# Structural Geology of the Crawfish Lake Quadrangle, Elkhorn Mountains, Oregon

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## INTRODUCTION

The Crawfish Lake Quadrangle is located in the Elkhorn mountains of northeastern Oregon. This paper will present field evidence indicating how and when the crust of the Crawfish Lake Quadrangle was deformed. In other words, it will be a synopsis of the structural history of the Crawfish Lake Quadrangle. In order to clearly present this, it is appropriate to begin with a regional geologic history.

The state of Oregon is on an active continental margin between the North American and the Pacific plates. It is estimated that two-thirds to three-fourths of the state is composed of rocks that originated elsewhere in the Pacific Basin. Regions of foreign rock such as these are known as accreted terranes. These are plate fragments such as volcanic arcs and seamounts that rotate in order to fit during accretion (Orr, 1992). Collision and accretion of the island terranes began in the early Triassic around the time that North America was breaking away from Europe and Africa. The Blue Mountain and the Klamath Mountain terranes accreted throughout the Mesozoic. (Orr, 1992)

Much of the Klamath and Blue Mountains are made up of ophiolites. There is ample evidence that the rocks in these areas did not originate where they currently reside. For example, the Triassic coral reefs in the Wallowa Mountains are of the type that are also found in the European Alps. The oldest fossils found in the Wallowas are icthyosaurs. Fossils similar to these are found in the western Pacific and Southwest China. Those found nearby in Nevada are very different. (Orr, 1992)

After the terranes started accreting in the Triassic, they were moved several times in a north-south direction by faulting (fig. 1) (Orr, 1992). Fossils found in the terranes suggest that they could have originated as far south as eighteen degrees north latitude (Orr, 1992).

| Triassic | South |
|---|---|
| Early and Mid Jurassic | North |
| Late Jurassic and early Cretaceous | South |
| Late Cretaceous | North |

Figure 1 (from Orr, 1992)

In the Cretaceous, following the accretion of exotic terranes, a vast shallow seaway covered most of the state and deposited thousands of feet of mud, silt, and sand. Fossils found in these formations include ammonites and other molluscs as well as marine reptiles.

The Columbia River Basalts (CRBs) poured out onto the Northwest during the time that the Basin and Range developed, from the end of the Oligocene through the Miocene. In northeastern Oregon these CRBs are known as the Grande Ronde formations. They covered everything but the crests of the Blue Mountains. This created a plateau which subsequently tilted northward. (Orr, 1992)

## BLUE MOUNTAINS

There are five major terranes found in the Blue Mountains: the Olds Ferry terrane, made up of volcanic and sedimentary rock; the Izee terrane, consisting of layered rocks from a forearc basin; the Baker terrane, containing deep ocean floor crust; the Grindstone terrane, containing sediments from a shallow backarc basin; and the Wallowa terrane, which is a volcanic archipelago (Orr, 1992).

The most important terrane in regards to this paper is the Baker terrane. The Baker terrane contains fossils that range in age from the Permian to the Upper Triassic. Microfossils indicate that it was a

"Tethyan" or tropical western Pacific environment. The Baker terrane consists of the Burnt River schist, the Canyon Mountain ophiolite complex, and the Elkhorn Ridge Argillite (fig. 2). As a whole, the Baker terrane is considered to be an accretionary wedge that formed southwest of the neighboring Wallowa island arc. It was deformed by faults and tight folds in the late Triassic and early Jurassic (Orr, 1992).

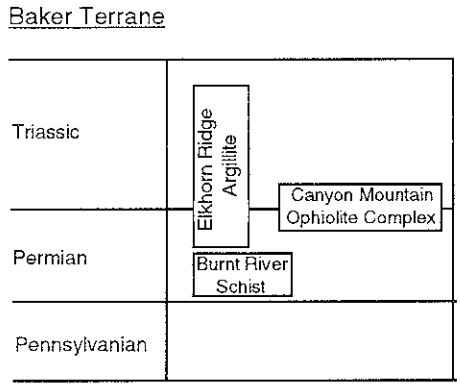


**Figure 2** (from Orr, 1992)

## MAJOR GEOLOGIC UNITS OF THE CRAWFISH LAKE QUADRANGLE

**Basement Rock:**

**Elkhorn Ridge Argillite**: This metamorphosed mudstone is found mostly in southwestern part of the quad. It has cherty characteristics in many places and also has platy cleavage.

**Metagabbro (Metadiorite?)**: This unit is found in the middle western part of quad. It is most likely a highly metamorphosed plutonic rock of seafloor affinity. It is often gneissic, easily fractured and interlaced with hydrothermal veins.

**The Bald Mountain Batholith** is a granitic rock which ranges from a diorite to course granite to leucogranodiorite. The source magmas of the batholith are derived from the Pacific plate subducting beneath the North American plate.

**Palaeocobbles and sandstones** of Oligocene age are scattered throughout the quad. They are stratigraphically located between the batholith/ basement rocks and the volcanics. Some lenses also occur within the volcanic section.

The **volcanic** rocks in the quad are Oligocene-Miocene basalts, porphyritic andesites , pyroclastic deposits and related epiclastic rocks that preceded the Columbia River Basalts.

**Glacial till and outwash** is characterized by large granodiorite boulders and poorly sorted sediments.

## STRUCTURE OF THE CRAWFISH LAKE QUADRANGLE

### Basement Deformation

The Crawfish Lake Quadrangle is located in the Bourne subterrane of the Baker Terrane (fig. 3). The Bourne subterrane is composed of the Elkhorn Ridge Argillite, a metagabbro/ metadiorite, interspersed diorite intrusions, basalt and andesite flows and breccias, tuffs, epiclastic sandstones, and Late Triassic bedded limestones that are interpreted to be volcanic arc fragments. In the Quadrangle the Bourne subterrane has been intruded by the Bald Mountain Batholith and has also been overlain by Tertiary volcanic rocks.

Elkhorn Ridge Argillite makes up much of the outcrop in the southern end of the quad. The Elkhorn Ridge Argillite in the Quadrangle is mainly southwest dipping argillite, massive chert, and ribbon chert which has been stratally disrupted.

There are 2 definite sets of folds found in the argillite. One set plunges 20 degrees N 64 W, which may correspond to F2 of Ferns and Brooks (1995). The other set plunges 30 degrees N 35 W and may correspond to F1. According to Crowley (pers. comm.) F2 is assymetrical, NE vergant, tight-isoclinal, and nearly upright. He has also found another set of folds which are almost symmetrical, open-tight, and nearly upright which plunge shallowly to the NE.

The sequence in which these folds formed is not known due to the inability to determine which set of folds has been superimposed on the others. One possible correlation is that of the similar trend of the unconformity between the batholith rock and the argillite and the trend of the axis of F2. The intrusion of the batholith may have caused the formation of F2. It now dips to the northwest due to the uplift of the Elkhorn range.

**Bald Mountain Batholith**

The Bald Mountain Batholith makes up almost half of the rock outcrop in the Crawfish Lake Quadrangle and has a total area of 450 $km^2$. South of 45° N, which is the northern border of the quadrangle, the Bald Mountain batholith consists of at least 9 distinct units which are compositionally zoned from a mafic margin (tonalite of Bald Mountain) to a felsic core (granodiorite of Anthony Lake) (Taubeneck. 1995). Within the quadrangle are three of these units. The most widespread unit is a granodiorite (KJgdt); there are two dike-like units contained within it. These are the leucogranodiorite of Trail Creek (KJltc) and the norite of Badger Butte (KJnbb).

**Mid-Tertiary Volcanics**

There are eight distinct units that make up the Mid-Tertiary Volcanics. Of these there are only three which are of considerable size. These are the olivine basalt (Tob), the mixed epiclastics-pyroclastics (Tep), and the andesite of Chicken Hill (Ta-ch). Unlike the other volcanic units, these three can be fairly easily interpreted. Tob appears to be the oldest of the three volcanic layers and it is succeeded by Tep and then Ta-ch. The other units are difficult to interpret because they appear somewhat randomly within other units. Only the porphyritic olivine basalt (Tpob) could possibly be placed in sequence between Tob and Tep in one area. An erosional unconformity exists between Tep and Ta-ch.

The geology of the volcanic units is complicated because the lava that formed these units flowed over an irregular landscape, possibly through canyons. This resulted in highly irregular joint orientations due to cooling of this lava. There is no evidence of post-depositional deformation in the volcanics other than a roughly north-south lineament which runs across Chicken Hill. This was only seen in air photos and no offset was found during field work.

## GEOLOGIC HISTORY OF THE CRAWFISH LAKE QUADRANGLE

The origin of the exotic terranes found in northeast Oregon had puzzled many until Vallier (1995) published his conlusions following many years of field work in the area. The following reconstruction is based on his theories as heard in lecture as well as field work done by the author and his research team.

In the late Permian-early Triassic the Elkhorn Ridge Argillite formed as an accretionary wedge on an island-arc in the proto-Pacific Ocean. The metagabbro/ metadiorite also formed at this time as possibly an ophiolite or an intrusive body derived from an oceanic protolith. From the late Triassic through the Jurassic, the rocks from the island arc moved toward North America as the Pacific plate was subducting beneath the continent. When they accreted to the continent they deformed themselves as well as the sediments of the continental shelf. In the early Cretaceous, magma created by the subduction zone caused another period of volcanism in the area. The volcanic rocks from this period are not found within the quad but the magma that caused the volcanism formed what is now the Bald Mountain batholith and other intrusive rocks in the area. These intrusive rocks caused further metamorphism and local deformation in the argillite and metagabbro/ metadiorite. A period of erosion ensued from the late Cretaceous to the Oligocene. During this time the quartzite cobbles were deposited from a vigorous river that originated in an unknown mountain range. Another period of volcanism followed this during the Oligocene. Basalts, andesites, and ash were all deposited unconformably over the Baker Terrane rocks and the Bald Mountain Batholith. Prior to the deposition of the Chicken Hill Andesite (Ta-ch) however, was a period of erosion which is mostly evidenced in the mixed epiclastic-pyroclastic deposits (Tep). As mentioned earlier, the unconformity lies between Tep and Ta-ch. Following this event the whole area was uplifted. The crest of

the Elkhorns is found on the eastern edge of the range due to a fault tilting the block to the west. It is because of this uplift that Columbia River Basalts were not deposited in the area.

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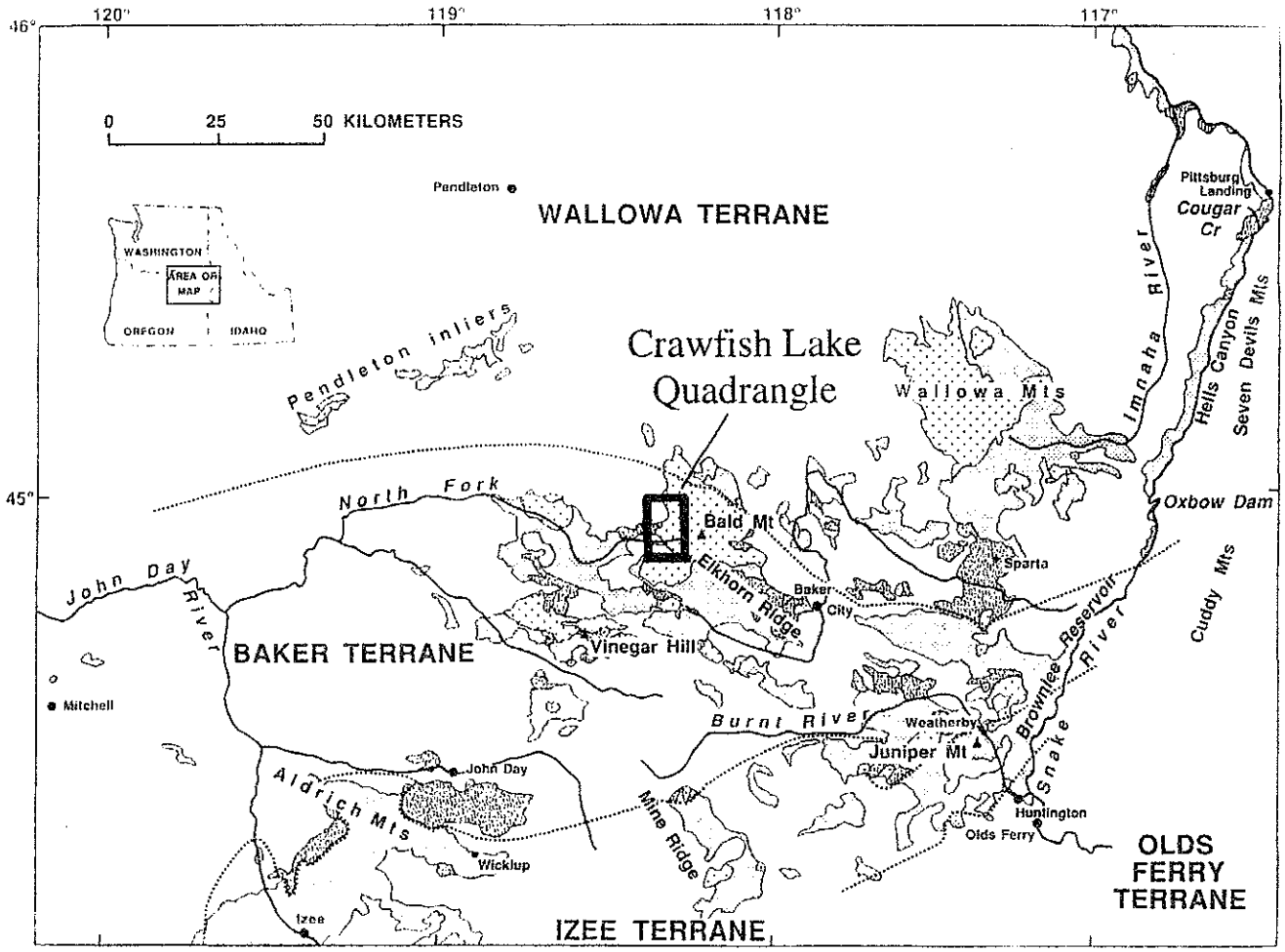


Figure 3

Location of the Quadrangle and surrounding terranes.



From Ferns and Brooks, 1995