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Rotational and accretionary evolution of the Klamath Mountains, California and Oregon, from Devonian to present time

By WILLIAM P. IRWIN AND EDWARD A. MANKINEN[1]

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[1] MENLO PARK, CA 94025

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OVERVIEW

The purpose of this report is to show graphically how the Klamath Mountains grew from a relatively small nucleus in Early Devonian time to its present size while rotating clockwise approximately 110 degrees. This growth occurred by the addition of large tectonic slices of oceanic lithosphere, volcanic arcs, and melange during a sequence of accretionary episodes. The Klamath Mountains province consists of eight lithotectonic units called terranes, some of which are divided into subterranes. The Eastern Klamath terrane, which was the early Paleozoic nucleus of the province, is divide into the Yreka, Trinity, and Redding subterranes. Through tectonic plate motion, usually involving subduction, the other terranes joined the early Paleozoic nucleus during seven accretionary episodes ranging in age from Early Devonian to Late Jurassic. The active terrane suture is shown for each episode by a bold black line. Much of the western boundary of the Klamath mountains is marked by the South Fork and correlative faults along which the Klamath mountains terranes overrode the Coast Range rocks during an eighth accretionary episode, forming the South Fork Mountain Schist in Early Cretaceous time.

Data for the clockwise rotations (paleomagnetic declinations) are all from measurements on Permian, Triassic, Jurassic, and Cretaceous rock of the Redding subterrance. The angles of rotation (the paleomagnetic declinations relative to stable North America, which is shown by north arrows) are known for only three of the accretionary episodes (Fort Jones, Western Hayfork, and Pickett Peak episodes). The paleomagnetic orientation of the Eastern Klamath terrane during the Central Metamorphic episode is unknown, and is shown as being similar to the Permian and Triassic strata of the Redding subterrane. Angles of rotation for episodes that are intermediate to those with measured rotations are estimated to be more or less evenly incremental. It should be noted that the Pickett Peak episode (~ 120-115 Ma) is substantially younger than the plutons of the Shasta Bally belt (~ 136-131 Ma) on which the paleomagnetic declination for the episode was measured. The diagrams of the episodes do not indicate pre-accretionary rotations that may have been experienced by the various terranes.

The distribution of terranes shown in "present time" (diagram 9) is modified from Irwin (1994). For simplicity, each terrane in this graphic presentation is conceived to be a crustal slab that is continuous from beneath the earlier accreted terrane on the east to the present western limit of exposure of the terrane. This generalization somewhat distorts the distribution of the terranes but avoids the depiction of certain post-accretionary structural complications such as the Condrey Mountain window.

The accretionary episodes are named for the accreting terranes. Ages assigned to the accretionary episodes are as young or younger than the youngest accreting rock. In instances where the subducting slab has been tectonically metamorphosed during accretion (Central Metamorphic, Fort Jones, and Pickett Peak episodes) the age of the accretionary episode is the isotopic age of the metamorphic rock. In other instances, the age of an episode is mainly deduced paleontologically (North Fork, Rattlesnake Creek, and Western Klamath episodes) or may be determined isotopically if the accreting terrane is volcanic rock (Western Hayfork episode. Most of the accretionary episodes described herein are comparable in various degrees to metamorphic events described by Coleman and others (1988) and to volcanoplutonic and metamorphic events described by Hacker and Ernst (1993).

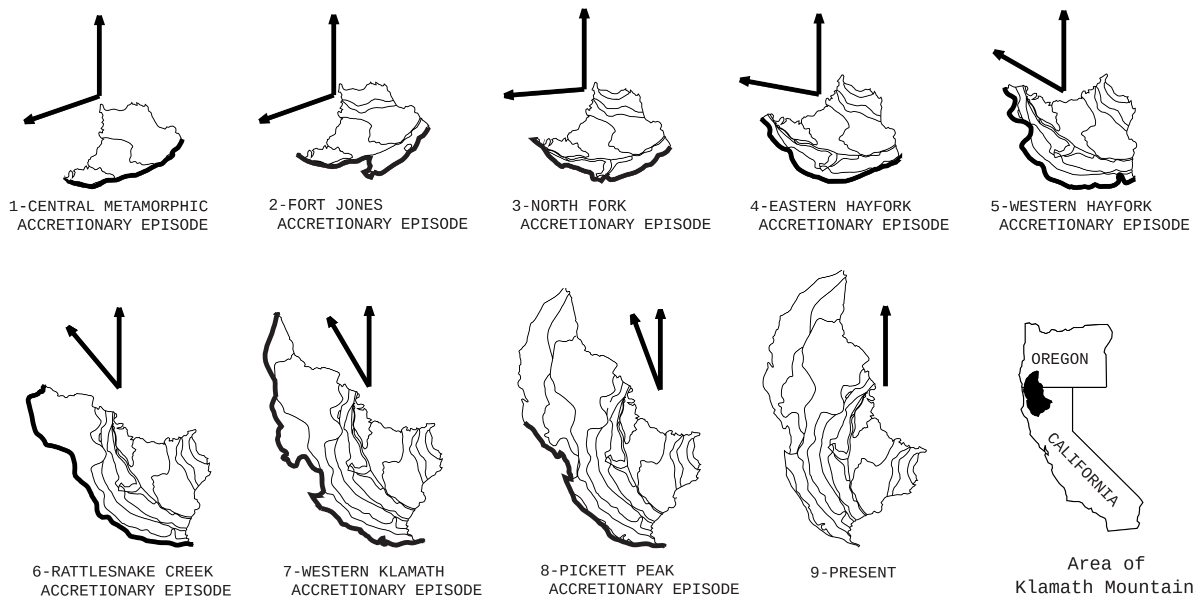

Figure 1. Simplified diagram illustrating the sequence of rotational and accretionary episodes listed and described below.

LIST OF ACCRETIONARY EPISODES

1- CENTRAL METAMORPHIC ACCRETIONARY EPISODE
EARLY OR MIDDLE DEVONIAN TIME (~399-380 Ma)

Protoliths of the Central Metamorphic terrane were subducted beneath the Eastern Klamath terrane. The Eastern Klamath terrane, which was the nucleus of the Klamath Mountains in Devonian time, was composed of the Yreka, Trinity, and Redding subterranes. It tectonically overrode volcanic and sedimentary oceanic rocks along the Bully Choop fault to form the Salmon and Abrams Schists that now constitute the Central Metamorphic terrane. The isotopic (Rb-Sr) age of the schist is ~380 Ma (Lanphere and others, 1968), and amphibolitic rocks that may be an extension of the Central metamorphic terrane in the Yreka area yield K-Ar ages 399-390 Ma (Holz, 1977). The paleomagnetic orientation of the Eastern Klamath terrane during Devonian time is not known, but is shown here as being similar to that of the Permian and Triassic strata of the Redding subterrane.

2- FORT JONES ACCRETIONARY EPISODE
LATE TRIASSIC (NORIAN)TIME (~220 Ma)

Protoliths of the Fort Jones terrane were subducted beneath the Central Metamorphic terrane. The paleomagnetic declination of ~110º for the Fort Jones episode was measured on Triassic volcanic and sedimentary strata of the Redding subterrane (Mankinen and Irwin, 1990). The Eastern Klamath and Central Metamorphic terranes overrode a subduction complex along the proto Siskiyou fault and its northern extensions. forming the Fort Jones (aka Stuart Fork) terrane. The age of the Fort Jones accretionary episode is Late Triassic (Norian) based on K-Ar isotopic ages of ~220 Ma measured on blueschist- facies metamorphic rocks of the terrane (Holz and others, 1977). Note the small structural outliers (ek) of Eastern Klamath terrane resting on Central Metamorphic terrane.

3- NORTH FORK ACCRETIONARY EPISODE
EARLY JURASSIC (PLIENSBACHIAN) TIME (~198-193 Ma)

Protoliths of the North Fork terrane were overridden along the Siskiyou and correlative faults by the Fort Jones, Central Metamorphic, and Eastern Klamath terranes. Note the structural inlier (FJ) of the Fort Jones terrane. The terranes are estimated to have rotated clockwise, progressively closer to the Middle Jurassic paleomagnetic orientation of the Redding subterrane. The protoliths of the North Fork terrane were a subduction complex including dismembered ophiolite, mafic volcanic and sedimentary rocks, limestone, and radiolarian chert. They range in age from Late Paleozoic to Jurassic. The youngest fossiliferous rocks are radiolarian chert of Early Jurassic (Pliensbachian) age (Blome and Irwin, 1983), which is the basis for the approximate age (198-193 Ma) assigned to the North Fork accretionary episode.

4- EASTERN HAYFORK ACCRETIONARY EPISODE
EARLY(?) MIDDLE JURASSIC (~BAJOCIAN) TIME (~180 Ma)

Protoliths of the Eastern Hayfork were subducted beneath the North Fork terrane along the Twin Sisters and correlative faults. The paleomagnetic declination is estimated to be ~80º. The protolith of the Eastern Hayfork terrane was a melange of exotic oceanic rocks including mafic volcanic and sedimentary rocks, limestone lenses, thin-bedded chert, and scattered blocks of schist. Fossils in the limestone and chert are mainly Late Permian and Triassic. None is clearly Jurassic. Some of the Late Permian fossils are of Tethyan faunas that are unknown to most of North America. The age of the accretionary episode is estimated to be ~180 Ma, approximately midway between the preceding and following episodes.

5- WESTERN HAYFORK ACCRETIONARY EPISODE
LATE MIDDLE JURASSIC (EARLY CALLOVIAN TIME) (~168 Ma)

Protoliths of the Western Hayfork subterrane were subducted beneath the Eastern Hayfork subterrane along the Wilson Point and correlative faults. The paleomagnetic declination is -60º, based on measurements on volcanic and sedimentary strata of the Lower and Middle Jurassic Arvison and Potem Formations of the Redding subterrane (Mankinen and Irwin, 1990). The protoliths were a volcanic arc consisting mainly of the Hayfork Bally Meta-andesite and cogenetic plutons. Their isotopic ages range from 177 to 168 Ma (Fahan, 1982; Lanphere and others, 1968; and Wright, 1981), the youngest of which is assumed to approximate the age of subduction.

6- RATTLESNAKE CREEK ACCRETIONARY EPISODE
LATE MIDDLE TO MIDDLE LATE JURASSIC (CALLOVIAN TO KIMMERIDGIAN) TIME (~160±8 Ma)

Protoliths of the Rattlesnake Creek terrane were subducted beneath the Western Hayfork terrane along the Salt Creek and correlative faults. The paleomagnetic declination is estimated to be -40º. The protoliths of the Rattlesnake Creek terrane were a melange of mainly ophiolitic rocks, bodies of limestone, chert, minor blocks of amphibolite, and Early Jurassic plutons. The limestone and chert contain late Paleozoic, Triassic, and Early to Middle Jurassic fossils. The chert is mostly Late Triassic and Early to Middle Jurassic, some of which may be as young as Bathonian. The time of subduction is broadly constrained to Callovian-Kimmeridgian time (160(8 Ma).

7- WESTERN KLAMATH ACCRETIONARY EPISODE
LATE JURASSIC (LATE KIMMERIDGIAN OR EARLY TITHONIAN) TIME (~150±2 Ma)

Protoliths of the Western Klamath terrane were subducted beneath the Rattlesnake Creek terrane along the Bear Wallow and correlative faults. The paleomagnetic declination is estimated to be -30º. A volcanopelagic section overlying Josephine ophiolite beneath Galice Fm. has yielded late Callovian and early Oxfordian radiolarians (E. A. Pressagno, oral comm., 1990). Shelly fossils in Galice Fm. are Oxfordian and Kimmeridgian in age. Zircon from tuff breccia in Rogue Fm. yielded a Pb/U isotopic age of 157 Ma (Saleeby, 1984). The Summit Valley pluton, which yields a Pb/U zircon age of 150±2 Ma, cuts both plates of the thrust that separates Galice Fm. from the overlying Rattlesnake Creek terrane (Harper and others, 1986). The age of the Western Klamath episode is constrained to late Kimmeridgian or early Tithonian time (~150±2 Ma).

8- PICKETT PEAK ACCRETIONARY EPISODE
MIDDLE EARLY CRETACEOUS TIME (~120-115 Ma)

Protoliths of the Pickett Peak terrane were subducted beneath the Western Klamath terrane along the South Fork and correlative faults. The paleomagnetic declination of -18±14º was measured on plutons of the Shasta Bally plutonicbelt (Makinen and Irwin, 1990). The isotopic (zircon) age of the principal pluton, Shasta Bally batholith, is 136±2 Ma (Lanphere and Jones, 1978). The Western Klamath terrane overrode and metamorphosed sedimentary and volcanic strata (Franciscan rocks?) along the South Fork fault, forming the South Fork Mountain Schist and Chinquapin Metabasalt of the Pickett Peak terrane of the California Coast Ranges. The isotopic (K-Ar) age of the schist is ~120-115 Ma (Lanphere and others, 1978). Structural outliers of Colebrooke Schist, a correlative of South Fork Mountain Schist, lie west of the Klamath Mountains in the Coast Ranges of Oregon.

9- PRESENT TIME

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