A detailed study of the contact between Archean rock suites, southern Tobacco Root Mountains, southwestern Montana

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Rocks exposed in the Tobacco Root Mountains in southwestern Montana are primarily Archean gneisses. The Spuhler Peak Formation (SPF), an assemblage consisting primarily of amphibolite gneisses, sillimanite schist, and quartzite, and interpreted to be of possible oceanic origin, is located structurally above the Indian Creek Metamorphic Suite (ICMS), interpreted to be metamorphosed continental margin sediments, and below the Pony-Middle Mountain Metamorphic Suite (PMMMS) which is lithologically similar to the ICMS. The contact between the ICMS and the SPF lies just east of Branham Lakes, in the southwest of the Tobacco Root Mountains. The nature and origin of this contact has been unclear. Data gathered in this projec elucidates the nature and history of the contact. Burger (1967) interpreted the contact as a fault based on apparent truncation of folds along the contact, and apparently different metamorphic histories across the contact. Gilmeister (1971) explains the contact as an unconformity, stating that the SPF depositionally overlies the ICMS and PMMMS. The planar spread of isoclinal folds axes and the presence of sheath folds in the SPF suggest a history of simple shear. Structural analyses of this fold indicate a direction of transport of the SPF in the hanging wall down to the northeast. Parallelism of mineral lineations and fold axes and of foliation within the girdle of fold axes suggests related development. Data suggest that the contact between the SPF and the surrounding rocks may be isoclinally folded in the same orientation as the isoclinal and sheath folds observed in the SPF. The folding of this contact is potentially the result of this simple shearing event, and it is postulated that the contact itself is also a result of this event.

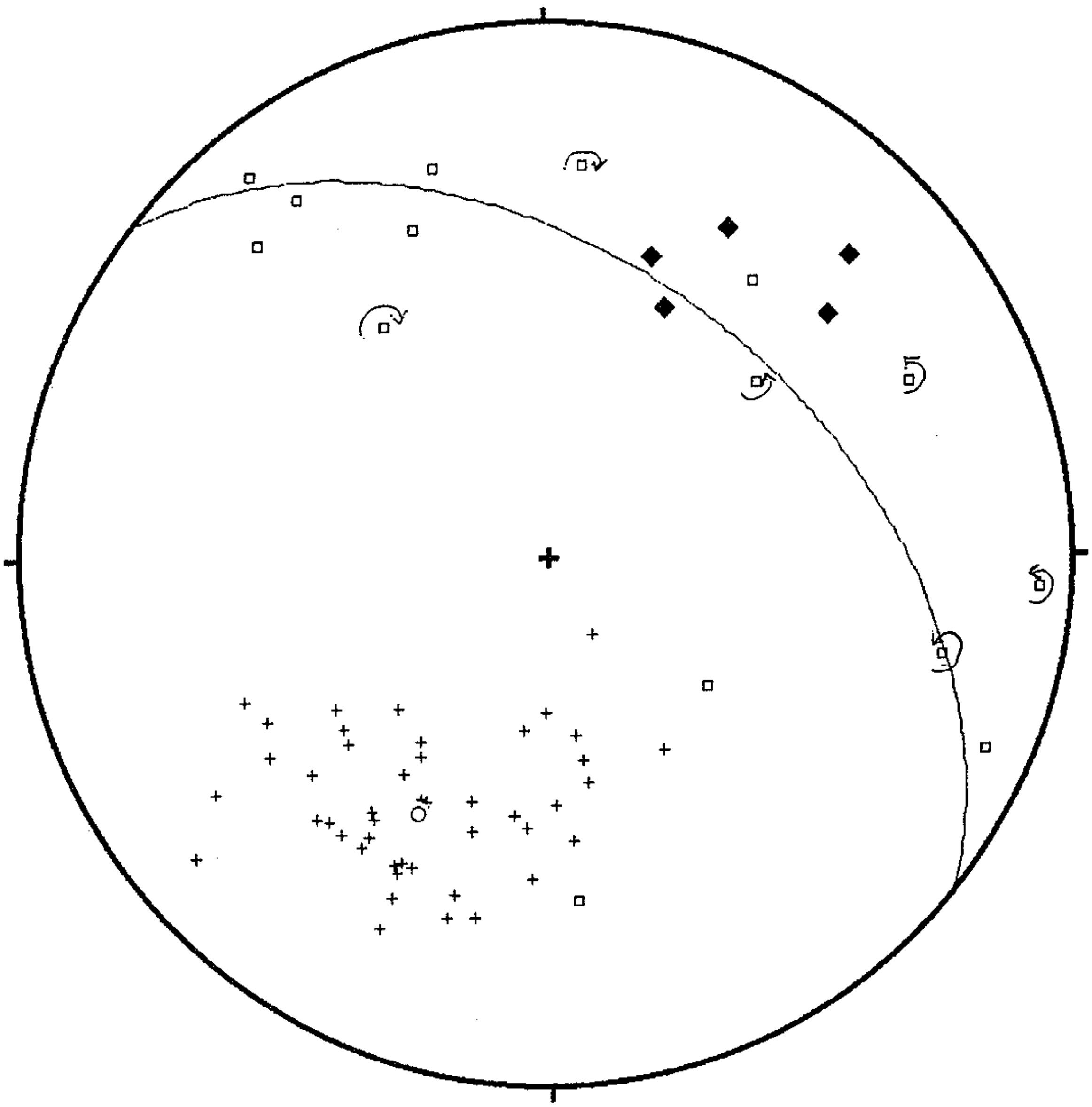
Four types of folds occur in the SPF, referred to here as isoclinal, sheath, open and ptygmatic. The "isoclinal" folds are rounded, inclined, isoclinal, meter-scale folds found in both the SPF amphibolite layers and its quartzofeldspathic layers (though more common in the latter). Only one sheath fold was actually observed in the field, folding mafic layers and their foliation. The isoclinal and sheath fold axes lie in or near an a plane oriented at 308°44°. Dispersion from this plane can be attributed to rotation about the open fold fold axes. The "open" folds are rounded, sinusoidal, open meter-scale folds which form an interlimb angle of between 50° and 130°, and have an average fold axis 038°40° (Syncock, 1994). Both foliation and compositional layering, and the axial planes of the isoclinal folds are folded around them. "Ptygmatic" folding describes irregular folds on a 10s of cm scale, which are rounded, tight to isoclinal, asymmetric, and steeply inclined to recumbent. This type of folding is abundant in the quartzofeldspathic layers featuring biotite, sillimanite and garnet. The ptygmatic folds show no systematic distribution and are not considered in this analysis. While smaller intrafolial folds do exist in the ICMS, they are less commonly observed, and less amenable to analysis than those in the SPF.

The presence of sheath folds, and the dispersion of isoclinal and sheath fold axes within a girdle indicates the presence of penetrative simple shear in the SPF. This girdle of fold axis orientations coincides approximately with the average orientation of the foliations measured throughout the Branham Lakes area, (298° 40°), suggesting a simultaneous origin of the foliation and the isoclinal / sheath folds, both of which are folded by the later, open folding event. (Fig. 1) Stereonet analysis of asymmetry of the isoclinal and sheath folds reveals a direction of transport and sense of shear of approximately 30° 30° and a normal, top down motion to the northeast within the area. Correspondingly, mineral lineations observed in the field and in thinsection run subparallel to this transport direction.(e.g. 026° 47°, 046°20°) Asymmetric feldspar augen also demonstrate rotations which lie subparallel to this transport direction (050° 30°, 020° 40°). Three-point analysis of the contact surface (as mapped by Vitaliano, et al.) may suggest that the contact itself is isoclinally folded similar to the isoclinal and sheath folds in the SPF. (Lowell, 1994) It is conceivable that both the folding of the contact surface, and perhaps the contact itself, are the result of this large scale shearing event.

Amphibole Ar^{40}/Ar^{39} dating across the contact should provide time constraints to these deformational events.

Fig. 1. Synoptic lower hemisphere projection of key structures.
+ = pole to foliation
o = pole to average foliation
□ = isoclinal/sheath fold axis showing sense of rotation where known
◆ = mineral lineation

Great circle projection shows best fit girdle for isoclinal/sheath fold axes.



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Petrological and Structural Constraints on the History of the Spuhler Peak Formation Near Noble Lake, Tobacco Root Mountains, Montana

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Introduction

The Spuhler Peak Formation (SPF) is particularly well exposed along the narrow ridge that snakes from Noble Lake up and over Spuhler Peak. This study involved a traverse of Spuhler Ridge, from the SPF's southern contact with the Indian Creek Metamorphic Suite (ICMS) through its northern contact with the Pony-Middle Mountain Metamorphic Complex (PMMMC). Field observations, structural analyses, petrological and geochemical samples were all collected in the hopes of elucidating the murky history of this unusual package of Archean rocks.

Little previous work has focused specifically on the SPF. Gillmeister (1971) concluded that the contact between the SPF and the ICMS and PMMMC is an unconformity, with the SPF structurally on top. Friberg (1976) constructed a detailed stratigraphic column across the SPF, and described the metamorphic history of the SPF in terms of two events; an inital upper amphibolite grade event, and a later, possibly Cretaceous biotite-chlorite grade event, related to the emplacement of the nearby Tobacco Root Batholith.

Significant evidence exists, however, to support the following conclusions of this study:

1) The contact between the SPF and the ICMS and PMMMC is interpreted as a fault rather than an unconformity, as originally suggested by Burger (1969).

2) There appears to have been an additional, lower pressure metamorphic event that overprinted the original upper amphibolite assemblages, before the emplacement of the Tobacco Root Batholith. This event was associated with melting and folding of the SPF.

Stratigraphy: Major Units of the SPF

The Spuhler Peak Formation is comprised of hornblende-plagioclase amphibolites, ortho-amphibolites (containing gedrite and anthophyllite), aluminous quartzites, and occasional meta-ultramafic pods. Along Spuhler Ridge, the seven lithologic units described by Friberg were found to be difficult to distinguish. Due to the great variety of textures and appearances, his five different amphibolite units have been regrouped into two major units for the purposes of this study. There are five units within the SPF in the study area (Fig. 1).

1) Quarzite Package: This unit has previously been referred to as the Basal Member, due to its frequent occurrence at or near the contact. However, it is not in fact present at all contact locations. It ranges in thickness from 0 to 30m, and is predominantly quartzite, with quartz, garnet, plagioclase, and biotite, and sometimes kyanite, sillimanite, and microcline. Amphibolites containing hornblende, plagioclase, garnet, quartz, and biotite are interlayered with the quartzites on a cm to 2m scale. Ortho-amphibolites with gedrite, plagioclase, quartz and garnet form layers and lenses under 1m thick.

2) Wispy Amphibolite: Immediately above the QP is the WA, an 80 to 150m thick, migmatized hornblende- amphibolite with abundant felsic melt pockets, or "wisps" of plag (55%) and quartz (40%). The mafic restite is accordingly depleted in quartz and plag, with up to 90% hornblende, and minor garnet. Hornblende crystals are large and often euhedral, and all minerals appear to have crystallized at the same time. Foliation is weak.

3) Massive Amphibolite: The WA grades into the MA, which ranges from 50 to 200m in thickness. Overall hornblende, plagioclase and quartz percentages are similar to the WA, but it has not been migmatized, so the mafic and felsic minerals are evenly distributed. Crystals are smaller and more poorly formed than those of the WA, and foliation is more strongly developed. Biotite (up to 15%) and pyroxene (up to 8%) are present in the MA but not in the WA. The crystallization sequence is well preserved, with pyx early and garnet late.

4) Aluminous Quartzite: The most visually distinctive unit of the SPF is the AQ, a 10 to 40m thick, orange quartzite containing up to 30% sillimanite and 15% biotite. Quartz grains have been coarsely recrystallized.

5) Ultramafics: Clinopyroxene-rich meta-ultramafic pods are scattered throughout the SPF, with one pod present just southeast of the summit of Spuhler Peak. Samples of the UM were too altered for much detailed study.

Although they are a significant component of the SPF, and mineralogically distinct, ortho-amphibolites have not been included as one of the major units due to their lateral discontinuity and irregular distribution within the various other units. These rocks include both gedrite and anthophyllite, and may be nearly mono-mineralic, or contain large amounts of garnet, plagioclase, quartz, and sometimes cordierite. Garnets as large as 10 cm, and orthoamphiboles as long as 15 cm were observed.