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Terrane deletion in northern Guerrero state

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RESUMEN

La evolución tectonoestratigráfica del margen sur de la placa Norteamericana en México es materia de debate. Los escenarios recientemente propuestos muestran la acreción de terrenos oceánicos durante el Campaniano-Eoceno. Aquí presentamos nuevos resultados del mapeo a escala 1:100,000 de un transecto de 30 x 250 km en el norte del Estado de Guerrero, de Huetamo, Michoacán a Papalutla, Guerrero. Nuestro objetivo al mapear esta región fue caracterizar los límites de terrenos que han sido propuestos a lo largo de este transecto y el análisis de su evolución tectonoestratigráfica.

Nuestro mapa, sección estructural y análisis de la sección estratigráfica de 9 km de espesor, son consistentes con información regional. En el área mapeada se desarrolló una cuenca Jurásica-Cretácica temprana (de retro-arco?) en la cual se depositaron rocas volcánicas submarinas predominantemente andesíticas y sedimentarias, sobre un basamento continental Pérmico tardío-Triásico temprano. Una transgresión Aptiana/Albiana propició el depósito de una plataforma carbonatada Cretácica media y facies de cuenca en el margen occidental del ámbito Tetisiano. Esta plataforma fue ahogada por la sedimentación de un flysch Cretácico tardío. La orogenia Laramídica de edad Cretácico tardío-Paleogeno resultó en un acortamiento de aproximadamente 60 km debido al plegamiento y cabalgamiento con dirección ENE. La extensión Terciaria post-orogénica dio paso a un volcanismo terrestre, sedimentación fluvial siliciclástica y a la formación de un graben con dirección norte y con un relieve estructural de 3 km.

Se han propuesto tres diferentes versiones del límite de los terrenos Guerrero-Mixteca y del límite del subterreno Arcelia-Teloloapan que se ubican en la región cubierta por nuestro transecto. No hemos encontrado incompatibilidades estratigráficas o estructurales que requieran la existencia de ninguno de estos límites. Por lo tanto, estos terrenos y subterrenos deberían de ser eliminados en el área que hemos mapeado.

PALABRAS CLAVE: Terrenos, norte del estado de Guerrero, mapeo geológico, estratigrafía, estructura, sur de México.

ABSTRACT

The tectonostratigraphic evolution of the southern margin of the North America Plate in Mexico is still in debate. Recent explanations assert Laramide age (Campanian-Eocene) accretion of oceanic terranes. Here we report new mapping results obtained from a 1:100,000 scale, 30 km x 250 km transect of northern Guerrero State, from Huetamo, Michoacán, to Papalutla, Guerrero. Our mapping objectives were to characterize terrane boundaries that have been proposed to cross the transect and to assess the tectonostratigraphic evolution of the transect.

Our map, structural cross section and assessment of the 9 km thick stratigraphic section are consistent with regional information. The area that we mapped was the site of a Jurassic-Early Cretaceous (back-arc?) basin, filled with predominantly andesitic, submarine volcanics and sedimentary rocks, that formed on Late Permian-Early Triassic continental basement. Aptian/Albian transgression resulted in deposition of mid-Cretaceous carbonate 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 age orogenesis resulted in approximately 60 km of shortening due to ENE directed 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.

Three different versions of the Guerrero-Mixteca terrane boundary and the Arcelia-Teloloapan subterrane boundary have been proposed to cross our transect. We found no stratigraphic incompatibilities or structures that require the existence of any of these boundaries. Therefore, these terranes and subterranes should be deleted in the area that we mapped.

KEY WORDS: Terranes, northern Guerrero State, geologic mapping, stratigraphy, structure, southern Mexico.

INTRODUCTION

The southern Mexico problem

In the first modern plate reconstruction of Pangea, 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). Campa and Coney (1983) added the suspect terrane hypothesis (Figure 1A); which itself has been subjected to numerous revisions (cf. Sedlock *et al.*, 1993) (Figure 1B). According to Campa and Coney (1983), the terranes of southern and western Mexico are exotic crustal blocks of uncertain paleogeographic origin, that were accreted to the North America Plate in Campanian-Eocene time, during the Laramide Orogeny. But structural measurements reported by Ratschbacher *et al.* (1991) and Meschede *et al.* (1996) show that the terranes of southern Mexico form tectonic elements integral to the mid-Cretaceous-Cenozoic evolution of the southern North America Plate. These results are consistent with Ross and Scotese's (1988) plate reconstructions that show no overlap problem and no terrane accretion in southern Mexico since Early Cretaceous time. Thus, the Mesozoic tectonostratigraphic evolution of the southwestern margin of the North America Plate in Mexico is still in debate.

Purpose

In 1989, we began an effort to bring new data to this debate through 1:100,000 scale geological mapping along a transect in northern Guerrero State, southwestern Mexico (Figures 1 and 2). Monod *et al.* (1994) suggested that this type of basic geological mapping is critically needed for determining the tectonostratigraphic evolution of southern Mexico. Here we 1) review the geological framework of southern Mexico as it relates to our transect, and 2) summarize our mapping results which led to our main conclusion: there are no stratigraphic or structural incompatibilities that require the existence of accreted terranes along our transect.

Our mapping started as a feasibility study to test the applicability of methods for basin analysis aided by remote sensing developed in Wyoming (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-Cano, 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 2 and Figure 3).

RESULTS

Geological framework

The line of transect was selected to cross the Guerrero-Mixteca terrane boundary as defined by Campa and Coney (1983) (Figure 1). Running from Huetamo, Michoacán, to Papalutla, Guerrero, the transect traverses northern Guerrero State south of the Mexican Volcanic Belt, an east-west trending belt of Neogene-Holocene, terrestrial volcanic rocks that form a topographic plateau across central Mexico.

Our assessment of published descriptions of the regional geological 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 (Herrmann *et al.*, 1994; Ortega-Gutiérrez, 1981; Ortega-Gutiérrez *et al.*, 1992, and 1995; Suter, 1987). Ortega-Gutiérrez (1978) discovered early to middle Paleozoic crystalline basement near Acatlán which he assigned to the Acatlán Complex (Ortega-Gutiérrez, 1981; Yañez *et al.*, 1991).

(2) These crystalline basement rocks are overlain by Paleozoic to Early Cretaceous rocks that include low grade metamorphics as well as unmetamorphosed continental and marine strata (Herrmann *et al.*, 1994; Yañez *et al.*, 1991; Ortega-Gutiérrez *et al.*, 1992);

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

(4) During Late Cretaceous through Eocene time, east-west shortening resulted in fold and thrust deformation in the Sierra Madre Oriental (Figure 1) that was kinematically and temporally similar to Sevier/ Laramide-style orogenesis in the U.S. Cordillera to the north (Suter, 1984 and 1987; Enos, 1983). The Sierra Madre Oriental fold and thrust belt extends into southern Mexico (Campa, 1985) where it has been related to the eastward drift of the Chortis block along the Pacific margin of Mexico (Herrmann *et al.*, 1994; Meschede *et al.*, 1996; Ratschbacher *et al.*, 1991);

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

(6) Cretaceous to Paleogene granitic batholiths intrude older rocks in a belt along the Pacific coastal margin (Herrmann *et al.*, 1994; Ortega-Gutiérrez *et al.*, 1992; Schaaf, 1991; Schaaf *et al.*, 1996; Morán-Zenteno, 1992);

(7) The youngest structures are primarily extensional and include ubiquitous Tertiary-Holocene normal faults and grabens, which are best documented north of the Mexican Volcanic Belt (Meschede *et al.*, 1996; Ortega-Gutiérrez *et al.*, 1992; Henry and Aranda-Gómez, 1992);

(8) No Mesozoic melange, blueschist or ophiolite sequence has been confirmed anywhere in the region covered by Figure 2, although Mesozoic marine volcanics (primarily pillow andesites and rare basalts) in the area

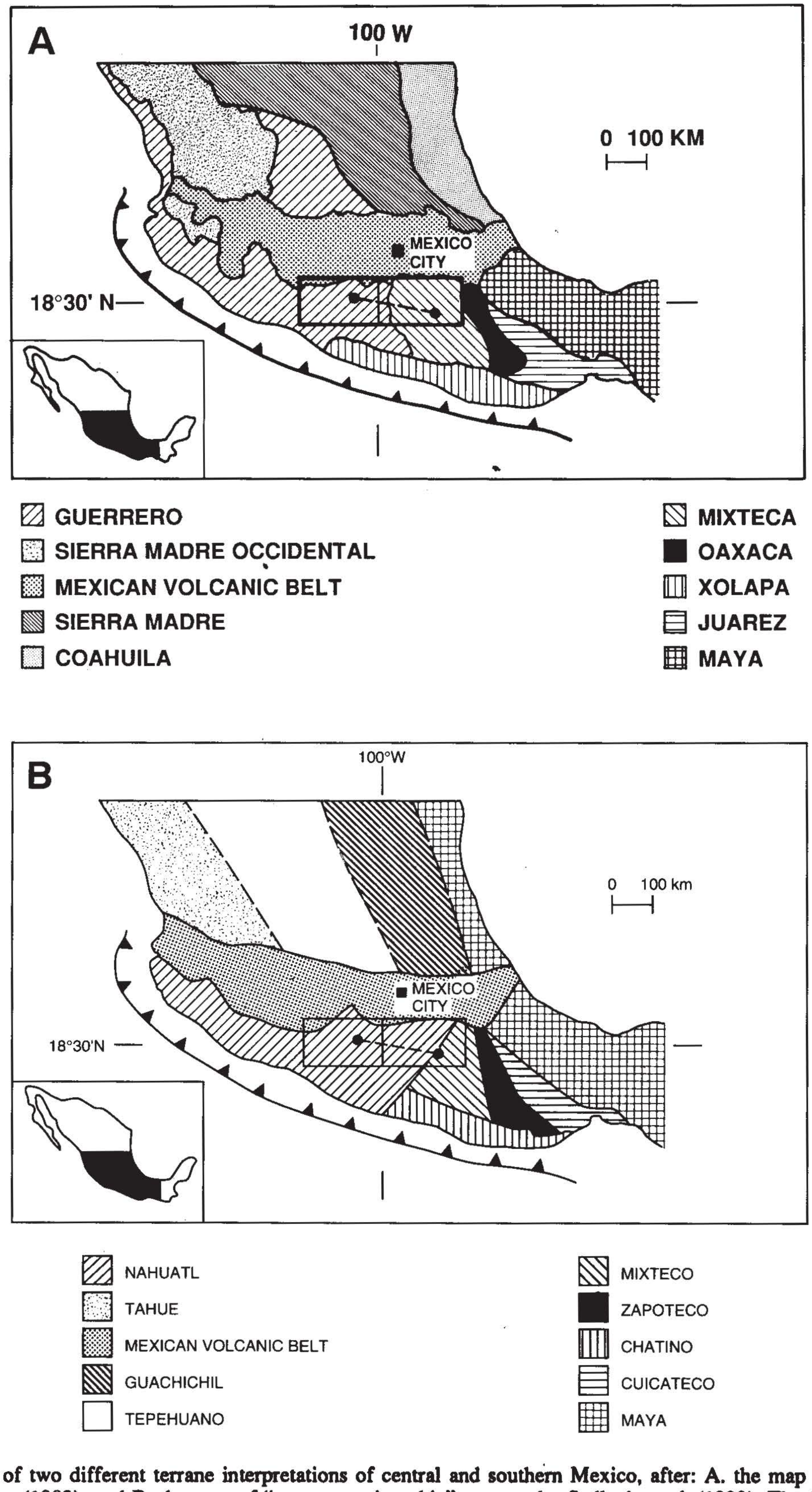

Fig. 1. Comparison of two different terrane interpretations of central and southern Mexico, after: A. the map of "suspect" terranes by Campa and Coney (1983), and B. the map of "tectonostratigraphic" terranes by Sedlock *et al.* (1993). The Sierra Madre (A) and Guachichi (B) terranes coincide with the Laramide age 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 (18-19°N; 98-102°W); and the line of transect mapped in this study.

that we mapped have been considered "ophiolite sequences" despite the lack of the other diagnostic lithologies such as serpentinized ultramafic rocks, cumulate ultramafic or gabbroic rocks, or sheeted diabase dikes (e.g., Centeno-García *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 latitudinal displacements since at least Early Cretaceous time (Guerrero *et al.*, 1990; Böhnel *et al.*, 1989; and Böhnel 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 consistent with continental affinity (García-Pérez, 1995; Urrutia-Fucugauchi and Molina, 1992; and Arzate *et al.*, 1993).

Stratigraphy

As depicted on Figures 3 and 4, our mapping fits well with the regional geology described above. Along the transect, the total exposed section is approximately 9 km thick. We followed standard lithostratigraphic procedures (North American Commission on Stratigraphic Nomenclature, 1983) and assigned strata to formations using the lithostratigraphic nomenclature of Pantoja-Alor (1959) and Fries (1960), with revisions suggested by Ontiveros-Tarango (1973). In Johnson *et al.* (1991), Jansma *et al.* (1991), Jansma and Lang (1996), Cabral-Cano (1995), and Barros (1995) we provided detailed discussion of these units and their ages. Here we summarize that information.

The two lowest lithostratigraphic units (Figure 4) form a predominantly chlorite grade metamorphic sequence composed of: (1) the Taxco Schist Formation, which contains pre-Jurassic(?) phyllitic metapelites and metatuffs, overlain unconformably by (2) the Roca Verde Taxco Viejo Formation 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 Elías-Herrera and Sánchez-Zavala (1990) this unit is approximately 1.5 km thick near Zacazonapan (Figure 2), where it rests unconformably on granitic basement of continental affinity, which they consider Late Permian-Early Triassic age.

The metamorphic sequence is overlain unconformably by 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, carbonaceous limestones, shales (locally phyllitic), and chert of basin origin. The 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 paralic, deltaic, 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 of this cover are well-indurated, red fluvial 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

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 predominantly west-dipping thrust faults as well as local east-dipping backthrusts and lateral ramps such as those west of Iguala and at Papalutla (Figure 3A). Based on slip-line measurements at outcrops, we determined an average transport direction to the ENE (Cabral-Cano,1995; Barros, 1995; Johnson, 1990) which is consistent with the overall map pattern of folds and thrust faults (Figure 3). Bed length restoration and area balancing of the Figure 3b cross section reveals E-W shortening of approximately 60 km, or about 20-25%, due to folding and thrust faulting. The direction and magnitude of shortening are nearly identical to those reported by Suter (1987) to the north in the Xilitla region of the Sierra Madre Oriental (Figure 2), and to the west, south and east by Ratschbacher *et al.* (1991) and Meschede *et al.* (1996).

Along the transect, fold and thrust belt structures are unconformably covered by the less-deformed upper Balsas volcaniclastic and undifferentiated volcanic rocks. Hypabyssal bodies, apparently related to the volcanics, intrude all older strata. Ubiquitous normal faults cut the entire stratigraphic sequence. A prominent NNW striking graben that we discovered between Ciudad Altamirano and Arcelia records E-W extension associated with the normal faulting (Jansma and Lang, 1996). We estimate post-Morelos subsidence associated with this graben to be approximately 3 km.

As suggested by Campa (1985), we consider the fold and thrust structures to be a southern arm of the well-documented Laramide belt of the Sierra Madre Oriental. Subsequent extensional structures 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-Gómez, 1992) (Figure 2).

DISCUSSION

Our mapping crosses four proposed terrane boundaries (Figures 3B and 4). From west to east, as numbered on Figure 3B, these are: (1) the Arcelia/Teloloapan subterrane

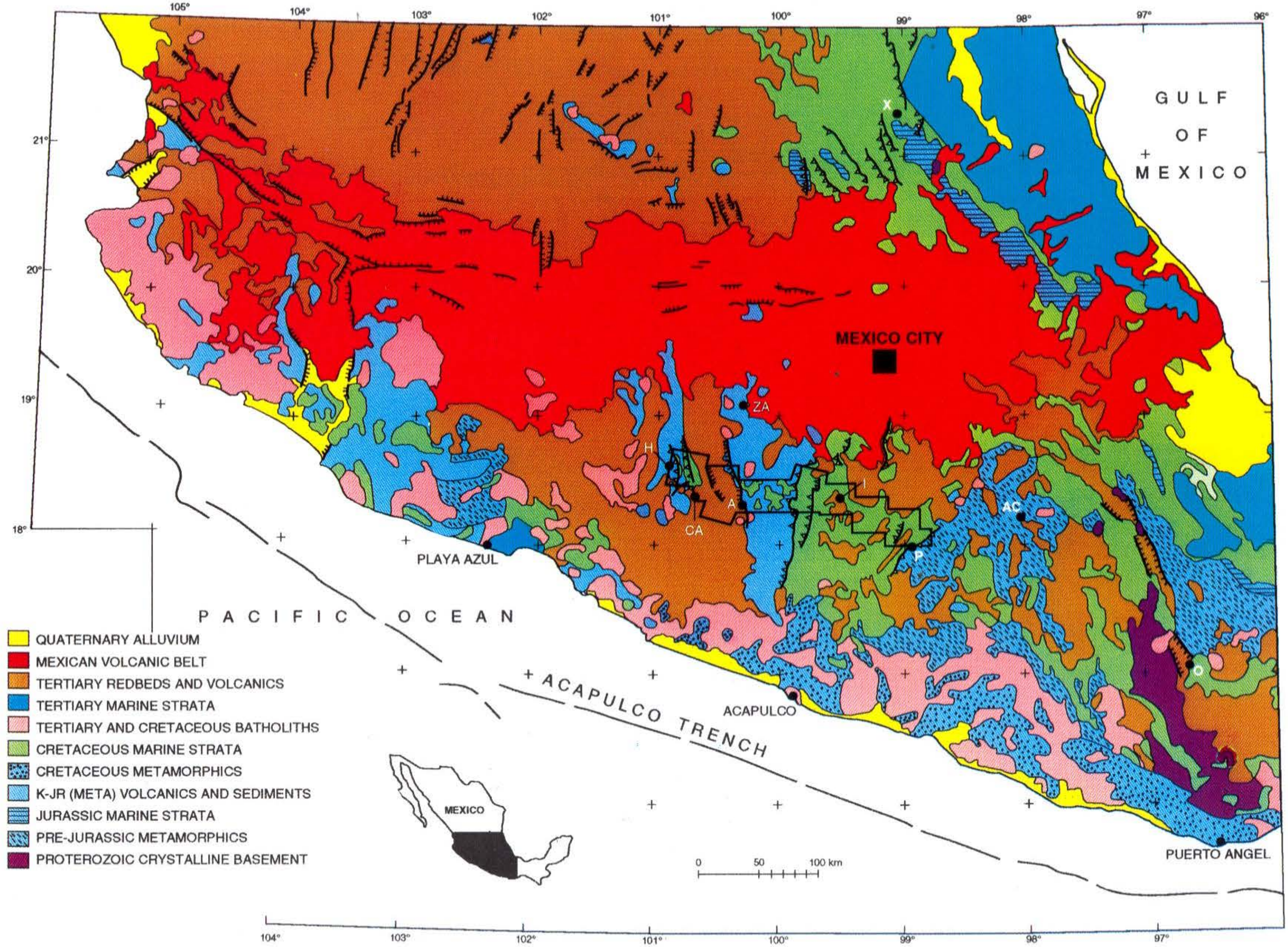

Fig. 2. Simplified geologic map of central and southern Mexico, compiled from published mapping, including Ortega-Gutiérrez *et al.* (1992), INEGI (1985a and 1985b), Henry and Aranda-Gómez (1992), and Suter (1987), plus our own mapping. Compare to terrane maps of Figure 1. Area mapped in the Guerrero transect is outlined. Cities and villages mentioned in text include; H: Huetamo, CA: Ciudad Altamirano, A: Arcelia, ZA: Zacazonapan, I: Iguala, P: Papalutla, X: Xilitla, AC: Acatlan, O: Oaxaca.

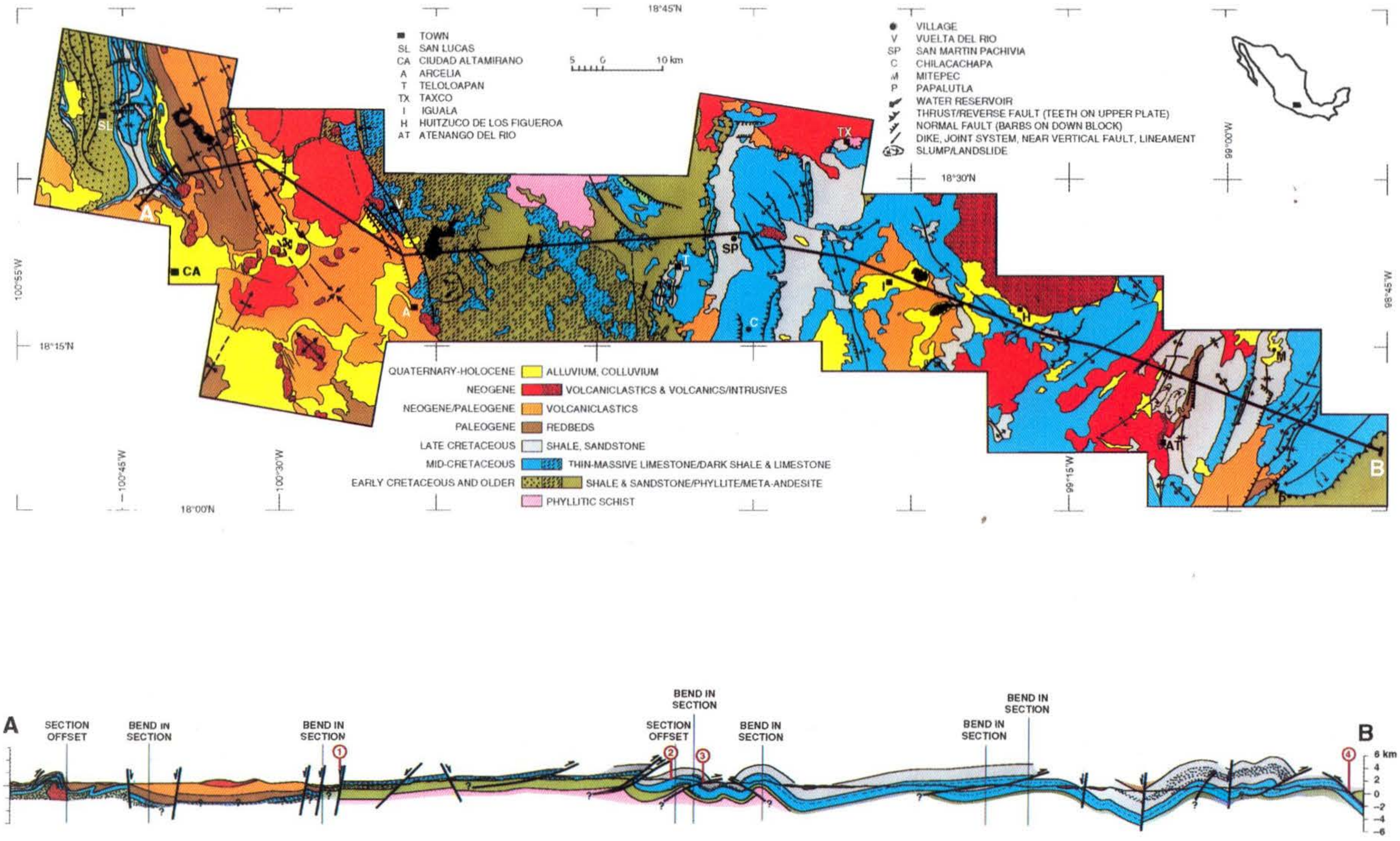

Fig. 3. Geology of the Guerrero transect (for location see Figure 2). A. Geological map (for lithostratigraphic nomenclature see Figure 4). B. East-West geological cross section (no vertical exaggeration). Dashed horizon in the blue unit identifies the contact between the Cuautla Formation and the Morelos Formation in the eastern part of the cross section. Dot pattern in the g:ay unit (Mexcala Formation) identifies major sandstone intervals in this flysch sequence. Surface locations of purported terrane boundaries, which are discussed in the text, are identified by numbered red lines.

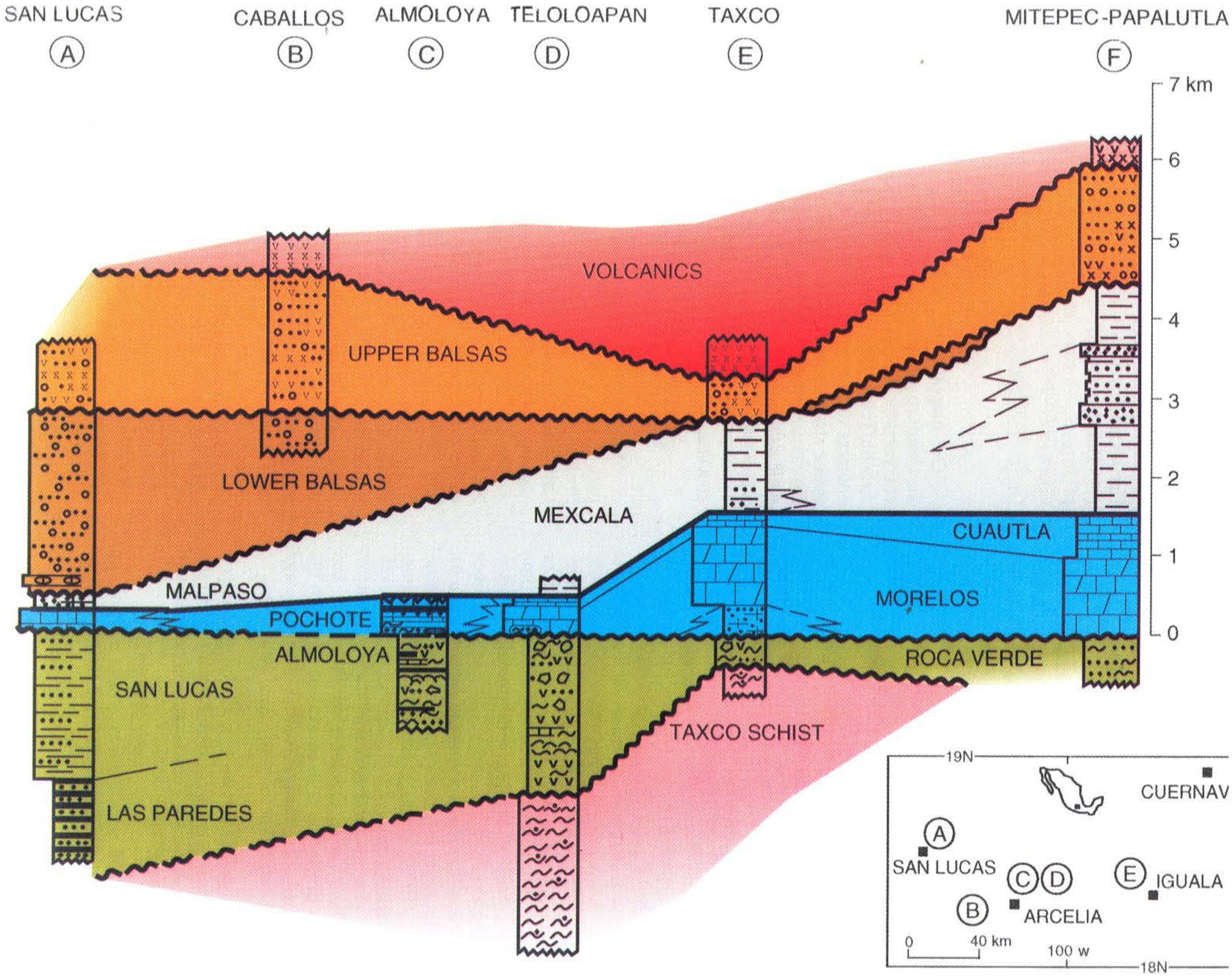

Fig. 4. Panel diagram, hung on Aptian/Albian base of Morelos Formation and equivalents, depicting stratigraphic relationships and lithostratigraphic nomenclature that we used for mapping the Guerrero transect. Colors correspond to those used in Figure 3; lithologies are described in the text. As labelled on Figure 3B and discussed in the text, terrane boundaries have been proposed between A and C, D and E, and E and F. A, after Johnson *et al.* (1991); B, Jansma *et al.* (1991) and Jansma and Lang (1996); C and D, Cabral-Cano (1995); E, Barros (1995); F, this study.

boundary of Campa *et al.* (1981), Centeno-García *et al.* (1993a and 1993b) and Talavera-Mendoza *et al.* (1995); and three different versions of the Guerrero-Mixteca terrane boundary or its equivalent proposed by: (2) Centeno-García *et al.* (1993a and 1993b) and Talavera-Mendoza *et al.* (1995); (3) Campa *et al.* (1981) and Campa and Coney (1983) (Figure 1A), and (4) Sedlock *et al.* (1993) (Figure 1B). According to the accepted definition, these terranes should be "fault-bounded package[s] of rocks of regional extent characterized by a geologic history which differs from that of neighboring terranes" (Howell *et al.*, 1985, p. 4). Our mapping shows that the proposed terrane boundaries within our transect (Figures 1 and 3B) coincide with normal faults, normal stratigraphic contacts, or thrust faults. Furthermore, we find no stratigraphic incompatibilities that suggest juxtaposition of terranes across any of the boundaries (Figure 3B and 4). Interpretation of our stratigraphic and structural results provides a coherent picture of the tectonostratigraphic evolution of the northern Guerrero transect, without recourse to terrane accretion.

A Jurassic-Early Cretaceous basin existed in the region that we mapped. West of the map area, the basin's exact configuration is poorly constrained because of poor stratigraphic exposures resulting from Cretaceous and younger truncation, uplift, erosion and/or cover along the present continental margin of western Mexico (Schaaf *et al.*, 1996). This basin may have formed in a back arc setting, inboard from an arc near the present Pacific margin of Mexico as described by Ratschbacher *et al.* (1991). In the area that we mapped, the basin formed on the Taxco Schist Formation and the continental basement exposed near Zacazonapan. This basin was part of a more extensive, predominantly marine, basin system along the entire length of western Mexico during Late Jurassic/Early Cretaceous time (Cserna, 1976). The basin filled with siliciclastic sediments, minor carbonates, chert and volcanics of the Roca Verde Taxco Viejo Formation and equivalents (Figure 4), 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 with deposition of the Morelos Formation and throughout much of Mexico with equivalent strata, on the western margin of the Tethys realm. Laramide age (Cenomanian-Mid Eocene) deformation resulted in:

(1) Generally eastward but locally westward, depending on local relief, marine regression, deposition of the flysch sequence of the Mexcala Formation, and cessation of carbonate platform growth;

(2) Metamorphism of pre-Morelos strata as well as Morelos basinal equivalents, during Late Cretaceous uplift (Cabral-Cano, 1995);

(3) East directed thrust faulting and folding;

(4) Paleogene synorogenic deposition of redbeds of the Balsas Formation.

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

This interpretation is consistent with Alencaster's (1984) analysis of the Mesozoic biostratigraphic record of southern Mexico, Cserna *et al.*'s (1978) and Enos' (1983) tectonostratigraphic models of the Mesozoic-Tertiary evolution of Mexico, Ross and Scotese's (1988) Cretaceous-Tertiary plate reconstruction of the North America-Caribbean-South America region, Ratschbacher *et al.*'s (1991) and Meschede *et al.*'s (1996) kinematic assessment of Jurassic-Tertiary structures in southern Mexico, and Cserna's (1976) evaluation of tectonostratigraphic controls on the distribution of mineral deposits in Mexico.

CONCLUSION

Our mapping and tectonostratigraphic assessment of the Guerrero transect shows that boundaries of three different versions of the Guerrero/Mixteca terranes and the Arcelia/Teloloapan subterranes are normal stratigraphic contacts or faults. Across these boundaries we found no major stratigraphic incompatibilities that would support the existence of any of these terranes. Published paleomagnetic studies and crustal gravity models also do not require that separate terranes and their boundaries exist in the area. These proposed terranes should therefore be deleted in the area that we mapped.

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