The Deformational History in the Vicinity of Pete's Point, Eagle Cap Wilderness Park, Northeastern Oregon

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INTRODUCTION

The Jewett Lake region in the Wallowa Mountains has undergone severe deformation characterized by repeated folding, faulting, metamorphism, uplift, and erosion. This deformation has not been closely studied since the advent of plate tectonic theory, thus the possible tectonic causes of the deformation have not been evaluated. Instead, much of the deformation and metamorphism in the region has been attributed to emplacement of the Wallowa Batholith. In the current study, I intend to develop a structural and metamorphic history of my field area, just south of Jewett Lake (Figure 1). This history will aid in evaluating possible causes of deformation and stress in the context of mass displacement due to batholith intrusion as well as what is now known about plate tectonics and accretion.

LITHOLOGIES

There are two major formations present in the field area; the Martin Bridge Formation and the overlying Hurwal Formation. The Martin Bridge and Hurwal Formations occur throughout northeastern Oregon and western Idaho as the upper members of the accreted Wallowa arc terrane. The Martin Bridge Formation is predominantly a massive and thinly bedded platform limestone (Vallier, 1974) with localized reefs (Nolf, 1966). Lying conformably atop the Martin Bridge is the Hurwal Formation, a transgressive-regressive sequence of shale and limestone (Brooks and Vallier, 1978). By examining fossils in both formations, Smith and Allen (1941) have concluded that the Martin Bridge Formation was deposited during the Upper Triassic, mostly during the Carnian. It appears that the boundary between the two formations closely approximates the boundary of the Carnian and the Norian. The top of the Hurwal Formation has never been observed; it is assumed that the majority of deposition occurred during the Norian, however, the exact time that deposition ceased is unknown.

In the Jewett Lake region, the Martin Bridge Formation can be subdivided into an upper and a lower member. The younger, upper member is a dark grey, rhythmically layered limestone and silty limestone which is only present locally and is not observed in my study area. The older and more prominent unit is a light to medium grey metamorphosed limestone with minor siltstone interbeds. The member is not exposed in its entirety anywhere in the region, but the thickness is in excess of 200 m. Two distinctive beds of a dark grey, coarse grained limestone fossil mash approximately 1 m in width contain fragments of crinoids, brachiopods, limpets, sponge spicules, and well-rounded clasts of sandstone and shale. Though distinctive, these layers cannot be used as regional marker beds because they are extremely localized. In thin section, the rocks consist primarily of twinned calcite grains and minor amounts of diopside and quartz indicating amphibolite facies metamorphism. The Martin Bridge limestone has been ductilely deformed, producing both annealed and mylonitic fabrics.

The Hurwal Formation can be subdivided into three members. The lowermost member is a 20 m transitional zone consisting of interbedded argillite and limestone. This member grades from thick beds of limestone with sparse layers of argillite at the base upward to predominantly argillite and sandstone beds. Above this transitional zone is a 0-100 m thick grey, tan, or rusty, rhythmically weathered bedded argillite with minor limestone and sandstone. Capping the Hurwal Formation is at least 200m of black, rhythmically bedded argillite and siltstone with very minor limestone, which weathers to a rust color. The entire Hurwal Formation has been metamorphosed to amphibolite facies, as indicated by the thin section mineral assemblage of amphibole+feldspar+diopside, with minor amounts of calcite, quartz, and opaques.

In the field, distinction between the two upper members was based primarily upon coloration of weathered surfaces and the relative abundance of limestone. The separate members were examined by X-Ray Fluorescence (XRF) Spectrometry to compare chemical compositions. The upper, rust colored member contains generally higher concentrations of calcium, although the variation of calcium content within the members is greater than the variation between members. The rust colored member also contains lower concentrations of iron, which may seem contrary to megascopic observations of rust staining. However, the coloration could be due to the oxidation state of the iron. The rust colored member was observed to have a characteristic presence of pyrite; perhaps the iron in the grey unit is in the form of magnetite or hematite. Oxidation states cannot be determined by XRF Spectrometry. Finally, when analyzed for ten major elements, the rust colored member had lower concentration totals. It is plausible that sulfur, which was not analyzed, contributes significantly to the composition of the rust colored member, accounting for the metamorphosed rocks, we can infer that the bulk composition must have been dolomitic, rather than calcitic, in nature.

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deficit in total concentration. Thus, with x-ray analysis some general differences in the chemistry of the rust colored and grey colored members have been identified, which supports their classification as two separate members.

There are several other lithologies which are recognized in Jewett Lake. Undifferentiated Miocene Columbia River Basalt outcrops as both flows and dikes in the mapped section. Cross cutting dikes of Wallowa batholith granodiorite, trondjhemite, and an intermediate material are also present (see West and Dodds, this volume).

GEOLOGIC HISTORY

During the Carnian, the Martin Bridge Formation was deposited in a shallow marine environment where reefs could form. This depositional setting is indicated by the fossils of many organisms which require sunlight in order to live. A general subsidence of the area is reflected in the grading of the Martin Bridge limestone into the Norian Hurwal siltstone. In much of the Hurwal, a repeated sequence of sandstone grading upward into cross-bedded siltstone topped by an abrupt truncation is present. This sequence is commonly associated with turbidite deposition, suggesting that the area may have once been an abyssal plane or a back arc basin, both of which are deep marine environments than can sustain the formation of limestone.

The bedding was deformed by a series of low angle faults. Minimal displacement (<100 m) is seen along the fault planes, and deformation may be related to continued subsidence and resulting compression of the Martin Bridge and Hurwal Formations. Cross-cutting the low angle faults are two separate groups of trondjhemite and intermediate dikes. In several locations the intermediate dikes can be seen cutting across the trondjhemite dikes, implying that the intermediate dikes were the latter of the two intrusive events.

The first major deformational event is manifested in two separate yet related structures. First, large scale thrust faults striking NE-SW and dipping to the NW result in extensive compression of the stratigraphy. Two such thrust faults are present in my field area (Figure 1). These faults were identified in the field by an abrupt change in the dip of bedding and the slope of topography, truncation of bedding and dikes, and a break in stratigraphy. Second, massive folding warped the thrust faults, dikes, and bedding. The compiled mapping from this project indicate that my area is on the upper limb of an overturned syncline with an axial plane striking NE and dipping to the SE. Sedimentary structures in my area indicate that younging is to the west ,and bedding becomes more steeply dipping westward as the fold hinge is approached. The fold hinge is approximately one mile to the northeast of my area (Blackburn, this volume). The geometry and kinematics of the area indicate that the two events, folding and thrust faulting, are related. Specifically, the axial surface of the fold is parallel to a foliation dipping SE suggesting that the foliation was formed during folding and was not subsequently deformed. Lineations cluster at 90° from the fold axis orientation, implying a transport direction of NW-SE.

Prior to the folding and thrusting event, and thus, not as a result of batholitic intrusion, metamorphism altered the rocks to amphibolite facies. The best evidence for this order of events is found in thin section analysis. The limestone both in the Martin Bridge and the Hurwal Formations was found not to be annealed. Shearing along the thrust faults is the primary cause of the deformation, and metamorphism of the limestone would lead to annealment. Therefore, metamorphism of the rocks had to occur pre-thrust faulting in order for them to posess their current texture.

In the Late Jurassic to Early Cretaceous (160-120 Ma), the Wallowa batholith and associated dikes intruded the country rock (K-Ar and Rb-Sr dating, Armstrong et. al., 1977). The batholith covers nearly 1580 km^2 and is is primarily composed of quartz diorite and granodiorite (Smeads, 1959). The contact with the batholith in the Jewett Lake area lies just to the west of my field area. These dikes contain no foliation and are not metamorphosed; therefore, post-deformation.

Subsequent to the intrusion of the batholith, uplift and erosion occurred, creating the topography to be flooded by the Miocene Columbia River Basalts 15 Ma (Smeads, 1959). The various flows of the Columbia River Basalts have been extensively studied and differentiated (Reidel and Hooper, 1989), however, in this study they are considered as one undifferentiated unit. Throughout extrusion of the lava flows, uplift continued resulting in basalt capping many high peaks in Oregon and Idaho.

The last major structural deformation to occur (perhaps contemporaneous with uplift) was the development of high angle normal faults striking N-S and dipping almost vertically (Figure 1). These faults offset every major structure and bedding in the area, and have not been folded. There is relatively little offset along the faults as can be seen by the easternmost fault in my area. Although the absolute offset cannot be determined, the offset is not so great as to juxtapose two different lithologic units. Finally, during the Pleistocene, glaciation occurred, creating numerous Quaternery sedimentary deposits. Since the retreat of the glaciers, only erosion from rivers, streams, and snow melt has altered the topography.

REGIONAL INTERPRETATION

The general orientation of stress for the Jewett Lake area has a direction of maximum compression trending NW-SE. The major thrust faulting and folding episode resulted in material being overthrust from the northwest to the southeast. Folding resulted in a foliation lying parallel to the axial surface of the prominent fold and dipping to the southeast. Lineations within the limestone and some argillites show a similar direction of material transport.

There are three possible interpretations for the causes of the stress regime for the Jewett Lake region. The theory proposed in much of the literature is that intrusion of the Wallowa batholith has displaced and metamorphosed the surrounding country rock. This theory is not supported by the findings in this region. Metamorphism occured prior to emplacement of the batholith, which can be concluded from the unannealed nature of the limestone, and the metamorphic fabric related to deformation is cross-cut by plutonism. A second cause of stress could possibly be mass displacement and metamorphism of country rock due to the presence of the batholith far beneath its final resting place prior to its emplacement. If this were true, structures surrounding the entire batholith would have a direction of compression radiating outward. Thirdly, the deformation could be a result of accretion of the Wallowa island arc terrane onto the continent. One could then expect to observe the same type of deformation with similar orientations surrounding the entire batholith.

Therefore, it can be concluded that metamorphism and deformation are not primarily associated with emplacement of the Wallowa batholith, as has commonly been presumed. Further study of areas surrounding the batholith is essential to completely characterize the sources of the region's stress. The Jewett Lake region has, however, been useful in placing initial constraints upon the tectonic events of the region.

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Figure 1: Explanation

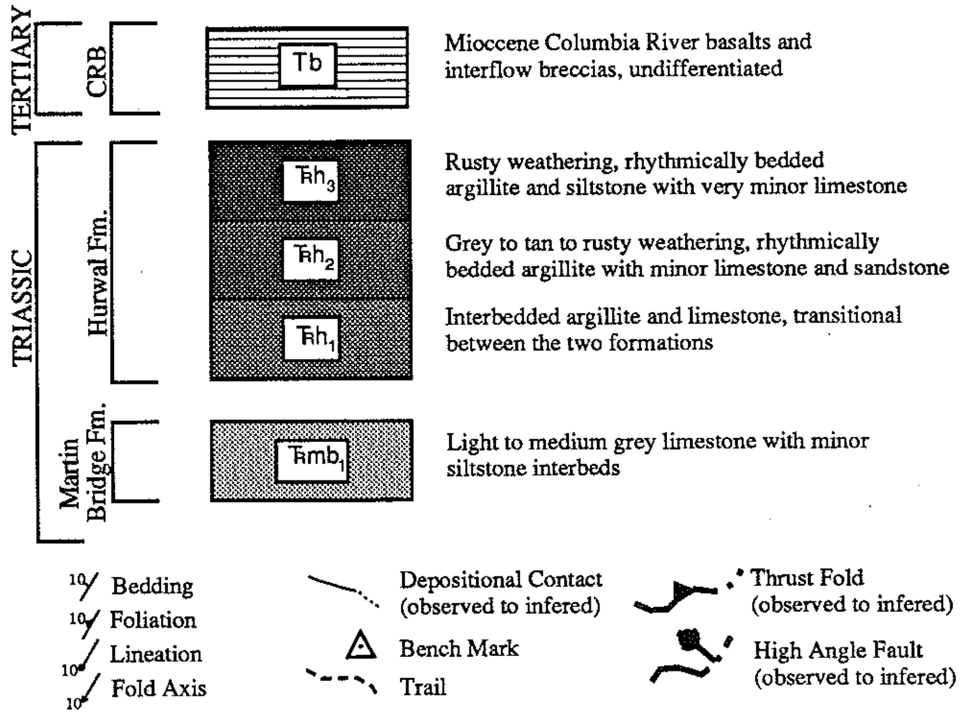
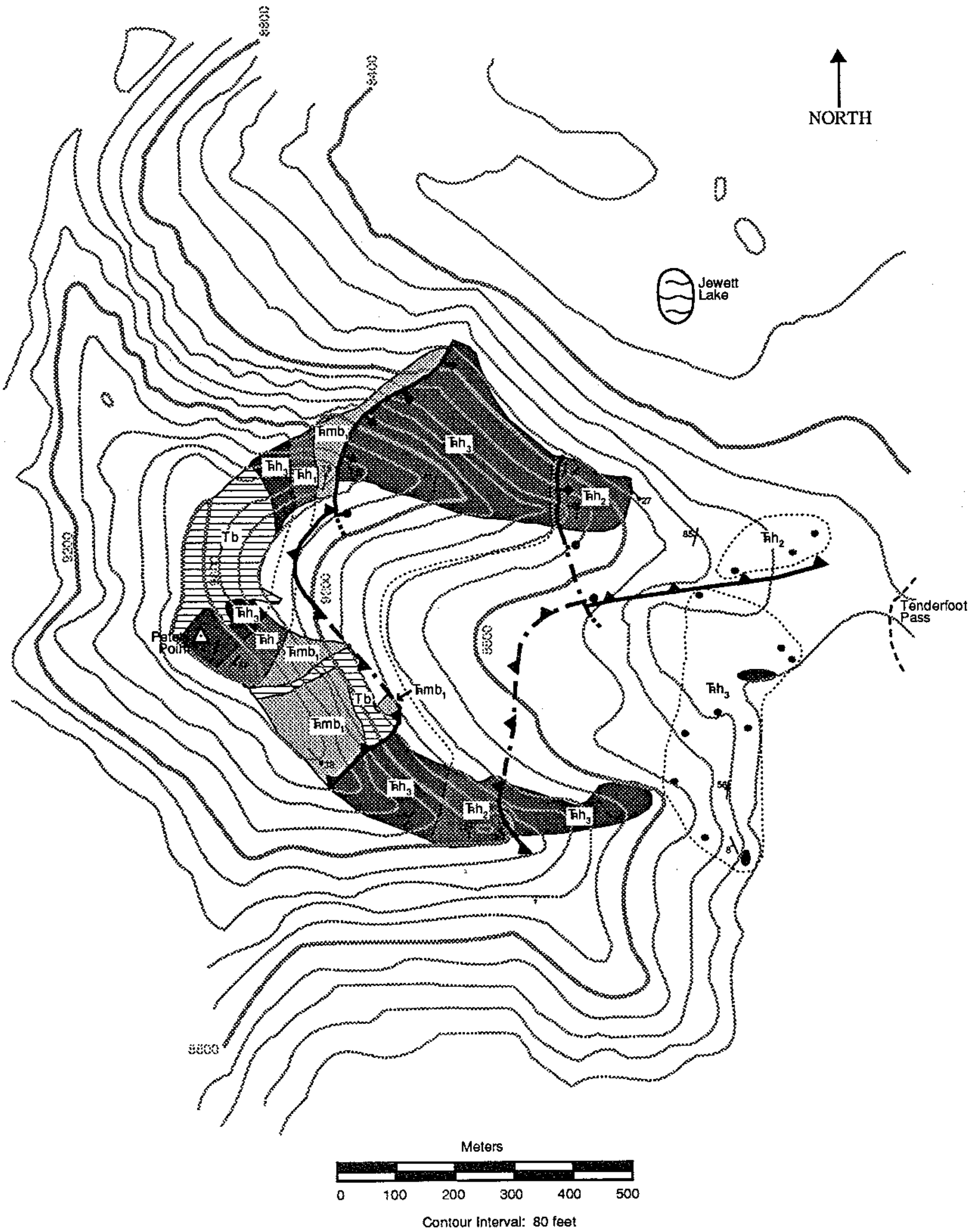


Figure 1: Map of field area showling lithologic contacts and major structural features



THE ORIGIN OF THE MAFIC ENCLAVES WITHIN THE WALLOWA BATHOLITH, OREGON

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INTRODUCTION

Mafic enclaves are ubiquitous throughout the Craig Mountain pluton of the Mesozoic Wallowa Batholith. The Wallowa Batholith is located within the Eagle Cap Wilderness Area of the Wallowa Mountains, northeastern Oregon. The mafic enclaves of the batholith were first described by Krauskopf (1943). Since then no specific studies have been done on the mafic enclaves. The density of the mafic enclaves is relatively the same throughout the batholith and they are not concentrated in certain areas.

It is believed that mafic enclaves can be the products of the mixing of magmas, differentiation by fractional crystallization of magma, incomplete melting of the source material (restite), or incorporation of the country rock (xenoliths) (Dodge and Kistler, 1990). Three different types of enclaves, based on petrography and geochemistry, were sampled from the field area. The most abundant type is medium-grained (finer than the host rock), contains 25%-45% mafic minerals (dominantly hornblende and some biotite), and has phenocrysts of plagioclase feldspar. Only one specimen of each of the other two types of enclaves were taken, so detailed work has not been done on them and they will not be mentioned. The purpose of this study is to determine the origin of these mafic enclaves using petrographic methods and both major and trace element data obtained with an inductively coupled argon plasma spectrometer (ICAP).

FIELD AND PETROGRAPHIC DESCRIPTIONS

Tonalites

The plutons of the Wallowa Batholith are classically zoned, being more granodioritic in the center and more tonalitic on the margins (Piwinskii and Wyllie, 1970). The host rocks of the mafic enclaves that were sampled plot as tonalites on the Streckeisen diagram (see figure 1). The host rock consists of mostly hornblende and biotite as the mafic minerals, and apatite, sphene, and zircon as the accessory minerals. In thin section the host rock has a strong poikilitic texture. Plagioclase crystals surround hornblende and hornblende crystals surround plagioclase. The composition of the plagioclase is between An_{36} and An_{40}.The tonalites are uniformly medium grained. Very few structures, such as flow lineations, are found in the study area.

Mafic enclaves

Mafic enclaves are relatively evenly distributed throughout the study area. In no outcrops do the enclaves seem to be in any preferred alignment. They range in size from 4 to 75 centimeters in diameter, and generally are either round or elliptical. The enclaves are always finer grained than the host tonalite. The contacts between the enclaves and host rocks are gradational and show no reaction or cooling zones.

In outcrop and hand specimen the enclaves are medium to medium fine grained and lack any sort of structure. The mineralogy consists of dominantly plagioclase, hornblende, and biotite. There are phenocrysts of plagioclase, and to a lesser extent, of biotite. Minor amounts of quartz and potassium feldspar can also be identified. The mafic enclaves display a large degree of homogeneity in both texture and mineral relationships within themselves.

Thin sections of seven of the mafic enclaves were studied. All the enclaves exhibit minerals with a very strong poikilitic texture. Plagioclase crystals are found within larger