THE ORIGIN AND EVOLUTION OF THE SPUHLER PEAK FORMATION ALONG THE WESTERN RIDGE OF THOMPSON PEAK, TOBACCO ROOT MOUNTAINS, MONTANA.

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Introduction

The Spuhler Peak Formation (SPF) has been interpreted as a distinct package of rocks within the Archean terrain of the Tobacco Root Mountains (Burger, 1966; Gillmeister, 1971). The Tobacco Root Mountains are contained within the northernmost part of the Wyoming Province as defined by Condie (1976). One of the fundamental characteristics of the SPF is the presence of orthoamphibole bearing rocks. Orthoamphiboles indicate that the rocks in which they are housed have been depleted in Ca and the alkalis and enriched in Mg. Spear (1993) has proposed that the most likely mechanism to explain the anomalous bulk composition of the orthoamphibole rocks is that of premetamorphic alteration by weathering, deuteric alteration, or hydrothermal alteration by sea water. This explanation is especially attractive when applied to the SPF, as it is consistent with the possibility that the SPF is a slice of Archean oceanic crust (since hydrothermal processes on the ocean floor are common in areas of volcanic and tectonic activity). Furthermore, because the extent of alteration depends upon the local access of sea water, which is most likely regulated by the local fracture density, this model can explain the interbedding of orthoamphibole- and calcic amphibole- bearing rocks. An alternative hypothesis to account for the intercalation of Mg-rich and normal basaltic rocks is that the SPF is a fragment of an Archean greenstone terrain and the Mg-rich rocks represent metamorphosed komatiite sequences. In either case, the SPF now resides on a supracrustal sequence, the ICMS, which consists of a sequence of quartzites, marbles, felsic gneisses, aluminous gneisses, and amphibolites.

Purpose and Methods

The objective of this study is to characterize the lithologies exposed along the western ridge of Thompson Peak in order to better constrain the origin and subsequent evolution of the Spuhler Peak Formation. This is being executed both on a macroscopic level, via a strip map illustration which shows the lithologic variation of the SPF exposed along a nearly continuous section (see Figure 1), and on a microscopic level, via analysis of the rocks in thin section. Specially attention has been focussed upon the occurance of cordierite, which has been previously overlooked in the rocks of the SPF. Over 60 hand samples were collected in the field, of which approximately 50 have been made into thin sections. Using the Zeiss Digital Scanning Electron Microscope (SEM) with a LINK Energy Dispersive Spectrometer (EDS), mineral composition data have been obtained from six SPF samples. This data will subsequently be employed in geothermometery and geobarometery in order to constrain the pressure and temperature of the package's metamorphic history.

Results

The western ridge of Thompson Peak contains a repetitive sequence of quartzites, amphibolites, and gneisses, as shown by Figure 1. Because the lithologies along the ridge have been extensively folded, unambiguous interpretation of field relationships is at best limited. The intercalated lithologies may reflect original emplacement or, more likely, indicate that the ridge is part of a large scale fold. Some rocks (especially the amphibolites) are well foliated but did not appear to be folded, whereas others (such as the pelites) commonly have small scale folds.

Most of the quartzites are aluminous and consistently contain silliminite, which is commonly strikingly coarse grained. One notable exception is the quartzite (which Gillmeister defines as the "basal quartzite") that marks the contact between the SPF and the ICMS. It is not aluminous, but does contain feldspar.

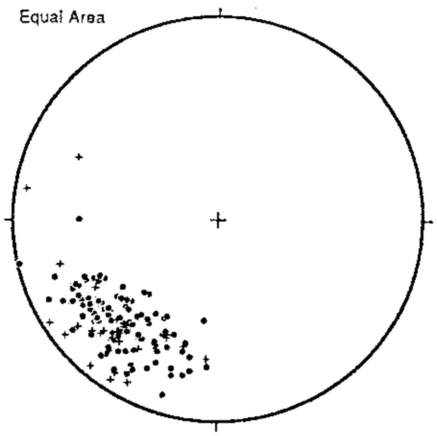

Figure 2. Poles to Foliations for Gneiss (+) and Amphibolites (·).

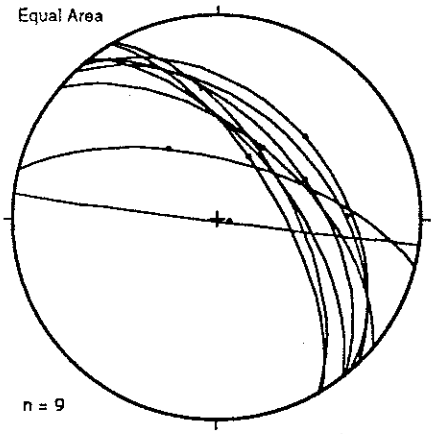

Figure 3. F1 Hinge Lines and Axial Surfaces.

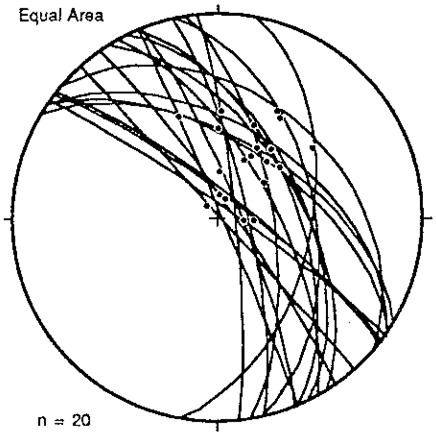

Figure 4. F2 Hinge Lines and Axial Surfaces

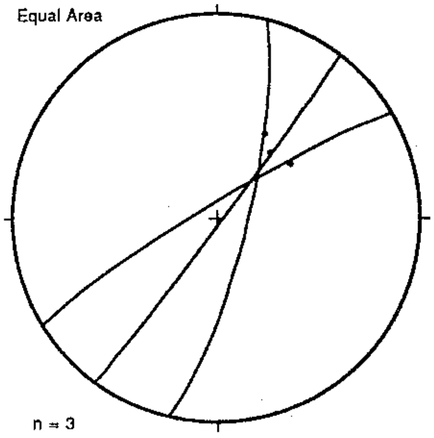

Figure 5. F3 Hinge Lines and Axial Surfaces

Table 1.Whole Rock Chemistry for Twelve Lithologic Samples (N/A means composition not available)

Sample #	6	11	15	17	30	1	14	19	22	24	27	28
Lithology	q.f. gneiss	garnet q.f. gneiss	q.f. gneiss	q.f. gneiss	quartzite	amphibolite	amphibolite	ultramafic	ultramafic	ultramafic	ultramafic	ultramafic
Major Elements												
SiO2	67.03	53.09	68.28	67.02	94.91	50.26	52.22	44.08	47.51	43.16	43.1	48.32
TiO2	0.64	0.82	0.54	0.9	0.14	0.9	2.07	0.22	0.19	0.26	0.21	0.3
Al2O3	15.38	16.35	13.8	14.68	2.57	13.76	12.28	4.81	5.26	4.34	5.16	4.16
Fe2O3	7.6	18.43	7.99	7.99	1.01	13.81	13.82	12.81	11.93	12.32	13.84	9.01
MgO	3.89	5.54	4.3	4.01	0.57	7.64	6.19	30.48	30.42	31.69	30.29	27.34
CaO	0.39	2.34	0.86	0.15	0.09	10.97	9.82	3.53	1.66	3.14	3.57	6.31
Na2O	0.29	0.15	1.74	0.25	0.18	0.98	1.91	0.18	0.12	0.21	0.24	0.29
K2O	2.83	0.55	2.84	3.67	0.47	0.55	0.48	0.05	0.03	0.57	0.07	0.27
P2O5	0.02	0.05	0.04	0.02	0.02	0.09	0.24	0.03	0.03	0.03	0.02	0.03
MnO	0.9	4.43	0.25	0.38	0.01	0.2	0.24	0.27	0.36	0.43	0.35	0.29
LOI	2.31	0.23	1.13	1.47	N/A	0.97	0.56	3.25	2.21	2.67	3.03	2.72
TOTAL	101.28	101.98	101.77	100.54	99.97	100.13	99.83	99.71	99.72	98.82	99.88	99.04
Trace Elements												
Ba	669	146	744	1194	N/A	41	77	4	9	112	4	38
Be	0.6	0.3	1.2	0.6	N/A	1.4	0	0.5	0.5	0.5	0.5	0.7
Ce	45	58	36	44	N/A	11	18	3	9	1	6	6
Co	23	37	23	23	N/A	59	41	101	103	96	114	73
Cr	317	394	331	367	N/A	162	45	2896	3582	4890	2666	3755
La	24	34	19	22	N/A	30	29	10	4	7	8	20
Sc	13	21	12	17	N/A	40	41	13	13	14	16	22
Sr	9	8	39	10	N/A	89	100	3	8	7	2	13
Ti	0.56	0.85	0.47	0.67	N/A	0.87	1.89	0.19	0.16	0.23	0.19	0.28
V	118	122	92	122	N/A	280	410	89	78	96	94	98
Y	13	25	11	19	N/A	20	48	6	3	5	6	10
Yb	1.3	2.7	0.9	1.9	N/A	2.1	5.9	0.53	0	0.1	0.5	0.8
Zr	156	168	144	225	N/A	63	135	19	12	9	33	36

The pelitic gneisses most consistently contain cordierite. It commonly occurs in the groundmass as intergrowths with silliminite and biotite. It may also fill the fractures and rim broken garnet crystals. This texture is indicative of decompression, which coincides with observations made by Archuleta (1994, this volume). Some of the the garnets in the pelites have such strong chemical zoning that it is obvious even in backscattered images on the SEM (see Figure 2). Representative Mg/Mg+Fe ratios for garnets similar to the one pictured vary from .264 at the core to .171 at the rim. Although the Grossular component does not change significantly from the cores to the rims, the Pyrope and Almandine components decrease at the rim and the Spessartine component increases. This is consistent with the interpretation that cordierite is growing at the expense of garnet, since while the cordierite depletes the garnet in Mg and Fe, it does not require Mn (so the garnet rims become enriched in Mn). It is also significant that each individual garnet fragment is zoned, as this indicates that the zoning (and thus the cordierite growth) occurred after fragmentation of the garnets.

The amphibolites vary slightly in color, garnet content, and grain size. They also contain different combinations of hornblende, magnesio-hornblende, and cummingtonite. The cummingtonite in the amphibolites varies in habit. In addition to forming typical,subhedral crystals, it also occurs along the edges of hornblende crystals. At least one rock contains both cummingtonite and cordierite (enveloping fractured garnet). This assemblage is rare and is indicative of low pressure (<4 kb) (Spear 1993).

Although both gedrite and anthophyllite have been found in different rocks of the SPF, they have yet to be observed coexisting in one rock. This is consistent with the temperatures at which the rocks of the SPF are thought to have been metamorphosed, as they are higher temperatures than the gedrite-anthophyllite miscibility gap which lies at approximately 600-625 degrees Celsius at roughly 5 kbar (Spear, 1993). The mineral assemblages in the SPF are summarized according to rock type in Table 1. These assemblages are consistent with upper amphibolite facies metamorphism and constrain the package's metamorphic history. Specifically, the occurance of cordierite and cummingtonite, cordierite and garnet, and the lack of two coexisting orthoamphiboles coincides with the interpretation that the SPF must have undergone high T, low P metamorphism. However, the presence of remnant kyanite indicates that these rocks were once at higher pressures. These observations both strengthen and extend the model proposed by Archuleta (1994, this volume).

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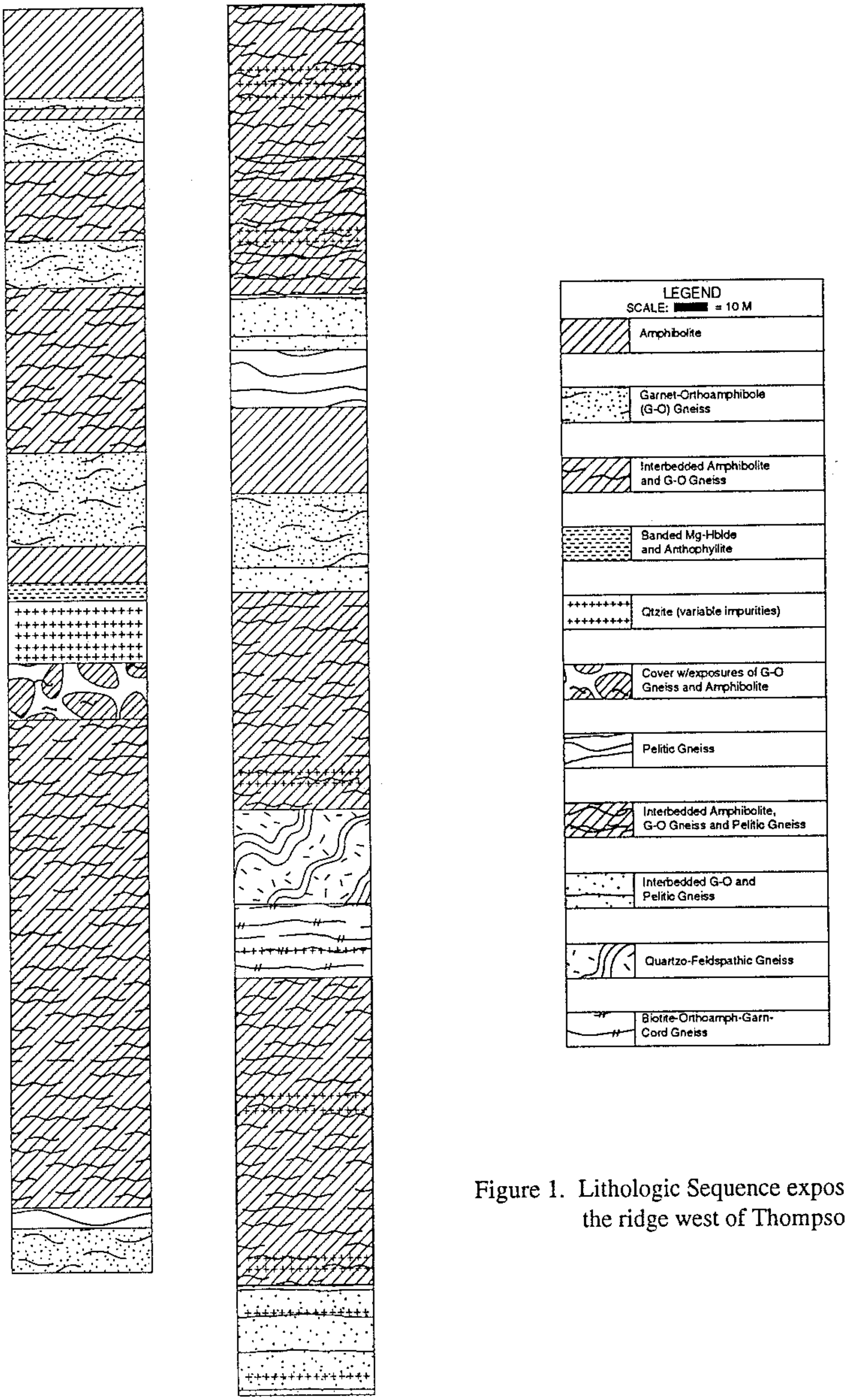

Figure 1. Lithologic Sequence exposed along the ridge west of Thompson Peak.

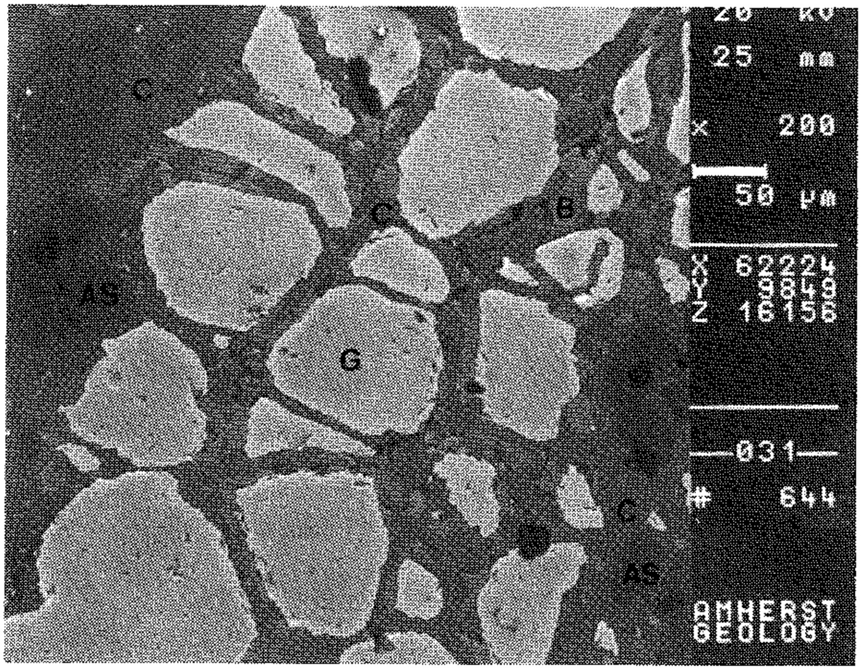

Figure 2. Backscattered image of pelitic gneiss displaying zoned, fractured garnets enveloped by cordierite, and cord-aluminosilicate intergrowths. G=Garnet; C=Cordierite; B=Biotite; AS=Aluminosilicate

Quartzite:	Qtz-Plag-Bio-Chte
	Qtz-Sill-Fuc-Musc
Amphibolite:	Hblde-Cumm-Garn-Plag-Qtz-(Bio-Clte)
	Hblde-Cumm-Cpx-Bio-Plag-Qtz
	Hblde-Cumm-Garn-Cord-Plag-Qtz
	Hblde-Garn-Plag-Qtz
	MgHblde-Cumm-Garn-Plag-Qtz-(Bio-Clte)
	Anth-MgHblde
Pelitic Gneiss:	Garn-Bio-Sill-Cord-Plag-Qtz
	Garn-Bio-Sill-{Kyan}-Cord-Plag-Qtz
G-O Gneiss:	Anth-Garn-Cord-Plag-Qtz-(Bio)
	Ged-Bio-Garn-Plag-Qtz

Table 1. Common Mineral Assemblages in SPF rocks.

CONSTRAINING BALANCED CROSS-SECTIONS IN FORELAND FOLD AND THRUST BELTS

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