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NATIVE TERRANES OF THE CENTRAL KLAMATH MOUNTAINS, CALIFORNIA

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Abstract. The Klamath Mountains of northern California and southern Oregon contain several good examples of terranes which have developed in situ. The term "native" is proposed for five of these terranes and all terranes whose development can be tied to an adjacent cratonal area. The Klamath terranes discussed herein include disrupted, stratigraphic, and metamorphic types. Three disrupted terranes, the Rattlesnake Creek, eastern Hayfork, and North Fork, contain fossiliferous blocks derived from both North American and exotic sources. The unique mixed faunal assemblage, stratigraphic ties to North America in the source terranes of the blocks, and paleomagnetic evidence indicate that the tectonic and sedimentary processes responsible for mixing these blocks occurred in proximity to North America, not distant from the terranes' present positions. Coeval blueschist metamorphism in a fourth, inboard terrane, the Stuart Fork, suggests that all four terranes developed during a Late Triassic to Early Jurassic subduction event. A fifth, stratigraphic terrane, the western Hayfork, was constructed upon the assembled disrupted and metamorphic terranes in the Middle Jurassic. Disrupted terranes with similar mixtures of North American and exotic faunas occur throughout the Cordillera from central California possibly as far north as British Columbia. Late Triassic deformation has been documented in several of these terranes, suggesting that (1) subduction operated along at least this portion of North America during the Late Triassic-Early Jurassic, and (2) many additional Cordilleran terranes should also be considered native.

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INTRODUCTION

The recognition that much of the North American continental margin may be comprised of exotic crust transported long distances represents a major breakthrough in the interpretation of continental margin geology. Many apparent problems arising from poor matches in the geologic histories between adjacent areas now appear to be best explained through the accretion of microplates and other crustal fragments far from their sites of origin. The tectonic fragments which comprise these complicated orogens have been called terranes [Irwin, 1972], signifying that they are fault-bounded units with stratigraphic, deformational, and/or metamorphic histories that are different from adjacent units. Accordingly, terranes are generally considered to be "suspect," i.e., potentially far traveled from their sites of origin [Coney et al., 1980]. Reviews of the suspect terrane concept and its application to Cordilleran geology have also been presented by Blake et al. [1982], Jones et al. [1983], and Saleeby [1983].

The suspect terrane concept has, by design, emphasized the exotic or potentially exotic origin of any particular terrane. This is exemplified by the fact that a genetic term for nonexotic terranes does not exist. There is a growing recognition, however, that many terranes have developed in situ or are close to their sites of origin [Varga, 1982; Gray and Wright, 1984; Oldow et al., 1984; Blodgett and Clough, 1985; Herzig et al., 1984; Turner, 1985]. I propose that the term "native" be used for terranes whose origins can be tied to a known cratonic area and which are autochthonous or parautochthonous with respect to that area.

This paper presents a broad range of data which indicate that several native terranes occur within the Klamath Mountains in northern California. Close counterparts to these Klamath terranes are present within the Sierra Nevada foothills, northeastern Oregon, and eastern British Columbia, suggesting that native terranes are common within the Cordillera.

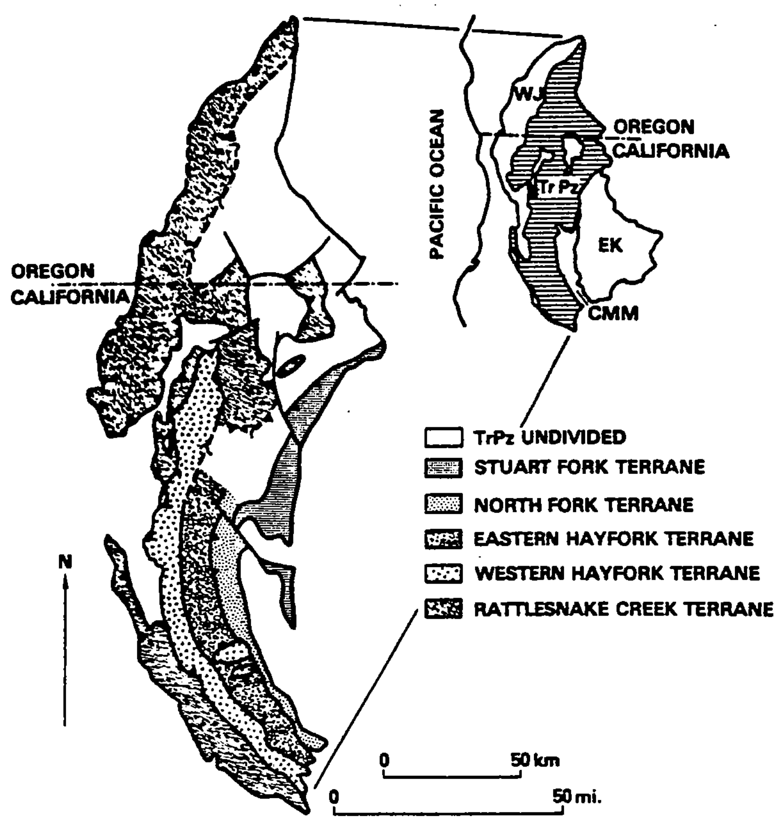

Fig. 1. Terranes of the western Paleozoic and Triassic belt (TrPz) [after Irwin, 1972; Davis and Lipman, 1962; Davis et al., 1978; Wright, 1982; and Gray, 1985]. Additional references cited in text. Inset shows belts of the Klamath Mountains: WJ, western Jurassic; ruled area, the western Paleozoic and Triassic; CMM, central metamorphic; and EK, eastern Klamath [from Irwin, 1966].

DEFINITIONS

Terrane Nomenclature

The term "terrane" in this paper is used in the sense of Irwin [1972], as a descriptive term for a fault-bounded rock unit which has a stratigraphic, deformational, and/or metamorphic history "unique" from its neighbors. Terranes thus defined have been classified as either stratigraphic, disrupted, metamorphic, or composite on the basis of their most prominent descriptive characteristics [Blake et al., 1982; Howell and Jones, 1984].

The terms "native," "suspect," and "exotic" are used as genetic modifiers when a terrane's origin is discussed. As defined in this paper, a terrane is native if it can be proven that it formed (i.e., by deposition, disruption, metamorphism, or a combination of these events) upon or close to the adjacent continent. If such a terrane has been removed from its site of origin by transcurrent faulting but still resides next to the continent where it originated, it is considered a displaced native terrane. The term exotic is reserved for terranes for which a large separation can be proven between the terrane when it formed and the presently adjacent continent. Such a separation should be indicated by both distinct fauna and discordant paleomagnetic signatures between the terrane and the presently associated continent. Terrane-bounding sutures, while important, can be greatly modified by post-accretionary processes and therefore their presence or absence is not diagnostic. The term suspect is used for all the remaining terranes whose site of origin is unknown, indeterminable, or intermediate between purely native or exotic.

Note that this system of terrane nomenclature makes an important distinction for disrupted terranes. For such a terrane to be considered exotic, it must be demonstrated that the terrane was assembled, tranported en masse a great distance, and then emplaced in its present locality adjacenet to a new continental mass.

Terrane Boundaries

An integral part of the definition of a terrane is the idea that the terrane entity is bounded on all sides by faults. Thus it is fundamental to establish the presence of boundary faults in order to define a terrane. Some workers, however, feel that it is better to assume that faults exist around any geologic entity until linking relations to adjacent units can be established [Blake et al., 1982; Jones et al., 1983; Howell and Jones, 1984]. All terranes discussed in this paper are bounded by proven, mappable faults.

The type and sense of offset of the terrane-bounding faults

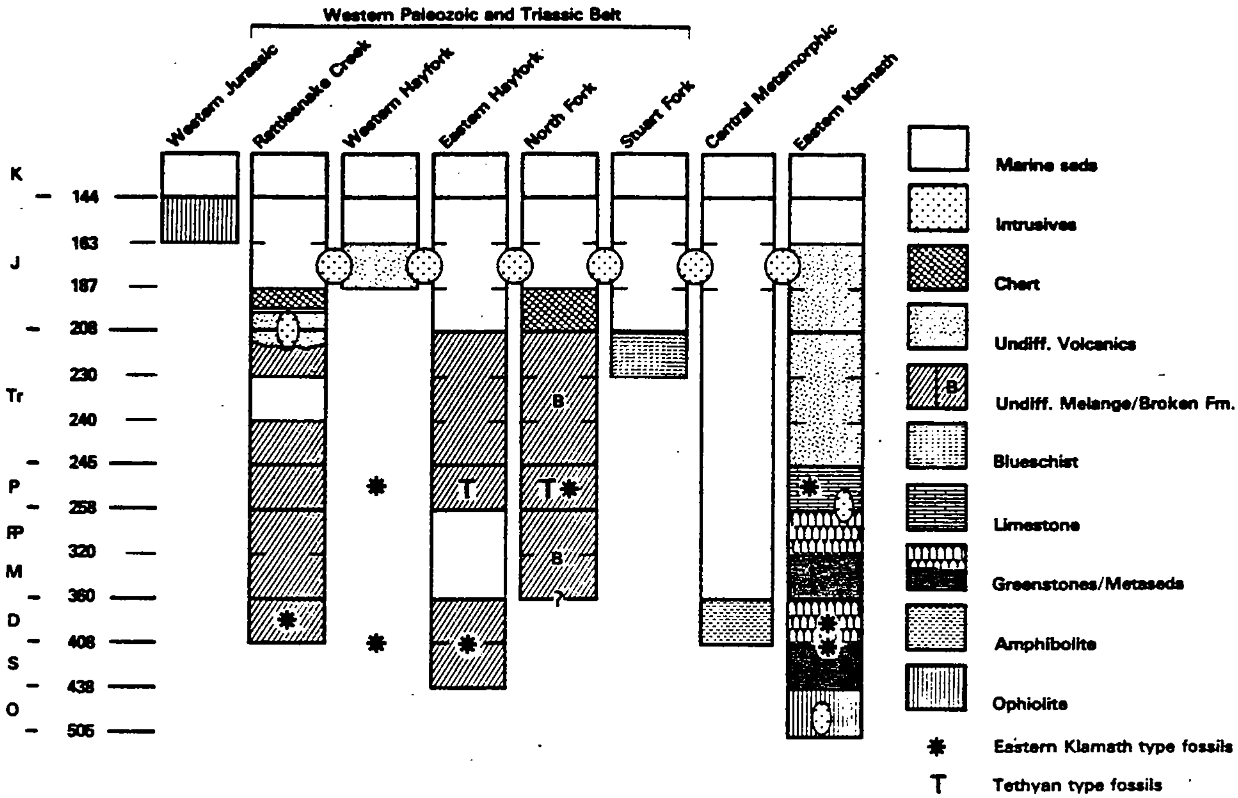

Fig. 2. Correlation chart of the terranes within the Klamath south-central Mountains. Note that the columns are arranged in the present relative geographic positions. Lithologic symbols are listed in the column on the right. Absolute age is shown on the left. Diagonal ruled pattern represents chaotic unit (Late Triassic melange and/or broken formation) which contains older fossils from the time span shaded. Asterisks indicate the presence of recycled fossils and their interpreted source horizons in the eastern Klamath belt. In the western Hayfork terrane this represents a cobble of Permian McCloud limestone contained within younger strata. T indicates fossils with Tethyan affinity. Data from Skinner and Wilde [1965], Albers and Robertson [1961], Irwin [1972, 1977], Irwin and Galanis [1976], Harper [1980], Irwin et al. [1977, 1982, 1983], and Blome and Irwin [1983].

in turn have an important effect on the interpretation of a terrane's history. High-angle normal faults and high-angle reverse faults can juxtapose a stratigraphic sequence against its basement resulting in large "discontinuities" in age, metamorphic grade, and deformational history. If such faults are not recognized, large translations between the resulting essentially autochthonous terranes might be interpreted.

Disrupted terranes (e.g., melanges) pose a special problem when considering the nature of terrane boundaries. Blocks within a melange fit the strict definition of terrane (i.e., unique from the adjacent rocks, bounded by faults) [Irwin, 1972; Blake et al., 1982; Howell and Jones, 1984], however the "faults" bounding a melange block do not represent fundamental breaks between separate lithotectonic units. The basic lithotectonic unit in this case is the melange (i.e., a disrupted terrane) which now contains this block.

KLAMATH TERRANES

The term terrane, as defined in the preceeding section, was first applied to three geologic units in the Klamath Mountains of northern California [Irwin, 1972]. These terranes are subdivisions of the western Paleozoic and Triassic belt, which is one of four major belts that comprise the Klamath Mountain province [Irwin, 1960, 1966] (Figure 1). The large, north-south trending belts, the eastern Klamath, central metamorphic, western Paleozoic and Triassic (hereafter abbreviated TrPz), and western Jurassic, are east dipping units which are thrust-bounded and are younger structurally downsection to the west [Irwin, 1977, 1981].

Five adjacent TrPz terranes are discussed in this paper (Figures 1 and 2). These are the Stuart Fork terrane, the North Fork terrane, the eastern and western Hayfork terranes, and the Rattlesnake Creek terrane. These terranes include the three original terranes of the TrPz [Irwin, 1972] but with the Hayfork terrane divided into the eastern Hayfork and western Hayfork terranes [Wright, 1982]. The Stuart Fork terrane [Davis and Lipman, 1962] (also called the Fort Jones terrane by Blake et al. [1982]) was not included in the original division of the TrPz by Irwin [1972].

The stratigraphic ages of these five TrPz terranes and the adjacent Klamath belts are shown in Figures 2 and 3. Four of the five terranes are highly deformed and contain Early Jurassic and/or older rocks. The ages and stratigraphy of the TrPz

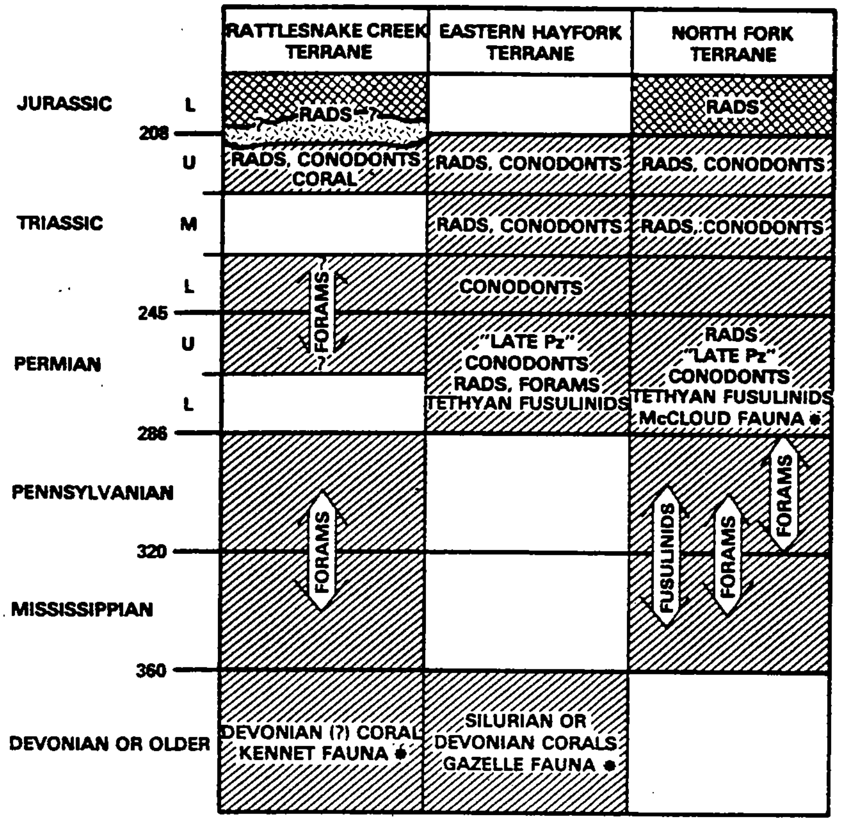

Fig. 3. Correlation chart showing age and fauna types within the TrPz basement terranes. Lithologic symbols same as those used in Figure 2. Data from Irwin [1972, 1977], Irwin and Galanis [1976], Irwin et al. [1977,1982, 1983], and Blome and Irwin [1983].

terranes together are distinctly different from those of the adjacent belts, confirming the interpretation of Irwin [1960] that the boundaries of the four major belts are the fundamental structural breaks within the Klamaths. Note also that the western Hayfork terrane is distinctly younger than the adjacent TrPz terranes and that it overlaps in age with plutons which intrude all of the adjacent TrPz terranes. In the following section the TrPz terranes are discussed in ascending structural order from west to east, with the exception of the younger Middle Jurassic western Hayfork terrane, which is discussed in a later section.

PRE-MIDDLE JURASSIC TrPz TERRANES

The Rattlesnake Creek terrane is the westernmost and structurally lowest of the four pre-Middle Jurassic TrPz terranes (Figures 1 and 2). The Rattlesnake Creek is everywhere separated from the other TrPz terranes by the western Hayfork terrane (Figure 1). The Rattlesnake Creek is a disrupted terrane composed primarily of an "ophiolitic" serpentinite-matrix melange containing variable amounts of volcanic and sedimentary blocks, plus rare quartzose metasediment and amphibolite blocks [Irwin, 1972; Donato et al., 1982; Gray and Wright, 1984; Gray, 1985]. Fossiliferous blocks within the melange range in age from Devonian (?) to Early Jurassic, but Late Triassic blocks are predominant [Irwin and Galanis, 1976; Irwin et al., 1978, 1982, 1983]. Major and trace element abundances from pillow lava blocks within the melange consistently plot within mid-ocean ridge basalt (MORB) fields on standard discrimination plots [Gorman, 1985]. Most blocks within the melange exhibit some effects of penetrative deformation.

Relatively undeformed volcaniclastic rocks, with minor interbedded flows and epiclastic rocks, overlie this melange in an apparent depositional contact [Gray and Petersen, 1982; Gray and Wright, 1984; Wright and Wyld, 1985; Gray, 1985]. These rocks are lithologically and chemically different from the MORB blocks in the melange and are interpreted to be arc-related deposits [Gray, 1985; Gorman, 1985]. In the vicinity of Orleans, California (Figure 1), these volcanic rocks postdate the incorporation of Late Triassic limestone into the melange but, together with the melange, are cut by plutonic rocks dated by U/Pb methods at 208-194 Ma and are therefore latest Triassic to earliest Jurassic in age [Gray and Wright, 1984, in prep.; Gray, 1985].

The eastern Hayfork terrane is a disrupted (melange) terrane consisting of blocks of alkalic basalt, chert, reef limestone, and other blocks in a sheared chert-argillite matrix [Wright, 1982]. The eastern Hayfork also contains rare (undated) blueschist inclusions [Fahan, 1982; Ando et al., 1983]. Definitive fossils younger than Late Triassic have not been recovered from this unit [Irwin and Galanis, 1976; Irwin et al., 1982].

The North Fork terrane is considered to be a stratigraphic terrane by Wright [1982] and Ando et al., [1983]. It is, however, highly dissected by thrust faults [Ando et al., 1983] and is considered a disrupted terrane in this discussion. Ophiolitic rocks which yield disordant Permian ages and associated sediments are overlain by Late Triassic cherts and carbonates, which in turn are overlain by, or are in fault contact with, Early Jurassic tuffaceous cherts [Irwin et al., 1977, 1982; Ando et al., 1983; Blome and Irwin, 1983; Mortimer, 1984]. The Late Triassic sequences have been cut extensively by thrust faults which may, in part, predate the deposition of the Early Jurassic sediments [Ando et al.,1983, p. 249; Gray, 1985]. The North Fork terrane has been interpreted to be a disrupted Permian (?) seamount on which Late Triassic pelagic and reef (?) sediments and Early Jurassic volcanic-rich sediments were deposited [Ando et al., 1983; Mortimer, 1985a]. Tectonic disruption within the North Fork increases structurally downward (westward) and is transitional into the underlying eastern Hayfork terrane melange [Wright, 1982]. A thin septum of serpentinized peridotite marks the boundary between the North Fork and eastern Hayfork terranes [Irwin, 1972; Wright, 1982].

The Stuart Fork terrane, the structurally highest and easternmost member of the TrPz belt, is a metamorphic terrane containing pillow basalts, cherts, and pelitic rocks which were disrupted and intermixed prior to the culmination of overprinting blueschist facies metamorphism at 219-227 Ma [Hotz et al., 1977; Borns, 1980]. The protolith age or ages of the Stuart Fork are unknown because of the pervasive metamorphism. This terrane is in thrust fault contact with the North Fork terrane, and the fault is cut by 164 to 171 Ma plutons [Hotz, 1973; Borns, 1980; Cotkin et al., 1985].

FAUNAL CHARACTERISTICS OF THE TrPz TERRANES

The faunal characteristics of the three fossiliferous TrPz terranes are summarized in Figure 3. The Stuart Fork terrane has not yielded identifiable fossils, presumably because of the blueschist facies metamorphism and accompanying high shear strains that have affected these rocks (Borns, 1980). The Rattlesnake Creek, eastern Hayfork, and North Fork terranes contain olistostromal and tectonic blocks of limestone that have apparently been derived from two distinct faunal provinces; the eastern Klamath-type and "Tethyan" realms [Irwin, 1972; Nestell, 1980; Wright, 1982; Luken et al., 1985; Miller and Wright, 1985]. The eastern Klamath-type fragments included within these terranes are Devonian (?) coral (Kennet fauna) in the Rattlesnake Creek terrane, Silurian or Devonian corals (Gazelle fauna) within the eastern Hayfork terrane, and Permian limestone (McCloud fauna) in the North Fork and eastern Hayfork terranes [Irwin, 1972; Irwin and Galanis, 1976; Wright, 1982].

The "Tethyan" fragments within the TrPz terranes include Verbeekinid-bearing blocks in the eastern Hayfork terrane, and *Yabeina* - bearing limestone lenses within younger North Fork correlative volcanics [Irwin and Galanis, 1976; Elliott and Bostwick, 1973; Mortimer, 1984; Luken et al., 1985; Miller and Wright, 1985] (Figure 3). All of these blocks are Permian in age, and may represent seamount accumulations [Yancey, 1975; Wright, 1982; Ando et al., 1983; Stevens, 1985]. In addition, a Permian radiolarian fauna reported from cherts within the North Fork terrane [Blome and Irwin, 1983], and Late Triassic ammonite fauna in the Rattlesnake Creek terrane also appear to be unlike typical North American assemblages [Silberling and Irwin, 1962; Irwin, 1985].

ORIGIN OF THE TrPz BELT

Age of Deformation

All four of the TrPz basement terranes appear to have experienced extreme deformation in the Late Triassic, ranging from complete tectonic disruption to pervasive thrusting and folding. The age of deformation is tightly constrained in the Rattlesnake Creek and Stuart Fork terranes. Late Triassic limestone boulders were incorporated into the Rattlesnake Creek melange prior to the construction of a 200 Ma volcaniclastic and plutonic complex [Wright, 1982; Gray, 1985]. In the metamorphic Stuart Fork terrane, three generations of isoclinal folds formed synchronously with Late Triassic blueschist facies metamorphism [Borns, 1980].

The age of deformation within the North Fork and eastern Hayfork terranes is less tightly constrained. Both of these disrupted terranes contain an abundance of rocks as young as Late Triassic. The oldest undeformed plutons which cut the eastern Hayfork terrane are approximately 174 Ma (U/Pb zircon [Wright and Sharp, 1982]), thus deformation in the eastern Hayfork terrane can only be constrained within latest Triassic to early Middle Jurassic time. The North Fork terrane differs from the eastern Hayfork in that it contains a few localities of deformed Early Jurassic (Pleinsbachian) radiolarian chert [Blome and Irwin, 1983; Mortimer, 1984]. The oldest plutons which cut the North Fork are 171 Ma (Rb/Sr whole rock isochron [Cotkin et al., 1985]). Thus many workers have interpreted the deformation of this terrane to be younger than that of the neighboring terranes [Mortimer, 1985b and references therein]. Ando et al. [1983], however, suggest that some deformation of the ophiolitic rocks in the North Fork terrane occurred prior to the depostion of the Early Jurassic rocks. These ophiolitic rocks yield discordant Permian U/Pb ages and are associated with Permian radiolarian cherts, indicating a post-Permian, pre-Jurasic age for this earlier deformational event. In summary, Late Triassic deformation is well constrained in the Stuart Fork and Rattlesnake Creek terranes and is permissible, if not probable, in the North Fork and eastern Hayfork terranes.

Significance of Tethyan and Eastern Klamath-Type Blocks in TrPz Terranes

The paleogeographic significance of Tethyan fauna has been extensively debated [Douglass, 1967; Yancey, 1975; Danner, 1976; Orchard, 1985], in part because of a lack of knowledge about the distribution of these fauna within the Cordilleran Belt [Yancey, 1975]. There are also significant differences between the fauna present at individual Tethyan occurrences [Stevens, 1985]. In many instances, however, so-called "Tethyan" faunas are so unlike any known North American assemblage that it is probable that they were not in proximity to the North American continent when they were deposited [Stevens, 1985]. Thus many of the scattered occurrences of Tethyan limestones in North America appear to be truly exotic. The Permian radiolarian fauna from cherts

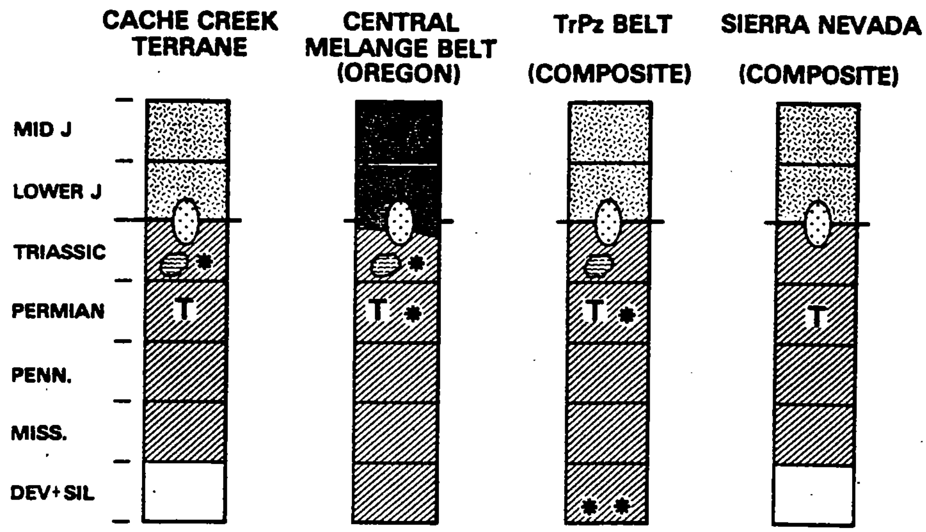

Fig. 4. Correlation chart comparing the combined TrPz terranes from the Klamaths with the Cache Creek assemblage of British Columbia, the central melange belt of eastern Oregon, and the central belt of the Sierra Nevada foothills. Horizontal line pattern indicates flysch deposits; other lithologic symbols as in Figure 2. Sources cited in text.

within the North Fork terrane and Late Triassic ammonite fauna from a limeatone block in the Rattlesnake Creek terrane may also represent pieces that are exotic to North America [Silberling and Irwin, 1962; Blome and Irwin, 1983; Irwin, 1985]

As stated previously, Silurian to Permian age blocks containing a fauna similar to localities in the eastern Klamath belt are also found within in the TrPz terranes (Figures 2 and 3). The presence of blocks from three different eastern Klamath stratigraphic intervals argues strongly that the eastern Klamath belt was the source for these blocks. The eastern Klamath belt, in turn, has many ties with North America. Silurian corals in the eastern Klamath belt appear to be North American [Elias and Potter, 1984]. The Permian McCloud limestone of the eastern Klamath belt has several forms in common with North America, while sharing only one species with known Tethyan localities [Skinner and Wilde, 1965; Miller and Wright, 1985; Yancey and Hanger, 1985]. Permian McCloud-type fusulinids have also been found interbedded with more typical North American forms in southwest Nevada [Magginetti, 1984]. Blocks of the McCloud Limestone are also found within units in northwest Nevada [Skinner and Wilde, 1966, Lupe and Silberling, 1985].

The Middle Triassic Hossulkus Limestone overlies both the eastern Klamath belt and the eastern Sierra Nevada, demonstrating that stratigraphic ties between the eastern Klamath belt and North America continued into the Middle Triassic [McMath, 1966]. In addition, paleomagnetic studies on Devonian through Middle Jurassic strata in the eastern Klamath belt indicate that none of these strata have undergone latitudinal translation relative to the North America [e.g., Mankinen et al., 1984; Scott et al., 1985]. Thus all available evidence indicates that the eastern Klamath-type fossiliferous blocks found within the TrPz terranes were derived from the presently adjacent eastern Klamath belt and that the eastern Klamath belt is a native element of the North American Cordillera.

Tectonic Model

The mixing of these very different block types within the TrPz terranes appears to have occurred by a combination of sedimentary and tectonic processes [Irwin et al.,1978; Wright, 1982; Gray, 1985]. The inclusion of blocks derived from the eastern Klamath belt within these terranes indicates that the sedmentary and tectonic mixing must have occurred in close proximity to the eastern Klamath belt and hence to North America.

Each of the four TrPz terranes appears to have undergone at least partial disruption during the Late Triassic. All available evidence indicates that blocks from the two faunal sources were incorporated into the terranes at this time. Blueschist facies matamorphism was also occurring within the inboard terrane. Together the synchroneity of deformation and blueschist metamorphism, the creation of serpentinite-matrix and argillite-matrix melanges, and the mixing of very different faunal provinces within these terranes are best explained through the creation of these terranes in a Late Triassic subduction zone environment against the margin of North America. Thus even though these terranes contain exotic material, the terranes themselves formed in proximity to the presently adjacent continental mass and are still in situ, therefore they are native terranes.

WESTERN HAYFORK TERRANE

The reinterpretation of the above terranes as products of in situ Late Triassic deformation has important implications for a fifth TrPz terrane, the western Hayfork terrane. The western Hayfork is a stratigraphic terrane consisting of a coherent

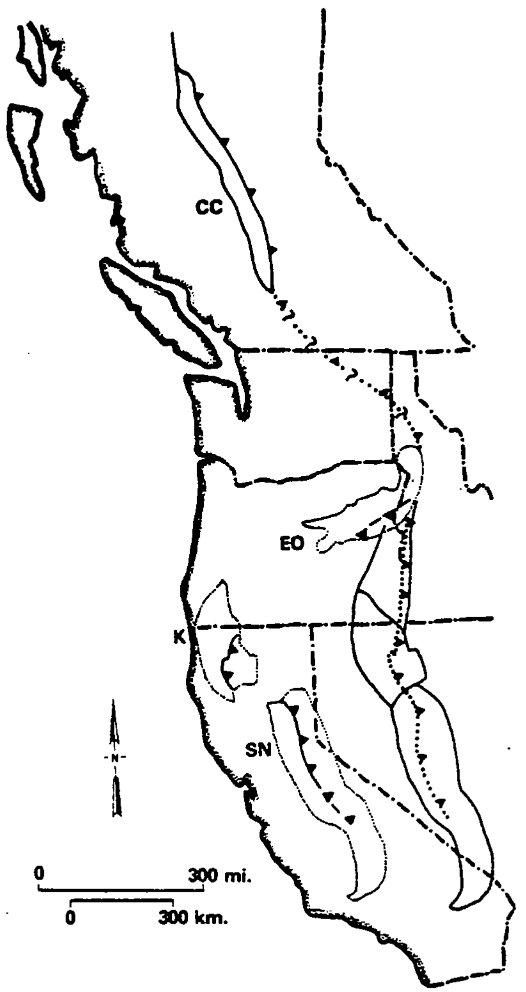

Fig. 5. Late Triassic subduction-related assemblages along the western Cordillera. Dotted areas are the present positions of the four provinces. Solid lines outline the pre-Cenozoic location of these areas and the resulting position of the Late Triassic subduction assemblages. Late Triassic subduction complexes after Davis et al. [1978], Burchfiel and Davis [1981]. Pre-Cenozoic reconstruction modified after Hamilton [1978], Magill and Cox [1980], Bogen and Schweickert [1985], and Heller et al. [1985]. Letters correspond to areas summarized in Figure 4. CC indicates Cache Creek terrane; EO, eastern Oregon, Central Melange terrane; K, Klamath Mountains, TrPz belt; SN, Sierra Nevada foothills melanges.

sequence of interbedded volcaniclastics, argillites, and coeval plutons (Figure 1). Both the volcanic and plutonic members of this terrane yield Middle Jurassic K/Ar and U/Pb ages [Wright, 1982; Fahan and Wright, 1983, 1984]. The western Hayfork lies in thrust contact betweeen the Late Triassic eastern Hayfork and Rattlesnake Creek terranes. The fact that the younger western Hayfork terrane is completely surrounded by older, apparently unrelated terranes has given rise to the interpretation that the western Hayfork is a suspect terrane [e.g., Irwin, 1985]. This interpretation also suggests that the outboard Rattlesnake Creek terrane is a suspect terrane.

Recent work within the Rattlesnake Creek terrane however, has shown that this terrane and all the pre-Middle Jurassic TrPz terranes are intruded by plutons that are coeval with the western Hayfork terrane (Figure 2) [Harper and Wright, 1984, and references therein]. These crosscutting relationships provide an independent line of evidence indicating that all of the pre-Middle Jurassic terranes were together prior to the construction of the western Hayfork terrane. Furthermore, limestone cobbles interpreted to have been derived from the Permian McCloud Limestone and Silurian Gazelle Formation have also been found within western Hayfork strata [Irwin, 1972; Wright, 1982]. Thus the western Hayfork was deposited in proximity to the eastern Klamath belt. The crosscutting relationship of Middle Jurassic plutons, the presence of recycled blocks of eastern Klamath formations, and the evidence presented previously that terranes on both sides of the western Hayfork were assembled prior to its origin indicate that the older TrPz terranes served as the depositional basement for the western Hayfork terrane. The present fault-bounded nature of the western Hayfork is due to synplutonic to postplutonic deformation which has imbricated this stratigraphic terrane with its basement [Fahan, 1982; Fahan and Wright, 1983, 1984]. Therefore the western Hayfork terrane should also be considered a native terrane because it can be tied by independent means to a North American basement and is still parautochthonous with respect to that basement.

EXTENT OF THE LATE TRIASSIC SUBDUCTION ZONE IN WESTERN NORTH AMERICA

The series of tectonic events documented within the central Klamath Mountains can be traced along most of the western margin of North America [Davis et al., 1978; Schweickert, 1978; Hamilton, 1978; Burchfiel and Davis, 1981; Saleeby, 1982, 1983] Three areas in particular, the central belt of the Sierra Nevada Foothills, the Central Melange belt of northeastern Oregon, and the Cache Creek terrane of eastern British Columbia, show a similar sequence of deformational, igneous, metamorphic events and similar fauna to the TrPz belt terranes (Figures 4 and 5).

Sierra Nevada

Several units within the western Sierra Nevada foothills metamorphic belt are lithologically and structurally similar to the TrPz. These units include the following: the Auburn Melange (chert-argillite and metasedimentary units of Day et al. [1985]) and the depositionally (?) overlying Lake Combie Complex [Rogers et al., 1984; Day et al., 1985]; the Late Triassic (?) Tuolumne ophiolite melange and the crosscutting and overlying 190 Ma Cedar Camp-Don Pedro volcanic-plutonic complex [Morgan,1976; Stern et al., 1981; Saleeby, 1982; Bogen, 1985]; the Bear Mountains ophiolite melange and overlying pre-Callovian volcanics [Behrman, 1978; Behrman and Parkinson, 1978]; and the Kaweah ophiolite melange with overlying Jurassic-Triassic (?) volcanics [Saleeby, 1978, 1982; Saleeby and Sharp, 1980]. Like their Klamath counterparts, these Sierran melanges have both serpentinite and sediment matrices and contain

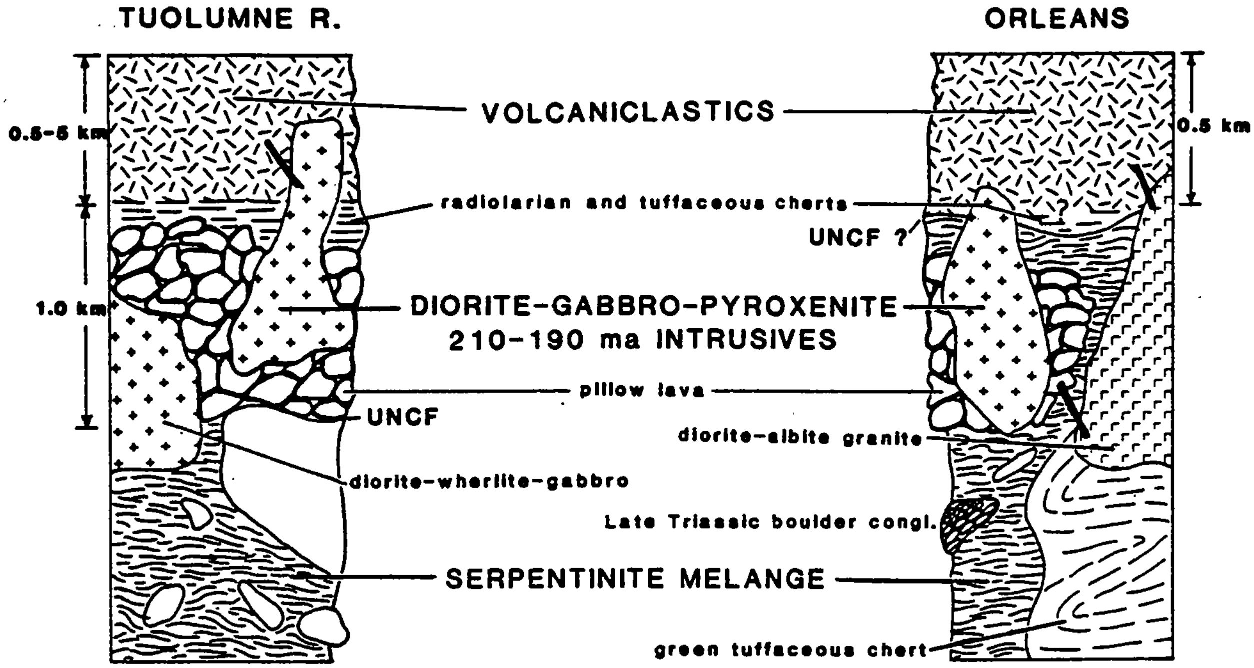

Fig. 6. Comparative stratigraphic sections from the Rattlesnake Creek terrane in the Orleans area, Klamath Mountains [Gray, 1985], and the Tuolumne River area, Sierra Nevada Foothills (modified after Saleeby [1982]; Bogen [1985])

Carboniferous to Late Triassic limestone blocks, some of which are "Tethyan" [Douglass, 1967]. The age of deformation within this disrupted sequence has been interpreted to be Jurassic-Triassic [Hamilton, 1978; Davis et al., 1978; Schweickert, 1978; Oldow et al., 1984]. The presence of Jurassic-Triassic volcanic-plutonic sequences crosscutting both the Tuolumne and Kings River melanges presents particularly striking similarities to the Rattlesnake Creek terrane and is shown schematically in Figure 6. Jurassic-Triassic plutons are also found east of the Sierra Nevada batholith, suggesting that a single magmatic belt may have extended from eastern Nevada to the western Klamaths, crosscutting the Late Triassic subduction zone, and providing yet another tie of these terranes to North America [Davis et al., 1978].

Eastern Oregon

The Central Melange belt in eastern Oregon also shares many features with the TrPz belt terranes (Figures 4 and 5). It contains Devonian to Late Triassic blocks in both serpentinite- and argillite-matrix melanges, Late Triassic blueschists, and an admixture of locally derived (North American) and exotic (Tethyan) blocks similar to that of the TrPz [Dickinson and Thayer, 1978; Brooks and Vallier, 1978; Dickinson, 1979; Nestell, 1980; Nestell and MacLeod, 1984; Oldow et al., 1984]. Limestone blocks with a distinctive "McCloud fauna" (type section in the eastern Klamath belt) are found here, and Late Triassic to Jurassic-Triassic plutons cut this melange [Skinner and Wilde, 1966; Dickinson and Thayer, 1978; Avè Lallemant et al., 1980].

Canada

The Cache Creek terrane of eastern British Columbia [Monger and Ross, 1971] (Figures 4 and 5) contains an assortment of exotic and locally (?) derived melange inclusions of Carboniferous to Late Triassic ages and Late Triassic blueschists [Monger, 1977, 1984; Davis et al., 1978; Danner, 1985; Orchard, 1985]. Crosscutting and overlying Jurassic-Triassic arc-related volcanic rocks, the Takla-Nicola group, reflect a tectonic history very similar to the areas described earlier. Much of the evidence concerning the paleogeographic position of these rocks prior to late Cretaceous time is in conflict, however, so the reconstruction of this terrane into a Late Triassic configuration shown in Figure 5 is not well constrained (compare Klepacki and Wernicke [1985]; Irving et al. [1985]; Rees et al. [1985]; Tipper and Smith [1985]).

SUMMARY

The major tectonic boundaries in the Klamath Mountains are those which separate the four large lithotectonic belts. Comparison of the fauna, timing, and style of deformation within four of the five pre-Middle Jurassic terranes which comprise the western Paleozoic and Triassic belt suggests that each was assembled within a Late Triassic subduction zone adjacent to North America. After their creation at the continental margin, these terranes served as the basement for Triassic-Jurassic and Middle Jurassic arc volcanics. Late Triassic-Early Jurassic deformational, metamorphic, and plutonic events can also be identified in Oregon and British

Columbia. The many similarities between these widely separated terranes suggest that a convergent plate boundary existed along the length of the northwestern Cordillera in the Late Triassic. These autochthonous or parautochthonous terranes are herein referred to as native terranes, since their origin can be tied to a known continental area, and they are still relatively in situ with respect to that area.

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