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CRETACEOUS-TERTIARY DETACHMENT SURFACE—CERRO EL VIGÍA, STRUCTURAL BLOCK IN THE BANÁMICHI-SAN ANTONIO REGION, CENTRAL SONORA, MEXICO

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ABSTRACT

The Cerro El Vigía, in east-central Sonora, is a structural block that was detached along a major low-angle fault. This fault, La Ramada-Agua Caliente detachment fault, separates an autochthonous early Tertiary igneous complex (the Aconchi batholith) from chaotically deformed Paleozoic and Early Cretaceous strata in Cerro El Vigía. The La Ramada-Agua Caliente fault accommodated extension, denudation, and gravitational sliding deformation that ranges in age from Late Cretaceous to mid-Tertiary. Tectonic denudation affected a thick sequence (10–15 km) of Precambrian igneous and metamorphic, Paleozoic sedimentary, Mesozoic sedimentary and volcanic, and Tertiary sedimentary and volcanic rocks.

The upper plate of the Cerro El Vigía block consists of Paleozoic quartzite and siltstone, and Early Cretaceous limestone, shale, and sandstone. The lower plate is composed of granitic rocks that has yielded mainly Tertiary ages (56–69 Ma and 36–32 Ma).

Reconstruction of Cerro El Vigía block indicates northeastward slip of the upper plate along a detachment produced by gravity sliding of Precambrian, Paleozoic and Mesozoic cover rocks from the underlying Mesozoic to Tertiary granitic rocks. At least 40 km tectonic transport is estimated based on lithologic offset of Paleozoic facies that occurs to the west in the Aconchi batholith.

Keywords: Detachment surface, Banámichi-San Antonio region, Sonora, Mexico.

RESUMEN

El Cerro El Vigía se localiza en la parte centroriental del estado de Sonora y constituye un bloque estructural desplazado a lo largo de una falla de bajo ángulo. Esta falla, a la que se ha denominado "falla de desprendimiento La Ramada-Agua Caliente", separa rocas autóctonas (placa inferior), constituidas por un complejo ígneo del Paleógeno-Cretácico Tardío (batolito de Aconchi, compuesto por rocas graníticas de 56–69 Ma y 32–36 Ma), de rocas fuertemente deformadas de edad paleozoica y cretácica temprana que constituyen el cerro El Vigía. A lo largo de la falla de desprendimiento La Ramada-Agua Caliente se presenta deformación extensional, denudación y deslizamiento por gravedad que ocurrieron entre el Cretácico Tardío y el Terciario medio. La denudación tectónica afectó una gruesa secuencia, de entre 10 y 15 km de espesor, constituida por rocas ígneas y metamórficas precámbricas, rocas sedimentarias del Paleozoico, rocas sedimentarias y volcánicas del Mesozoico, y rocas sedimentarias y volcánicas del Terciario.

El bloque Cerro El Vigía, que es parte de la placa superior, está constituido por cuarcita y limolita del Paleozoico más caliza, lutita y arenisca del Cretácico Temprano.

La reconstrucción de movimientos del cerro El Vigía indica deslizamiento por gravedad hacia el noreste a lo largo de una superficie de desprendimiento de la cubierta precámbrica, paleozoica, y mesozoica encima de rocas mesozoicas y terciarias graníticas. Se ha estimado un transporte tectónico de al menos 40 km, basado en similitudes litológicas de facies paleozoicas que afloran hacia el oeste, en el batolito de Aconchi.

Palabras clave: Superficie de desprendimiento, región Banámichi-San Antonio, Sonora, México.

INTRODUCTION

The Banámichi - San Antonio region in central Sonora is part of a complex tectonic pattern that have been evolved in the Jurassic through Tertiary times. Structures, including thrust faults (that superposes Precambrian crystalline basement rocks over Jurassic), strike-slip faults, low-angle detachment faults, and normal faults are characteristic in the region. Thrust faults have been related to the evolution of the Mojave-Sonora megashear (Anderson and Silver, 1979; Rodríguez-Castañeda, 1984, 1990, 1994), which is a major strike-slip fault accompanied by transpression along its trace (Connors *et al.*, 1989; Caudillo and others, in press). Anderson and Silver (1979) indicated that left-lateral movements have been occurred on the basis of apparent offset of stratigraphic trends of Precambrian and Paleozoic rocks. Extensional tectonics, or the onset of the metamorphic core complex deformation, is

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responsible for detachment faulting, while normal faulting is caused by the Basin and Range extensional deformation. Normal faults expose deformed older rocks that display a variety of structural styles.

Laramide structures remain as an unsolved problem with its structural interpretations. Several contrasting interpretations included Taliaferro (1933), Rangin (1977, 1982), Himanga (1977), González-León (1978, 1988, 1989, 1994), Jacques-Ayala (1983, 1993), Herrera-Urbina and Bartolini (1983), Palafox and Martínez (1985), Minjarez-Sosa and others (1985), Pubellier (1987), González-León and Jacques-Ayala (1988, 1990), Castro-Rodríguez and Morfín-Velarde (1988) among others, advocate compressional origin for most of the structural features (thrusting, folding and fracturing) observed in the Early Cretaceous rocks in northern and central Sonora.

Structural interpretations of Early Cretaceous rocks are difficult because of isolation outcrops and distance between them. However, recent investigations (Rodríguez-Castañeda and García y Barragán, 1995; Rodríguez-Castañeda *et al.*, 1996, 1997; Rodríguez-Castañeda, 1997), suggest an alternate model—different to the Laramide model—that can explain diverse structural features observed in Early Cretaceous rocks, in particular in the Banámichi-San Antonio region although, this hypothesis can be extended to other places in Sonora.

The present author propose that Paleozoic and Early Cretaceous rocks that constitute the Cerro El Vigía (Figures 1 and 2), northeast of Banámichi, were detached from the Aconchi - El Jaralito - Pajaritos - Mazatán batholith (for the purpose of this work these rocks are referred to as the Aconchi batholith) and transported to the east-northeast, along a low-angle detachment fault or faults that formed contemporaneously with the emplacement of the Late Cretaceous and Paleogene granitic bodies. The northeast transportation was about 40 km. Paleozoic rocks in Cerro El Vigía resemble well-known, nearby Paleozoic rocks (Los Changos quartzite, Rodríguez-Castañeda, 1984, 1994) that crop out to the west in Cerro Los Changos, Sierra El Jucaral, and Cerro El Carrizo among others. Apparent offset of these sedimentary rocks occurs along the La Ramada-Agua Caliente detachment fault (Rodríguez-Castañeda, 1996).

The likely displacement path of Cerro El Vigía block (CEVB) was to the northeast, although its original position has not been precisely located because a comparable section has not yet been found.

ROCK UNITS

The CEVB consist of two distinctive, contrasting structural, and lithologic bodies separated possibly by an extremely sharp dislocation. The core of the Cerro El Vigía is mainly composed of Paleozoic rocks and Early Cretaceous Mural Limestone (Figure 3). A Late Cretaceous sedimentary sequence discordantly covers Paleozoic and Early Cretaceous rocks. The Paleozoic sequence is composed of two members. The lower member consists of red to purple, medium- to thick-bedded shale, siltstone and quartzite (Figure 4). The upper member is composed of reddish to reddish gray, medium- to thick-bedded quartzarenite (Figure 5). Comparable rocks to the upper member are present in the Los Changos quartzite which crops out to the west in Cerro Los Changos and Sierra El Jucaral (Rodríguez-Castañeda, 1984, 1994). The Los Changos quartzite is reddish gray to very light brown, medium- to thick-bedded that occupies the highest parts of rugged mountains. In Sierra El Jucaral the Los Changos quartzarenite is a pink to red rock with intercalated shale and conglomerate. At Cerro El Vigía the Mural Limestone (Figures 2 and 3) is composed of fossiliferous limestone, sandstone and shale. Similar Early Cretaceous rocks are found to the west of Cerro El Vigía, near the Aconchi batholith.

The hypothesis proposed here is that the CEVB sometime overlay or was part of a more complete sedimentary sequence including Precambrian, Paleozoic and Mesozoic rocks above the Aconchi batholith. The original thickness of the sequence is impossible to determine, but some relations allow an estimate of the original stratigraphic thickness. Rodríguez-Castañeda (1996) around Opodepe reported a migmatitic gneiss along Cañada La Jarillas within an extensional shear zone at deep levels, perhaps ten kilometers or even more. Thus, a stratigraphic column of at least 10 to 15 km may have covered the Aconchi batholith, where the most intense denudation certainly occurred. Remnants of Precambrian, Paleozoic and Mesozoic rocks can be seen today as roof pendants above the Aconchi batholith (Peabody, 1979; Chávez-Aguirre, 1978; Roldán-Quintana, 1989). Rocks that crop out west of the Aconchi batholith (Cerro de Oro locality) could be part of this thick column. Therefore CEVB was uplifted vertically and then slided northeast to reach its actual position.

EVIDENCE OF BLOCK DETACHMENT

Structural and lithologic elements support the hypothesis that the CEVB was detached from the Aconchi batholith and transported to the northeast. CEVB is interpreted to be derived from tectonic denudation. The model proposed here links denudation faults or detachment faults with evolution of Cretaceous and Tertiary intrusives of the Aconchi batholith. Denudation faults are intrinsically associated with the vertical uplift of the Aconchi batholith. The model also involves reinterpretation of certain structures reported west of the Aconchi batholith, the Cerro de Oro area.

The Aconchi batholith is composed of granites which vary in age from 51–69 Ma to 32–36 Ma (Damon *et al.*, 1983; Roldán-Quintana, 1989, 1991). Older granites range in composition from quartzmonzonite to granodiorite, while the younger intrusive is a two mica granite. The granite was covered by approximately 10- to 15-km-thick section of Precambrian, Paleozoic, and Mesozoic rocks that existed at least in the Early Cretaceous time. Absence of this sequence requires either ero-

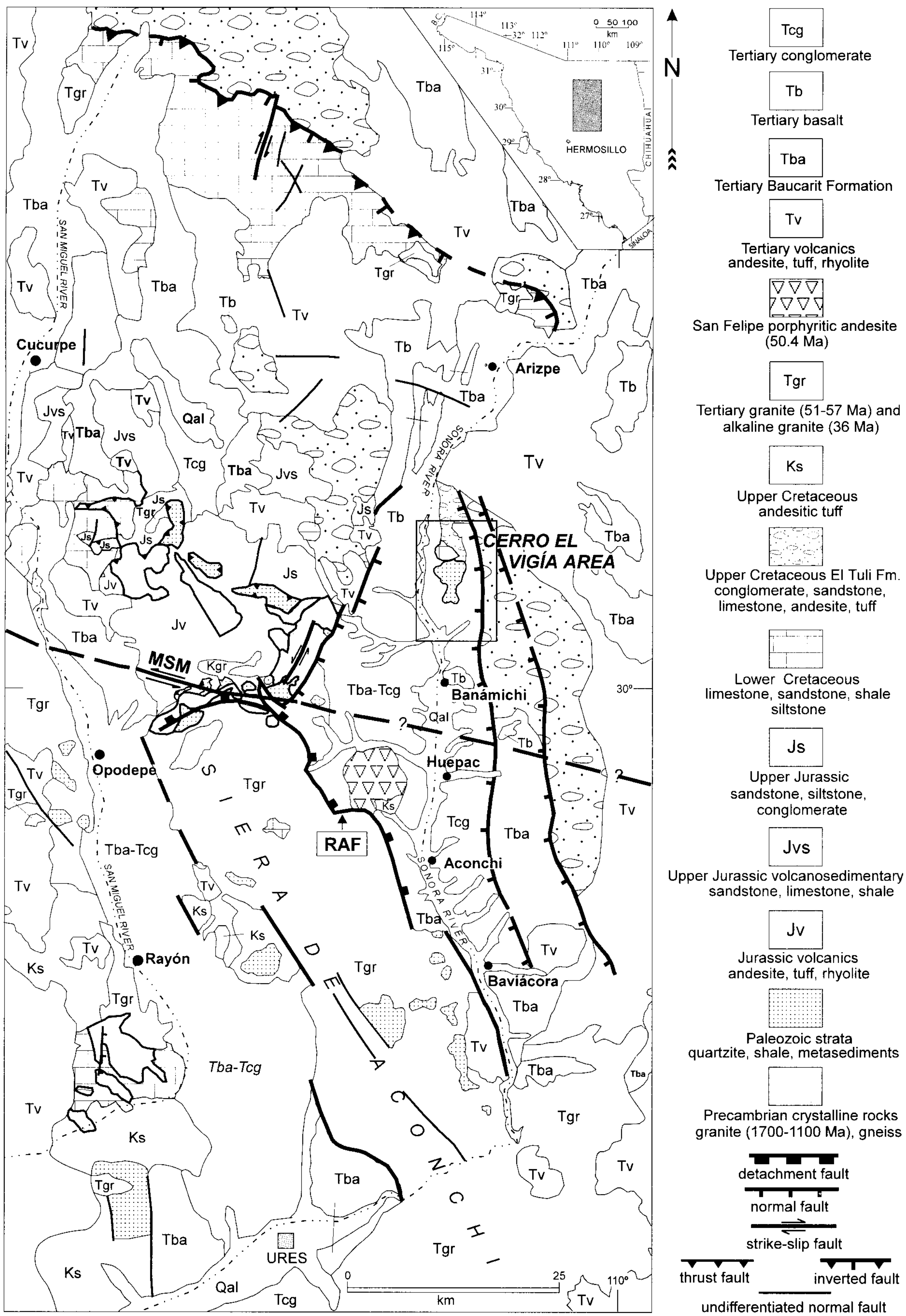

Figure 1. Generalized geologic map of central-east and northeast Sonora (modified from Chávez-Aguirre, 1978; Roldán-Quintana, 1991; Rodríguez-Castañeda, 1984, 1994, 1996, 1997). RAF = La FigurRamada-Agua Caliente detachment fault, MSM = Mojave-Sonora megashear.

Figure 2. Panoramic view of the Cerro El Vigía block and Cerro El Cuervo in central-east Sonora. The large hill to the left is the Cerro El Vigía, that is composed of quartzite (main body of the hill) and quartzite and siltstone to the right. In the right half appears the Mural Limestone. In the background it is possible to see the Aconchi batholith.

sion or tectonic denudation. As erosional debris are not recognized in adjacent areas, east and west of the batholith, tectonic denudation seems to be more likely. In the other hand, rocks that underlie Cerro El Vigía are not found in the eastern margin of the Sonora river. The most likely explanation for this fact is that the original sedimentary section that now is part of the CEVB was tectonically transported farther to the east.

Motion along the eastern flank of the Aconchi batholith is largely extensional, being concentrated on the La Ramada - Agua Caliente detachment fault (RAF) defined by Rodríguez-Castañeda (1996); this fault extends 40 km along the eastern flank of the Aconchi batholith (Figure 1). The La Ramada - Agua Caliente detachment fault was initially described by Chávez-Aguirre (1978) as the Agua Caliente normal fault that separates an Eocene rhyolite from a Jurassic volcano-sedimentary sequence. Roldán-Quintana (1989, 1991) defined the Agua Caliente fault as a normal fault (1989, fig. 6; 1991, fig. 2). Nourse and others (1994) described a northeast-dipping detachment fault that superposed an upper plate composed of Miocene sedimentary and volcanic rocks of the Baucarit Formation on top of a peraluminous granite in the lower plate. The Agua Caliente fault was named as the El Amol detachment fault by Calmus and others (1996) (RAF and the El Amol are the same). The El Amol fault separates porphyritic andesite from the El Jaralito granite.

Nourse and others (1994) interpreted mylonitic foliation with associated northeast lineation in the peraluminous granite (36 Ma) as a northeast transport direction. However, Calmus and others (1996) indicated that foliation and mineral lineation are not present in the Aconchi granite, but they emphasize that rocks in the upper plate were detached a few kilometers from its original position.

It is supposed that northeastward transport of the CEVB occurred on a structurally lower detachment fault that correspond to earlier stages of the La Ramada - Agua Caliente fault or maybe along a system of parallel detachment faults. RAF must extend through out a large part of the Sonora river valley to the east and it has been modified by Basin and Range normal faulting that borders the Aconchi batholith to the east. Structurally, the Aconchi batholith is a horst, while a graben structure controls the trace of the Sonora river. Also, the Sierra El Oso-Sierra El Bellotal, east of Sonora river constitutes a horst.

Paleozoic strata of CEVB belonging to the hanging wall of RAF are displaced by a high-angle fault (Figure 3) that would extend to or cut the RAF detachment zone. At Cerro El Vigía locality, it is not possible to see the detachment zone because of Tertiary sedimentary cover.

Nourse and collaborators (1994), and Calmus and collaborators (1996) recognized that structural features present in the eastern flank of the Aconchi batholith were caused by normal faulting. Tilting of the Baucarit Formation against the fault dip is a consequence of detachment, as well as secondary low-angle normal faulting that displaced andesitic dikes north or northeast (Calmus *et al.*, 1996). Cretaceous andesite and Tertiary San Felipe porphyry (Calmus *et al.*, 1996) rocks that form the upper plate are in fault contact with the Aconchi granite that forms the lower plate. Several blocks of Paleozoic quartzite covered partially by Tertiary sedimentary rocks are found north of the Aconchi batholith. These blocks are interpreted as a result of northeast detachment movement.

Rocks of the CEVB, as envisioned here, were part of the Paleozoic and Early Cretaceous sedimentary strata that rested unconformably over the Aconchi batholith (Chávez-Aguirre, 1978; Peabody, 1979; Roldán-Quintana, 1989). Remnants of Paleozoic quartzite, conglomerate, marble, schist, limestone, and skarn strata, appear as roof pendants at the top of Tertiary batholithic rocks. Peabody (1979) considered a Cambrian-Ordovician and Pennsylvanian-Permian age for these strata. To the north in Sierra el Jucaral, Rodríguez-Castañeda (1994) reported a Cambrian(?) quartzite that structurally overlies Precambrian crystalline and Jurassic volcanic rocks. Early Cretaceous strata crop out around Santa Rosa mine (Chávez-Aguirre, 1978) and Los Locos mine (Calmus *et al.*, 1996).

The mica schist and quartzite described by Peabody (1979) resemble lithology of Paleozoic rocks of CEVB, while the conglomerate (quartzite and limestone clasts, horizon 2 of Peabody, 1979) is similar to the conglomerate (Late Cretaceous) that covers unconformably Paleozoic rocks in the CEVB.

The relationships of CEVB rocks with the Aconchi batholith suggest that movements of the detachment fault along with the CEVB is northeastward, and the RAF may be part of a crustal or intracrustal scale fault, similar to the type described by Wernicke (1985), at least during early stages of extension that cuts northeast and is rooted deep in the crust or in the upper mantle. Magmatic flux from mantle is concentrated beneath extended domain.

Along its trace, the RAF mainly presents cataclastic fabric (Calmus and others, 1996; Rodríguez-Castañeda, 1996); however, most of its features are similar with the evolution of

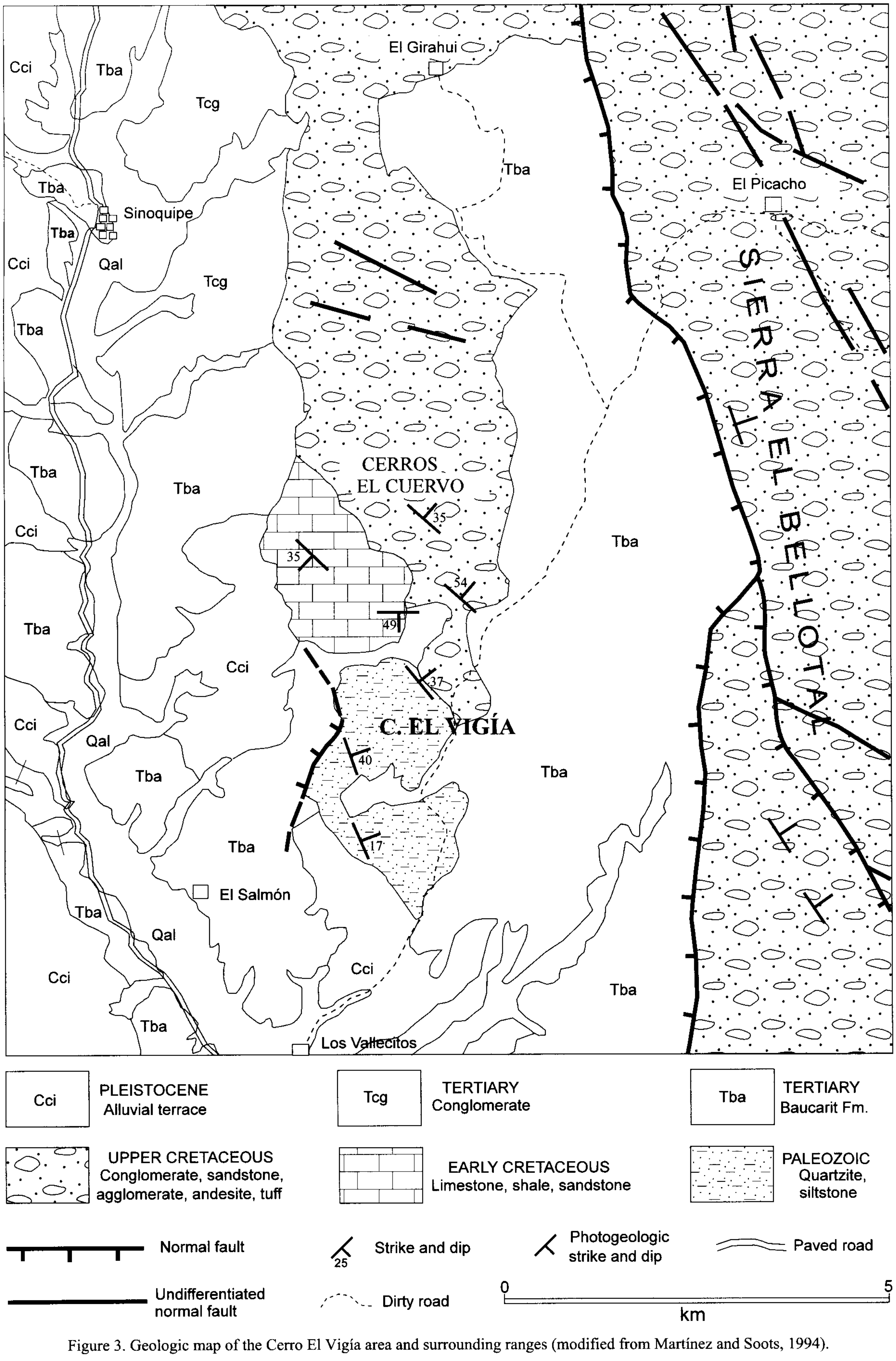

Figure 3. Geologic map of the Cerro El Vigía area and surrounding ranges (modified from Martínez and Soots, 1994).

Figure 4. Siltstone and quartzite of the lower member of the Paleozoic rocks in Arroyo El Salmón.

Figure 5. Thick bedded quartzite of the upper member of the Paleozoic rocks that conforms the main body of Cerro El Vigía. These strata resemble to the Los Changos quartzite that crop out west in Sierra El Jucaral.

the metamorphic core complexes that are common in Sonora (Nourse *et al.*, 1994). Rodríguez-Castañeda (1996) reports Precambrian and Tertiary crystalline rocks east of Opodepe (Cañada Las Jarillas) that record kinematic indicators related to a metamorphic core complex deformation. A major steep normal fault separates ductile hanging-wall rocks (Proterozoic basement) from a ductile deformed foot-wall (36 Ma granite).

TECTONIC HISTORY

Middle Tertiary deformation in Sonora has been related to the Cordilleran metamorphic core complexes. In Sonora, movements on detachment faults has been constrained to either the 36–15 Ma interval (Nourse *et al.*, 1994) or to the interval of 36–21 Ma according to Calmus and others (1996). However, extensional deformation mainly in central and northeastern Sonora is known since Late Jurassic time. Extension in Late Jurassic is recorded by the Glance Conglomerate that was deposited in northwest elongated basins in which fluvial conglomerate accumulated (Bilodeau *et al.*, 1987; Nourse *et al.*, 1994). McKee (1991) postulated the presence of a positive land, the Cananea High, that is structurally associated with northwest normal faulting (Titley, 1976). The normal faulting, basins, and the Cananea High possibly formed during a transtensional regime, perhaps related to the evolution of the Mojave-Sonora megashear (Anderson and others, 1995). In Early Cretaceous time, siliciclastic marine sediments and carbonates (Bisbee Group) were deposited on Jurassic rocks. These Early Cretaceous strata show deformational structures developed due to gravity sliding as result of vertical uplift that have been occurred during Aptian-Albian time (Rodríguez-Castañeda, 1997). Early Cretaceous large carbonate slided masses hundreds of meters in length and tens of meters wide represent this deformation (McKee, 1991; Rodríguez-Castañeda, 1997). During Late Cretaceous, extension has been also documented (Rodríguez-Castañeda and García y Barragán, 1995). The thick volcano-sedimentary sequence overlying unconformably (Figure 6) Paleozoic (CEVB), Jurassic, and Early Cretaceous rocks is indicative of a basin filled by synorogenic deposits. The angular unconformity (of pre-Laramide age) below the Late Cretaceous strata extends northward 100 km away from the Banámichi region. The origin of the basin is related to evolution of strike-slip fault and associated extension (Rodríguez-Castañeda *et al.,* 1997). Olistoliths in the Upper Cretaceous sequence in the San Antonio region, north of area, are interpreted here as a result of vertical uplift and subsequent sliding. The Upper Cretaceous strata was deposited in nonmarine to shallow-water depositional environments that seems to be typical of a foreland basin, although Upper Cretaceous volcano-sedimentary strata record uplift and structural features that are not typical of thrust belts. It is necessary to emphasize the absence of Late Cretaceous and Tertiary folds, thrust faults belt, and undeformed basement in the area that suggest a foreland basin. The present author believes that evidence for dating extensional deformation is

Figure 6. Angular unconformity that separates underlying Paleozoic quartzite from overlying Late Cretaceous conglomerate of the El Tuli formation. The right foot of the man is in the contact.

founded around Sierra Azul (localized to the north in Figure 1) recently mapped by Rodríguez-Castañeda (1997) and studied by McKee (1991).

An important consideration is that detachment faulting and movement of CEVB may be contemporaneous with the evolution of the magmatic bodies. Displacement of CEVB is interpreted in two ways. First, CEVB was controlled tectonically by extension associated initially to a detachment fault (Wernicke, 1985) and later with evolution (inflation) of magmatic chambers (granitic bodies in Sonora have been evolved from 90 to 40 Ma; Damon *et al.,* 1983) or upwelling of the asthenosphere followed by tectonic denudation that occurred during or after deposition of the Late Cretaceous El Tuli formation (Rodríguez-Castañeda, 1997). The El Tuli formation and the underlying units permit the interpretation that most of the Precambrian, Paleozoic, and Mesozoic rocks were largely removed by denudation along near horizontal or low-angle extensional faults (Figure 7). However, a thick sequence of Precambrian, Paleozoic, and Mesozoic rocks are exposed north of the Aconchi batholith (Rodríguez-Castañeda, 1994). Rodríguez-Castañeda (1994) concluded that the Paleozoic Los Changos quartzite was thrusted above Jurassic volcanic rocks in Late Jurassic time. However, the thrusts seem to be low-angle normal faults or at least a reactivated thrust fault, and that the quartzite was transported to the north during extension. Similarly, Early Cretaceous Mural Limestone along the Arroyo La Huerta in the Tuape region shows evidence of sliding to the north. During middle Tertiary probable reactivation of these faults took place contemporaneous with the metamorphic core complex development (Figure 7).

A second interpretation suggests that probably CEVB was detached during middle Tertiary time as indicated by some Los Changos quartzite masses and a detached porphyritic andesite where displacement along RAF has been estimated to be 8 to 10 km or less (Calmus and others, 1996). There is a general agreement that these structures are Tertiary, as they posdate and involve Tertary rocks. In this case sediments of the El Tuli formation need to be assigned to the Tertiary, but stratigraphic relationships indicate an Upper Cretaceous age. In Sonora there was a Tertiary denudation represented by the displacement of the San Felipe porphyritic andesite and Miocene Baucarit Formation. Tertiary sliding is locally important as in the San Felipe porphyritic andesite (Figure 5), where Baucarit Formation is lying on older rocks. The geometry at that place suggests development of extension along high or low-angle normal fault.

In this way it is possible that gravitational sliding and extension could explain denudation and aid to interprete the structure of the Aconchi batholith as a deeply exposed normal imbricate fault denudation structure that evolved since Late Cretaceous to Tertiary. Large scale sliding involves movements of sheets of sedimentary strata that are hundreds meters thick and 5 km long.

Basin and Range normal faulting cut and modified detachment fault(s) and controled modern morphology of the area.

CERRO DE ORO AREA

Another crustal block affected by Late Cretaceous-Tertiary thermal and stress regimes that display contrasting responses occur in the west flank of the Aconchi batholith, the Cerro de Oro area. Precambrian and Mesozoic rocks are similar to roof pendants in the Aconchi batholith. Apparently, no detachment fault is known that might accomodate extension to the northwest, but movements in this flank can be along a zone of steeply-dipping normal faulting (Figure 7). Offset of Precambrian, Paleozoic and Mesozoic rocks is estimated as no more than 10 km. The difference in apparent offset on both sides of the Aconchi batholith seems to depend on how the rocks were affected by the granitic plutons and how the crust was structurally fragmented. The reconstruction proposed here, follows the idea that rocks of the Cerro de Oro area and rocks of CEVB were part of a thick sequence affected by Late Cretaceous and Tertiary extension. These crustal blocks display contrasting responses to regional thermal and tectonic stress regimes.

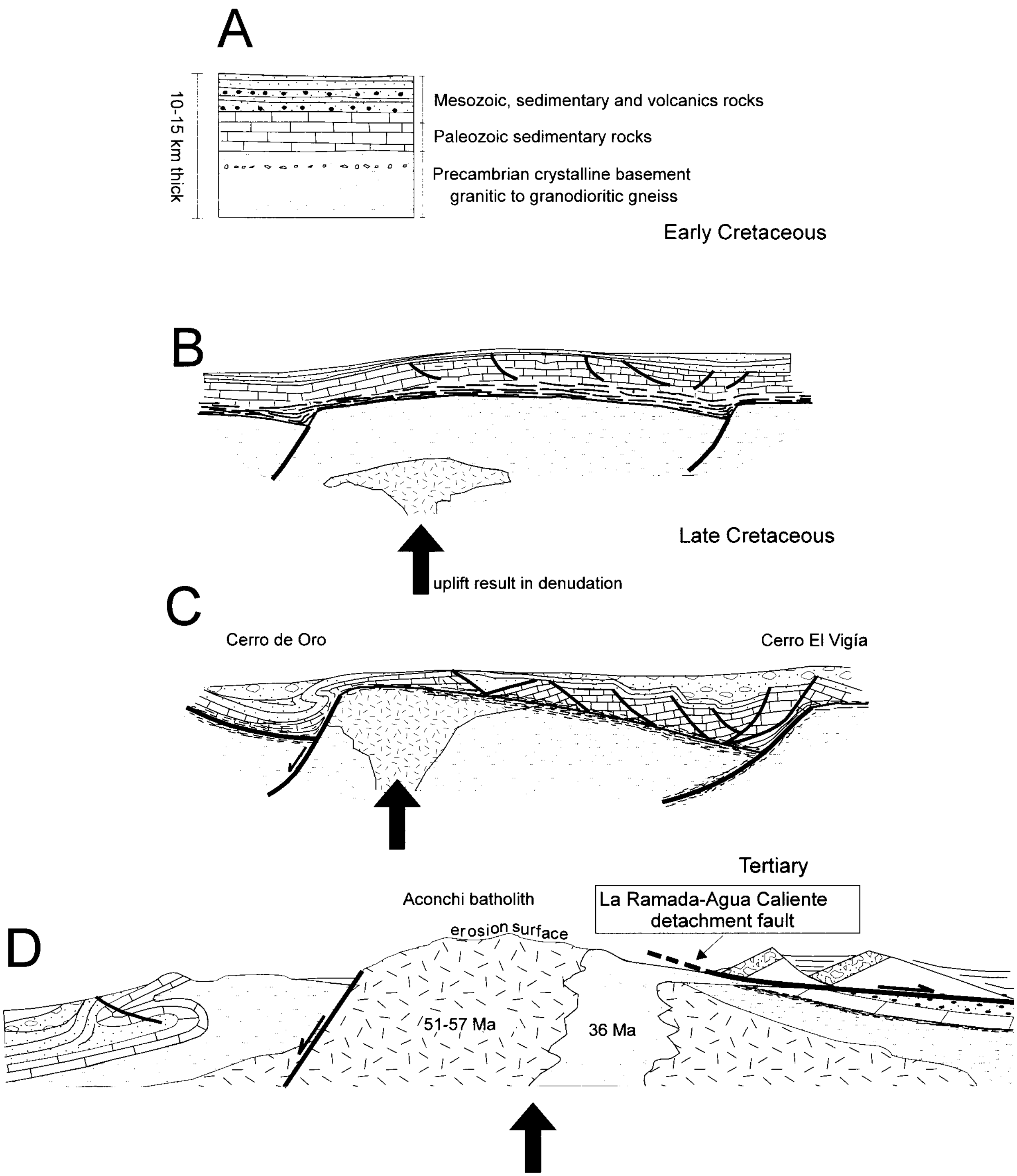

Figure 7. Schematic geologic model of evolution in central-east Sonora. Model shows progressive development of a thick column (A) composed of Precambrian, Paleozoic and mesozoic rocks. (B) The thick column is affected by upwelling of the Late Cretaceous magmatic chambers that produced incipient gravity sliding of overlying rocks. (C, D) Detachment, denudation, and sliding associated with inflation of granitic bodies. A great unconformity appears at this stages. (D) Indicate metamorphic core complex deformation. Modified and adapted from Davis and Coney (1979).

Structural similarities have been recognized in other regions of Sonora: in the Moctezuma region (Sierra de Oposura) and the Sahuaripa-Arivechi region. It is suggested that there is a genetic relationship among thermal uplift, denudation, and sliding of large rock bodies.

CONCLUSIONS

Paleozoic and Early Cretaceous rocks of the CEVB are remnants of an upper plate allochthon on a northeast dipping detachment fault (RAF), active during the Late Cretaceous.

RAF may be rooted deep in the crust or extended through the crust. In addition, detachment faulting is associated with a region where crust was previously warmed and upwelled by Cretaceous and Tertiary granitic plutons (51.8–69.6 Ma, Roldán-Quintana, 1991) and modified by Tertiary peraluminous granite of 36 Ma (Roldán-Quintana, 1991). Rocks, east of the Aconchi batholith, in particular the El Tuli formation, seem to be autochthonous and overlie unconformably the rocks of CEVB.

Geologic relationships of CEVB and Aconchi batholith data (69.6–51.8 Ma) support the concept that denudation and gravity sliding occurred in Late Cretaceous time. Presence of mid-Tertiary plutonic rocks indicate that metamorphism and mylonitization of lower-plate rocks is related to Miocene denudation faulting.

Translation of CEVB seems that took place along a low-angle normal fault. Late Cretaceous El Tuli formation does not show rotation, although in Arroyo El Salmón, hundred of meters east of Cerro El Vigía, an inverse-imbricate structure is observed.

The gravity sliding model is proposed here to explain denudation along a preferred zone of detachment (RAF) that evolved from Late Cretaceous (Albian-Cenomanian) to mid-Tertiary. Gravity sliding is occurring in an area that covers several thousands of square kilometers with a transport direction mainly to the east-northeast and also, although not conclusive, to the southwest (sequences of Cerro de Oro area). Interpretation of movements suggest that sliding zone(s) were sites of considerable movement at one or more times mainly during the Mesozoic. East-northeastward movements of upper-plates were more likely during the Mesozoic, while down-dip movements took place during the Neogene.

Significant differences exist between this model and the crustal shortening as genetic explanation for folds and thrust as proposed by other authors. A plausible genetic connection between extension and thermal uplift structures can be taken seriously when it proves applicable elsewhere along northern Sonora.

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