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Plio-Quaternary tectonics of the central Mexican Volcanic Belt and some constraints on its rifting mode.

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RESUMEN
La estratigrafía y la estructura del sector central del Cinturón Volcánico Mexicano (CVM) fueron investigadas para reconstruir su evolución tectónica, la dirección de los esfuerzos y sus valores relativos. Fueron reconocidos tres periodos principales caracterizados por diferentes mecanismos de deformación que están limitados al CVM y pueden ser agrupados en un ciclo de deformación único. El periodo de deformación del Plioceno Tardío se caracteriza por el desarrollo de fallas de rumbo inducidas por un esfuerzo principal máximo (r1) horizontal y de dirección ENE-OSO y un esfuerzo principal mínimo (r3) de NNO-SSE. Desde el Pleistoceno Temprano hasta el Pleistoceno Medio se ha desarrollado un fallamiento normal izquierdo de acuerdo con el mismo r3 y con un esfuerzo principal máximo horizontal (rhmax) de dirección ENE-OSO correspondiente al esfuerzo principal intermedio (r2), que en este caso se aproxima al valor de r1. En el Pleistoceno Tardío-Holoceno ocurrió un fallamiento normal producido por un r3 con una pequeña rotación en sentido izquierdo. Las estructuras desarrolladas durante estos periodos representan la expresión superficial de un cizallamiento izquierdo profundo de dirección Este-Oeste inicialmente paralelo y posteriormente divergente. Esta situación cinemática y la uniformidad de las trayectorias de esfuerzo durante el Plio-Cuaternario sugieren la intervención de las fuerzas producidas por movimientos debidos a la tectónica de placas y un modelo de "rifting" pasivo. En este sentido se considera que la gran cantidad de magma extruído está relacionada con una anomalía térmica producida por el proceso de "rifting" y que afecta también a la placa subducida.

PALABRAS CLAVE: Eje Volcánico Mexicano; Michoacán; Querétaro; ciclos tectónicos; extensión pasiva; subducción.

ABSTRACT
Stratigraphy and structure of the central sector of the Mexican Volcanic Belt and adjoining areas were investigated in order to evaluate its Plio-Quaternary tectonic evolution, the stress directions, and their relative values. Three main periods, characterized by different mechanisms of deformation limited to the MVB area, may be grouped in a single deformation cycle. The Late Pliocene period was characterized by strike-slip faulting induced by a horizontal ENE-WSW maximum principal stress (r1) and NNW-SSE least principal stress (r3). In Early-Middle Pleistocene left-lateral normal faulting occurred with the same r3 and a ENE-WSW intermediate principal stress (r2). During Late Pleistocene-Holocene, normal faulting with a slight clockwise rotation of r3 developed. These structures correspond to the surface expression of E-W left-lateral wrenching which was initially parallel and later divergent. The kinematics and the uniformity of the stress trajectories during Plio-Quaternary times suggest plate tectonic control and a passive mode of rifting. In this framework the large amount of magma extruded is believed to be produced by a thermal anomaly induced by the rifting and affecting also the subducted slab.

KEY WORDS: Mexican Volcanic Belt; Michoacán; Querétaro; tectonic cycles; passive rifting; subduction.

INTRODUCTION

Several hypothesis have been put forward in order to explain the oblique alignment of the MVB with respect to the Middle America Trench, its contrasting geochemical associations and its tectonic features. Most difficulties arise because detailed geological mapping is still spotty and field structural studies are rare.

During the last years Italian researchers have been studying the central sector of MVB and adjoining areas in order to carry out a complete survey of the geology of this area, covering about 30,000 sq. kms. This project included field structural mapping at an 1:50,000 scale integrated with the use of aerial photographs at 1:25,000 and 1:50,000 scales. Measurements include orientation of fault planes, slickensides, crystal fiber lineations and other indicators like those recommended by Petit *et al.* (1983), gash fractures, and layering attitude. An earlier paper (Pasquarè *et al.*, 1988) is concerned with the general structural evolution of the area. In the present paper we focus on the Plio-Quaternary tectonics including new structural and stratigraphic data and the reprocessing of the original structural data with a more reliable computer program (Carey, 1979). The results enable us to determine the mechanisms of deformation and the degree of homogeneity of the stress field for each tectonic phase and to evaluate the possible influence of plate tectonics as compared with various models of extensional tectonics.

GEOLOGICAL OUTLINE

Structural framework of the Mexican Volcanic Belt

The Mexican Volcanic Belt has been divided into three sectors (Western, Central and Eastern) according to the dominant tectonic and volcanic features present in each (Pasquarè *et al.*, 1986, 1987). From the structural point of view, the western sector features a transcurrent-rift-transtension triple junction formed by the Colima, Tepic-Zacoalco, and Chapala arms wich developed since Late Pliocene (Allan and Luhr, 1982; Tibaldi, 1989a).

Tensional features characterize the Colima graben where 2.5 km of vertical displacement have been inferred from gravity data (Allan, 1985). Right-lateral strike-slip faults control the Tepic-Zacoalco arm (Nieto *et al.*, 1985) during the Quaternary (Tibaldi, 1989a), while the Chapala arm is dominated by a left-lateral transtensional regime (Tibaldi, 1989a). The Colima graben may represent an incipient phase of continental rifting following an eastward jump of the East Pacific Rise (Luhr *et al.*, 1985). This structure, together with the Tepic-Zacoalco arm, limits the Jalisco Block (Bourgois *et al.*, 1989) which is presently moving westward away from mainland Mexico (Pasquarè *et al.*, 1986; De Metz and Stein, 1989).

In the central sector, *i.e.*South-East of Lake Chapala, structural trends are largely hidden under recent volcanics pertaining to the Michoacán-Guanajuato Volcanic Field (Hasenaka and Carmichael, 1985). Two trends (NNE-SSW and ENE-WSW) of alignment of volcanic centers are evident (Connor, 1987; Pasquarè *et al.*, in press a). ENE-WSW trending faults are particularly dominant in the Lake Cuitzeo region where they control a structure of tilted blocks (Tibaldi, 1989b).

The boundary between the Central sector and the Eastern sector is the NNW-trending Taxco-Querétaro fault system (Demant, 1981; Pasquarè *et al.*, 1986, 1987). Within the Eastern sector large stratovolcanoes rise along major tectonic lines trending mainly N-S and ENE-WSW. Important tensional features connected with the Gulf of Mexico tectonics are evident along the "altiplano" border, where the eastern alkaline province developed (Cantagrel and Robin 1979, Robin, 1982). Similar NNW to N-S trending faults are responsible for the Cofre de Perote-Pico de Orizaba volcanic chain, the oldest centres of wich appear to be strongly affected by these tensional faults (Negendank *et al.*, 1985).

Geological outline of the studied area

The area of this study includes most of the central sector of MVB (Fig.1). Pre-volcanic basement outcrops both North and South of the volcanic arc but it consists of different tectonostratigraphic assemblages. North of the area sedimentary rocks of the Soyatal Fm., belonging to the Sierra Madre Oriental fold-thrust belt, outcrop at various sites North of Querétaro and Celaya. To the South, low-grade metamorphic sedimentary and volcano-sedimentary rocks of the Guerrero terrane (Campa and Coney, 1983) are exposed in the Tzitzio and Tlalpujahua areas; near Zitácuaro the same rocks are thrusted over carbonate sequences bearing Tethian affinities (Israde and Martínez, 1986). In the South these basement rocks are overlain unconformably by molasses-type deposits of early Tertiary age wich reach their maximum thickness to the South-East of Tzitzio. Volcanic rocks cover the major part of the area; they range in age from the Oligocene to the Present (Pasquarè *et al.*, in press b). These products are the result of the superposition of the volcanic activity of the Sierra Madre Occidental and of the Mexican Volcanic Belt.

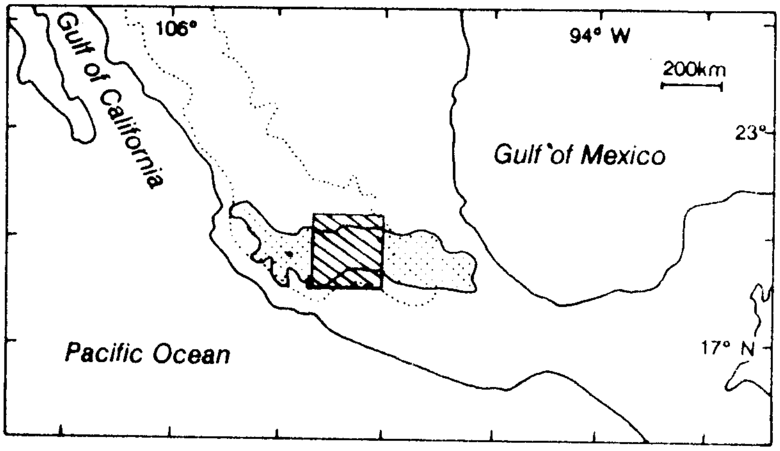

Fig. 1. The Plio-Quaternary Mexican Volcanic Belt (dotted). The dotted line encircles the Sierra Madre Occidental Cenozoic volcanism. Studied area is boxed.

North-West of Celaya and North of Querétaro we find thick successions of rhyolites and ignimbrites of Oligocene (Gross, 1975) and Early Miocene age (Pasquarè *et al.*, in press b). These volcanics cover a wide area and represent a direct extension of the Sierra Madre Occidental ignimbritic plateau. In the Tzitzio area, covering a thick layer of volcanic conglomerate, there are alternating layers of ignimbrites, breccias and andesitic flows of about the same age. This volcano-sedimentary sequence is clearly distinguishable form the overlaying volcanic rocks, because the layers dip up to 30°. This structure pertains to the NNW trending Tzitzio anticline (Mavois, 1977) (Fig. 2). Middle to Late Miocene volcanics are represented by a thick succession of mainly andesitic lavas locally associated with dacitic products and ash-flows, which outcrops extensively between Tzitzio and Morelia. The central-eastern part of the area is dominated by large basaltic flows with a radiometric age between 8.0 and 6.0 M.a. overlain by rhyolitic complexes of 4 M.a. to the South of Querétaro (Ferrari *et al.*, in press). Ignimbritic flows, andesitic lava cones and subordinate dacitic domes of Late Pliocene age are present in the central part of the area. These volcanics yield radiometric ages between 2.9 and 1.4 M.a. (Pasquarè *et al.*, in press b). Young basaltic effusions and andesitic lava cones partially cover those of Pliocene age; K-Ar datings of these products range between 1.2 and 0.65 M.a. (Pasquarè *et al.*, in press b). Thus they are Early Pleistocene in age. In the southwestern part of the area of the study, Late Pleistocene-Holocene cinder cones are particularly abundant. This is the Michoacán-Guanajuato Volcanic Field (Hasenaka and Carmichael, 1985). To the East rhyolitic and dacitic rocks of Pleistocene age (Dobson, 1984) are also found in the Los Azufres volcanic complex: they may have been extruded after a caldera collapse (Ferrari *et al.*, 1989; Pradal and Robin, 1986).

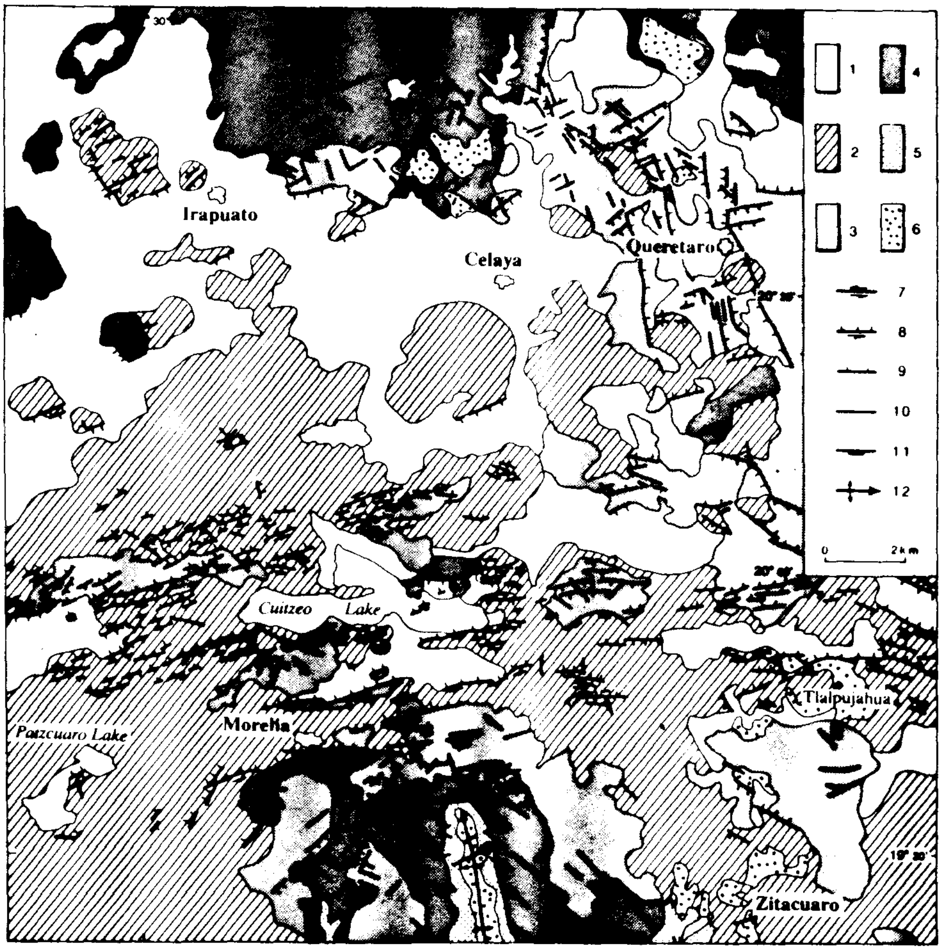

Fig. 2. Structural map of the studied area. 1.- Plio-Quaternary alluvial deposits; 2.- Plio-Quaternary volcanics; 3.- Middle-Late Miocene volcanics; 4.- Oligocene-Early Miocene volcanics; 5.- Eocene continental deposits; 6.- Basement; 7.- Strike-slip fault; 8.- Strike-slip normal fault; 9.- Pure normal fault or extensional fault with undetected striae; 10.- Lineament surveyed by aerial photographs; 11.- Volcano-tectonic collapse of Los Azufres; 12.- Anticline axis.

EVOLUTION OF THE DEFORMATION MECHANISMS

Pre-Late Miocene main structures

The metamorphic basement features several compressional phases which can be described by both plastic and brittle deformations. Folds of various scales can be grouped at least in two mutually perpendicular main sets (Tibaldi, 1986). The intersection of these folds yields "basin and dome" patterns (terminology after Ramsay, 1967). Cleavages, fractures and faults also reveal a multiphase compressional deformation.

A major structure outcrops near Tzitzio (Fig. 2). Here a moderately asymmetrical open anticline has a NNW axis over several tens of kilometers. Radiometric ages and stratigraphic relationships enable us to date the compressional phase to between 16 and 18 M.a. (Pasquarè *et al.*, in press b).

Younger volcanic units are more brittle, being pervaded only by fault and fracture systems. Normal (N160-180°) are mostly offsetting the strata up to Middle Miocene, thus suggesting that the area was affected by an extensional phase in Middle-Late Miocene.

Pliocene tectonics

Rock units up to Late Miocene (Fig. 2) are displaced by N25-45° right-lateral and by N60-75°left-lateral en echelon strike-slip faults. These sets of faults can be conjugated in a system intersecting at 30° to 90°(*e.g.* in Fig.5, site MX 1). Motions are characterized by pitches of less than 45° while the dip of the fault planes ranges between 65° and 90°. The same rock units are also disrupted by rare N145-160° en echelon reverse faults dipping between 35° and 70° and pitching between 75° and 90°. Net slips are of the order of tens of cm. From a regional point of view this style of deformation is confined to the MVB. All data fit the interpretation of Pliocene wrench tectonics characterized by N60-75° synthetic Riedel shear (R1), N25-45°antitethic Riedel shear (R2) (Fig. 6b) and N145-160° reverse faults bisecting the obtuse angle of the other two sets.

Early-Middle Pleistocene tectonics

Volcanic and sedimentary units up to the Early Pleistocene are disrupted by a pervasive system of N60-75°en echelon faults (Fig. 2 and 3) dipping mainly towards NNW. In some places these faults define narrow grabens. The S-shaped outlines of these grabens are due to changes in the direction of the faults (Tibaldi, 1989b). The longest fault follows the southern shore of Lake Cuitzeo, with a length of 16 km. The maximum dip-slips are in the order of hundreds of meters. The faults limit blocks that are mostly tilted 5° to 20° toward SSE. These blocks are closely fractured and displaced by secondary systems. This extensional pattern creates a topographical stairway, from the Tzitzio structural high to the Celaya-Querétaro depression. Cuitzeo Lake is located on an intermediate step of this system limited by WSW-ENE and E-W extensional faults. The N80°-100°faults constitute an important structural feature: although less developed, they displace all the other sets. The longest

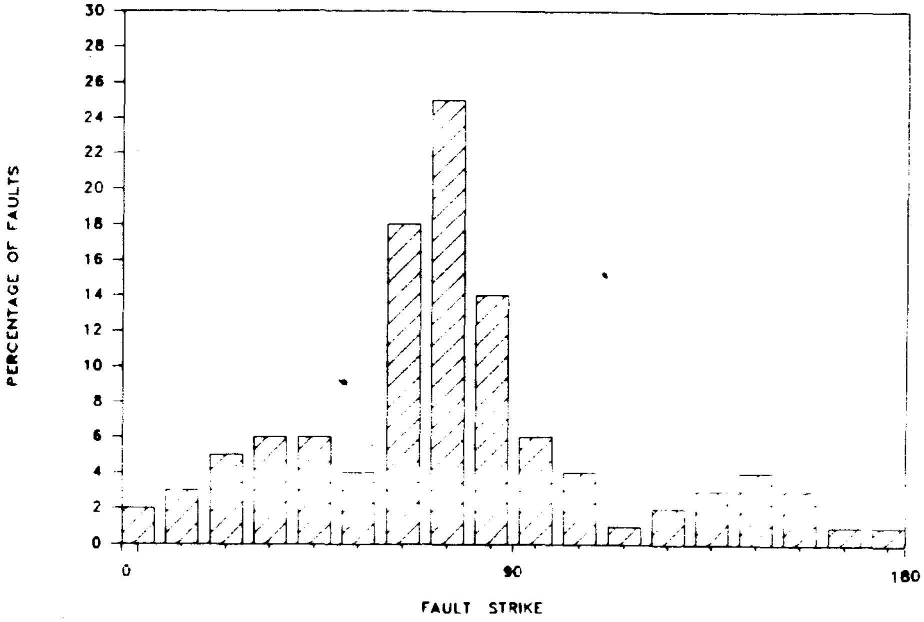

Fig. 3. Histogram of the azimuthal frequency of fault strikes. Angular intervals are 10 °.

fault of this system is the Morelia fault, which reaches a length of 15 km.

The N60°-100° faults are characterized by left-lateral normal movements. The slickensides have pitches higher than 50° (Fig. 4). The fault planes generally dip between 46°and 80°. Fault scarp morphology and displaced rock units suggest that the NNW-SSE normal faults of the area around Querétaro (Fig. 2) were active at least during Early Pleistocene. This grid-like fault distribution caused a block structure with tilting in various directions. We believe that the motions along the NNW-SSE system represent the reactivation of older fault planes which are widely developed to the North of the area of study.

On the whole, the data agrees with the development, in Early-Middle Pleistocene, of left-lateral transtensional tectonics (Fig. 7b) following an E-W divergent wrenching zone (in the sense of Wilcox *et al.*, 1973).

Late Pleistocene-Holocene

The limited number of good exposures allowed us to study only a few structural sites in rock units of Late Pleistocene-Holocene age. The collected data are consistent with the presence of normal and left-lateral normal E-W trending faults. Dips range between 55° and 80° and pitches are greater than 78° (Fig. 4).

This suggests that a slightly oblique extensional tectonics is taking place (Fig. 8b), which agrees with the left-lateral normal motion along an E-W fault plane in the 1912 Acambay earthquake (Astiz, 1986).

Stress trajectories

All the measurements collected at 81 structural sites, and partially published in Pasquarè *et al.*, 1988, were reprocessed and stress directions recalculated with Carey's method (1979). We also computed the tensor shape factors:

R = rv - rHmin / rHmax - rHmin, (1)

θ = tg [(2R-1) / v3] (Armijo *et al.*, 1982) (2)

Additionally, we estimated confidence limits for each structural site. Finally the trajectories of the stress field for each period were calculated.

Pliocene

In the Pliocene, the systems of N24°-45° and N60°-75° strike-slip faults and N145°-160° reverse faults are consistent with the average greatest principal stress (r1), which is horizontal and oriented N49°. The least principal stress (r3) is horizontal and shows an average N139°orientation.

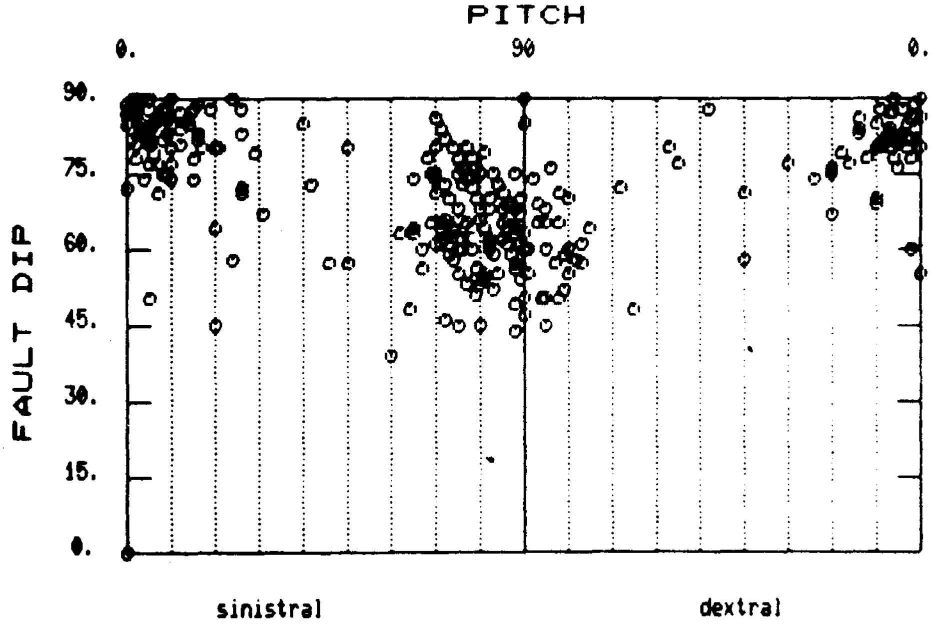

Fig. 4. Relationship between fault dip and obliquity of motion from field measurements. Abscissa shows the pitch of slickenside trends in degrees. Pure normal motion is 90°, pure strike-slip is 0° (left half-box, sinistral motions; right half-box, dextral motions). The ordinate shows dip of fault planes in degrees. Reverse faults are not shown.

Locally the r3 value tends to equal the intermediate principal stress value (r2) with θ ranging between 0° and 60°.

Early-Middle Pleistocene

The computed stress directions agree with an average value of N 149° for r3 with fluctuation between N 136° and N 165°. Exceptions are three structural sites located near Querétaro (Fig. 7a). Here r3 is rotated counterclockwise to N118°. r1 is usually subvertical and the average r2 is horizontal and ENE-WSW trending. Value of θ range from 30° to 60° because r2 approaches r1. Generally the direction of r3 is oblique to the fault planes as can be seen, for example, at the structural site located immediately to the South of Morelia (Fig. 5, site MX 2) and also to the South of Lake Cuitzeo (Fig. 5, site MX 3).

The stress trajectories show some distortion in the area between Pátzcuaro and Lake Cuitzeo (Fig. 7a) and in the area around Querétaro. The latter can be explained by the grid fault structure which characterizes the NE sector of the area of study.

Late Pleistocene-Holocene

The solutions of 9 structural sites can be referred to active tectonics. They suggest a direction of r3 ranging from N165° to N180° (Fig. 8a), which agrees with the result of the focal mechanism of the Acambay earthquake of 1912 (Astiz, 1986). This supports the hypothesis of a protraction of the transtensional motions in recent times.

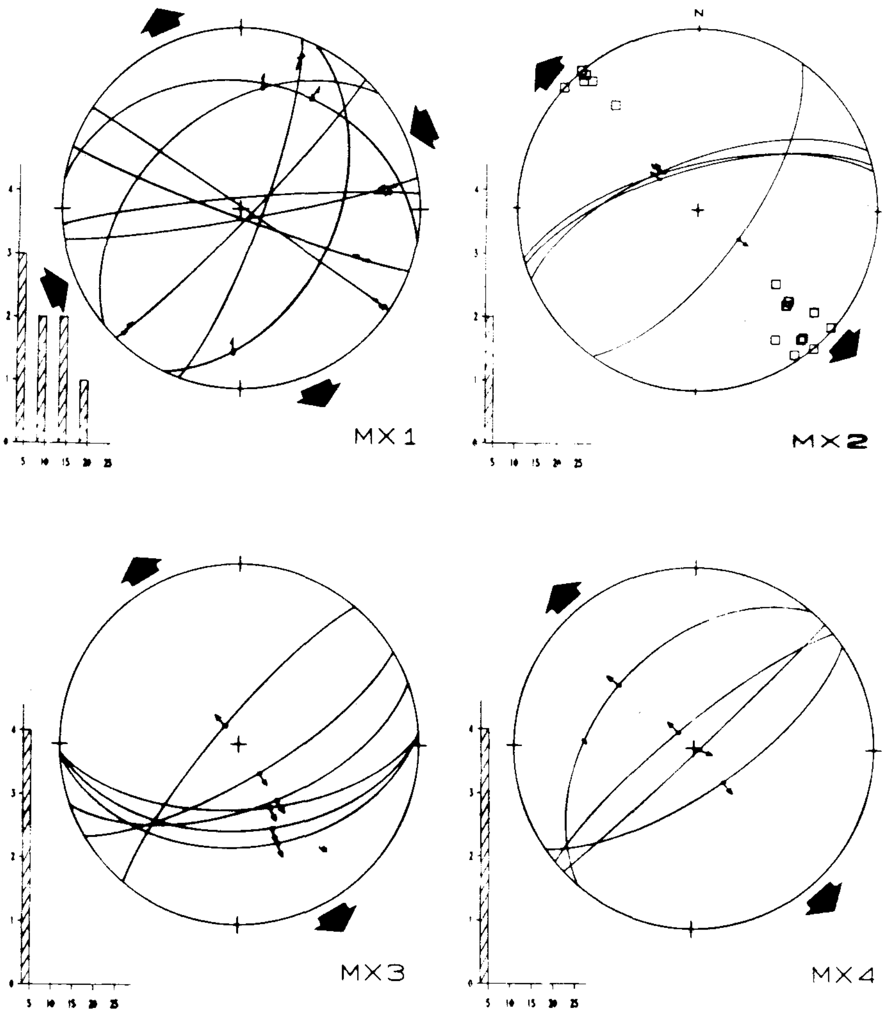

Fig. 5. Examples of reduced tensors from typical populations of faults. (Schmidt projection, lower hemisphere). Boxes represent poles of gash fractures. Convergent and divergent arrows represent direction of r1 and r3 respectively. Histograms show deviation between measured and predicted slip vector given in degrees of deviation (X axis) versus number of faults (Y axis). Faults with 0° deviation are not included. θ = R transformation of Armijo *et al.* (1982). For location of sites 1, 2, 3 and 4 see fig. 6.

However, the data are still too scarce to define the complete configuration of the active stress field. Further investigations are in progress.

DISCUSSION

The hypothesis of a crustal discontinuity under the MVB has been put forward by several authors. Gastil and Jensky (1973) suggested that a zone of crustal weakness with right-lateral strike-slip motions existed at the end of the Mesozoic beneath the area later occupied by the MVB. Additional motions in this zone would have occurred during Oligocene and Miocene times. Le Pichon and Fox (1971) suggested that the discontinuity under the MVB might represent a paleo-shear zone. Mooser (1969) proposed that the belt is a dividing line between northern and southern Mexico following a zig-zag pattern. Anderson and Schmidt (1983) interpreted it as a left-lateral megashear active during the Jurassic.

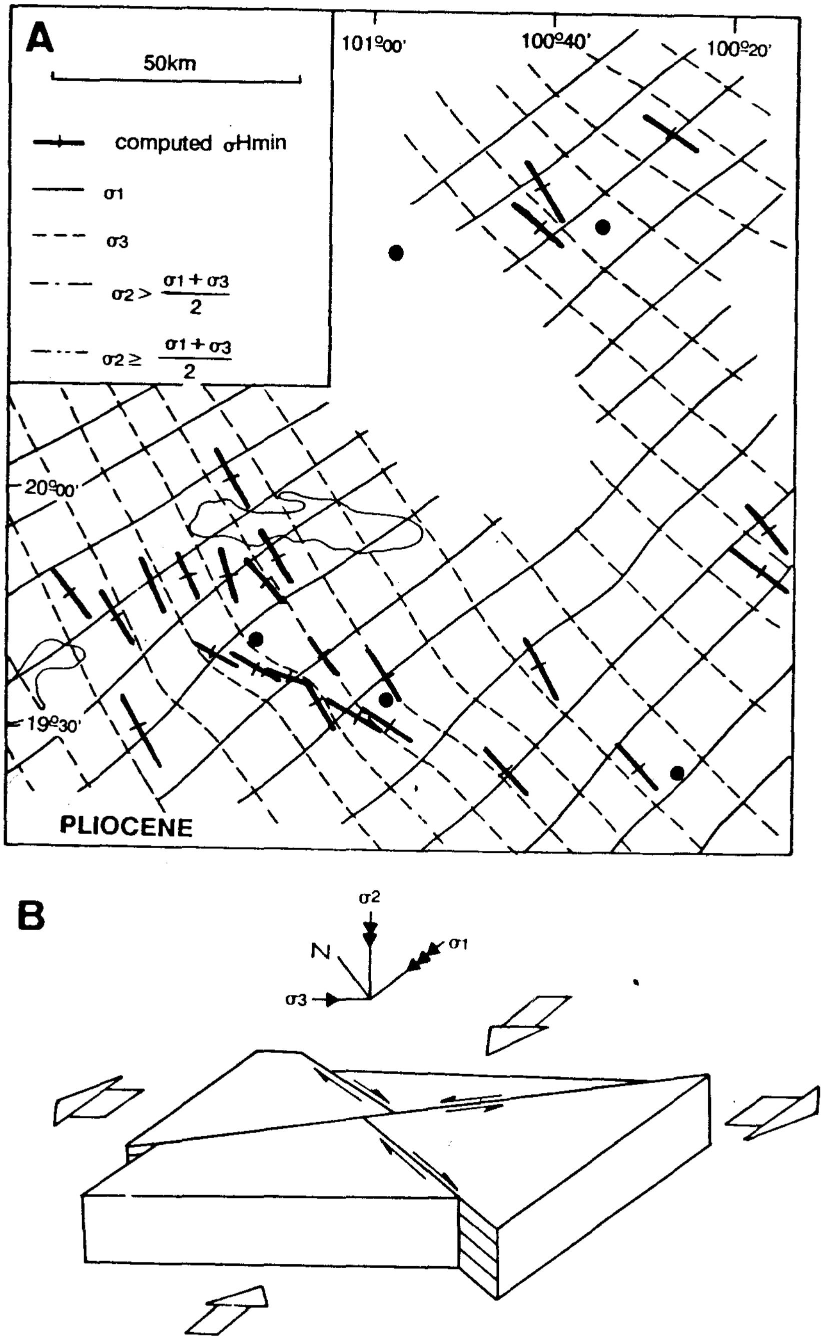

Fig. 6. (A). Stress trajectories during Pliocene. QU = Querétaro; CE = Celaya; MO = Morelia; TZ = Tzitzio; ZI = Zitácuaro. (B). Deformation mechanism and tensor shape during the same period. Numbers refer to localities in Figure 5.

Counterclockwise block rotation deduced from paleomagnetic data (Urrutia and Böhnel, 1987, in press) may suggest the existence of a large-scale left-lateral shear accross central Mexico. Other speculations include a right-lateral active shear zone (Shurbet and Cebull, 1984; Cebull and Shurbet, 1987). In the area of our study the stress trajectories are remarkably rectilinear and uniform for each tectonic phase. In the Early-Middle Pleistocene phase a slightly modified stress field can be recognized in the Querétaro area. This can be interpreted as related to the interference of the ENE-WSW left-lateral normal fault swarm with the NNW-SSE faults of the Querétaro fracture zone. During the Plio-Quaternary the average rHmin and rHmax directions show a minor clockwise rotation of 37°.

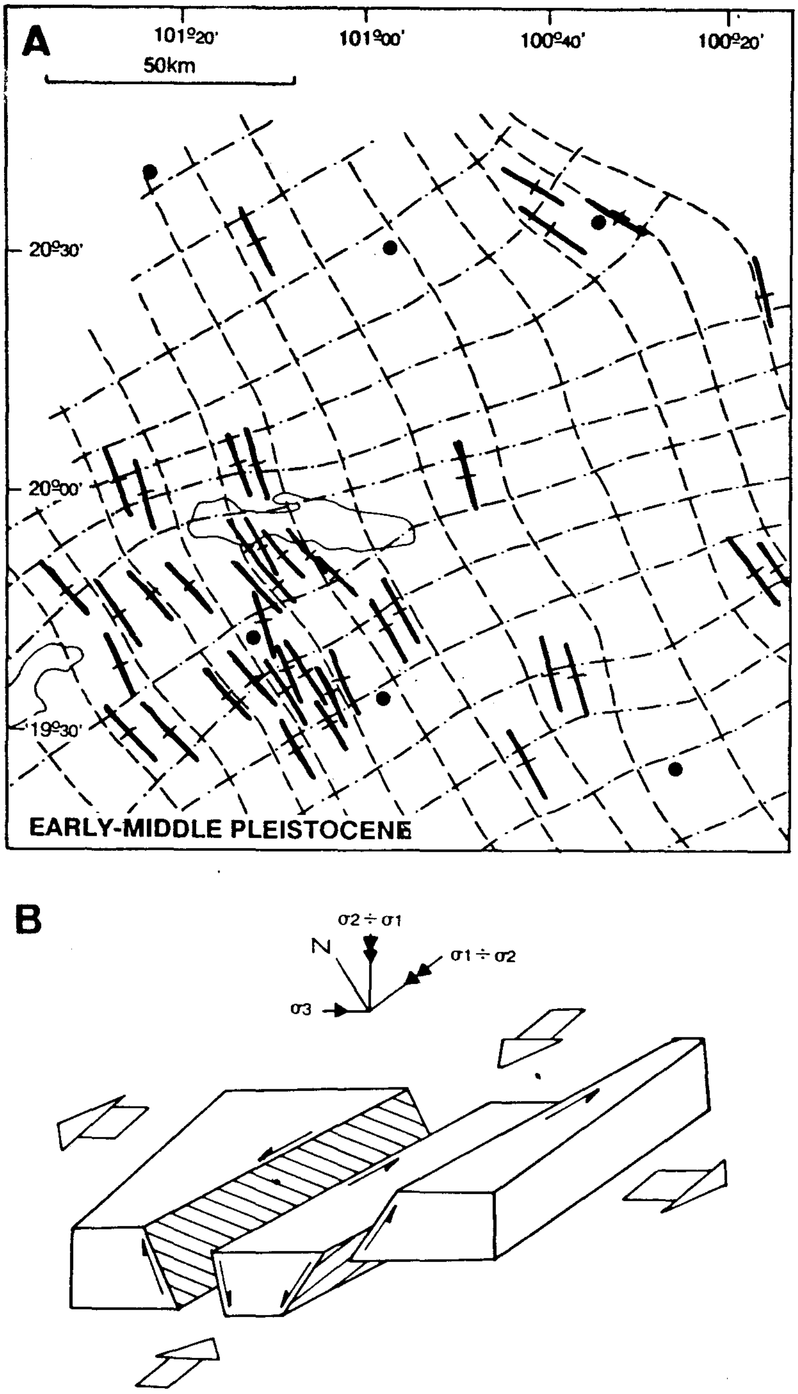

Fig. 7. Stress trajectories in Early-Middle Pleistocene (as in Fig. 6).

We suggest that the most plausible explanation for the rectilinear and uniform stress distribution may be the transmission of forces by motions at plate-boundaries. In fact our results are not easily explained by models of active rifting, in which ascending mantle convection would be responsible for lithospheric thinning, isostatic uplift, volcanism and traction forces acting on the base of the lithosphere (Neugebauer, 1978; Turcotte and Emerman, 1983). In the active rifting model, a tensile stress trajectory should be perpendicular to the contour line of

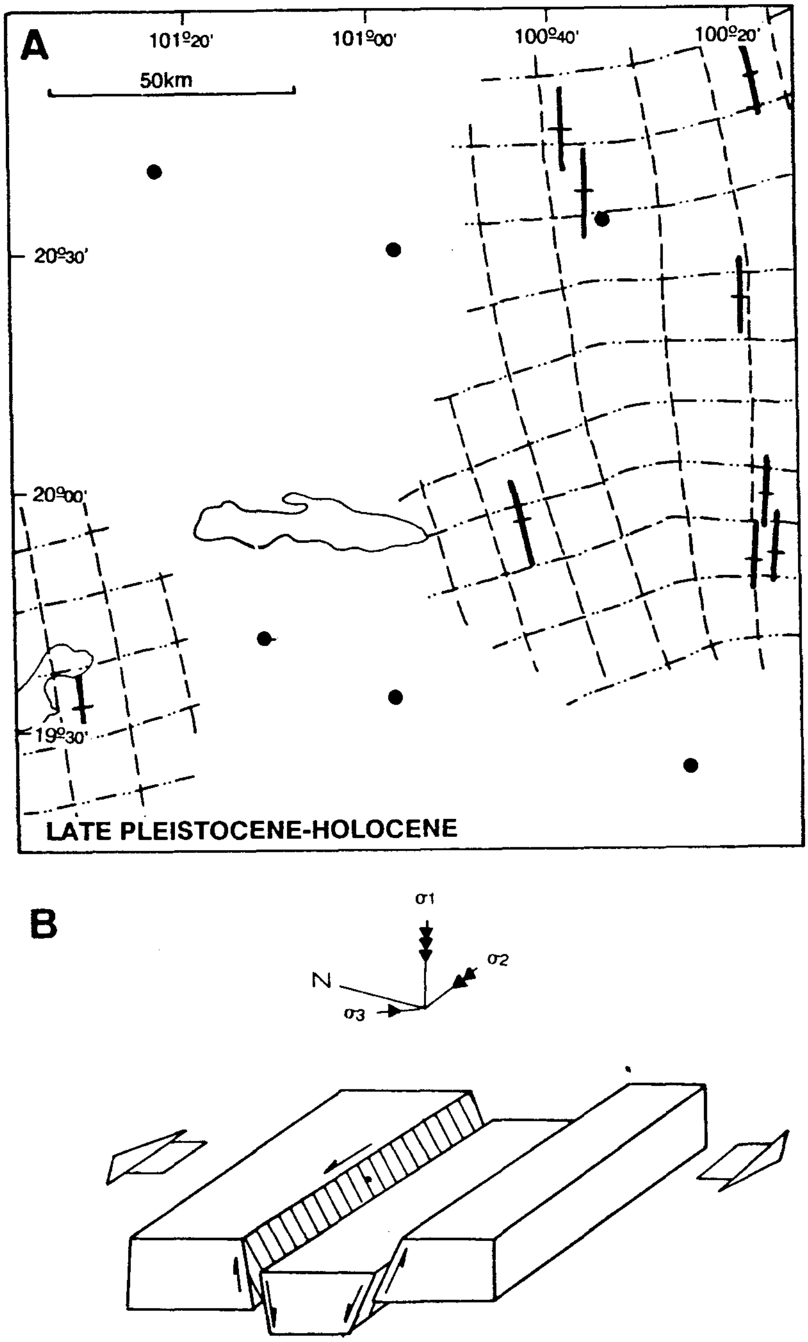

Fig. 8. Stress trajectories in Late Pleistocene-Holocene (as in Fig. 6).

the volcanic belt or uplifted zone, with no systematic oblique component. Also, strike-slip deformation is not contemplated in this model. By contrast, our data are compatible with a model of passive rifting during Quaternary time, with extensional deformations related to tensional stresses produced by plate-boundary forces (Sengör and Burke, 1978). The stress r3 is oblique to the E-W orientation of the fault zone, and the observed slip vectors of motions on the fault planes are consistent with oblique rifting as a mechanism of extension. The Pliocene strike-slip tectonics and the following transtension can thus be envisaged as a part of a single deformation cycle characteristic of an E-W left-lateral shear zone. The strike-slip deformations were generated by the first impulses of the incipient shear zone related to parallel wrenching. During the same period an ignimbrite suite dated 6 M.a. and acid dome complexes of 4 M.a. of age were emplaced in the eastern part of the area (Ferrari *et al*, in press). We suggest that this acidic activity could be related to the above compressional phase. The transtensional deformations represent the surface expression of the development of the shear zone with motions of divergent wrench type. This zone seems to be confined to the West by the triple junction Tepic-Chapala-Colima, and to the East by the structures related to the extensional tectonics of the Gulf of México (Fig. 9) (Pasquarè *et al.*, 1986, 1988).

Effusion of andesitic lavas took place near the beginning of the transtensional tectonics. Divergent wrenching allowed the extrusion of large amounts of magma and the emplacement of a generation of andesitic lava cones with radiometric ages between 1.2 and 0.65 M.a. (Nixon *et al.*, 1987; Pasquarè *et al.*, in press b). The ENE-WSW left-lateral normal faults also controlled the emplacement and morphometry of several cinder cones with a radiometric age less than 0.54 M.a. (Pasquarè *et al.*, in press a). During the Pleistocene, explosive events and acid lava flows formed a complex of rhyolitic and dacitic domes, dacitic flows and volcanoclastic deposits wich were connected with the Los Azufres complex. The persistence of acid volcanism in this area probably reflects an eastward late migration of the transtensional structures: these disappear 90 km East of Los Azufres.

According to the passive rifting model, volcanism would be considered a secondary result of lithosphere stretching (Turcotte and Emerman, 1983; Wernicke, 1985; Lister *et al.*, 1986). This stretching causes mantle instability and subsequent passive upwelling to fill the void created by the thinning lithosphere (Morgan and Baker, 1983). During this stage partial melting is likely to occur since the pressure decreases in the rising material. Related volcanism is typically alkaline in composition.

Since there is seismic evidence of subduction of the Cocos Plate under the MVB (Lomnitz, 1982; Burbach *et al.*, 1984; Hanus and Vanek, 1978 , 1984) and most of the volcanic material is of calcalkaline nature (Aguilar

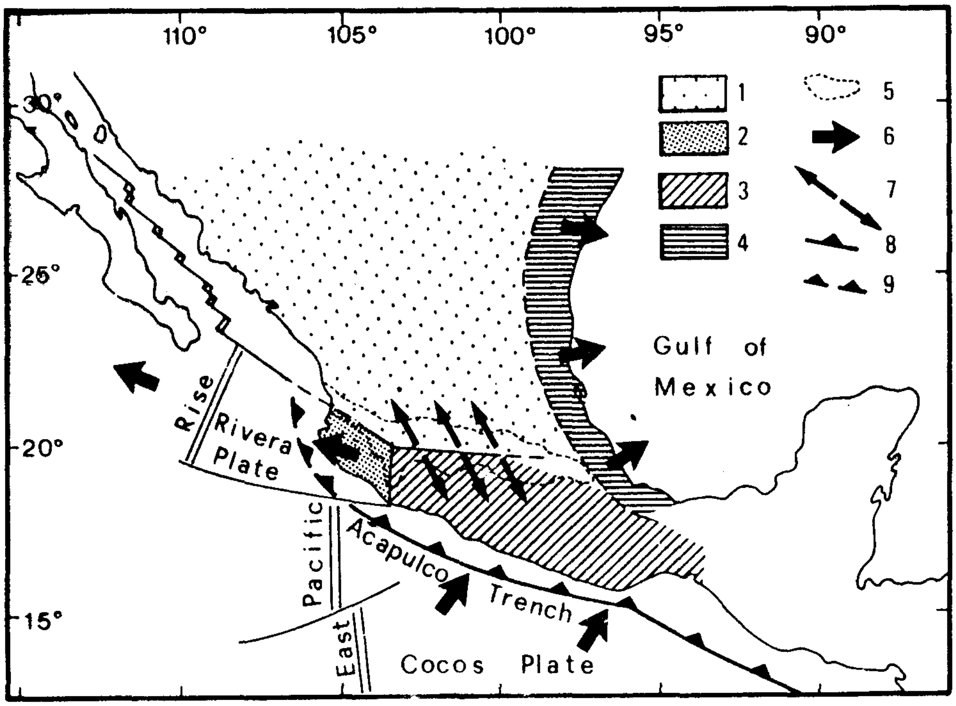

Fig. 9. Main Quaternary geodynamic features of South-Central Mexico (from Pasquarè *et al.*, 1986). 1. Relatively stable area; 2. Structures related to the Californian divergence; 3. Structures related to convergence along the Acapulco Trench; 4. Structures related to the Gulf of Mexico extension; 5. Boundaries of the Mexican Volcanic Belt; 6. Relative movements; 7. Main transtensional system; 8. Active trench; 9. Inactive trench.

and Verma, 1987), subduction cannot be ruled out among the causes responsible for magma characterization. The subduction process along the present Acapulco Trench started during Late Miocene (Karig *et al.*, 1978). Assuming a conservative rate of convergence of 6 cm/y, equal to the minimum present rate of relative convergence along the Acapulco Trench (Minster and Jordan, 1978) and an angle of subduction of 14° equal to the maximum present dip (Burbach *et al.*, 1984; LeFevre and McNally, 1985), we may project the slab for about 400 km inland from the trench. This zone corresponds to the northernmost part of the MVB. But the shallow angle of the Benioff zone deduced by seismology would not lead to a suitable depth for magma genesis for the slab under most of the MVB. We therefore hypothesize that during Quaternary times magma might have been produced by rising isotherms induced by lithospheric stretching along the passive MVB rift system. This idea is supported by the lack of seismicity under the arc wich could be related to an aseismic warm zone in the subducted slab.

CONCLUSIONS

Interpretation of structural data at the macro- and mesoscale in the context of a new reconstruction of the stratigraphic sequence (Pasquarè *et al.*, in press a), allows a definition of the deformation mechanisms and stress field evolution in the central sector of MVB during Plio-Quaternary times.

During Pliocene a pervasive system of en echelon strike-slip faults developed following a N 49° average direction of r1. Net slips along the fault planes were small. In Early-Middle Pleistocene left-lateral normal faults developed with net slips up to hundreds of meters. Average r3 was N 149°, while the N 59°rHmax was ranging from r1 to r2. Left-lateral normal tectonics continued until the Holocene, characterized by a slight clockwise rotation of r3 from NNW-SSE to N-S. The aforementioned mechanisms were recognized only in a E-W zone coincident with the central sector of the Mexican Volcanic Belt.

The most reasonable explanation for this rectilinear and uniform stress distribution for each period is control by plate tectonic forces. The evolution of the tensor shape and of the mechanism of deformation is consistent with the development of a major continental structure coincident with the E-W elongation of the MVB. The sector was controlled by a left-lateral shear zone evolving from parallel to divergent. Surficial structures connected to the same wrenching mechanism extend westwards until to triple junction of Tepic-Colima-Chapala.

The control of the structures of the Mexican Volcanic Belt by the plate boundary forces implies that the Quaternary extension must be explained by an oblique passive rifting model. The component of stretching of the lithosphere could cause an uprising of the isotherms and partial melting in the subducted slab which, in turn, could contribute to the magma characterization.

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