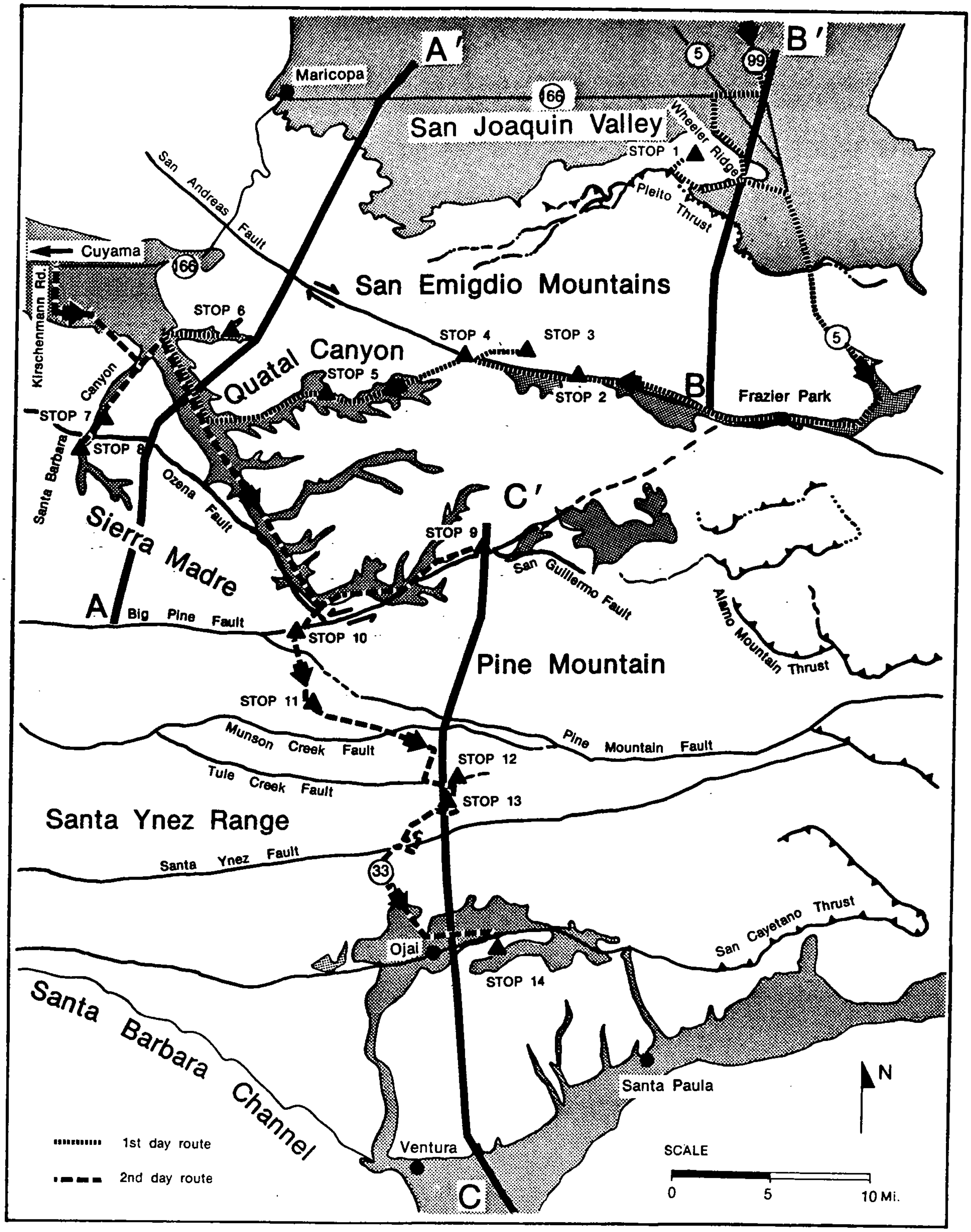
DAVID BLOOM Ingersoll

GEOLOGIC TRANSECT ACROSS THE WESTERN TRANSVERSE RANGES



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GEOLOGIC TRANSECT ACROSS THE WESTERN TRANSVERSE RANGES

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A STRUCTURAL OUTLINE OF THE SAN EMIGDIO MOUNTAINS

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ABSTRACT

Between the southern end of the San Joaquin basin and the crest of the adjacent San Emigdio Mountains is about 37,500' (11.4 km) of south-side-up structural relief on top of the Mesozoic-age crystalline basement. Integration of subsurface and surface data into regional, restorable cross sections strongly suggest the structural relief is partly the result of Oligocene (≈ 30 Ma) and late Cenozoic (≤3Ma) phases of fold and thrust belt development. Together the two thrust events have resulted in about 20,500' (6.25 km) of south-side-up structural relief on the top of the basement. A series of down-to-the-north normal fault movements on the White Wolf fault produced an additional 17,000 (5.2 km) of structural relief during latest Oligocene to latest Pliocene time.

INTRODUCTION

The San Emigdio Mountains are an east-west trending range at the juncture between the San Joaquin Valley and the Transverse Ranges of southern California (Figure 1). The range is bounded on the southwest and south by the San Andreas fault. The range consists of complexly folded and thrusted Mesozoic-age crystalline basement and Tertiary-through Quaternary-age sedimentary rocks. The general stratigraphy and structure of the range are described by Dibblee (this volume) and details of the Paleogene stratigraphy are described by Lagoe (this volume).

An understanding of the structural development of the San Emigdio Mountains during the Cenozoic requires addressing two main problems. First, there is about 37,500' (11.4 km) of structural relief developed on the Mesozoic-age crystalline basement between the San Emigdio Mountains and southern end of the San Joaquin basin. Any structural interpretation must show the structures responsible for this relief and timing. Secondly, these structures and other important features of the range such as folds and angular unconformities need to be understood in terms of structural style. The most frequently cited structural style to explain the origin of most of the Cenozoic deformation in the western Transverse Ranges and Coast Ranges is wrench faulting (Wilcox, et al., 1973; Harding, 1976; and Page 1981). A clear distinction must be made here between strike-slip faulting and the wrench fault structural style. Large-magnitude lateral-offsets of rock units are extremely well documented along the San Andreas fault (Hill and Dibblee, 1953; Crowell, 1962; 1975, 1979). On the other hand, the wrench fault structural style is a characteristic assemblage of structures such as "flower" structures, en echelon folds, and pull-apart basins (Sylvester, 1984).

Wrench Fault and Fold and Thrust Belt Structural Styles in the San Emigdio Mountains

A number of studies in both the laboratory and field have shown that progressive simple shear will produce a sequence of structural features with a given pattern and orientation along the shear or fault (Tchalenko, 1970; Wilcox, et al., 1973; Groshong and Rodgers, 1978). This structural style has geometric and kinematic requirements such as oblique-slip faults that steepen with depth (Lowell, 1972). In addition, the wrench fault model also requires a specific sequence of structural development. During the inital stages of shearing, a broad region is deformed by en echelon folding and short, discontinous en echelon faults. With continued shearing a main through-going fault begins to take up of the shear strain and the region of deformation narrows until it is confined to a zone immediately adjacent to the main fault (Wilcox, et al., 1973).

Construction of regional cross sections across the San Emigdio Mountains suggest the structural style and origin of the structural relief is much different than that expected by wrench tectonics. These cross sections integrate surface mapping by Hoots (1930) and Dibblee (1972, 1974a, b) with subsurface well control. The sections show a number of important structural relationships that suggest the structural style is in part due to development of fold and thrust belts during Oligocene and late Cenozoic times. These structural relationships include thrust faults that flatten with depth, decreasing deformation with depth, and fault-bend and fault-propagation folding. It will be demonstrated that north of the San Andreas fault the two major structures of the range (Caballo Canyon and Pleito faults) have had little or no strike-slip displacement. This absence of lateral-displacement allows for the construction of restorable (balanced) cross sections and constrains the possible structural solutions of the range.

The timing of deformation of the range is not compatible with wrench tectonics and the displacement history of the nearby San Andreas fault. As previously mentioned most of the deformation of the range took place during the Oligocene and the late Pliocene to present. It is well documented that the modern San Andreas fault began at about 10-12 Ma and according to wrench fault principles (Wilcox, et al., 1973) the maximum deformation should have soon followed.

The nature of the seismicity of the San Emigdio mountains also supports the idea of a late Cenozoic fold and thrust belt. Figure 2 is a map of focal plane mechanisms for the San Emigdio Mountains. North of the trace of the Pleito fault are several events that result either from a south or north dipping thrust fault(s). Structurally the south dipping fault plane solution is compatible with the known geometry and movement on the Pleito fault (Hoots, 1930; Davis, 1983). Although these seismic events are north of the trace of the Pleito fault they can be related to deeper thrusts such as the Wheeler Ridge thrust that belong to the Pleito

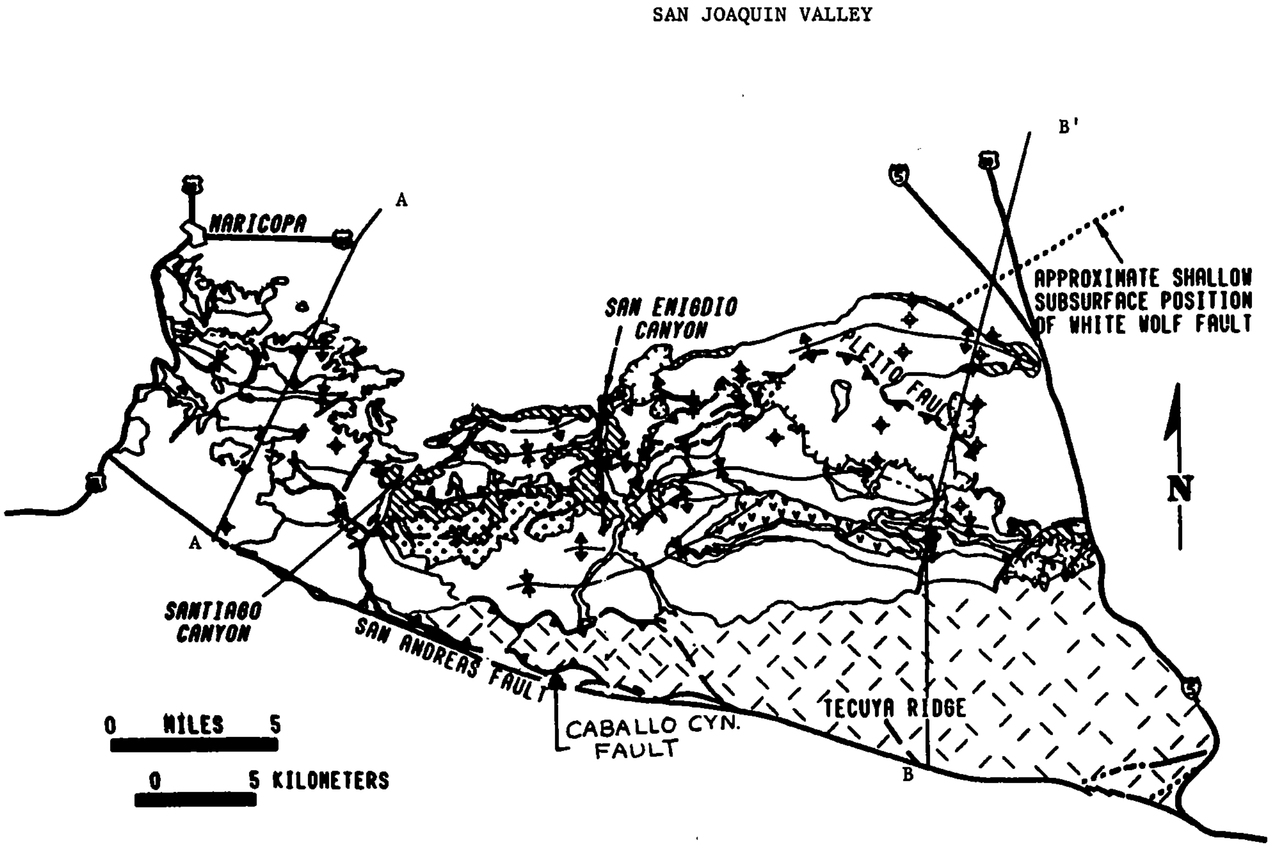

FIGURE 1. Generalized geologic map of the San Emigdio Mtns. (Modified from Dibblee 1972, 1974a,b)

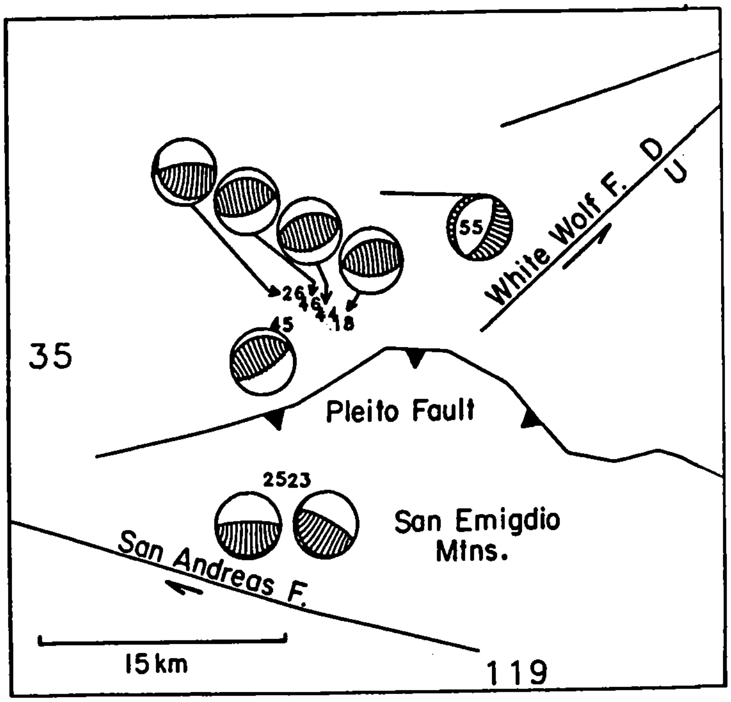

FIGURE 2. Map of focal mechanisms obtained for the San Emigdio Mountains. All are equal area projections of the lower focal hemisphere with compressional quadrants shaded (from Webb and Kanamori, in press).

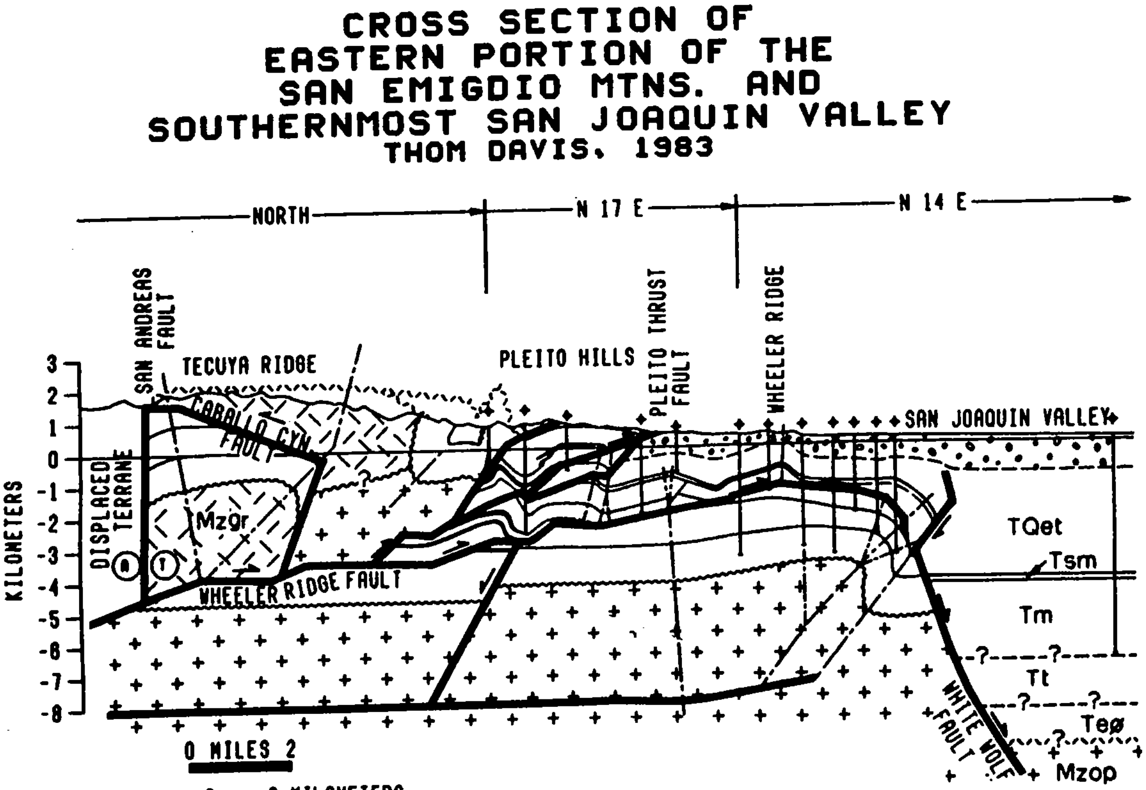

FIGURE 3. 0 2 KILOMETERS

fault system (Figure 3). These deeper thrusts are blind (do not reach the surface) and could pose a seismic risk if they are capable of generating larger earthquakes. For instance Namson, et al. (1983; in press) have postulated that the Coalinga earthquake of May 2, 1983 (M=6.7) was the result of movement on a blind thrust under the Coalinga anticline.

The subsequent parts of this paper present in chronological order the important geologic relationships, structures, and assumptions used to make the cross sections. This section is followed by an interpretation of the tectonic history of the San Emigdio Mountains based on the cross sections.

IMPORTANT STRUCTURAL FEATURES

Caballo Canyon Fault and Oligocene Uplift of the San Emigdio Mountains

The Caballo Canyon fault is an east-west striking, north-dipping, dip-slip fault that is discontinuously exposed for about 16 km along the north side of the San Andrea fault (Figure 1). The hanging wall of the fault consists of crystalline rocks and the footwall consists of Temblor and/or Monterey Formations (Davis, 1983). Pack (1920) first recognized the western part of the fault and considered it to be part of the San Andreas fault zone. Although the Caballo Canyon fault is close to and parallels the San Andreas fault, it will be shown that both its timing and sense of displacement are incompatible with the San Andreas fault. Van Amringe (1957) mapped a portion of the fault and named it the Caballo Canyon fault.

Dibblee (1972, 1974a) mapped much of the contact between basement and sedimentary rocks as an unconformity. However, this author has observed a wide zone of multicolored, fractured, sheared, and slickensided rock and gouge along much of the contact (Davis, 1983). In addition, extensive exposures of the contact show hundreds of meters of truncated strata against the basement. The best exposure is at the head of the east fork of Santiago Canyon and can be observed at STOP 4 on the field trip. In general the Caballo Canyon fault dips to the north about 30° to 60°.

Evidence show the Caballo Canyon fault was active during latest Oligocene to early Miocene time. Probably the strongest case for the timing of movement can be made from the overlap of its western end by uppermost Temblor or lower most Monterey Formations (Davis, 1983). Along the south side of the fault trace is a sedimentary breccia that grades into finer-grained strata of the Temblor(?) Formation away from the fault. The breccia facies is stratigraphically thick but in map area very narrow. The facies character, stratigraphic distribution and structural setting of the breccia is quite similar to the Violin Breccia along the San Gabriel fault (Crowell, 1982). The Violin Breccia and by analogy this breccia are the result of deposition along a fault scarp during a prolonged period of fault activity. The close spatial correspondence between high concentrations of distinctive clast types in the breccia and similar _in situ_ basement rocks directly across the Caballo Canyon fault suggest that lateral displacement was probably insignificant.

really?

Activity on the Caballon Canyon fault is coeval with other evidence that defines a period of mid-Tertiary tectonism in the San Emigdio Mountains. The earliest indicators of this activity are present along the north flank of the San Emigdio Mountains and are within the uppermost Eocene strata of the San Emigdio Formation (Hoots, 1930; Nilsen, et al., 1973). Within this unit are several large lens-shaped masses of crystalline rock debris that are lithologically similar to the basement rocks of Blue and Tecuya Ridges. In the western part of the San Emigdio Mountains the Eocene age Tejon and San Emigdio Formations and the late Eocene to early Oligocene age Pleito Formation are truncated along an angular discordance of up to 40° by the Oligocene to early Miocene age Temblor Formation. At the west end of Blue Ridge the Temblor Formation onlaps directly onto the crystalline basement.

Late Oligocene

Early Miocene Normal(?) Faulting

Throughout the San Emigdio Mountains are a series of steep faults that cut across the basement and Eocene through Oligocene age strata. These faults are generally overlapped by the middle Miocene beds of the Monterey Formation. On the surface these faults are generally north-south trending; however, well data indicates that similar age faults have nearly east-west trends (cross section A-A', Plate I). Rapid thickness changes in the Oligocene - early Miocene age Tecuya and Temblor Formations may be the result of growth faulting across these structures. The age of this faulting is coeval with a phase of calc-alkaline volcanism that occurred throughout the San Emigdio Mountains (Nilsen, et al., 1973).

White Wolf Fault

The White Wolf fault has a northeast strike across the southeastern San Joaquin Valley (Figure 1) and is obvious on the surface only along its northeast portion (Hoots, 1930; Buwalda and St. Amand, 1955). The fault is known largely from oil well data and seismicity associated with the 1952 Kern County earthquakes. The fault is believed to have been responsible for the main shock (M_L=7.2, Stein and Thatcher, 1981) and many of the numerous aftershocks. Oil well data indicate the fault is a high-angle structure with at least 15,000' (4.6 km) of down-to-the-north vertical separation on the top of the Mesozoic-age crystalline basement (Callaway, et al., 1969; cross section B-B', Plate I). About 3,000' (.9 km) of down-to-the-north vertical separation is speculated to have occurred on the White Wolf fault during late Oligocene to early Miocene time. This estimate is speculative and based on regional thickness considerations of the Temblor Formation. However, growth faulting on the White Wolf fault at this time would coincide with the previously discussed growth faulting in the San Emigdio Mountains. Strike-slip offset on the White Wolf fault is poorly constrained. Hill (1955) suggests the eastern limit of a lower Miocene marine sand is offset left-laterally about 5-6 mi. (8.0-9.6 km); however, Dibblee (1955) states that the lateral offset of the easterly pinchout of the Santa Margarita sand (late Miocene) by the White

Wolf fault is not appreciable and probably less than 2,000' (.6 km).

Much of the Neogene displacement history of the White Wolf fault can be deciphered from the large thickness changes in similar age units across the fault. No attempt was made to correct for compaction and thickness must be considered a minimum. Relating these thickness changes to strike-slip juxtaposition of units of varying thickness along the length of the fault can be dismissed on several grounds. Callaway, et al. (1969) and Davis (1983) show similar stratigraphic intervals of thickening along the north side of the fault and a unique set of circumstances would be required to produce these relationships from lateral offset. As previously mentioned, post-late Miocene lateral offset is rather small (less than 2,000') yet the base of the uppermost Miocene strata (undivided Chanac and Etchegoin Formations) are vertically separated 7,700' (2.3 km). Furthermore, even if the total left-lateral displacement since the early Miocene is 5-6 mi (8.0-9.6 km) the units do not vary enough in thickness along the strike of the fault to explain the observed thickness changes by strike-slip juxtaposition.

Cross section B-B' shows the growth fault relationships across the White Wolf fault just north of Wheeler Ridge. From these relationships the following displacement history on the fault can be constructed for the Neogene. The base of the Monterey Formation (Saucesian/Relizian contact) is offset vertically about 12,000' (3.7 km). However, this is a minimum amount because the Tenneco Sandhill 64x well never reached the Temblor Formation (Saucesian). On the down thrown side of the White Wolf fault middle to upper Miocene strata are about 3,700' (1.1 km) thicker than on the up thrown side of the fault. This indicates about 3,700' of vertical separation (down-to-the-north) during middle and late Miocene time. The base of the undivided uppermost Miocene to Pliocene section (Chanac, Etchegoin and San Joaquin Formations) is vertically offset about 7,700' (2.3 km) and there are an additional 6,800' (2.1 km) of these strata on the down thrown side of the fault. This indicates 6,800' of vertical separation during latest Miocene to Pliocene time. The base of the mostly Pleistocene Tulare Formation is vertically offset about 1,500' (.5 km) and strata on the down thrown side are about 1,500' thicker than strata on the up thrown side of the fault documenting about 1,500' of latest Pliocene to middle Pleistocene vertical separation.

Vertical separation on the White Wolf fault since middle Pleistocene has been insignificant. Croft (1972) mapped the E Clay of the Tulare Formation across the San Joaquin basin and up to the White Wolf fault. There the clay is no deeper than 174m (570') and is in the footwall block of the fault. The E Clay is about 0.7 Ma and is present in the upper part of the Tulare Formation. The base of the E Clay is probably equivalent to the Bishop Ash (Davis, et al., 1977) and the Bishop Ash is about 0.7 Ma on the basis of K-Ar (Dalrymple, 1980) and fission-track ages (Izett and Naeser, 1976), and paleomagnetic stratigraphy (Dalrymple, et al., 1965; Davis, et al., 1977).

This displacement history is contrary to the work of Stein and Thatcher (1981). These workers believe that the White Wolf fault has had about 10,000' (3 km) of vertical separation since 0.6-1.2 Ma. This interpretation is based on their correlation of the youngest ash recorded by oil and gas exploration wells in the footwall block of the fault to the Friant Pumice, Bishop Ash, or Bailey Ash. These units range from 0.6 to 1.2 Ma and Stein and Thatcher's interpretive correlation indicates a slip rate of 3 to 9 mm/yr for the White Wolf fault during much of the Quaternary. For several reasons the ash correlation of Stein and Thatcher are probably invalid and the White Wolf fault has not had significant vertical separation since at least 0.7 Ma. First, the work of Croft (1972) indicating the shallow depth of the E Clay on the down thrown side of the fault was not given consideration.

Second, Stein and Thatcher's sampling was too abbreviated and their ash correlations were not based on chemical or geochronological data. Most exploration wells in this portion of the San Joaquin Valley do not take sidewall cores or conventional cores from above 6,000' (2 km), because the section is unproductive. Although many operators examine drill cuttings and record these on the mud log for the entire well, these samples are almost never taken continuously and usually sample intervals no smaller than 30' (9.2m). It is possible that thin ash deposits were drilled without benefit of sampling or observation.

Stein and Thatcher believe that the ash encountered in the wells they reviewed cannot be as old as the Nomlaki Tuff Member of the Tehama Formation which is 3.3 Ma. They base this on the association of their ash with nonmarine deposits and the fact that much further north the Nomlaki Tuff pre-dates the last marine regression in the San Joaquin Valley. However, this reasoning is not applicable to the southernmost San Joaquin Valley where the marine regression is at the Etchegoin/San Joaquin contact which is about 6.5-7.0 Ma (COSUNA, 1984). Finally E-log correlations at the base of the Tulare Formation, which is about 2.5 to 3.0 Ma (Davis, 1983) is only offset about 1,500' (.5 km) vertically (cross section B-B').

Pleito Fault System

Surface mapping by Hoots (1930), Dibblee (1972, 1974 a, b), and Davis (1983), and data from oil and gas exploration wells (Davis, 1983) show that the Pleito fault system is a set of south-dipping, generally east-striking thrust faults with tectonic transport (overthrusting) to the north (Plate 1, cross sections A-A' and B-B'). The system is late Cenozoic in age and probably seismically active (Figure 2; T. Hall, 1983, personal communication). The system is known to consist of at least several faults strands (Figure 3): 1) the principal surface trace commonly called the Pleito fault, 2) in the eastern part of the area the Wheeler Ridge thrust, 3) in the western part of the area the Pioneer thrust (cross section A-A', Plate I), 4) an unnamed thrust encountered in the ARCO C-1 well near Salt Creek (cross section B-B'), and 6) a highly speculative thrust deep below the Wheeler Ridge thrust. The Wheeler Ridge, Pioneer faults and the specified deep thrust are blind thrusts.

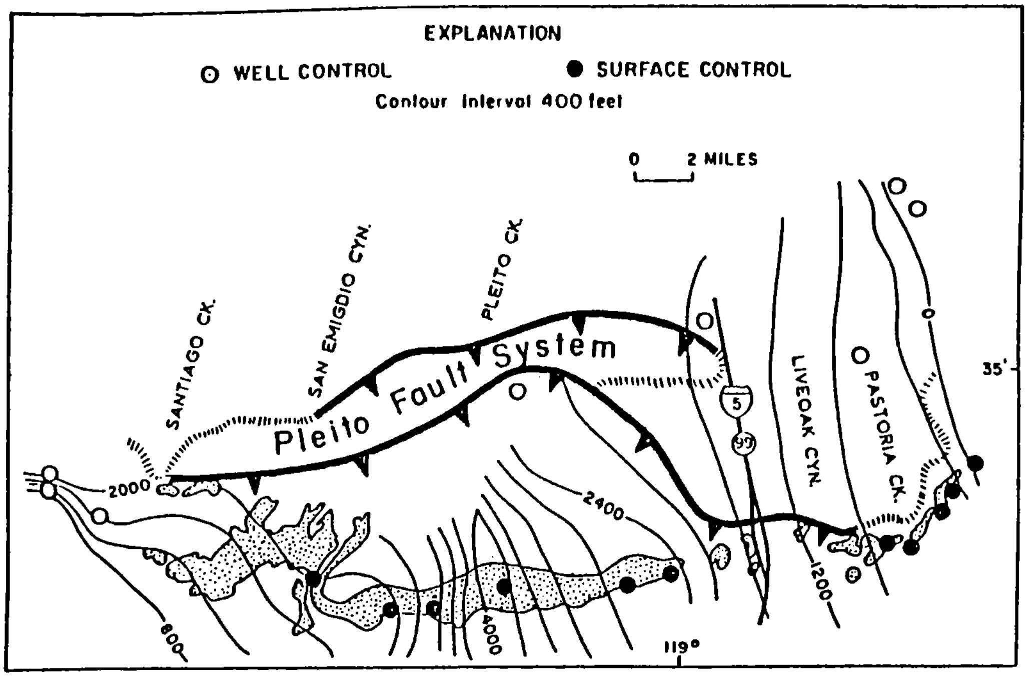

FIGURE 4. Isopach map of the Tejon Formation. Well control from A.H. Warne, Tenneco Oil Co. Modified from Nilsen, 1973

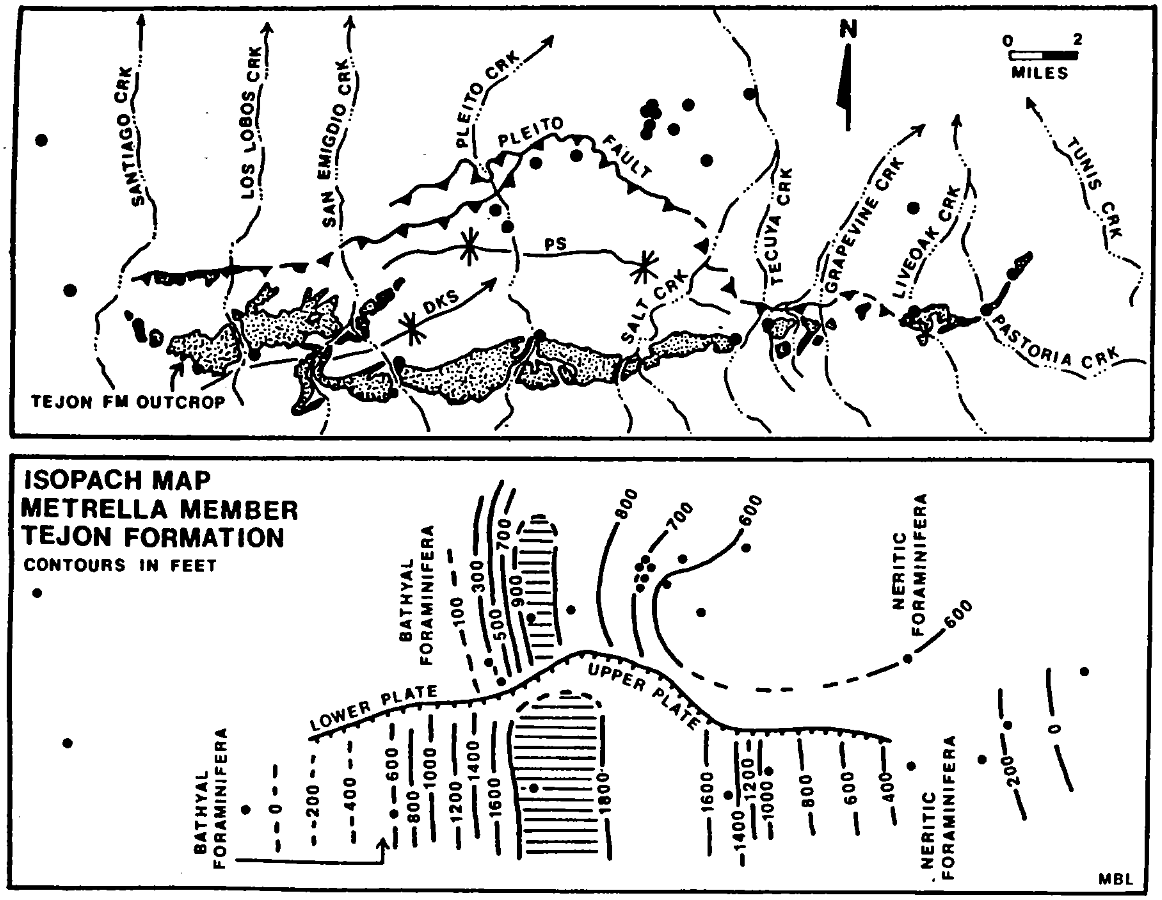

FIGURE 5. Top diagram shows distribution of Tejon Formation (Eocene) outcrops and well control used to make lower diagram. Lower diagram shows the thickest portion of the Metrella Member (line pattern) is not laterally offset by the Pleito fault (Davis and Lagoe, 1984).

Of the various members of the Pleito fault system only the Pleito fault is relatively well mapped in the surface and subsurface. The fault extends from at least several kilometers east of Grapevine Canyon westward, in an arc convex to the north, to several kilometers west of Santiago Canyon (Figure 1). Due to intense landsliding the actual zone of shearing associated with the Pleito fault zone is only well exposed at a few locations; however, its surface trace can be generally traced on the basis of geomorphic expression and juxtaposed rock types. At the east end of the Pleito fault zone there is a three meter high fault scarp at the mouth of Grapevine Canyon. This scarp is visible between the north and south bound lanes of Interstate 5, and just to the west of the freeway. West of Wheeler Ridge the surface trace of the Pleito fault zone consists of several strands which form a band about one kilometer wide. These strands splay and merge in a complicated manner and successively place Temblor Formation over Monterey Formation, and Monterey Formation over San Joaquin Formation. The fault zone is reasonably well exposed on the canyon walls of Pleito Creek (Davis, 1983). The fault zone continues westward to San Emigdio and Santiago Canyons where it is overlapped by upper Pleistocene Riverbank(?) gravel. Only along San Emigdio Canyon is there a suggestion the zone is present under the gravel cover. Here minor late Quarternary displacement on the northernmost branch of the zone has slightly folded the gravel into an anticline with flanks that dip less than 15°. Between San Emigdio and Santiago Canyons the southernmost splay of the Pleito fault zone coincides with the base of a steep slope that separates the principal uplift of the San Emigdio Mountains from the broad Riverbank(?) terrace along the base of the range. This splay thrusts gabbro and amphibolite over Tejon Formation (Davis, 1983).

The shallow level geometry and displacement of the Pleito fault is known from integrating well data with surface mapping. In cross section B-B' these data show the Pleito fault to be two splays with a dip range of 20°-30° to the south and total dip separation across the two splays of about 19,000' (5.8 km). These values are consistent with cross sections drawn to the west of cross section B-B' (Davis, 1983).

The Pleito fault has little or no component of strike-slip offset. Figure 4 is an isopach map of the Tejon Formation (Eocene) by Archer Warne (unpublished). This map integrates outcrop thickness (stippled pattern) with subsurface thicknesses from wells. Isopach contours intersecting the eastern portion of fault are not offset laterally. Additional documentation of this is provided in the isopach map of the Metralla Member of the Tejon Formation (Figure 5) which shows the thickest portions of the unit to be aligned across the Pleito fault. Furthermore, a distinctive neritic foraminiferal facies is aligned at the eastern end of the fault. The fact that the Pleito fault has little or no lateral component of offset is one of the strongest arguments for the validity of restorable cross sections in the direction of tectonic transport.

The Wheeler Ridge thrust has been known from oil exploration and development wells for 30 to 40 years (Figure 6, in roadlog; cross section B-B', Plate I; and Carls, 1955) despite the fact that it does not break through to the surface (Hoots, 1930; Dibblee and Nilsen, 1973; Davis, 1983). The steeply-dipping, small displacement faults exposed in the gravel pits of Wheeler Ridge (Davis, 1983) are almost certainly the result of flexural slip processes that occurred during folding of the steep north flank of Wheeler Ridge anticline.

Abundant deep wells at Wheeler Ridge anticline show this fold to terminate downward by the Wheeler Ridge thrust (Figure 6, guidebook; cross section B-B'). The thrust is south-dipping and cuts at a low angle across Miocene strata in the footwall block (Davis, 1983; Medwedeff, 1984). This thrust is probably a complex set of thrust slices with a total offset dip separation of about 5,000' to 6,000' (1.5 km to 1.8 km).

Wheeler Ridge is a good place to demonstrate the application of the fault-bend fold model (Figure 3 in road log) to a surface/subsurface problem. Surface mapping by Hoots (1930) and Dibblee and Nilsen (1973) show the anticline has a steep north flank (up to 60°) and a gentler back flank (about 20°). Along cross section B-B' the Wheeler Ridge thrust repeats the "Valv" Sand (Luisian) section in the KCL "L" 35-35 well and repeats the reserve sand (lower Mohnian) in the ARCO KCL "L" 51-35 well. In this area the thrust surface is bedding plane with respect to the overlying strata in the south flank of the Wheeler Ridge anticline. Wells to the north of Wheeler Ridge show the thrust does not cut above the Monterey Formation and must go bedding plane out into the southern San Joaquin Valley. Deep wells south of Wheeler Ridge show the thrust to be bedding plane along the base of the Monterey Formation. This flat-ramp-flat geometry of the thrust surface causes the upper plate to deform into the Wheeler Ridge anticline (see discussion in Introductory Comments, this volume).

Below the Wheeler Ridge thrust is a broad anticline with steep dips along its northern flank. This structure is the trap for deep Eocene oil production at Wheeler Ridge (Figure 6 in roadlog). On the basis of fold geometry this anticline is interpreted (Figure 3 and cross section B-B') as a fault-propagation fold. This interpretation requires a deep-level, south-dipping thrust fault of Quaternary age.

INTERPRETATION OF THE STRUCTURAL DEVELOPMENT OF THE SAN EMIGDIO MOUNTAINS

The interpretation of the structural development of the San Emigdio Mountains is shown on Figure 6. This model is primarly based on cross section B-B' (Plate I). It should be noted that although these cross sections integrate surface mapping and subsurface well data they are only well constrained at shallow depths along the front of the range. The deep structure on these cross sections and the structure of the core of the range are not well constrained and are largely determined by the cross section construction techniques. (Suppe, 1985; Woodward, et al., 1985).

During the Eocene (Figure 6A) the Tejon Formation was deposited directly on the Mesozoic-age crystalline basement along a west-facing paleoslope (Nilsen, 1973; Lagoe, this guidebook). This depositional setting was interrupted during Oligocene

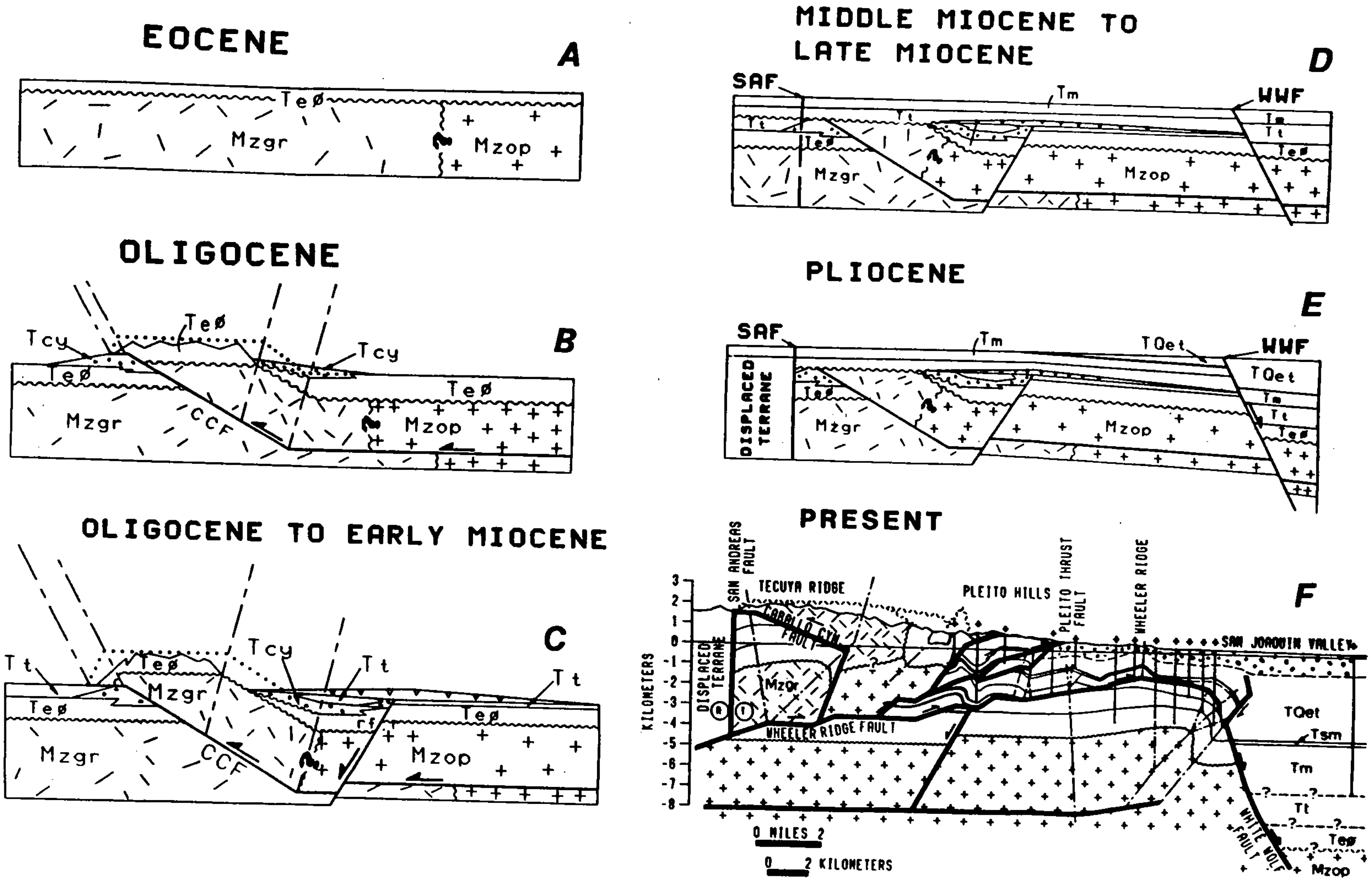

FIGURE 6. Sequential development of the San Emigdio Mountains from Eocene to present (Davis and Lagoe, 1984). View is west. See text for details.

time by the uplift of the ancestral San Emigdio Mountains. In Figure 6B the range is shown to be uplifted by the north-dipping Caballo Canyon fault (CCF).

In this interpretation the thrust steps-up from within the crystalline basement and cuts up section across Eocene and Oligocene age strata. The thrust becomes bedding plane in the Temblor Formation and the bend in the thrust surface produces a large hanging wall anticline or fault-bend fold. This antiform was the core of the ancestral San Emigdio Mountains (Nilsen, 1973; Davis, 1983). During late Oligocene to early Miocene time the ancestral San Emigdio Mountains were eroded down to about sea level (Figures 6C and 6D) and the shallow-marine sands of the Temblor Formation transgressed across the upturned strata along the flanks of the uplift and onto the crystalline basement (Figure 6D). This produced the large angular discordance in the western San Emigdio Mountains. Calc-alkaline volcanism and possible extensional faulting occurred during this period (Figure 6C). About 3,000' (.9 km) of down-to-the-north growth faulting is interpreted to have taken place on the White Wolf fault at this time (not shown on Figure 6C).

During Middle Miocene to mid-Pleistocene time about 12,000' (3.7 km) of vertical separation occurred on the White Wolf fault (Figure 6D and 6E). About 3,700' (1.1 km) of this separation occurred during Middle to Late Miocene time (Figure 6D), about 6,800' (2.1 km) during latest Miocene to Pliocene (Figure 6E) time, and about 1,500' (.5 km) during latest Pliocene to mid-Pleistocene time. Comparison of cross section B-B' with the regional section of Callaway et al. (1969) shows the White Wolf fault to form a half-graben basin at the southern end of the San Joaquin basin. On the basis of this structural setting and very rapid subsidence on the downthrown block, the White Wolf fault is interpreted to be a large normal fault throughout much of the Neogene.

The steep dips encountered by deep wells along the White Wolf fault (Callaway, et al., 1969; cross section B-B') and the compressive mode of the main shock of the 1952 Kern County earthquakes (Gutenberg, 1955) show the fault is presently behaving differently than the interpreted extension above. It is believed that this change to compression took place during the Pleistocene and an explanation of this change is shown in cross section B-B'. The upper portion of the White Wolf fault is shown to be rotated into a reverse fault by growth of a deep, but very young, fault-propagation fold. This young phase of thrust faulting is the result of the northward growth of the Transverse Ranges and perhaps the seismicity generally attributed to the White Wolf fault is a reflection of growth of these new deep structures.

From late Pliocene to present the San Emigdio Mountains were intensely folded, faulted and uplifted (Figures 6E to 6F). In the western part of the range crustal shortening began in late Miocene time (cross section A-A', Plate I). Well and surface data along the range front show that the Pleito thrust, flattens with depth and the thrust has little or no component of strike-slip (Figures 4 and 5). In addition, such data show that the Wheeler Ridge anticline and other anticlines within the San Emigdio Mountains lie within the hanging wall portions of thrusts and are probably fault-bend or fault-propagation folds. Many of these thrusts do not break through to the surface. This shallow level structural data and the focal mechanisms of local earthquakes (Figure 2) strongly suggest the Pleito fault system and related folds are deforming in a style similar to fold and thrust belts and not wrench tectonics.

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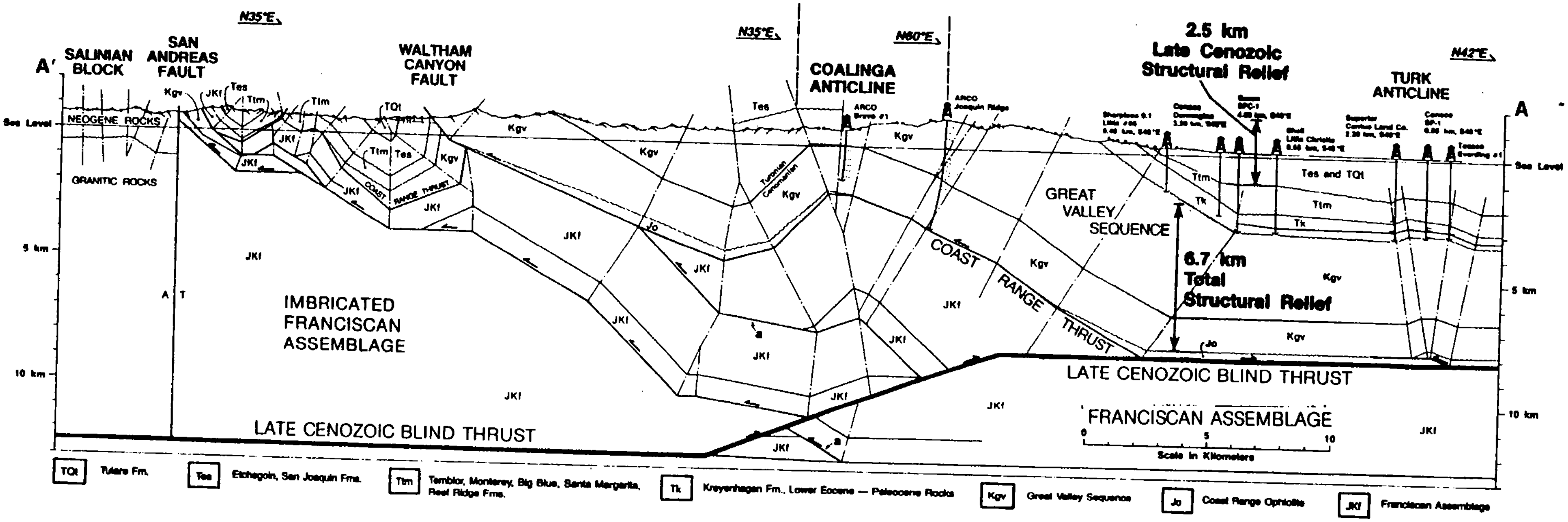

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SALINIAN BLOCK
SAN ANDREAS FAULT
WALTHAM CANYON FAULT
COALINGA ANTICLINE
TURK ANTICLINE
N35°E
N35°E
N60°E
N42°E
2.5 km Late Cenozoic Structural Relief
6.7 km Total Structural Relief
Sea Level
5 km
10 km
NEOGENE ROCKS
GRANITIC ROCKS
IMBRICATED FRANCISCAN ASSEMBLAGE
GREAT VALLEY SEQUENCE
COAST RANGE THRUST
LATE CENOZOIC BLIND THRUST
FRANCISCAN ASSEMBLAGE
Turonian Cenomanian
ARCO Bravo #1
ARCO Joaquin Ridge
Tes and TQt
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JKf
Ttm
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Scale in Kilometers
TQt Tulare Fm.
Tes Etchegoin, San Joaquin Fms.
Ttm Temblor, Monterey, Big Blue, Santa Margarita, Reef Ridge Fms.
Tk Kreyenhagen Fm., Lower Eocene — Paleocene Rocks
Kgv Great Valley Sequence
Jo Coast Range Ophiolite
JKf Franciscan Assemblage