ALTERNATIVE TECTONIC MODEL FOR LATE JURASSIC THROUGH EARLY CRETACEOUS EVOLUTION OF THE GREAT VALLEY GROUP, CALIFORNIA

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ABSTRACT

The Franciscan complex, Great Valley Group, and Sierra Nevada batholith have long been considered to represent a Cretaceous convergent margin assemblage. This subduction complex, forearc basin, and magmatic arc triad has also been considered to have formed essentially in place with little or no Cretaceous age translation between any of the three parts. Below we explore the possibility that the Great Valley Group accumulated in a basin that was translated parallel to the convergent margin as a forearc sliver during the Late Jurassic/Early Cretaceous. There are three different scales of evidence that lead to this hypothesis. The first comes from the processes operating at modern convergent plate boundaries. The second line of evidence is based on analysis of the geologic relations where the Coast Ranges meet the Klamath Mountains province in northern California. Thirdly, we explore published and some new detrital zircon age data in the context of a translational model for the Great Valley forearc basin. We conclude that the Great Valley forearc basin is bounded on its eastern and northern sides by a strike-slip fault that accomodated several hundreds of kilometers of dextral offset in the Late Jurassic/Early Cretaceous. This boundary is now a highly modified fault separating the Klamath Mountains province and the Coast Ranges, across which are juxtaposed two fundamentally different parts of the Great Valley Group. The boundary continues to the south between the Sierra Nevada and the Coast Ranges, where it is either buried beneath younger sediments of the Sacramento Valley and/or perhaps includes structures in the Sierran foothills such as the Melones fault. Detrital zircon data suggests to us that the most likely original location of the Coast Ranges Great Valley Group, prior to strike-slip offset, was offshore of the continental arc in the southwest Cordillera (southeast California to northwest Mexico). In addition, we discuss evidence that the boundary between the Franciscan subduction complex and Great Valley forearc basin experienced significant dextral displacement. Finally, we suggest that these plate boundary-parallel faults are part of an even larger system of Early Cretaceous dextral strike-slip faults in the U.S. Cordillera, including the Mojave-Snow Lake fault, western Nevada shear zone, and Idaho shear zone.

INTRODUCTION

The Cretaceous geology of northern California (Fig. 1) has been viewed as a classic example of an orthogonal convergent margin consisting of a subduction complex (Franciscan), forearc basin (Great Valley Group) and magmatic arc (Sierra Nevada batholith) (Burchfiel and others, 1992, and references therein). Recently, more and more evidence indicates that the Cretaceous was also a time period of major margin-parallel strike-slip faulting in the western U.S. Cordillera (e.g. Gabrielse, 1985, 1991; Umhoefer and Schiarizza, 1996; Hopson and Pessagno, 2005; Wyld and Wright, 2001, 2005; Wyld and others, in press). These major strike-slip fault systems most likely resulted from strain partitioning along the continental margin due to oblique subduction (e.g., Jarrard, 1986). The presence of these documented fault systems suggest that there may be others as yet unrecognized. Below we explore the evidence that the Great Valley Group basin may have been transported northward as a forearc sliver in the Late Jurassic-Early Cretaceous, building upon the initial hypothesis of Wright (2004).

MODERN CONVERGENT PLATE BOUNDARIES

Jarrard (1986) showed that forearc slivers bounded by a trench and an active strike-slip fault occur in approximately 50% of all modern convergent plate boundaries. From his analysis, Jarrard (1986) found that subduction obliquity (deviation from orthogonal convergence) angles of only 15 degrees are sufficient to produce plate boundary-parallel strike-slip faulting in the forearc, and that typical forearc slivers move at rates of 1 to 2 cm per year relative to the adjacent magmatic arc (Fig. 2). The western Sunda arc is an excellent modern example of a forearc basin being translated parallel to the plate boundary due to oblique subduction (Diament and others, 1992; Fig. 3). In addition to a bounding strike-slip fault between the Sunda arc and its forearc basin, there is also another strike-slip boundary that more or less separates the subduction complex from the forearc basin (Fig. 3). Thus, two forearc slivers are undergoing plate boundary-parallel translation in this example.

Considering the vast amount of geologic time (ca. 80 m.y.) over which the Great Valley Group was deposited, it seems unlikely that convergence remained orthogonal (< 15 degrees of obliquity) for the entire duration of forearc basin evolution. In fact, plate reconstructions for the Cretaceous (Engebretson and others, 1985) indicate significant periods of time during which plate convergence along western North America was highly oblique. Although their plate circuit model suggests the plate boundary might have been sinistral during the Late Jurassic and Early Cretaceous, a mounting body of geologic evidence favors a dextral margin at this time, at least in the western U.S. (e.g. Wyld and Wright, 2001, and references therein). It seems to us that the question is not *if* the Great Valley Group accumulated in a translational forearc basin but how much did the basin move and when did it move.

GEOLOGIC RELATIONS IN NORTHERN CALIFORNIA: KLAMATH MOUNTAINS-COAST RANGE-SIERRA NEVADA FOOTHILLS

In northern California, there are some interesting geological features that directly bear directly on our translational hypothesis for the Great Valley forearc basin (Fig. 4). In the Klamath Mountains province, the ca 165 Ma Josephine ophiolite is depositionally overlain by the Oxfordian/Kimmeridgian Galice Formation, and both units were subsequently deformed in the Late Jurassic Nevadan Orogeny (Saleeby and others, 1982; Harper and Wright, 1984; Wright and Wyld, 1986; Wyld and Wright, 1988). The northern part of the Great Valley Group, that lies depositionally on the southeastern Klamath Mountains, was deposited unconformably on the Nevadan orogenic belt (Fig. 4).

In contrast, the Coast Ranges farther south (Fig. 4) have a distinctively different geologic history. There the ca 165 Ma Coast Range ophiolite is depositionally overlain by Late Jurassic hemi-pelagic and volcaniclastic rocks which in turn are depositionally overlain by Late Jurassic and Early Cretaceous strata of the Great Valley Group (Fig. 4; Hopson and others, 1996). This stratigraphic succession was deposited during the Nevadan orogeny, indicating an abrupt termination of Nevadan deformation across the Cold Fork fault which now separates the Klamath Mountain and Coast Range provinces (Fig. 4). Similarly conflicting relations occur to the east, where the Nevadan orogenic belt continues from the Klamath Mountains to the Sierran foothills terrane (Schweickert and others, 1984), in contrast with the lack of Nevadan deformation across the Sacramento valley in the Coast Ranges (Fig. 4) . These relations seem to require that a strike-slip boundary originally separated the Klamath/Sierran province from the Coast Ranges, and that the Coast Ranges were only juxtaposed with the Klamath/Sierran province sometime after the Nevadan orogeny. The oldest Great Valley Group strata that can be shown to lie unconformably on Sierran foothill basement are Late Cretaceous (post mid-Cenomanian; Williams, 1997), and this provides an upper limit on the age of strike-slip displacement.

In an analysis of the southernmost boundary between the Klamath Mountains and the Coast Ranges, Constenius and others (2000) concluded that a series of normal faults separates the two provinces as well as offsetting the Great Valley Group (Fig. 5). Their downplunge view of this region serves to emphasize the dramatic geologic differences between the Coast Ranges and Klamath Mountains province (Fig. 5B). (1) Across the Cold Fork/ Sulfur Spring fault zones, two contrasting basements of the Great Valley Group are sharply juxtaposed: on the Klamath side (north) the Nevadan orogenic belt is unconformably overlain by the Great Valley Group, whereas on the Coast Range side (south) the Coast Range Ophiolite and its hemi-pelagic and volcaniclastic cover is conformably overlain by the Great Valley Group. (2) On the Klamath side of this tectonic boundary the oldest unit of the Great Valley Group is Hauterivian-Barremian in age whereas in the Coast Ranges the oldest unit is Tithonian. (3) The Hauterivian-Barremian section on the Klamath Mountains is vastly thicker than in the Coast Ranges to the south (Fig. 5B). Although syndepositional normal faulting could produce this contrast in thickness (e.g., Constenius and others, 2000), it could equally well be explained by the proposed strike-slip boundary. Two points need to be stressed about the current geometry of normal faults separating the Klamath Mountains and Coast Ranges, in relation to the proposed strike-slip boundary. If these faults were syntectonic with deposition of the Early Cretaceous Great Valley Group, as suggested by Constenius and others (2000), then they would have been translated by our proposed strike-slip fault system. In addition, the normal faults cut Late Cretaceous and in some cases younger strata (Fig. 5; Constenious et al., 2000) and thus clearly have a movement history postdating the proposed period of strike-slip faulting. Thus, the current geometry of the normal faults cannot be reliably used to infer the kinematics of Late Jurassic/Early Cretaceous strike-slip faulting.

Collectively, these geologic relations suggest to us that the boundary between the Klamath and Coast Range provinces (i.e., the Cold Fork fault) was originally a strike-slip fault that was later modified by younger normal faulting. If this analysis is correct, then the Great Valley Group deposited on the Klamath Mountains was not connected to the Great Valley Group deposited on the Coast Ranges during at least the early part of their respective histories. Since they are now connected (Figs. 4, 5), an overlap assemblage must have been deposited at some point across these two initially separate Great Valley Group assemblages. Below we explore how the provenance of detrital zircons may bear on these issues

DETRITAL ZIRCON PROVENANCE

Surpless and others (2006) carried out detrital zircon analyses of seven Great Valley Group samples from locations on the west side of the Sacramento Valley in the Coast Ranges (see their Figure 1 for exact locations). All of these samples were collected from what has been interpreted to be Late Jurassic strata. We have analyzed two additional samples from the Late Jurassic part of the section near the towns of Leesville and Paskenta (L and P in Fig. 5A). These new data are presented in Table 1. The focus of the Surpless and others (2006) paper was to suggest that much of the Late Jurassic section might actually be earliest Cretaceous (Neocomian) in age. A close inspection of their data along with the *estimated* error for the Jurassic/Cretaceous boundary (145.5 ± 4 Ma) by Gradstein and others (2004) and the very real possibility of Pb loss from some of the grains analyzed indicate to us that a Late Jurassic age is still permissible for most if not all of their samples. Regardless of this uncertainty, it is not important to our arguments whether the basal Great Valley Group is Late Jurassic or Neocomian. For simplicity, we consider the basal Great Valley Group to be Late Jurassic in the following discussion.

The data from all the Late Jurassic Great Valley Group samples are combined in the following plots. The first observation is that out of a total of 464 single grain analyses, 41% yielded ages of 260 Ma or older (Fig. 6). For the most part, we will restrict our analysis of the data to these 260 Ma and older grains. The younger detrital suite is not particularly diagnostic as far as provenance is concerned because late Paleozoic through Late Jurassic arc volcanic and plutonic rocks are exposed along the length of the Cordillera from the Black Rock Desert in northern Nevada to the Sonora province of northern Mexico. Paleoslope data for Late Jurassic-Early Cretaceous strata of the northern Sacramento Valley Coast Ranges indicate that coarse material deposited in submarine-fan channels was derived mostly from the north and east and that the basin had an overall regionally southwest-dipping slope (Suchecki, 1984). Thus, we begin our discussion by comparing the detrital zircon provenance of the Great Valley Group samples to possible local sources that occur to the north and east of the current outcrop belt of the group (Fig. 1).

In Figure 7, we have combined published detrital zircon data from a wide variety of potential local source areas for the >260 Ma multi-cycle grains of the Great Valley Group, including Paleozoic and early Mesozoic rocks of the Klamath Mountains, Sierra Nevada, Roberts Mountains and Golconda allochthons, and northwest Nevada (Fig. 1). It is qualitatively obvious from Figure 7 (and see also basement ages in Fig. 1), however, that these local sources are a poor match for the >260 Ma detrital zircons in the Great Valley Group as the local sources are dominated by a ca. 1.8-2.1 component and a Late Archean component, both of which are nearly absent in the Great Valley Group data. Furthermore the Great Valley Group contains a prominent detrital component in the 1.4 -1.6 Ga range, whereas the potential local sources lack a prominent component in this age range (Fig. 7). This suggests to us the need to look elsewhere for the source of the multi-cycle older detrital zircon component, and that perhaps the Great Valley Group deposited on the Coast Ranges has been displaced from its original site of accumulation.

An alternative potential source for the pre-260 Ma detrital zircons in the Late Jurassic Great Valley Group are the Jurassic erg deposits of the Colorado plateau, which are known to have migrated into the early Mesozoic continental arc of the southwest Cordillera (Fig. 8), forming distinctive rhyolite-quartzite associations (Busby-Spera, 1988). In Figures 9A and 9B, we compare the detrital zircon ages of the Jurassic erg deposits (Dickinson and Gehrels, 2003) with those of the pre-260 Ma grains in the Late Jurassic Great Valley Group. It is clear from these figures that the erg deposits offer a potential source for the three principal >260 Ma detrital zircon age components of the Great Valley Group that are not well accounted for by local sources (Paleozoic/Neoproterozoic, Grenville age, and 1.4-1.8 Ga components; compare Figs. 7 and 9). A similar conclusion is reached by comparing the Great Valley Group data to detrital zircon ages from Middle to Late Jurassic quartzites within the continental arc of the Mojave region (Califonnia) and Sonora, Mexico (Leggett and others, 2004; Stone and others, 2005; Tim Lawton, personal communication 2006). All have distinctive and very similar >260 Ma detrital zircon populations, comparable to that of the erg deposits. Basement rocks of the southwest Cordillera are also a possible source for the 1.4-1.8 Ga component in the Great Valley Group samples (see basement ages in Fig. 1).

As interpreted by Dickinson and Gehrels (2003) the detrital zircons within the erg deposits are believed to have been derived proportionately from the following sources: Appalachian orogenic belt (ca 50%), Mesoproterozoic and Paleoproterozoic basement of the ancestral Rocky Mountains (ca 25%), and Paleoproterozoic and Archean basement of the Laurentian shield and/or its sedimentary cover (ca 25%). Indeed, a comparison of detrital zircon ages between the Jurassic erg deposits and Paleozoic Appalachian foreland basin strata shows a striking match (Fig. 9B versus 9C). These figures, when compared with the Great Valley Group data in Figure 9A, serve to emphasize that there is one potentially significant difference between the Great Valley Group samples and the erg deposits; the “Grenville age” population of the Great Valley Group is not identical to that of the erg deposits. Specifically, in the erg deposits the dominant Grenville component is centered about 1.2 Ga, whereas the Great Valley Group samples instead have a probability peak at ca 980 Ma (Fig. 9). It seems unlikely that reworking of the erg deposits could lead to rarefication rather than further homogenization of detrital zircon ages. There is, however, a potential source for this age zircon in the southwest Cordillera; the Oaxaca terrane of Mexico (see Fig. 8 for location). This terrane contains basement rocks that have yielded ca 980-1200 Ma zircon ages (Anderson and Silver, 1971; Ortega-Gutierrez and others, 1977; Robinson, 1990; Silver and others, 1994; Keppie and others, 2001 and 2003; Solari and others 2003) and Paleozoic cover rocks that contain a preponderance of detrital zircon in this same age range (Gillis and others, 2005). In Figure 10, we compare the Grenville age detrital component of the Great Valley Group to that of the Oaxaca terrane cover rocks. The match is striking, as both contain an abundance of Grenville-age detrital grains less than 1.0 Ga, unlike any of the previously discussed Laurentian sources.

From the relations discussed above, we tentatively conclude that the old multi-cycle zircon component in the Late Jurassic Great Valley Group of the Coast Ranges was derived from a combination of southwest Cordillera sources, including the Jurassic erg deposits and related quartzites within the early Mesozoic continental arc, southwest Cordillera crystalline Precambrian basement and/or its cover, and the Oaxaca terrane of Mexico. Further support for this interpretation comes from a comparison of the Great Valley Group detrital zircon ages with those of the McCoy Mountains Formation in the southwest Cordillera (see Fig. 8 for location). We do this in order to demonstrate that the early Mesozoic and late Paleozoic detrital zircon component of the Great Valley Group, which we have not discussed up until this point, is also compatable with a southwest Cordillera sediment source.

The McCoy Mountains Formation was deposited in a Late Jurassic(?) to Late Cretaceous retroarc foreland basin that developed between the continental arc to the west and a basement-involved fold-thrust belt to the northeast (Barth and others, 2004). The older part of the McCoy Mountains Formation is either Late Jurassic or Early Cretaceous in age and contains abundant zircons derived from the early Mesozoic continental arc, in addition to grains derived from local basement sources (Barth and others, 2004). In Figure 11, we compare the <260 Ma detrital zircon ages from the McCoy Mountains Formation with the <260 Ma detrital zircon ages from the Late Jurassic Great Valley Group (older zircon age signatures are similar and are not plotted). As can be seen, there is excellent agreement in the detrital zircon age distributions, demonstrating that the Early Mesozoic continental arc of the southwest Cordillera is a possible source for the Mesozoic and Late Paleozoic detrital zircon component in the Late Jurassic Great Valley Group deposited on the Coast Ranges.

Since paleocurrent data indicate sediment transport mostly from north to south within the Late Jurassic/Early Cretaceous part of the Great Valley Group (Sucheckei, 1984), the southwest Cordillera source terranes discussed above require that the Coast Ranges Great Valley Group accumulated in a basin significantly farther south in the Late Jurassic than its present location. It is of course possible to envision a river system running northward from the southwestern Cordillera and eventually turning westward north of an in situ Great Valley basin, supplying sediment that could then be transported back to the south within the basin, although such a paleogeography would be rather complicated. This seems extraordinarily unlikely, however, as the river system would have had to maintain its southwestern-derived detrital zircon provenance without any significant additions along the drainage route from sources with other age grains. The simpler interpretation is that the Late Jurassic Great Valley Group of the Coast Ranges accumulated in a basin that was located offshore and south of the Mojave region, and that these rocks were later translated northward to their current location by strike-slip faulting between the arc and the forearc basin.

TECTONIC MODEL

In the preceding sections evidence has been summarized in support of an hypothesis that the Great Valley Group forearc basin was located much farther south in the Late Jurassic, and that it underwent margin-parallel northward translation as a forearc sliver during at least the early part of the ca 80 Ma of basin evolution. In this section, we present a more explicit model for this hypothesis.

We first evaluate the location of the Great Valley basin after known displacement on Cretaceous and younger strike-slip faults has been restored. In the western U.S. Cordillera, the principal strike-slip faults to restore are the San Andreas fault (Cenozoic) and the Cretaceous MSNI (Mojave-Snow-Nevada-Idaho) fault (Fig. 12A), which links the Mojave-Snow Lake fault of the Sierra Nevada (Schweickert and Lahren, 1990) to the western Idaho shear zone (Lund and Snee, 1988), via the western Nevada shear zone of northwest Nevada and southeast Oregon (Wyld and Wright, 2001, 2005). Dextral displacement of about 400 km along the MSNI fault occurred between the Late Jurassic and the late Early Cretaceous, most likely during the lull in Sierran magmatism from ca 140-125 Ma (Schweickert and Lahren, 1990; Wyld and Wright, 2001, and references therein; Wyld and Wright, 2005). This offset is restored in Figure 12B on the palinspastically-restored 100 Ma Cordillera base map of Wyld and others (in press) which also removes other Cretaceous and younger displacements in the U.S. Cordillera, including Basin-and-Range extension, shortening along the Sevier fold-thrust belt, and offset on the San Andreas fault. The reconstruction in Figure 12B takes the Cordillera back to ca 140-120 Ma during the early stages of Great Valley Group sedimentation and moves the site of deposition significantly south of its current position (compare Figs. 12A and 12B). We consider this as a minimum translational model for the Great Valley basin.

We now need to take into account the additional strike-slip displacement of the Great Valley Group that is indicated by the relations discussed in previous sections of this paper. We have argued that the fault boundary is clearly located in northern California, along what is now the Cold Fork fault between the Klamath Mountains province and the Coast Ranges (Figs. 5 and 12). We have also argued that the Great Valley Group of the Coast Ranges was displaced from an original Late Jurassic location much farther south. The strike-slip boundary between the Klamath Mountains and Coast Ranges must therefore continue south between the Coast Ranges and the Sierra Nevada, into the Sacramento and San Joaquin Valleys where it may be buried by younger sedimentary strata (Fig. 12). In order to evaluate this conclusion, we turn to what is known about the crustal structure beneath the San Joaquin Valley.

The velocity profile from Fleidner (1997) includes the region from the Sierra Nevada batholith west to the Coast Ranges, and indicates the presence of low velocity crust beneath high velocity crust under the San Joaquin valley (Fig. 13). The high velocity crust is interpreted to represent the Coast Range ophiolite, including mantle peridotites beneath the crustal section (Fleidner, 1997). Godfrey and others (1997) interpreted the underlying low velocity material to represent a continuation of the Sierra Nevada batholith and its wall rocks beneath the Coast Range ophiolite (Fig. 14 A). In their model, the Coast Range ophiolite was obducted onto Sierra Nevada basement during the Late Jurassic Nevadan Orogeny. If this interpretation is correct, then it precludes the possibility of a strike-slip fault buried beneath the valley fill. A number of authors, however, have argued against the Nevadan obduction model (Saleeby and Busby-Spera, 1992 and references therein). One of the most significant, but often overlooked problems with the obduction model is that there is no evidence that the Coast Range ophiolite was deformed during the Nevadan Orogeny (Fig. 4), nor is there any sedimentary record for ophiolite obduction. In Figure 14 B we present an alternative interpretation for the crustal velocity structure beneath the San Joaquin valley. We suggest that the low velocity material beneath the ophiolite could just as likely be underplated subduction complex material, perhaps analogous to the Pelona-Orocopia-Rand schists which occur beneath the Sierra Nevada batholith farther south (Saleeby and Busby, 1992). We also show only the Late Cretaceous part of the Great Valley Group overlapping Sierran basement, in keeping with actual observations. With these modifications, it is clear that the crustal velocity profile beneath the San Joaquin valley can be readily interpreted to indicate the presence of a steeply-dipping fault, orthogonal to the profile, between the Sierra Nevada and the pre-Late Cretaceous Great Valley Group and its basement (Fig. 14B). We suggest that this is the southern continuation of our proposed strike-slip fault (see Fig. 12). The location of the strike-slip boundary farther to the south is much less constrained but must be to the west of the inferred Mojave/Sonora sediment sources for the Late Jurassic Coast Ranges Great Valley Group (Fig. 12). To the north, we infer that the strike-slip fault continues along the western side of the Klamath Mountains province (Fig. 12A); this boundary is currently a steeply-dipping fault of poorly understood history , west of which lie rocks that have been interpreted to be dextrally-displaced fragments of the Franciscan complex, Great Valley Group and Coast Range ophiolite (Blake et al., 1988; McLaughlin et al., 1988; Jayko and Blake, 1993).

In Figure 12C, we present a speculative reconstruction of offset along the proposed Great Valley strike-slip fault shown in Figure 12B. In this Early Cretaceous (ca 140-120 Ma) reconstruction, the Great Valley Group of the Coast Ranges is moved south and away from the Great Valley Group deposited on the Klamath Mountains. We restore the Coast Ranges Great Valley Group to a position somewhere off the Mojave-Arizona-Sonora segment of the Mesozoic continental arc, based on the detrital zircon and paleocurrent data discussed previously. The location shown is a conservative one, however, and a position farther south cannot be ruled out. Minimum offset on the proposed fault is thus about 500 km.

We view the western Sunda arc as an excellent analog for our proposed model of strike-slip faulting between the arc and the Great Valley forearc basin (Figs. 3 and 12). Our reinterpretation of the crustal velocity structure beneath the San Joaquin valley also suggests that there may also be another strike-slip fault between the Franciscan complex and the Great Valley Group (Fig. 14B). If correct, this would be analogous to the fault which separates the subduction complex from the forearc basin in western Sumatra region (Fig. 3). Hopson and Pessagno (2005) have also proposed a strike-slip fault at this location. In addition, recent detrital zircon ages obtained from the Franciscan complex in the Diablo Range are distinct from those reported by Degraaff Surpless and others (2002) from Great Valley Group strata (Joesten and others, 2004), consistent with possible strike-slip faulting along the Franciscan-Great Valley boundary.

CONCLUSIONS

We have presented an alternative model for the Late Jurassic through Early Cretaceous evolution of the Great Valley Group forearc basin. Modern plate interactions along with Mesozoic plate reconstructions strongly imply that the Great Valley Group basin was unlikely to remain stationary during its 80 Ma of basin evolution due to oblique rather than orthogonal convergence. In addition, relations at the junction of the Klamath Mountains and Coast Range provinces seemingly require the presence of an Early Cretaceous strike-slip boundary in that location. Detrital zircon age data appear to be more compatable with a southwest Cordillera source for Late Jurassic strata of the Great Valley Group rather than an in situ source. Certainly, the detrital zircon data can be interpreted at least as convincingly in terms of a translational model rather than a fixed basin model. Finally, reconstructions of known Cretaceous strike-slip faults in the U.S. Cordillera indicate that, at a minimum, the Great Valley forearc basin was located at least 400 km south of its current location in the Late Jurassic which poses problems for any in situ interpretation.

If our model is correct, then there are at least two Late Jurassic/Early Cretaceous Great Valley basins, one floored by the Nevadan orogenic belt of the Klamath Mountains, and the other floored by the Coast Range ophiolite and its hemi-pelagic and volcaniclastic cover in the Coast Range province. Our model also predicts that the Coast Ranges Great Valley basin was originally located at least 500 km south of the Klamath Mountains Great Valley basin, and that these two disparate entities were only juxtaposed by later strike-slip faulting along the forearc basin-arc boundary, analogous to the situation in the modern western Sunda arc. According to Williams (1997), post-mid-Cenomanian strata can be shown to span the width of the Great Valley basin and overlap Sierran basement. We predict that Cenomanian strata will turn out to represent an overlap assemblage tying the Klamath and Coast Ranges basins together in the Late Cretaceous. Detailed detrital zircon transects have been collected from the Klamath province and from the immediately adjacent Coast Ranges across the Cold Fork fault (Fig. 5) to test this hypothesis.

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FIGURE CAPTIONS

Figure 1. Generalized geology of western U.S. Cordillera showing distribution of the Franciscan complex, Great Valley Group, Klamath/Sierran provinces, and other features and provinces discussed in the text. SAF is San Andreas fault. Solid grey line outlines Colorado plateau.

Figure 2. Diagram illustrating a plate boundary-parallel strike-slip fault and a forearc sliver produced by oblique convergence.

Figure 3. Geodynamics of the Sunda convergent boundary, modified from Diament and others (1992).

Figure 4. Generalized geology of northern California, illustrating differences between the Klamath/Sierran provinces and the Coast Ranges in terms of the effects of the Nevadan orogeny. Franciscan complex not shown (see Figure 1 for location).

Figure 5. (A). Geologic map of northern California showing structural, stratigraphic and basement relations between northern Great Valley Group (deposited on Klamath Mountains) and Great Valley Group of Coast Ranges (south of Cold Fork fault). For location, see Figure 4. (B) Downplunge-view cross-section from P in map north to Klamath basement. View is perpendicular to bedding and stratigraphic contacts in Great Valley Group. Modified from Constenius and others (2000). P and L refer to the location of samples collected for detrital zircon analysis.

Figure 6. Age probability plots, including histograms, of Late Jurassic samples from the Great Valley Group. A. 100-260 Ma grains; B. 260-2900 Ma grains. Source of data Surpless and others (2006), and this paper.

Figure 7. Age probability plots, including histograms, of >260 Ma grains from the Late Jurassic Great Valley Group (A) compared to likely local sources for multi-cycle zircon in this age interval (B). Sources of data: Darby and others (2000), Gehrels and Miller (2000), Gehrels and others (2000), Harding and others (2000), Riley and others (2000), Spurling and others (2000), Wallin and others (2000).

Figure 8. Distribution of Jurassic erg deposits and early Mesozoic (Triassic-Jurassic) continental arc of southwest U.S. Cordillera (from Dickinson and Gehrels, 2003), and location of Jura-Cretaceous McCoy Mountains Formation (Barth and others, 2004). Inset shows location of Oaxaca terrane and area of Mexico considered to be underlain by Oaxaca terrane (from Keppie and others, 2003).

Figure 9. Age probability plots, including histograms, of: (A) pre-260 Ma detrital zircons from Jurassic strata of the Great Valley Group, (B) the Jurassic erg deposits of the western U.S. , and (C) late Paleozoic strata of the Appalachian foreland. Erg data from Dickinson and Gehrels (2003); Appalachian foreland data from Becker and others (2005).

Figure 10. Age probability plots, including histograms, of Grenville age detrital zircon grains from the Oaxaca terrane (A) compared to those of the Great Valley Group (B). Oaxaca terrane data from Gillis and others (2005).

Figure 11. Age probability plots, including histograms, of 140-260 Ma detrital zircon grains of the McCoy Mountains Formation (A) compared to those of the Great Valley Group (B). McCoy Mountains Formation data from Barth and others (2004).

Figure 12. (A) Geology of western U.S. Cordillera, showing apporximate and inferred locations of Great Valley fault proposed herein and MSNI fault, which connnects the Mojave-Snow Lake fault of the Sierra (Schweickert and Lahren, 1990) to the western Idaho shear zone (Lund and Snee, 1988) via the western Nevada shear zone (Wyld and Wright, 2001, 2005). (B) Reconstruction for the Early Cretaceous showing restoration of 400 km dextral displacement on the MSNI fault, on a palinspastically-restored base map from Wyld et al. (in press, 2006). (C) Same as B, but now also showing restoration of inferred displacement on proposed Great Valley fault. Note separation of Klamath versus Coast Ranges portions of the Great Valley Group, and restoration of the latter to a position south and west of the continental arc of the southwest Cordillera.

Figure 13. Crustal velocity model from the Diablo Range across the San Joaquin Valley through the Sierra Nevada into the Basin and Range province. Modified from Fliedner and others (2000).

Figure 14. (A) Interpretation of the crustal structure beneath the San Joaquin Valley from Godfrey and others (1997). (B) Our alternative interpretation. Question marks beneath the San Joaquin Valley indicate uncertainty in whether the Coast Range Ophiolite actually extends this far east.