Structural transect of the southern Chihuahua Fold Belt between Ojinaga and Aldama, Chihuahua, Mexico

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Abstract. A restorable structural transect has been constructed across the southern end of the Chihuahua Fold Belt segment of the Cordilleran foreland fold and thrust belt of northeastern Chihuahua, Mexico, and west Texas. The 160-km transect begins near Ojinaga and ends near Aldama, Chihuahua. It has been found that the Mesozoic Chihuahua Trough was inverted by Laramide tectonism and regionally shortened approximately 20 km (about 9%) along the transect to form the Chihuahua Fold Belt. Along the transect the belt consists of two allochthons of opposing vergence directions. The décollement of the eastern, northeast vergent allochthon shallows from within the Jurassic evaporites, along the center of the belt, and surfaces in Upper Cretaceous clastic rocks at the eastern thrust front south of Ojinaga, Chihuahua. The eastern allochthon was shortened approximately 6 km and may be divided, from west to east, into main ranges and an eastern frontal zone. Structures of the main ranges are detached in Jurassic evaporites and were greatly influenced by syntectonic flowage, resulting in salt-cored anticlines and salt withdrawal synclines. To the east the décollement shallows over the Tascotal basement block which formed a buttress to northeastward transport forming a frontal zone containing ramp-related anticlines and emergent thrusts. The western allochthon is southwest vergent. The décollement cuts up section from the center of the belt, where Precambrian basement is detached in the Plomosas Uplift, to Lower Cretaceous carbonates of the western frontal zone. The western allochthon was shortened approximately 20 km at the Paleozoic level and approximately 11 km at the Mesozoic level. Local basement involvement in the Plomosas Uplift may result from strike-slip deformation along a northwest trending basement fault.

Introduction

The Chihuahua Fold Belt of the Sierra Madre Oriental is the southern continuation of the North American Cordilleran fold and thrust belt into Mexico. It is a NW trending belt that extends throughout most of eastern Chihuahua, Mexico, and adjacent parts of Trans-Pecos Texas (Figures 1 and 2). Until this study, no regional cross sections have been constructed for the Chihuahua segment of the Cordilleran fold and thrust belt. This paper presents a 160-km long cross section (Plate 1) constructed to study the style of deformation of the southern end of the belt and the results are used to propose a tectonic model for Laramide evolution of the region. Traverse mapping was conducted along the transect and integrated with well data, previous geologic maps, space shuttle and Landsat photography, and published geologic data to construct a restorable cross section. This traverse is possible because the Conchos River has removed the closed basin fill that buries Laramide structures to a higher level elsewhere in the fold belt.

It has been found that the sense of vergence of the belt was bidirectional, northeast on the eastern side and southwest on the western side. Therefore the belt can be divided into eastern and western allochthons. Each allochthon may be subdivided into main ranges and frontal zone tectonic domains. NE transport of the eastern allochthon halted as allochthonous Mesozoic rocks were stacked against the Diablo Platform in Texas and eastern Chihuahua, which acted as a buttress that restrained Laramide shortening. The eastern main ranges overlie regions of Jurassic or Early Cretaceous evaporites, which were mobile during thrusting. Folding and flowage of ductile material into upright to asymmetric folds accommodated more horizontal shortening than did thrust faulting. As is typical in fold and thrust belts with a thick evaporite décollement, the sense of vergence of structures of the eastern main ranges is bidirectional in the plane of transport [Davis and Engelder, 1985], however, northeast vergent structures predominate. East of the eastern main ranges, the regional detachment shallows to the level of Lower Cretaceous carbonates and parallels stratigraphy for 30 km, forming the eastern frontal zone. Deformation of the upper plate of the eastern frontal zone is characterized by ramp anticlines with less than 2 km of structural relief. The thrust surfaces on the eastern side of the belt near the Rio Grande, 5 km south of Presidio.

Precambrian and Paleozoic rocks deformed by Laramide tectonism occur at the surface in the Chihuahua Fold Belt only in the Placer de Guadalupe/Carrizalillo structural massif, herein called the Plomosas Uplift (Figures 1 and 2). The Plomosas Uplift is the dominant tectonic element of the western allochthon. It appears to have been high during early Chihuahua Trough time and remained free of evaporites. The Plomosas Uplift is herein proposed to have resulted from a combination of regional horizontal shortening and left-lateral wrench faulting along a NW trending strike-slip fault, herein named the Plomosas basement shear zone. The uplift consists of two thrusts which place Precambrian through Cretaceous rocks over Lower Cretaceous rocks forming the largest struc-
ture in the belt. The regional detachment parallels bedding west of the Plomosas Uplift forming a western frontal zone containing emergent thrusts and ramp anticlines, structures that are similar in geometry to those of the eastern frontal zone.

Phanerozoic Geologic History of the Region

Paleozoic Stratigraphy and Tectonics

A shelf environment existed through southeastern Arizona, southwestern New Mexico, and central Chihuahua during Cambrian to Mississippian time along the Paleozoic passive margin of North America. In eastern central Chihuahua and west Texas the passive margin evolved into the Pedregosa foreland basin, as tectonic activity associated with the Ouachita orogeny increased to the south and east [Greenwood et al., 1977] (see Figure 3). The dominant sediment types during the Pennsylvanian were limestone and shale, with large quantities of coarse terrigenous clastic debris eroded from surrounding uplifts. Armin [1987] conducted a detailed examination of Wolfcampian conglomerates in the Pedregosa Basin and concluded that the southern part of the basin, including the region of the Plomosas Uplift, subsided slowly during most of Paleozoic time but rapidly evolved into a deep foreland basin during early or middle Wolfcampian as a result of Ouachita tectonics. The lack of any deformation in the Plomosas Uplift which can be directly attributed to Ouachita tectonics implies that the Pedregosa Basin resided in the foreland northwest of the Ouachita orogenic front [Bridges, 1964; Flawn et al., 1961].

Mesozoic and Cenozoic Stratigraphy and Tectonics

Developing Mesozoic basins in northern Mexico formed a more or less continuous feature from the Gulf of Mexico. Basin development was probably linked intimately with the opening of the Gulf of Mexico in the Jurassic [Salvador and Green, 1980; Salvador, 1987] and probably reflects extensional or transtensional processes associated with the movement of South America away from North America during the early Mesozoic [Dickinson, 1981; Anderson and Schmidt, 1983].

A late Jurassic through middle Cretaceous marine transgression resulted in the deposition of 3650-6400 m of sedimentary rocks in the Chihuahua Trough which rest unconformably on rocks of the Pedregosa Basin [Gries and Haenggi, 1970]. Late Jurassic deposition of evaporites marks the beginning of marine deposition in the Chihuahua Trough [DeFord and Haenggi, 1970; Cordoba, 1970] (Figure 3). One of the Petroleos Mexicanos (PEMEX) Cuchillo Parado wells (Plate 1, well 5), located on the crest of an evaporite-cored anticline, drilled 2,300 m of rock consisting of 80% halite and 20% clastic material [Ramirez and Acevedo, 1957] which has been palynologically dated as Kimmeridgian [Salvador, 1987]. Hennings [1991] estimates that the evaporites had a depositional thickness of approximately 1000 m. In the Chihuahua Trough the Cretaceous sequence begins with a basal conglomerate, followed by interbedded quartzose sandstone and shale of Neocomian age [DeFord and Haenggi, 1970] (Figure 3). The clastic-dominated section grades upward into interbedded shale and limestone with minor amounts of evaporite in Aptian time. Platformal carbonate formations dominate the
Albian through early Cenomanian section and constitute the rigid structural member in the deformed Mesozoic sequence. Most anticlinal structures in the fold belt are eroded to the level of the Albian carbonates (Figure 4).

The structurally high Diablo Platform formed a steep-sided eastern basin margin for the Chihuahua Trough. The dramatic westward thickening of the Las Vegas Formation and to a lesser extent, the Cuchillo Formation and Aurora Group, are interpreted to be the result of extensional growth faulting along the western margin of the Diablo Plateau [Lehman, 1986; Hennings, 1991] (Figure 3). The pattern of stratigraphic thickening of the Lower Cretaceous section across the trough suggests that only the northeast side of the basin is fault bounded. The southwestern boundary of the basin is the
Aldama Platform which remained stable during Chihuahua Trough subsidence [Handschy and Dyer, 1987]. Subsidence confined to the Chihuahua Trough ceased in Cenomanian time prior to the deposition of Upper Cretaceous clastic rocks. The transition from marine to continental facies occurred in Santonian time [Lehman, 1986, 1991]. These Upper Cretaceous sediments, which are well-preserved in the Ojinaga Basin west of Ojinaga (Plate 1), are tectonostratigraphically correlative with the prepectonic to syntectonic Cretaceous clastic wedges found in other foreland areas of the North American Cordillera. By analogy this implies that the Chihuahua Fold Belt was distal to the interior of the
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Andres Mountains of southern New Mexico [Drewes, 1988]; undeformed volcanic rocks (47 Ma) in Sierra Samalayuca in northern Chihuahua [Drewes, 1991]; and undeformed ignimbrites (44 Ma) resting over thrust faulted ignimbrites (53 Ma) [Goodell et al., 1988; P. C. Goodell, oral communication, 1990]. On the basis of these dates and stratigraphic relationships, Cordilleran deformation in eastern Chihuahua ranged between 74 and 44 Ma.

Widespread rhyolitic volcanism blanketed the region in mid-Tertiary time. Along the transect between Cuchillo Parado and Aldama are remnants of thin but formerly extensive rhyolite lava flows, which unconformably overlie Cretaceous rocks and generally dip at lower angles [King and Adkins, 1946].

Late Cenozoic normal faulting, possibly associated with the southern continuation of the Rio Grande Rift, has overprinted many of the preexisting Mesozoic structures in the Chihuahua Fold Belt [Gries, 1979]. The general trend of Late Cenozoic faulting is parallel to the Laramide structural grain and has accentuated the elongate range/intermontane basin physiography which is characteristic of the region.

Intermontane basins (bolsons) in the southern segment Chihuahua Fold Belt generally contain up to 100 m of Quaternary age coarse gravel interbedded with clay named the Conchos gravels [Burrows, 1910].

Cordilleran orogeny during Late Cretaceous time, but the ensuing deposition of coarser clastics during Santonian time implies that the deformation front was progressing eastward.

Laramide tectonism produced a north-northwest trending fold and thrust belt with an arcuate eastern front that roughly parallels the Texas-Chihuahua border between El Paso and Presidio (Figure 1). The exposed portion of the Chihuahua Fold Belt, east of the Tertiary ignimbrite cover of the Sierra Madre Occidental, is approximately 200 km wide and extends 400 km south from northwest of El Paso to an abrupt southern termination south of Presidio. The structure and evolution of the southern segment of the Chihuahua Fold Belt is the subject of this paper.

Precise dating of Cordilleran deformation in the Chihuahua Fold Belt is difficult because there are few preserved syntectonic deposits. However, timing brackets may be placed on the deformation by combining the following data: dikes (65 Ma) with preferred orientation in the Sierra Del Cuervo area; deformed Cenomanian rocks (97-91.5 Ma) cut by an undeformed andesite dike (47 Ma) in the Jijayez Mountains of northern Chihuahua [Handschy and Dyer, 1987]; syntectonic debris (74-58 Ma) of Chihuahua Trough provenance in the Tornillo Basin of west Texas [Lehman, 1986, 1991]; transition from syntectonic to post-tectonic deposition of the Paleocene to Eocene Love Ranch Formation (57-44 Ma) in the San

Figure 4. View east of the Rio Conchos canyon through Sierra Grande showing exposures of the Cretaceous Aurora Group (see Plate 1 for location). Canyon is approximately 300 m deep. Abbreviations are L, Loma Plata Formation; B, Benevides Formation; and F, top of Finlay Formation.

Structural Transect of the Southern Chihuahua Fold Belt

The formation of the southern Chihuahua Fold Belt will be summarized by describing a transect between Ojinaga and Aldama, Chihuahua (Plate 1). The location of the transect has been chosen so as to cross all significant structures of the southern Chihuahua Fold Belt and depict the overall structural geometry of the region. The eastern half of the transect is constructed from new field mapping at 1:25,000 scale augmented by data from five PEMEX wells. The western half was traverse-mapped at 1:50,000 scale and augmented by previous studies in the region of the Plomosas Uplift. The cross section is shown in deformed and restored states. Where possible, the methods of Suppe [1983], Jamison [1987], and Mitra [1990, 1992] were used to aid in projecting surface geometry to depth.

Eastern Frontal Zone

Structures of the eastern frontal zone of the Chihuahua Fold Belt are exposed throughout the Ojinaga Basin (Plate 1). These fault-related folds are detached within the Lower Cretaceous carbonate section. The thrust front is exposed on the Mexican side of the Rio Grande in segments between 12 km south and 37 km northwest of Presidio. Along the transect the frontal structure is called Sierra La Santa Cruz which is an east vergent, fault-cored anticline exposed at the level of the Loma Plata Formation (Figure 5 and Plate 1). Its structural relief is approximately 1.6 km and topographic relief is 300 m. The controlling thrust is west dipping and places Loma Plata Formation over Upper Cretaceous clastic rocks. Modeling Sierra La Santa Cruz as a fault propagation fold predicts that the controlling thrust ramps up section from the Benevides Formation. Detachment at this level along the eastern side of
Figure 5. West view across the Rio Grande (RG) of Sierra la Santa Cruz (see Plate I for location). The range is a fault propagation fold in the hanging wall of the eastern thrust front of the Chihuahua Fold Belt. The fold plunges into the subsurface at either side of the view. The exposure is at the level of the Loma Plata Formation (L); the vergence direction is toward viewer. Topographic relief is approximately 250 m.

The eastern frontal zone is corroborated by data from the PEMEX Ojinaga I (Plate 1, well 1), located 18 km to the southwest of Sierra La Santa Cruz, where the Benevides and Loma Plata Formations are repeated by a thrust fault. The western normal fault of the Presidio Bolson (graben) cuts the eastern limb of Sierra La Santa Cruz. The Bolson contains at least 800 m of late Cenozoic fill [Groat, 1970].

The level of regional décollement deepens to the west under a fault-bend fold named Sierrita. The PEMEX Chapo 2 (Plate 1, well 3), along strike of Sierrita, drilled a thrust fault that places Benigno over Del Rio Formation. The southwest limb of Sierrita dips more steeply than the northeast limb because there is a west vergent back thrust in the core of the structure.

The eastern frontal zone contains the largest area of preserved Upper Cretaceous rocks in the region, herein called the Ojinaga Basin. This present-day structural and topographic low coincides with a Bouguer gravity high called the Tascotal Uplift [Handschy et al., 1987], which was topographically high during sedimentation in the Chihuahua Trough. A relatively thin Las Vegas and lower Aurora section is present on the Tascotal Uplift (block), and there are no Jurassic evaporites [Cantu et al., 1985]. In addition, the PEMEX Ojinaga 1 well encountered no Paleozoic units younger than Devonian and drilled into basement consisting of quartz-monzonite, yielding a Rb/Sr age of $977\pm78$ Ma [López, 1988]. These data, in addition to the observations of Handschy et al. [1987], strengthen the postulate that the Tascotal block was uplifted and eroded as an "ancestral Rocky Mountains" block [Kluth and Coney, 1981] in the foreland of the Ouachita orogenic front. Although covered by all formations of the Lower Cretaceous system, the Tascotal block remained relatively high until Albian deposition of the Finlay Formation which is the oldest stratigraphic interval to be deposited across the Chihuahua Trough and Tascotal block with relatively constant thickness. Therefore the Tascotal block can be considered to be a southern continuation of the Diablo Platform into Chihuahua during Mesozoic time.

**Eastern Main Ranges**

Sierra Grande is the easternmost structure of the main ranges tectonic domain. In the region of the transect map it is a broad anticline with a slightly steeper eastern limb (Figure 6). As a topographic feature, it extends 250 km to the north into the Eagle Mountains of west Texas. In the map area, Sierra Grande has 1 km of topographic relief and 2 km of structural relief. At depth the structure is interpreted as an east directed step-up in the level of décollement from Jurassic evaporites to the Aurora Group carbonates, over an older normal fault that was inverted during Laramide thrusting. Gries and Haenggi [1970] and Gries [1980] believe Sierra Grande marks the eastern depositional limit of Kimmeridgian evaporites. I agree and believe this is a normal fault boundary that forms the western edge of the Diablo Platform. Presumed down-to-the-west motion on the normal fault(s) formed the margin of the Jurassic evaporite basin (early Chihuahua Trough) and provided a mechanism for westward thickening of the Las Vegas through Aurora section (Figure 3) [Lehman, 1986; Hennings, 1991]. Similar tectonostratigraphic relationships are proposed for the Diablo Plateau/Chihuahua Trough boundary as far north as the Eagle and Quitman Mountains segment of the Chihuahua Fold Belt [Hennings, 1991]. Reversal of motion along the normal fault during Laramide time is herein invoked to explain the structural elevation of the region between Sierra Grande and the
Cuchillo Parado anticline compared with that of the Ojinaga Basin.

Structures west of and including Sierra Grande are detached at the level of Jurassic evaporites. The anticlines are broad, and many have been breached to the level of the evaporites, leaving distinct hogbacks of Las Vigas and younger rocks. Outcrops of evaporites are scarce because they are typically covered with a thin veneer of alluvium. The Cuchillo Parado anticline, with 3.5 km of structural relief, is cored by evaporites and is the largest structure in the eastern main ranges (Figure 7). Palinspastic reconstructions [Hennings, 1991] indicate that the source of the salt was the Sobaco syncline to the west where complete salt withdrawal results in a presumed disconformable "salt weld" between the Las Vigas Formation and Paleozoic rocks.

Characteristically associated with breached anticlines in the eastern main ranges of the Chihuahua Fold Belt, including the Cuchillo Parado anticline, are overturned panels...
Figure 8. Aerial view south of a "pop-up" anticline (P) located 5 to 10 km north of the Rio Conchos (RC) and Chihuahua Highway 16. It is adjacent to an overturned panel of Loma Plata Formation (O) on the eastern flank of Sierra Grande. Pop-up is approximately 500 m wide. See text for explanation.

of upper Aurora Group limestone which form recumbent folds after delaminating along shale sequences in the Cox or Benevides Formations (Figure 8). Adjacent to the overturned panels, it is typical to find a narrow symmetric anticline (Plate 1, "pop-up") with length equal to that of the overturned panels. The wavelength of these folds and the dip of their limbs indicate detachment is at the base of the Loma Plata Formation implying considerable flowage in the underlying Benevides shale section. The pop-ups form as accommodation structures for material that moved out of the

Figure 9. Kink folds in Cox Formation on eastern limb of Cuchillo Parado anticline (see Plate 1 for location). The outcrop is approximately 50 m high.
Figure 12 -- Plate I. Structural transect of the southern Chihuahua Fold Belt between Ojinaga and Aldama, Chihuahua. -- (top) Strip geologic map of the transect. (bottom) Present day structural geometry, transect restored to pre-Laramide configuration. Pz is Paleozoic section, Mz is Mesozoic section.
adjacent recumbent folds. The limbs of the evaporite-cored folds are typically cut by numerous tear faults, which separate overturned panels from those which remained upright.

Three scales of folds are associated with the Cuchillo Parado anticline. The upright to overturned limb of Cuchillo Parado anticline, the first-order fold, has been greatly thickened by second-order kink folds (Figure 9). Third-order folds are found in outcrops of highly contorted Navarette Formation on the east side of the core of the anticline (Figure 10). These third-order folds are interpreted to directly overly evaporites and therefore provide a hint to their structural complexity. The three orders of folds have a parallel trend, suggesting contemporaneous formation.

The southwest limb of Sobaco syncline is truncated by a down-to-the-west normal fault, forming the northeastern boundary of the Llano de Chilicote, which is, in turn, truncated on its southwestern side by another down-to-the-west normal fault. The Llano de Chilicote is mainly flat lying along the transect, but to the south it is folded into broad northwest trending anticlines and synclines, forming the westernmost exposure of the eastern allochthon. Southwest of the Llano de Chilicote, the effects of syntectonic evaporite flowage are absent.

**Figure 10.** Highly contorted Navarrete Formation at the southern end of Cuchillo Parado anticline (see Plate 1 for location). These beds overlie evaporites and attest to their complex deformation. Outcrop is 3 m high.
Figure 11. Southwest view of Plomosas uplift from Chihuahua Highway 16 (see Plate 1 for location). P is Permian conglomerates in hanging wall of the Monillas thrust (see text); W is west dipping panels of west side of Plomosas uplift.

gypsum beds do occur in both the La Casita and Cuchillo Formations. Thus the western limit of Jurassic evaporites that form the regional detachment for the eastern allochthon must lie between the Llano de Chilicote and the eastern limb of the Plomosas Uplift. The transition from an evaporite to clastic-dominated Jurassic section is schematically shown in Plate 1.

Western Frontal Zone

Structures to the southwest of the Plomosas Uplift lie in the western frontal zone of the western allochthon. These structures result from detachment, back thrusting, and folding above the Solis thrust which I interpret to be continuous from the Plomosas Uplift to the western edge of the Chihuahua Fold Belt. Sierra Morrion is a northeast vergent, emergent back thrust off the Solis thrust. The back thrust is on the northeast side of the range and places carbonates of the Aurora Group against Upper Cretaceous clastics. The hanging wall of the back thrust dips to the southwest in the northern parts of the range but is folded into an anticline to the south.

The westernmost structures along the transect at the southern end of Sierra de Gomez are interpreted to be a pair of west vergent, fault propagation folds, each with approximately 1.6 km of structural relief. These folds coalesce to the north into a single anticlinal structure, forming the main body of Sierra de Gomez. There are numerous west vergent contractional structures along Highway 16 road cuts through Sierra de Gomez (Figure 12). These, along with the asymmetric geometry of the first-order Sierra de Gomez folds, attest to the overall west vergence of the structure.

Sierra del Cuervo (see Figure 14) lies 23 km west of Sierra de Gomez at the transition between the Chihuahua Fold Belt and the Tertiary volcanic cover of the Sierra Madre Occidental. West of Sierra del Cuervo, the cover of Tertiary volcanic rocks prevents observation of underlying structures. Precambrian through Cretaceous rocks crop out in Sierra del Cuervo, but Laramide deformation was minor [Handschy and Dyer, 1987]. Therefore I believe that Sierra de Gomez forms the western boundary of the Chihuahua Fold Belt.

Discussion

A restoration of the transect has been performed to check the viability of the structural interpretation and to determine the magnitude of shortening across the fold belt (Plate 1). Because of the opposing vergence directions of the eastern and western allochthons, the pin lines for the restoration are the east and west ends of the transect. The loose line for both sides of the transect has been placed near the center of the belt on the east side of the Plomosas Uplift. Tertiary age normal faults were removed first by elevating the downthrown side to the level of the upthrown block. Contractional folding and faulting were then removed by layer-parallel shear. The salt was restored by area balance. Gaps and overlaps along the loose lines for the two allochthons were minimized. The entire belt was shortened approximately 20 km or 9%.

The Mesozoic section of the eastern allochthon was shortened approximately 6 km. The detached mass is a northeast-erly tapering wedge which varies in thickness from 5 km on the southwest side to 2 km at the eastern thrust front. The autochthonous block of Paleozoic and older strata was not shortened other than minor inversion along the preexisting normal fault under Sierra Grande.

The Paleozoic section of the western allochthon was shortened approximately 20 km by displacement and folding along the Solis and Monillas thrust faults that form the Plomosas Uplift. However, the Mesozoic section was shortened only 11
requires the existence of a detachment at the base of the
This has not been observed in the field, although Paleozoic-
Jurassic section along the eastern flank of the Plomosas Uplift.
allochthon relative to its Mesozoic section. During shortening
excess length of the Paleozoic section of the western
Cuchillo Formations [King and Adkins, 1946]. Several minor
Formation, are in thrust contact with underlying Las Vigas and
and Deford, 1961], probably belonging to the Benigno
Jurassic contacts along the eastern flank of the Plomosas Uplift are
isolated, small, and poorly exposed. The isolated domal
outcrops of Albian carbonates at Estacion Picachos [Bridges
and Deford, 1961], probably belonging to the Benigno
Formation, are in thrust contact with underlying Las Vigas and
Cuchillo Formations [King and Adkins, 1946]. Several minor
thrust splays at the base of the Picachos suggest they traveled
northeast relative to their footwall. King and Adkins [1946]
believed these blocks to be klippe representing the farthest
outlier of a major thrust, which guided their interpretation that
the Plomosas Uplift is a northeast vergent structural massif.
Alternatively, I suggest that they result from a splay off the
upper detachment of the Monillas thrust wedge.

The isolated involvement of the entire Phanerozoic section
and the deep level of detachment in the Plomosas Uplift sug-
gest that the mechanism of origin is different than that of the
rest of the fold belt. There is evidence in the central part of
the transect suggesting that left-lateral wrench faulting
occurred in conjunction with horizontal shortening to form the
Plomosas Uplift. A prominent ESE trending discontinuity,
evident on Landsat images (Figure 14), extends east from the
Sierra Madre Occidental across the southern Chihuahua Fold
Belt. It crosses the transect between Estacion Picachos and
the Plomosas Uplift. I suggest that the syncline NW of
Estacion Picachos and the folds in the Llano de Chilicote owe
their anomalous NW trends, compared the typical NNW
trends of the southern Chihuahua Fold Belt, to left-lateral
shear displacement along a deep-seated strike-slip fault zone.
In addition, I suggest that the isolated involvement of the
total Phanerozoic section in the Plomosas Uplift was the
result of contractional deformation at a right step along the
strike-slip zone. The strongest evidence in support of this is
the limited lateral extent of the structures within the uplift,
compared to its deep detachment level. This implies that the
driving mechanism that incited deep detachment was also of
limited lateral extent. Several NW trending shear zones have
been postulated to exist in northern Mexico and west Texas,
including the Mojave-Sonora Megashear [Anderson and
Schmidt, 1983], the San Marcos Fault [see McKee et al.,
1990], the La Babia Fault [Charleston, 1981], and the Texas
Lineament [Muehlberger, 1980]. The most significant of
these is the Mojave-Sonora Megashear which is thought to
have accommodated 800 km of left-lateral offset during the
Late Jurassic. The Texas Lineament is thought to have
accommodated left-lateral strike-slip displacement during
Laramide deformation.

Figure 12. South view of one of numerous, minor, west directed contractional structures in Loma Plata Formation along Highway 16 road cuts through Sierra de Gomez (person is 1.6 m high, see Plate 1 for location). These contractional features provide additional evidence indicating west vergence of the parent structure.
Summary

The main goal of this work has been to characterize the general morphology of the southern Chihuahua Fold Belt so that a first tectonic model could be devised. It has been shown here that a model invoking Laramide basin inversion, horizontal shortening, and minor basement wrenching can fully account for the observed surface structures in the southern end of the fold belt. The most critical issue remaining in unraveling the tectonic history of the region is a more thorough understanding of the structure and kinematics of the Plomosas Uplift and how it interacted with the rest of the fold belt.

Eastern Allochthon

The eastern allochthon extends the entire length of the Chihuahua Fold Belt and may be divided into two tectonic domains. The eastern frontal zone is characterized by a relatively thin Mesozoic section, no Jurassic evaporites, an emergent thrust front, and fault-related folds which are detached within the Aurora Group. The eastern main ranges are characterized by a relatively thick Mesozoic section which is folded into asymmetric evaporite-cored anticlines and salt withdrawal synclines which are detached in Jurassic evaporites. The regional décollement for the eastern allochthon shallows from Jurassic evaporites under the main ranges to Upper Cretaceous clastic rocks at the thrust front of the eastern frontal zone. The allochthon was shortened 6 km. The eastern frontal zone rests on the Tascotal Uplift which was high during Late Paleozoic and pre-Albian Mesozoic time. The western margin of the Tascotal Uplift is modeled as a normal fault which formed the eastern facies limit of Jurassic evaporites, controlled the thickness of the Las Vigas and Aurora section, and formed a buttress that restricted northeastward motion of the eastern allochthon, resulting in the formation of Sierra Grande and structures to the west.

Western Allochthon

The Plomosas Uplift, a fault bend fold with several hanging wall thrust splays, forms the central structure of the western allochthon. Its deeply rooted detachment level is the result of left-lateral wrenching along a NW trending strike-slip fault zone in basement. The regional décollement shallows from Precambrian rocks under the Plomosas Uplift to within the Cuchillo Formation, forming the fold and thrust structures of the western frontal zone. The western allochthon was shortened 20 km at the Paleozoic level and 11 km at the Mesozoic level.

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Figure 14. Landsat image of central Chihuahua, Mexico, showing the proposed location of the shear zone associated with the Plomosas Uplift. The location of the image and other known northwest trending strike-slip faults are shown in the inset map [after Anderson and Schmidt, 1983; Charleston, 1981; McKee et al., 1990, Muehlberger, 1980].
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