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TERRANE DELETION IN SOUTHERN MEXICO

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ABSTRACT

The tectonostratigraphic evolution of the southern margin of the North America Plate in Mexico is still in debate. Recent explanations rely on Laramide (Campanian-Eocene) accretion of far-ravined oceanic terranes. Here we report new mapping results from a 30 km x 250 km transect of northern Guerrero State, from Huetamo, Michoacan, to Papalutla, Guerrero. Our objectives were to evaluate proposed terrane boundaries and assess tectonostratigraphic evolution of the transect.

Published mapping shows that the distribution of exposures of Grenville-age continental basement, mid-C setaceous rudist reef carbonates and associated facies, a Laramide fold and thrust belt, and post-Laramide basin and range extensional structures link Mexico north and south of the Mexican Volcanic Belt. No Mesozoic melange, blueschist or ophiolite sequence exist. Gravity modelling shows that the crust is continental and paleomagnetic measurements require paleogeographic coherence.

Our map, structural cross section and assessment of the 9 km thick stratigraphic section are consistent with the above regional information. The area was the site of a Jurassic-Early Cretaceous back-arc basin, filled with andesitic, submarine volcanics and sedimentary rocks, and formed on Late Permian-Early Triassic continental basement. Aptian/
Albian transgression resulted in deposition of mid-Cretaceous platform and basinal facies on the western margin of the Tethys realm. The platform was drowned by Late Cretaceous flysch sedimentation. Late Cretaceous-Paleogene Laramide orogenesis resulted in approximately 60 km shortening due to NE E-vergent folding and thrust faulting. Tertiary postorogenic extension led to terrestrial volcanism, fluvial siliciclastic sedimentation, and formation of a prominent, N-trending graben with 3 km of structural relief.

No stratigraphic incompatibilities suggesting terrane accretion exist. The proposed Arcelia/Teloloapan subterrane boundary is a normal fault on the eastern edge of a Tertiary graben, the Guerrero/Mixteco terrane boundary is a normal contact between flysch and platform strata on a Laramide fold limb; and the Guerrero/Mixteca and Nahuatl/Mixteco terrane boundaries are Laramide thrust faults. These terranes and subterranes should therefore be deleted.

KEY WORDS: Terranes, Northern Guerrero State, Geologic Mapping, Stratigraphy, Structure, Southern Mexico
INTRODUCTION

THE SOUTHERN MEXICO PROBLEM

In the first modern plate reconstruction of Pangaea, Bullard et al. (1965) considered southern Mexico an anomaly because of the apparent overlap of Mexico and South America. Attempts to explain this overlap led to numerous *ad hoc* hypotheses, including: (1) "arbitrary rotation" (e.g., Dietz and Holden, 1970, p. 4944) of most of southern Mexico into the Gulf of Mexico or elsewhere prior to Jurassic time; and (2) the proposition that "megashears" isolated most of Mexico from the rest of North America during various stages of the evolution of the Caribbean, eastern Pacific, and North America plates (e.g., Coney, 1978; Silver and Anderson, 1983; Burke, 1988; Gastil, 1991). To these, Campa and Coney (1983) added the suspect terrane hypothesis (Figure 1A) which itself has been subjected to numerous revisions, most recently by Sedlock et al. (1993) (Figure 1B). According to Campa and Coney (1983), terranes of southern and western Mexico were accreted in Campanian–Eocene time, during the Laramide Orogeny. But some recent plate reconstructions (e.g., Stockhert et al., 1995, Figure 3) show no overlap problem and no terrane accretion in Mexico since Early Cretaceous time. Thus, the tectonostratigraphic evolution of the southwestern margin of the North America plate in Mexico
is still uncertain.

PURPOSE

In 1989, we began an effort to bring new data to this debate through field mapping along a geological transect in southwestern Mexico (Figures 1 and 2). Monod et al. (1994) suggested that this type of work is critically needed for determining the tectonostratigraphic evolution of southern Mexico. Here we summarize the major results that led to our main conclusion: there are no stratigraphic or structural problems in the region that require the existence of accreted terranes.

Our work in Mexico started as a feasibility study to test the applicability of methods developed in Wyoming for basin analysis aided by remote sensing (Lang et al., 1987 and Lang and Paylor, 1994) to the less well known southern Mexico region. Success of the feasibility study (e.g., Barros et al., 1989; Johnson et al., 1991; Jansma et al., 1991; Johnson et al., 1992) led to a major field mapping effort that incorporated use of Landsat Thematic Mapper data (Lang and Cabral-Cane, 1993). The objective was to characterize proposed terrane boundaries and assess the tectonostratigraphic evolution of a region covered by a 30 km X 250 km geological transect of northern Guerrero State (Figure 3).
RESULTS

GEOLOGICAL SETTING

The line of transect was selected to cross the Guerrero-Mixteca terrane boundary (Figure 1). Running from Huetamo, Michoacan, to Papalutla, Guerrero, the transect is located south of the Mexican Volcanic Belt, an east-west trending belt of Neogene-Recent volcanic rocks that form a topographic plateau across Mexico. Review of published descriptions of the basic regional stratigraphic framework for this part of Mexico (Figure 2) shows that:

(1) Grenville-age (1100 Ma), anorthosite and gneiss, continental basement is exposed in a belt from north of Puerto Angel to west of Oaxaca and northward in isolated exposures to southeast of Xilitla, cropping out beneath volcanics of the Mexican Volcanic Belt (Ortega-Gutierrez, 1981; Ortega-Gutierrez et al., 1992; Suter, 1987);

(2) Basement is overlain by rocks that range in age from Paleozoic (high grade metamorphic exposed near Acatlan) to Jurassic and Early Cretaceous rocks that include low grade metamorphic as well as unmetamorphosed continental and marine strata (Yanez et al., 1991; Ortega-Gutierrez et al., 1992);

(3) The region was blanketed by mid-Cretaceous marine carbonates, now exposed as erosional remnants of rudist reef, bank, platform and
basin deposits, that formed the western margin of the Albian Tethys realm (Alencaster, 1984; Jenkyns, 1991; Enos, 1983). These primarily Albian strata provide an important stratigraphic marker;

(4) During Late Cretaceous through Eocene time, east-west shortening resulted in fold and thrust deformation in the Sierra Madre Oriental that was cinematically and temporally similar to Laramide orogenesis in the U.S. Cordillera to the north (Suter, 1984 and 1987; Enos, 1983). This fold and thrust belt extends into southern Mexico (Campa, 1985);

(5) Tertiary rocks are primarily terrestrial elastics, volcaniclastics and volcanics except for a belt of marine elastics along the Gulf coast margin and one remnant on the Pacific margin near Playa Azul (Ortega-Gutierrez et al., 1992; Henry and Aranda-Gomez, 1992);

(6) Cretaceous to Paleogene granitic batholiths intrude older rocks in a belt along the Pacific coastal margin (Ortega et al., 1992; Schaaf, 1991; Schaaf et al., 1995; Moran-Zenteno, 1992);

(7) The youngest structures are primarily extensional and include ubiquitous normal faults and grabens (Ortega-Gutierrez et al., 1992; Henry and Aranda-Gomez, 1992);

(8) No Mesozoic melange, blueschist or ophiolite sequence has been reported anywhere in the region covered by Figure 2, although
Mesozoic marine volcanics (primarily pillow andesites and rare basalts) have been considered "ophiolite sequences" despite the lack of the other diagnostic lithologies (e.g., Centeno-Garcia et al., 1993a; and Talavera-Mendoza et al., 1995).

Paleomagnetic data show that the region has maintained its present relative position with respect to the rest of North America and has not experienced major internal displacements since at least Early Cretaceous time (Guerrero et al., 1990; Bohnel et al., 1989; and Bohnel and Negendank, 1988). Lack of published borehole or seismic reflection data south of the Mexican Volcanic Belt has hindered determination of deep crustal structure, but gravity modelling shows that the crust is approximately 40 km thick with a density structure showing continental affinity (Garcia-Perez, 1995; Urrutia-Fucugauchi and Molina, 1992; and Arzate et al., 1993).

STRATIGRAPHY

As depicted on Figures 3 and 4, our mapping is well with the regional geology described above. The total exposed section is approximately 9 km thick. Strata were assigned to formations using the lithostratigraphic nomenclature of Pantoja-Alor (1959) and Fries (1960), with revisions suggested by Ontiveros-Tarango (1973) and us (Johnson et al., 1991; Jansma et al., 1991; Jansma and Lang, 1995; Cabral-Cane, 1995;
Barros, 1995).

The two lowest lithostratigraphic units form a predominantly chlorite grade metamorphic sequence composed of: (1) the Taxco Schist which contains pre-Jurassic (?) phyllitic metapelites and metatuffs overlain unconformably by (2) the Rota Verde ("greenstone") Taxco Viejo and equivalents which contain Jurassic-Early Cretaceous graywackes, metandesites and rare metabasalts of marine (pillows) and terrestrial (breccias and agglomerates) origin, phyllites and interbedded cherts, and graded sandstones/conglomerates of probable marine turbidite origin. The base of the Taxco Schist is not exposed along our traverse, but according to Elias-Herrera and Sanchez-Zavala (1990) this unit is approximately 1.5 km thick near Zacazonapan (Figure 2), where it rests unconformably on Late Permian-Early Triassic granitic basement of continental affinity.

Unconformably above these units is the Morelos Formation and equivalent strata: primarily Albian, massive- to medium-bedded rudist limestones and dolostones of reef, platform, bank and backreef origin that grade into thin-bedded dark, limestones, shales (locally phyllitic), and chert of basin origin. Late Cretaceous marine shales and sandstones of the Mexcala Formation constitute a flysch sequence in conformable, but sharp, contact with Morelos strata. In the eastern area of the transect (F, Figure 4), a large body of Maastrichtian sandstone and conglomerate of
littoral, deltaic, paludal and fluvial origin exists within the Mexcala Formation (Tilton et al., 1993).

The Cretaceous marine sequence is covered unconformably by Paleogene and younger terrestrial rocks. At the base are well-indurated, fluvial redbed conglomerates and sandstones and volcaniclastic sandstones/siltstones assigned to the Balsas Formation. These rocks are overlain unconformably by undifferentiated tuffs, flows, pyroclastic rocks and associated dikes, plugs and larger hypabyssal bodies. These volcanic rocks exhibit variable, but predominantly rhyolitic compositions. Poorly-indurated, fluvial volcaniclastic sandstones and conglomerates are interbedded with the volcanics locally. Gypsiferous beds also occur in the Tertiary sequence.

STRUCTURE

At 1:50,000 scale, fold axes and faults generally strike NW-SE, ranging through N-S to NE-SW. Deformation of lower Balsas and older strata resulted in an east-verging fold and thrust belt with local backthrusts such as those west of Iguala and at Papalutla (Figure 3A). We determined an average transport direction to the NEE, based on structural measurements at outcrops (Cabral-Cano, 1995; Barros, 1995; Johnson, 1990). Restoration of the Figure 3B cross section suggests E-W shorten-
ing of approximately 60 km, or about 20%, due to folding and thrust faulting. This transport direction and percentage shortening are nearly identical to those reported by Suter (1987) in the Xilitla region of the Sierra Madre Oriental (Figure 2).

Along the transect, fold and thrust belt structures are unconformably covered by the less-deformed upper Balsas volcaniclastic and undifferentiated volcanic rocks. Related hypabyssal bodies intrude all older strata. Ubiquitous normal faults cut the entire stratigraphic sequence. A prominent graben that we discovered between Ciudad Altamirano and Arcelia records extension associated with the normal faulting (Jansma and Lang, 1995). We estimate post-Morelos subsidence associated with this graben structure to be approximately 3 km.

We consider the fold and thrust belt to be the southern extension of the well-documented Laramide belt of the Sierra Madre Oriental, Subsequent normal faulting and graben development exhibit similar geometry to basin and range structures that affected much of western Mexico and the US southwest since Neogene time (Suter, 1991; Henry and Aranda-Gomez, 1992) (Figure 2).

DISCUSSION

Our mapping shows that proposed terrane boundaries (Figures 1 and
3B) coincide with normal faults, normal stratigraphic contacts, or thrust faults. No stratigraphic incompatibilities that would suggest juxtaposition of far-travelled terranes exist across any of the boundaries (Figure 3B and 4). Modelling of gravity data agrees with our Figure 3B structural interpretation (Garcia-Perez, 1995). We suggest an alternative model for the tectonostratigraphic evolution of the region more consistent with the results of our stratigraphic and structural observations.

A Jurassic back-arc basin existed along the western margin of the region covered by Figure 2. Its exact configuration is poorly constrained because of poor exposure due to more recent truncation, uplift, erosion and/or cover along the continental margin of western Mexico (Schaaf et al., 1995). The basin formed on the continental basement exposed today near Zacazonapan and between Puerto Angel and Xilitla. This back-arc basin was the southern extension of a more extensive basin system along the entire length of western Mexico during Late Jurassic/Early Cretaceous time. The basin filled with siliciclastic sediments, chert and volcanics, which were subjected to seafloor metamorphism (Talavera-Mendoza et al., 1995), through Early Cretaceous time. Mid-Cretaceous transgression resulted in widespread development of rudist platforms and associated carbonate facies, locally and throughout much of Mexico, on the western margin of the Tethys realm. Laramide (Cenomanian-Mid Eocene) deforma-
tion resulted in:

(1) Generally eastward but locally westward, depending on local relief, marine regression;

(2) Incipient metamorphism of pre-Morelos strata as well as Morelos basinal equivalents, associated with Late Cretaceous uplift;

(3) East verging thrust faulting and folding;

(4) **Paleogene** synorogenic redbed deposition.

Cessation of Laramide deformation was followed by Late Eocene-Neogene extension, normal faulting, volcanism, hypabyssal intrusion and local hydrothermal alteration of older rocks.


**CONCLUSION**

Our mapping and tectonostratigraphic assessment of the Guerrero transect shows that boundaries of the Guerrero/Mixteca, Guerrero/Mixteco, and Nahuatl/Mixteco terranes and the Arcelia/Teloloapan
subterrane are normal stratigraphic contacts or faults. Across these boundaries we found no major stratigraphic discontinuities. Paleomagnetic studies and crustal gravity models also do not indicate that separate terranes and their boundaries exist in the area. These proposed terranes and subterrane should therefore be deleted.

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FIGURE 1. Comparison of two different terrane interpretations of central and southern Mexico. A. map of “suspect” terranes (after Campa and Coney, 1983). B. map of “tectonostratigraphic” terranes (after Sedlock et al., 1993). The Sierra Madre (A) and Guachichi (B) terranes coincide with the Laramide Sierra Madre Oriental fold and thrust belt. Also identified are: the trace of the Acapulco-Mid America trench (bold line with teeth) which marks the southern edge of the North America plate; the areas covered by the Ciudad Altamirano (west rectangle, INEGI, 1985a) and Cuernavaca (east rectangle, INEGI, 1985b) 1:250,000 scale geologic map sheets (18-1 9"N; 98-102"W); and the line of transect mapped in this study.

FIGURE 2. Simplified geologic map of central and southern Mexico, compiled from published mapping, including Ortega-Gutierrez et al. (1992), INEGI (1985a and 1985b), Henry and Aranda-Gomez (1992), and Suter (1987), plus our own mapping, Compare geology to terrane maps in Figure 1. Area mapped in the Guerrero transect is outlined. Selected cities and villages are identified; PV: Puerta Vallarta, TP: Tepee, MA: Manzanillo, C: Colima, GU: Guadalajara, PA: Playa Azul, AR: Arteaga, AG: Aguascalientes, AP: Arperos, G: Guanajuato, H: Huetamo, PO: Placeres del Oro, Z: Zihuatanejo, CA: Ciudad Altamirano, AL: Arcelia, ZA: Zacazonapan, TJ:
FIGURE 3. Geology of the Guerrero transect (for location see Figure 2). A. Geological map (for lithostratigraphic nomenclature see Figure 4). B. East-West geological cross section (no vertical exaggeration). Dashed horizon in the blue unit identifies the contact between the Cuautla Formation and the Morelos Formation in the eastern part of the cross section. Dot pattern in the green unit (Mexcala Formation) identifies major sandstone bodies in this flysch sequence. Surface locations of selected, purported terrane boundaries are identified by numbered red lines. From west to east, these are: (1) the Arcelia/Teloloapan subterrane boundary of Campa et al. (1981), Centeno-Garcia et al. (1993a and 1993b) and Talavera-Mendoza et al. (1995); (2) the Guerrero/Mixteco terrane boundary of Centeno Garcia et al. (1993a and 1993b) and Talavera-Mendoza et al. (1995); (3) the Guerrero/Mixteca terrane boundary of Campa et al. (1981) and Campa and Coney (1983), and (4) the Nahuatl/Mixteco terrane boundary of Sedlock et al. (1993). The change in spelling from “Mixteca” to “Mixteco” was presumably made for Spanish grammatical reasons: adjective (mixteco) - noun (terreno) gender agreement.
FIGURE 4. Panel diagram, hung on base of Morelos Formation and equivalents (Aptian/Albian), depicting stratigraphic relationships and lithostratigraphic nomenclature that we adopted for mapping the Guerrero transect. Colors correspond to those used in Figure 3; lithologies are described in the text. As cited on the Figure 3A caption, terrane boundaries have been proposed between A and C, D and E, and E and F. A is after Johnson et al., 1991; B, Jansma et al., 1991, and Jansma and Lang, 1995; C and D, Cabral-Cane, 1995; and E, Barros, 1995. Here we report F for the first time,
TERTIARY MARINE SEDIMENTS

TERTIARY AND CRETACEOUS BATHOLITHS

MIO-LATE CRETACEOUS CARBONATES

PRE-CRETACEOUS METAMORPHIC

PROTEROZOIC GNEISS
Fig 3A
Long et al.
Fig 3B
Long et al.
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