A Geochemical Characterization of the Indian Creek Metamorphic Suite in the Noble Lake Area, Southern Tobacco Root Mountains, Southwestern Montana

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Introduction

One of the major Archean lithologic packages in the Tobacco Root Mountains is the Indian Creek Metamorphic Suite (ICMS). Dominant rock units of this package are quartzofeldspathic gneiss, amphibolite/hornblende gneiss, aluminous schist, marble, iron formation, and quartzite, with metabasite intrusions. Units outcropping in the Noble Lake area are primarily quartzofeldspathic gneiss, amphibolite, and metabasite. One of the main purposes of this project is to determine the protoliths for these units and, to the degree possible, their subsequent history.

Another concern is the relationship of the Spuhler Peak Formation (SPF) to the ICMS (and the Pony-Middle Mountain Metamorphic Suite (PMMMS)). The contact between the SPF and the underlying gneiss complex is poorly-understood, and has been interpreted as both a fault and an unconformity.

Methods

X-Ray fluorescence was used to determine the concentration of major and trace elements in Noble Lake quartzofeldspathic gneiss, stratiform amphibolite, and metabasite. Twenty-nine samples (16 quartzofeldspathic gneiss samples, 10 metabasites, and 3 amphibolites) were selected for both major and trace element analyses. At present, major element concentrations for 4 quartzofeldspathic gneisses and 6 metabasites are available.

Garnet-clinopyroxene geothermometry was applied to metabasite samples from the Noble Lake area and from samples collected southeast from Noble Lake in a dike swarm in the Ramshorn Creek area. Spectra were collected through scanning electron microscopy/x-ray microanalysis, and results were calculated using a geothermometry software program (John and Spear, 1990).

Three amphibolite samples (1 from the ICMS and 2 from the SPF) and two metabasite samples were prepared for $^{40}Ar/^{39}Ar$ age dating at the Massachusetts Institute of Technology.

DISCUSSION

Quartzofeldspathic Gneiss

Both Heinrich (1960) and Smith (1980) suggest that quartzofeldspathic gneisses from lithologic packages similar to the ICMS quartzofeldspathic gneisses in the neighboring Ruby Range represent a metamorphosed pluton. Rare-earth element analyses of similar quartzofeldspathic gneiss from the Blacktail Range by Clark and Mogk (1986) indicate the protolith to be granitic or tonalititc in composition. However, an intrusive source does not seem likely, because of concordance of quartzofeldspathic gneiss foliation with that of surrounding gneisses (Cordua, 1973), although this concordance may be a function of intense deformation and flattening.

Inter-layering of the quartzofeldspathic gneisses with rocks of obvious sedimentary origin (marble, aluminous schist, iron formation) advocates a sedimentary rather than an igneous protolith for these gneisses. The quartzofeldspathic gneisses are corundum-normative ($Al_2O_3 > CaO + Na_2O + K_2O$), which suggests a sedimentary origin. The presence of rounded zircon grains in the quartzofeldspathics also supports the argument of sedimentary parentage (Cordua, 1973).

Wilson (1981) suggests that the quartzofeldspathic gneiss and amphibolite in the ICMS reresent a 5 km-thick sequence of metamorphosed sandstones interstratified with basaltic and rhyolitic volcanics.

The chemical analyses of the quartzofeldspahic gneiss are not diagnostic. They can be interpreted as supporting both an igneous or sedimentary origin for the samples. CIPW norm calculations suggest a granitic/rhyolitic protolith for the quartzofeldspathic gneiss. (Table 1) This determination is based on normative plagioclase totals of approximately 40-55 wt% and quartz totals of approximately 30-35 wt% applied to the IUGS classification of igneous rocks (Plilpotts, p.102). However, the chemical analyses of the Noble Lake quartzofeldspathic gneisses are also similar to the chemistry of arkosic sandstones.

	Weight Proportions of Normative Minerals							
Sample	Quartz	Albite	Anorthite	Orthoclase	Hypersthene	Corundum	Ilmenite	Apatite
LJ5	30.17	41.67	9.74	14.58	3.22	0.45	0.25	0.09
LJ8	32.04	29.18	5.68	27.42	4.58	0.79	0.42	0.13
LJ47	31.16	39.91	13.16	7.91	6.04	1.37	0.47	0.19
LJ53	32.27	38.3	9.32	11.32	6.55	1.7	0.48	0.17

Table 1. CIPW norm calculations of representative ICMS quartzofeldspathic gneisses.

It seems likely that the abundant quartzofeldspathic gneisses are both metamorphosed arkosic sandstones and volcanics. The Indian Creek Metamorphic Suite would then represent a metamorphosed sequence of interlayered marine sediments and volcanics.

Metabasites

Metabasite sills and dikes are found in all Archean lithologies in the Tobacco Root Mountains and surrounding mountain ranges, except for the Spuhler Peak Formation. Therefore these intrusions possibly play a key role in unraveling the relationship between the SPF and the ICMS. The absence of metabasites in the SPF leads to the assumption that the intrusions occurred before the assemblage of the ICMS and the SPF. The SPF, if indeed it is allochthonous, must have been reasonably far away at the time of intrusion, so as not to be affected. If these assumptions are correct, there may be a difference in the metamorphic histories of the two gneiss complexes.

Metabasite samples from the Noble Lake and Ramshorn Creek areas have chemical compositons similar to those of island arc tholeiites or mid-ocean ridge basalts (Fig. 1). This determination is based on concentrations of MnO, TiO_2, and P_2O_5 (Mullen, 1983).

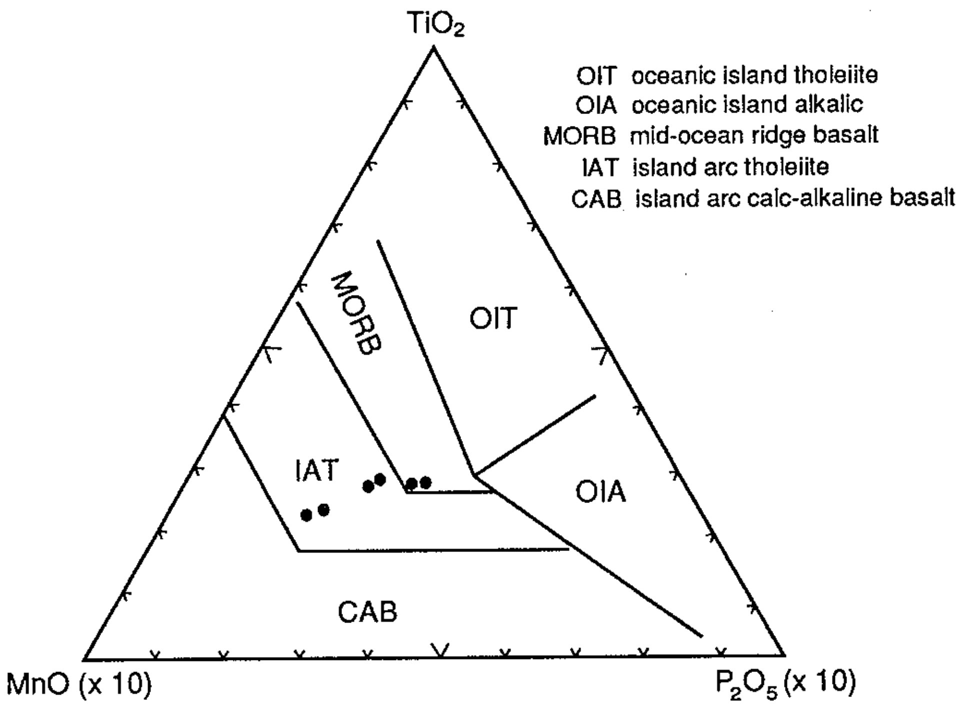

Figure 1. MnO-TiO_2-P_2O_5 discrimination diagram for oceanic basaltic rocks (after Mullen, 1983).

Low- and high-angle discordance of the metabasite intrusions with the foliation of the Indian Creek rocks indicates that the metabasites are younger than the gneissic banding event (Figure 2). The metabasites are fairly high-grade rocks, metamorphosed by a late-stage event relative to the deformation of the ICMS. Presumably, the metabasites were fairly pristine at the time of onset of this event, and therefore the metamorphic temperatures and pressures of the metabasites indicate the conditions of the metamorphic event. Garnet-clinopyroxene geothermometry supports temperatures of approximately 700-800° C (Fig. 3) which indicates lower granulite to upper amphibolite facies. However, the presence of water during deformation and metamorphism may affect mineral chemistry in such a way as to obscure actual metamorphic temperatures.

Figure 2. Metabasite intrusion cross-cutting folded quartzofeldspathic gneiss foliation.

Conclusions

A logical tectonic/depositional model for the Indian Creek Metamorphic Suite is that of a fore-arc basin (Wilson and Hyndman, 1990). The ICMS (and PMMMS) represent accretionary-wedge sediments interstratified with related volcanics from a collisional island-arc setting. The younger metabasites then poossibly represent island arc basaltic intrusions.

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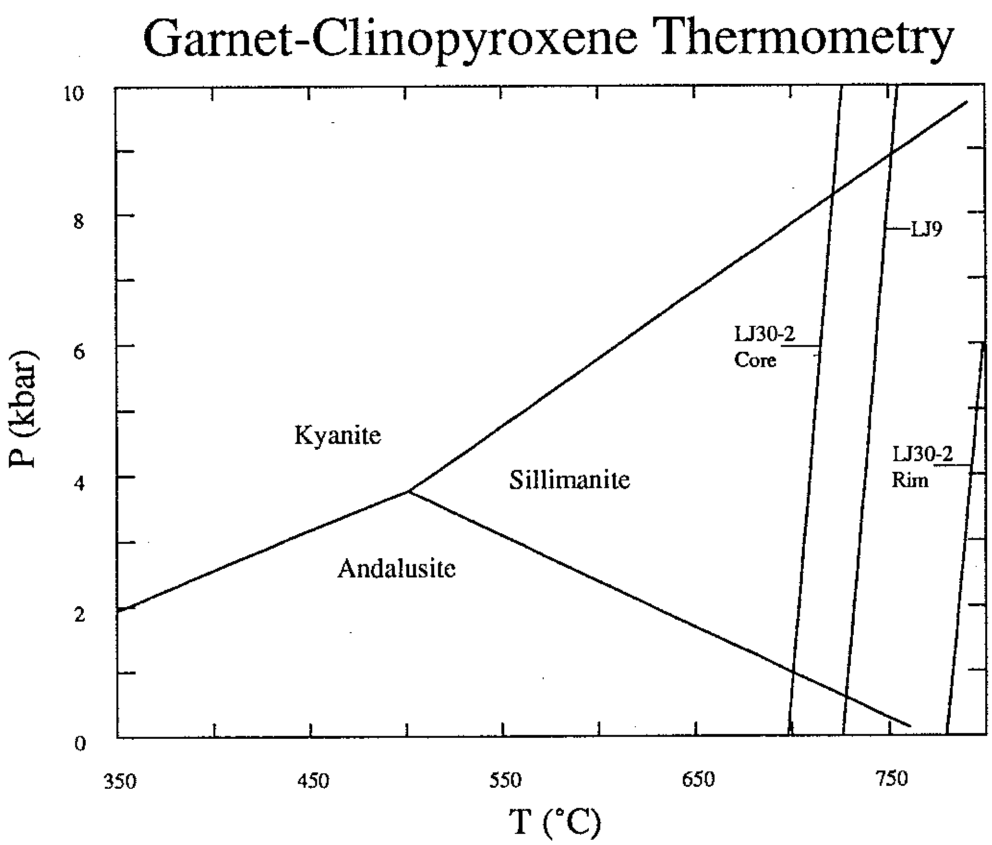

Figure 3. Garnet-clinopyroxene geothermometry plot for metabasite samples LJ9, from the Ramshorn Creek area, and LJ30-2, from the Noble Lake area. Calibrations by Ellis and Green (1979) applied to data. Rim and core temperatures are given for LJ30-2.