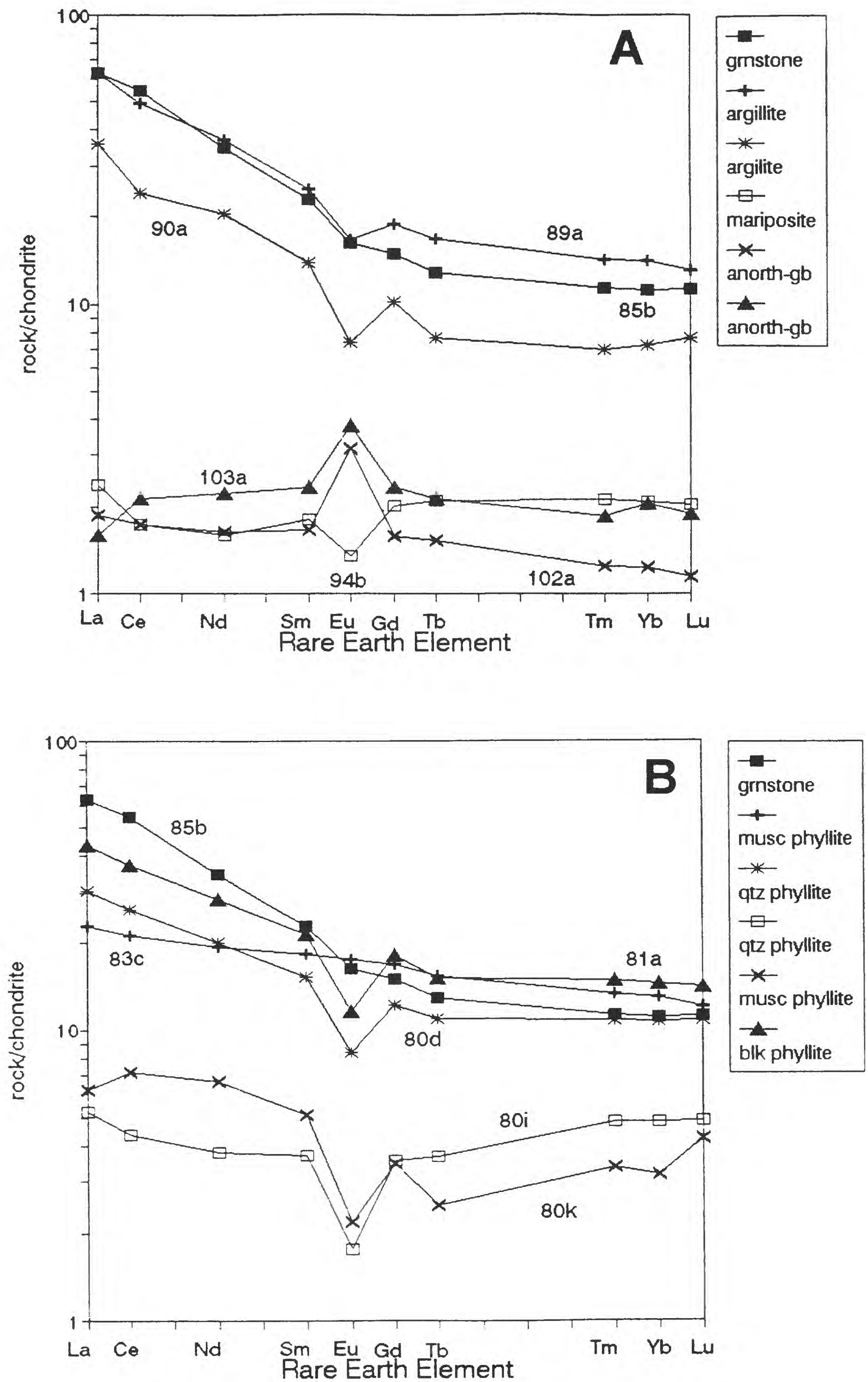

Fig. 14. Chondrite-normalized REE plots for rocks from the Greens Creek mine and vicinity. Data from this study.

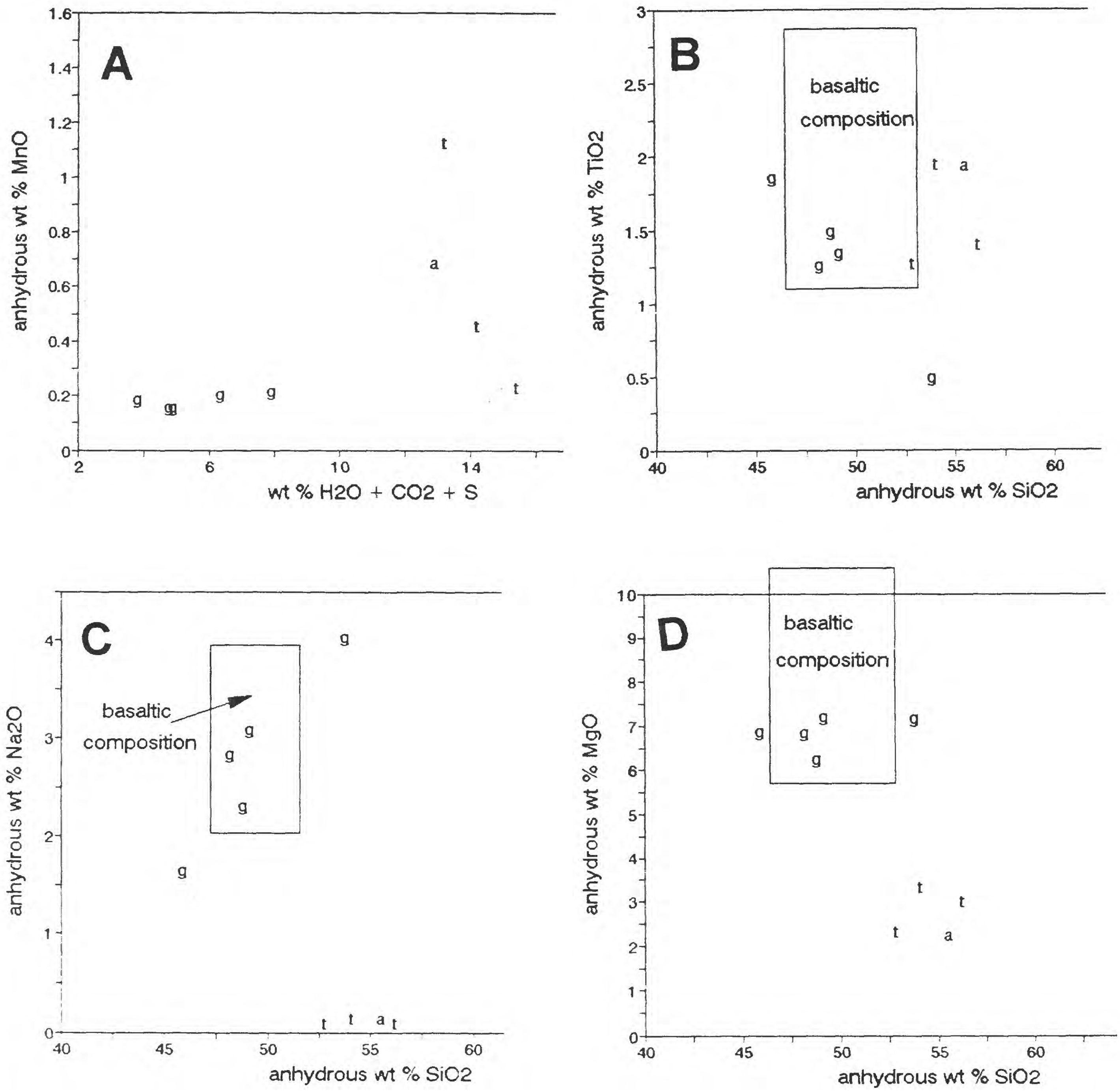

Fig. 15. Major element compositional diagrams for metavolcanic rocks of Woewodski Island. Symbols are defined in Table 8. Data is from this study.

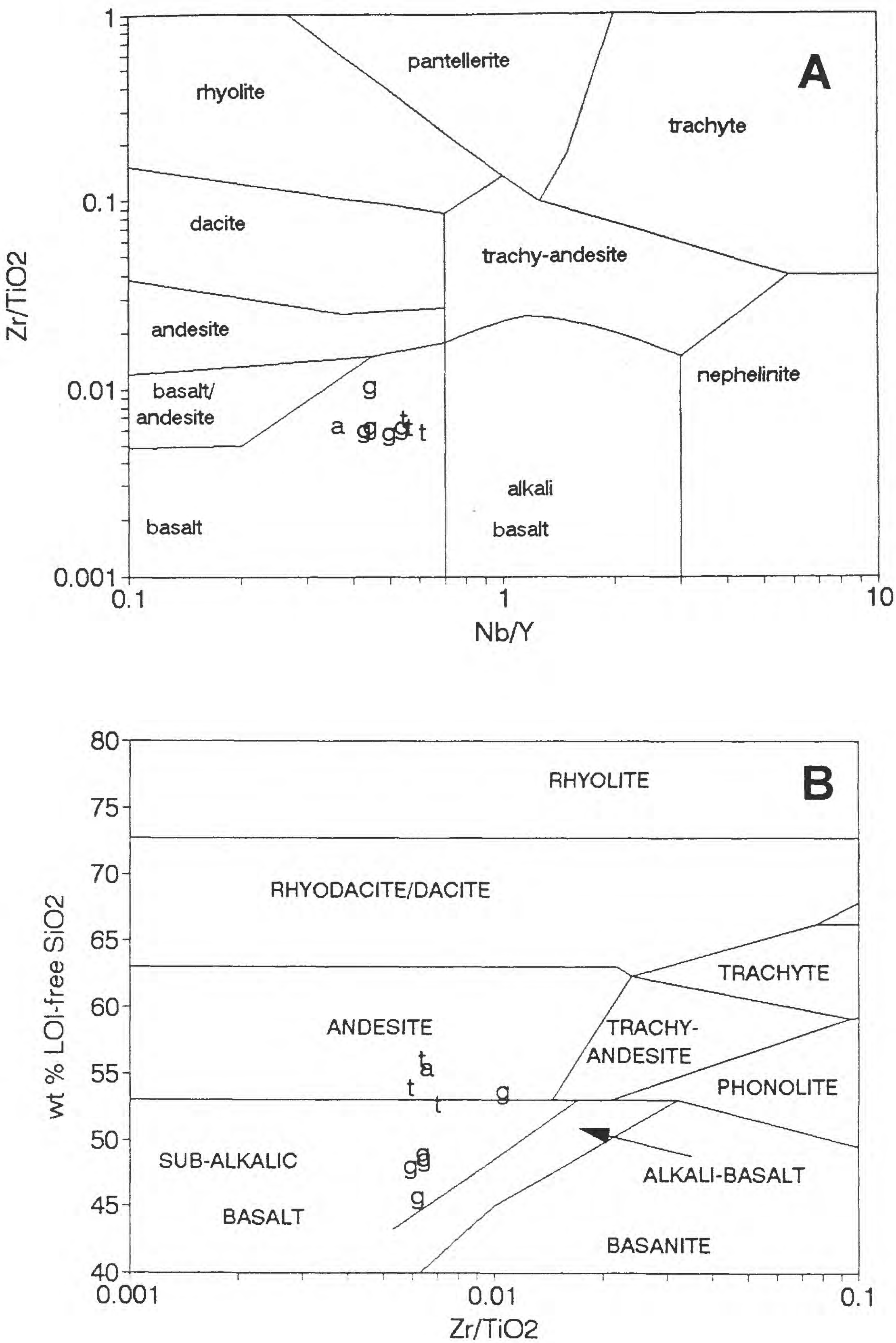

Fig. 16. Classification of metavolcanic rocks on Woewodski Island using discrimination diagrams of Winchester and Floyd (1977). Symbols are defined in Table 8. Data is from this study.

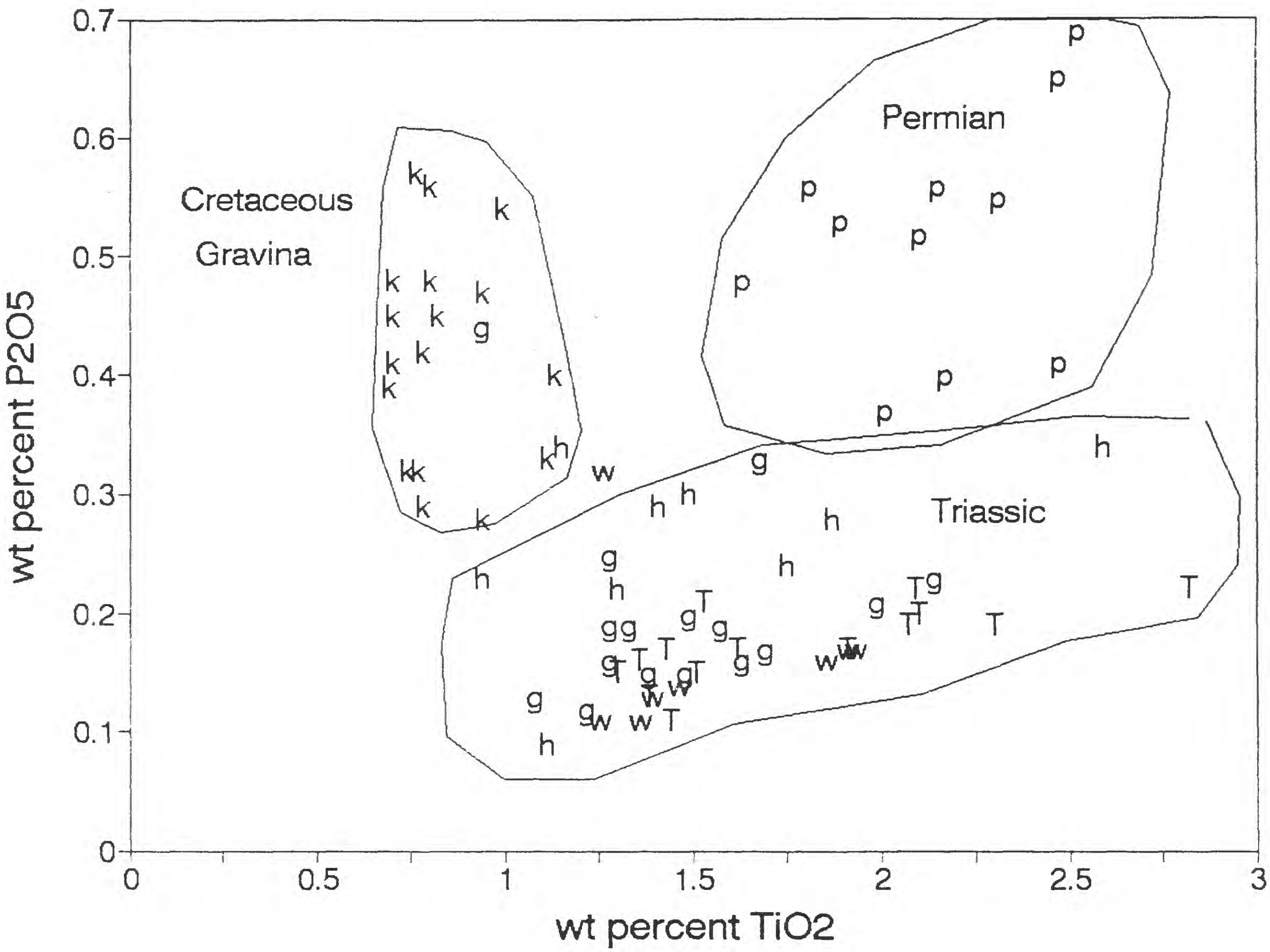

Fig. 17. Anhydrous wt % P2O5 vs. TiO2 for metavolcanic rocks of northern SE Alaska, showing discrete compositional ranges for rocks of different ages. Metavolcanic rocks from Woewodski Island clearly fall in the range defined Triassic basalts. Modified from Newberry and others (1995) with data from Ford and Brew (1993) and this study.

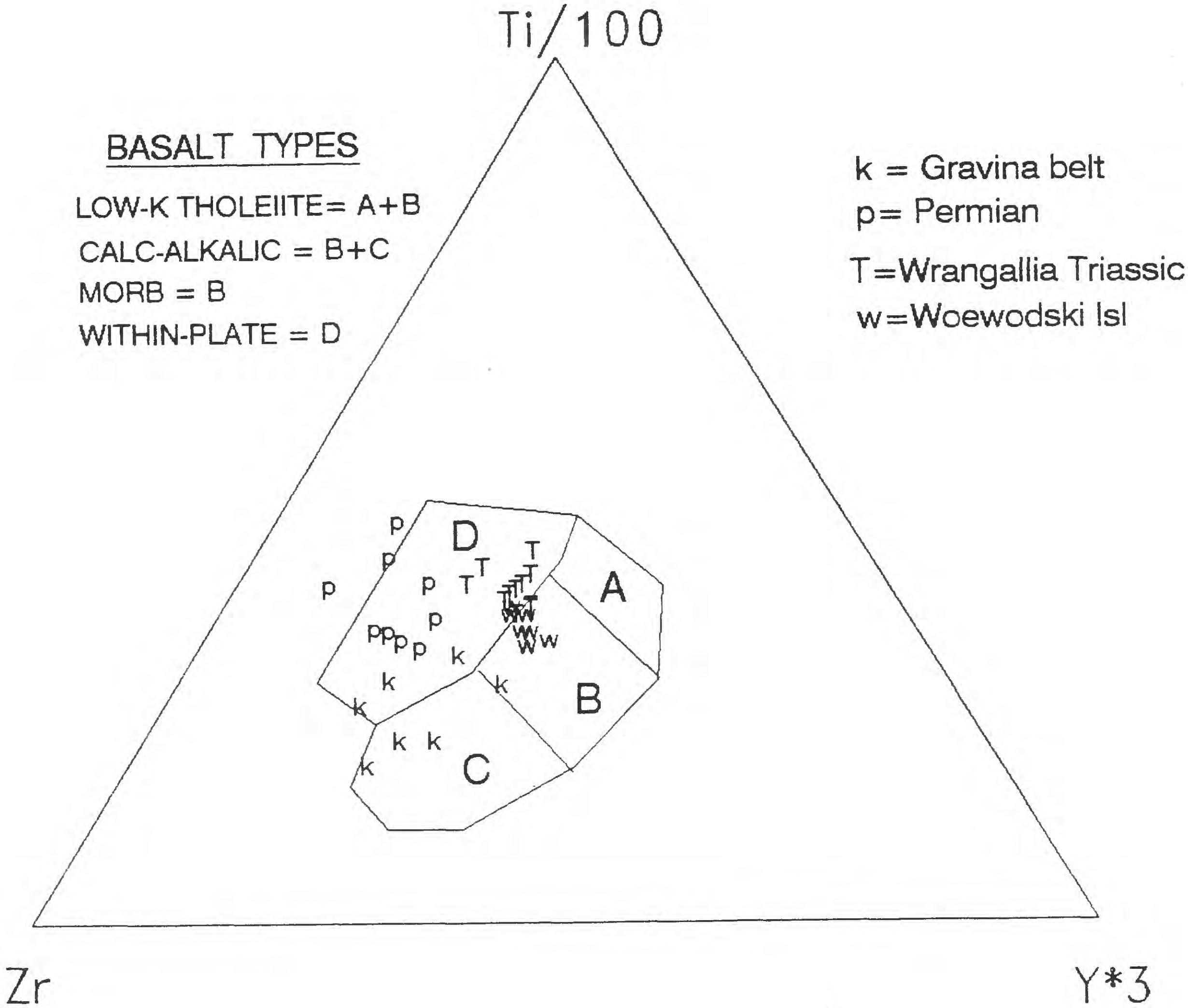

Fig. 18. Basalt tectonic environment diagram of Pearce and Cann (1973) compared to data from Woewodski island metavolcanic rocks and other metavolcanic rocks of northern SE Alaska. Data from Davis and Plafker (1980), Gehrels and others (1991), McClelland and others (1991), Gehrels and Barker (1993), and this study.

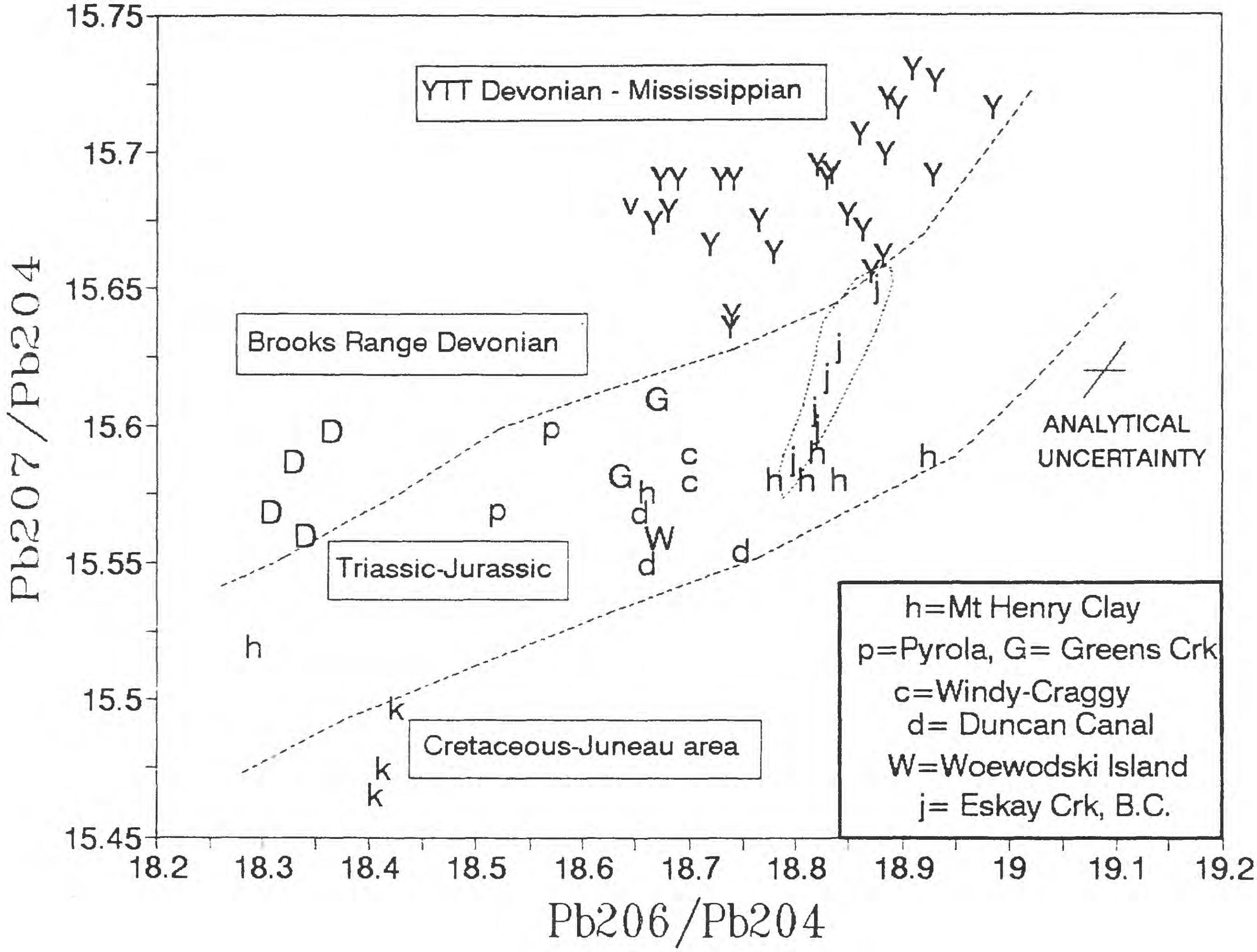

Fig. 19. Common Pb isotopic data for selected VMS deposits and prospects of Alaska and adjacent Canada. Age boundaries from Newberry and others (1997). Data from Godwin and others (1988), Gaccetta and Church (1989), Church (writt. comm., 1996), Childe (1997), and this study.