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MORPHOLOGICAL AND STRUCTURAL MODEL OF MEXICAN VOLCANIC BELT

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RESUMEN

Con base en datos geológicos, geomorfológicos y estructurales se reconocieron las principales unidades estructurales que constituyen el Cinturón Volcánico Mexicano (CVM). Estas unidades se formaron durante varias etapas tensionales desde el Oligoceno, y muchas de las estructuras vinculadas con ellas siguen todavía activas.

Dentro del CVM se reconocieron tres sectores principales. El sector occidental, activado en el Plioceno, presenta un sistema de grábenes en dirección NW-SE, y está asociado a la apertura del Golfo de California. El sector central está representado por un sistema de bloques fallados y basculados en dirección WSW-ESE, que rodean a una depresión central. En el sector oriental, las estructuras distensivas están representadas esencialmente por un sistema de fallas en dirección N-S. Estas fallas están relacionadas con los grandes estrato-volcanes del CVM.

El CVM atraviesa las antiguas estructuras de bloques fallados N-S y NNE-SSW, que pertenecen a la provincia Basin and Range. En los sectores central y occidental del CVM se reconocieron lineamientos tensionales reactivados, pertenecientes a esa provincia.

A lo largo del margen meridional del CVM, todas las estructuras distensivas mencionadas se interrumpen, desarrollándose un amplio colapso en dirección E-W, coincidente con el valle del Río Balsas.

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ABSTRACT

On the basis of geological, geomorphological and structural data, the main structural units forming the Mexican Volcanic Belt (MVB) were recognized. They have been generated during several tensional phases since Oligocene. Many of the structures connected with these units are still active.

Three main sectors were recognized inside the MVB. The western sector, activated during Pliocene times, shows a NW-SE trending graben system, associated to the opening of the Gulf of California. The central sector is represented by a block-faulted and tilted WSW-ENE trending graben system, surrounding a central depression. In the oriental sector the disjunctive structures are represented by N-S fault systems affecting the rigid basement of Sierra Madre Oriental, and controlling the development of the largest strato-volcanoes of the MVB.

The MVB intersects older N-S and NNE-SSW block-faulted structures, belonging to the Basin and Range province. Reactivated tensional lineaments belonging to the same province were recognized inside the western and the central sector, and probably in the eastern one too.

Along the southern margin of the same volcanic belt all the described distensive structures are interrupted, and huge E-W collapsed structures coincident with the Río Balsas valley develop.

INTRODUCTION

Central Mexico is crossed from E to W by a Plio-Quaternary volcanic belt, forming one of the outstanding geological and physiographical features of the country. Its transversal setting with respect to the Sierra Madre Occidental and Sierra Madre Oriental orogenic belts and to Meso-American Trench, explains its name, well known in literature as Trans-Mexican Volcanic Belt (in the present paper the name Mexican Volcanic Belt is preferred, as in Mooser, 1969). Several authors tried to explain the existence of the Mexican Volcanic Belt (MVB) working out geodynamical syntheses, not supported by a specific knowledge of its geological evolution (Mooser, 1969; Pal and Urrutia, 1977; Urrutia and Del Castillo, 1977; Lomnitz, 1982; Anderson and Schmidt, 1983; Shurbet and Cebull, 1984).

Regional geological researches, directed to clarify more concretely and specifically the MVB geological history through geochemical and geochronological analyses of the volcanic products, are to be mentioned (Mooser, 1969; Demant and Robin, 1975; Thorpe, 1977; Demant, 1978; Pal *et al.*, 1978; Robin and Tournon, 1978; Cantagrel and Robin, 1979; Demant, 1979; Gastil *et al.*, 1979; McDowell and Clabaugh, 1979). But even if in some of these works (Negendank, 1972; Demant, 1975, 1978, 1979; Cantagrel and Robin, 1979) outlines of regional structures of the MVB are suggested, the meaning of these remains vague.

This paper intends to propose a preliminary structural synthesis of MVB, based on

the interpretation of geological, geomorphological and structural data, collected by direct and indirect methods. The principal aim of this study is to single out the main morpho-structural units which compose the MVB, their relations to the development of volcanic activity and to the underlying and adjacent structural units.

This work is the result of numerous geological observations carried out by the first author during many vulcanological and geothermal field-explorations performed since 1977. The other authors worked during 1984.

METHODOLOGY

Our analysis is mainly based on the comparison among geological, geomorphological and structural data on a regional scale. Geological data were obtained from field-works and from the existing literature and maps (see references). The field-work allowed the identification of stratigraphic relationships among the volcanic sequences which compose the MVB. The lithostratigraphic units related to the MVB activity were separated from those connected with Sierra Madre Occidental volcanic province.

Relative tectonic deformation analysis was always carried on with stratigraphical observations. Particular attention was given to structural lineaments, to their mutual relationships and to the development of volcanic centers. Radiometric ages of the previous literature were considered together with some unpublished data, kindly put at our disposal by Comisión Federal de Electricidad. Geomorphological analyses were conducted with qualitative and quantitative methods, allowing to recognize the main morphological regional units and their relative dislocations. In this context an analysis based on morphometrical elaborations concerning Central Mexico (Lugo *et al.*, 1985) was particularly useful.

The data obtained were elaborated on 1:50 000 DETENAL topographic maps, and then summarized in a 1:500 000 map. In addition 1:1 000 000 LANDSAT images and their 1:500 000 enlargements covering the whole area, were used. Limited but particularly important areas were analyzed with 1:50 000 aerial photographs.

The association of the previously described parameters singled out the morpho-structural units forming the investigated area (Fig. 1). As a conclusion of this work a sketch, showing the major structural provinces recognized, is presented (Fig. 2).

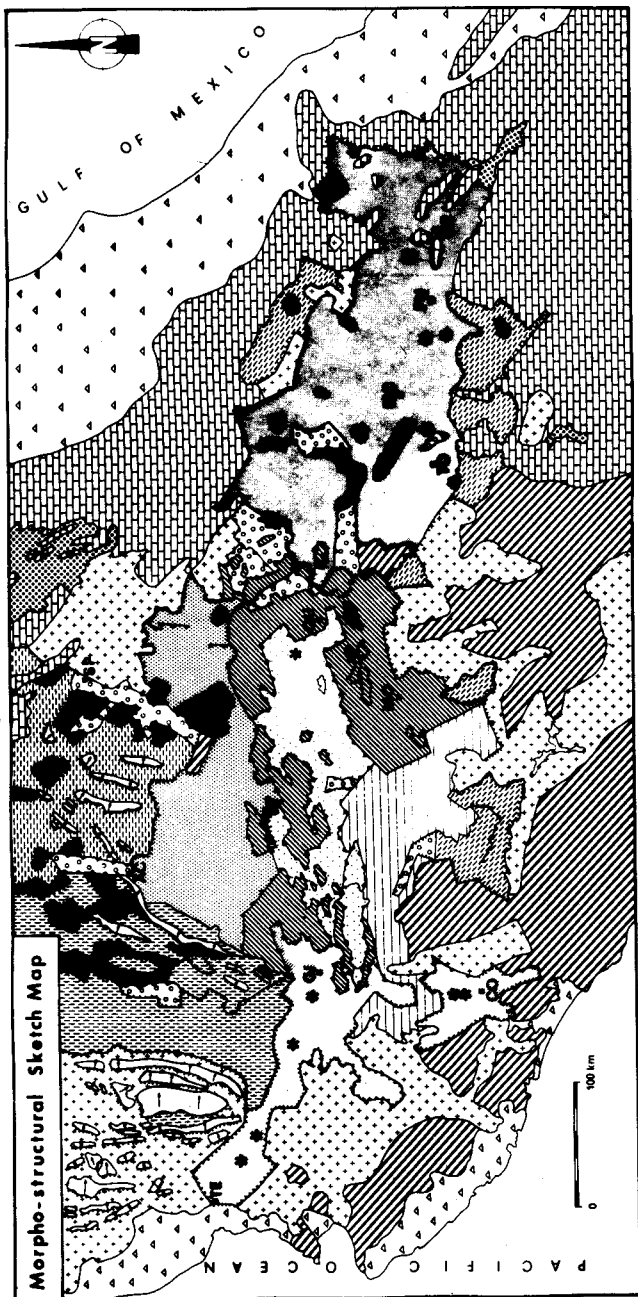


Fig. 1. Morpho-structural Sketch Map of Mexican Volcanic Belt and Conterminous Areas.

MVB UNITS

Western Sector

- 1) Tepic-Guadalajara and Colima grabens

Central sector

- 2) Central depression
- 3) ENE-SW faulted blocks
- 4) Leon-Guanajuato Plateau
- 5) Tarascan Plateau

Eastern sector

- 6) Eastern Plateau
- 7) Pre-Pliocene relict volcanic centers

I Recent and/or active faults

II Recent grabens

III Old faults

IV Passive limits

Main volcanic centers

CONTERMINOUS UNITS

- a) Coastal Plains
- b) Intermontane Plains
- c) Cordilleran orogenic belts
- d) Sierra Madre Oriental folded belt

- e) Sierra Madre Occidental volcanic plateau
- f) Sierra Madre Occidental tectonic depressions
- g) Sierra Madre Occidental horsts
- 1 - dissected units
- 2 Preserved structural surfaces
- h) Mexican central plateau
- i) Marginal tectonic depressions

AC: Aguascalientes, CO: Colima, GJ: Guadalajara,
 MC: Mexico City, MO: Morelia, OR: Orizaba,
 PU: Puebla, QU: Querétaro, SP: San Luis Potosí,
 TE: Tepic, TO: Toluca

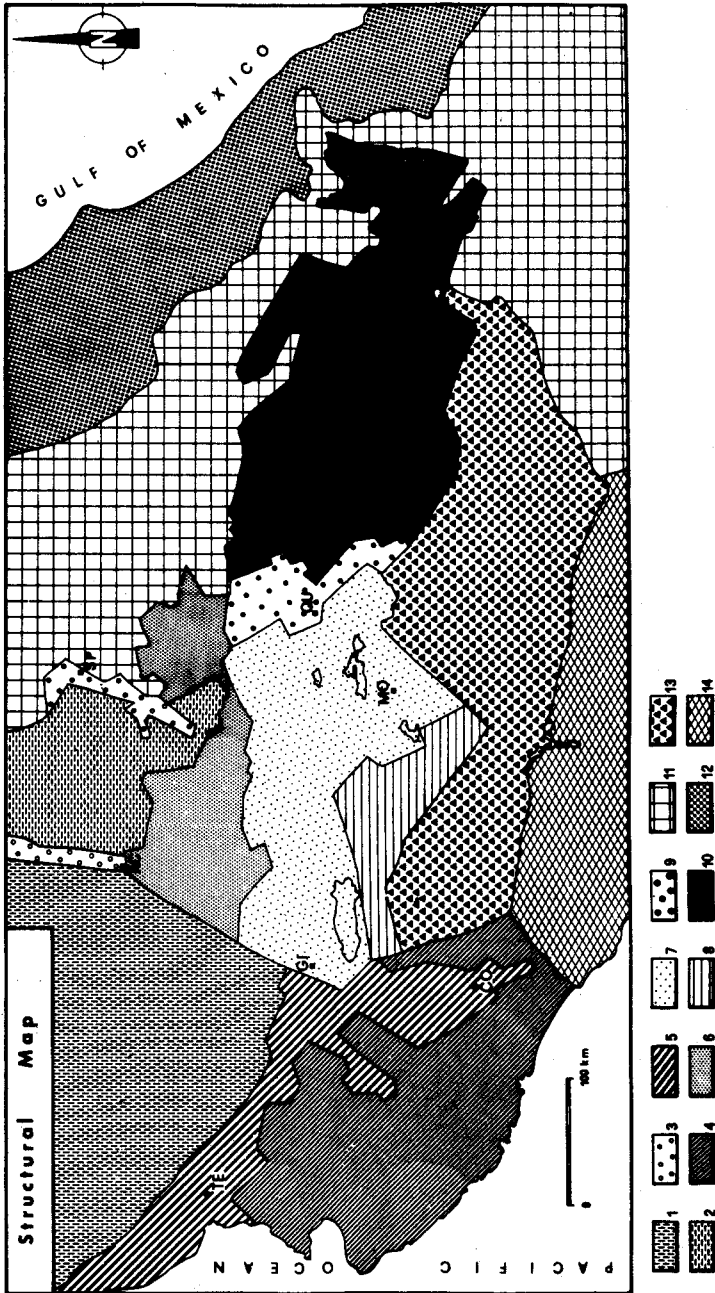


Fig. 2. Structural Map of Central Mexico

BASIN AND RANGE PROVINCE

- 1) Guadalajara-Durango block-faulted area
- 2) Mexican central plateau
- 3) Recently reactivated grabens

CALIFORNIAN PROVINCE

- 4) Slightly block-faulted area
- 5) Tepic-Guadalajara and Colima graben system

MVB CENTRAL PROVINCE

- 6) Guanajuato plateau
- 7) Chapala-Cuitzeo depression

- 8) Tarascan plateau
- 9) Querétaro fracture zone

SIERRA MADRE ORIENTAL PROVINCE

- 10) MVB eastern plateau
- 11) Uncollapsed folded belt
- 12) Coastal plains

SIERRA MADRE DEL SUR PROVINCE

- 13) Southern MVB collapsed margin
- 14) Uncollapsed orogenic belt

MVB REGIONAL GEOLOGICAL FRAMEWORK

The MVB is an almost continuous calco-alkaline volcanic belt with subordinate amounts of alkaline products (Aguilar-y-Vargas and Verma, 1987), extending from E to W between the Mexican Atlantic and Pacific coasts, along the 20th parallel. Pliocene and Quaternary volcanic centers form the belt; some of the Quaternary ones are still active. Many doubts still persist on the beginning of volcanic activity and on the tectonic events which have characterized its evolution. The MVB is placed in a nodal sector of Mexico, where the principal structural units of southern North-America, consisting of Sierra Madre Occidental, Sierra Madre Oriental and Sierra Madre del Sur, join each other.

The Sierra Madre Occidental represents a major orogenic segment belonging to the Cordilleran system, developed along the western side of the North-American craton, as a consequence of the interaction of Pacific and North-American plates (Campa and Coney, 1983). The belt corrugated during several tectonic, metamorphic and volcano-plutonic events, in Jurassic, Cretaceous and Paleocene times. Thick sequences composed of andesitic-basaltic lavas and Pyroclastic flow deposits, similar in age to those outcropping in extensive areas of U. S. A., extensively cover the Sierra Madre Occidental orogenic complexes.

The present structural framework of Sierra Madre Occidental is strongly affected by the distensive tectonics established since the end of Miocene with a system of faulted blocks, known as Basin and Range Province of the western U. S. A. This system of faulted blocks is present in west-central Mexico with mainly N-S trends as well. During Miocene, along the Californian continental margin the same tensional stresses, associated with important NW-SE wrench movements, originated the Gulf of California and Peninsular Ranges.

Sierra Madre del Sur also belongs to the cordilleran orogenic system, and consists of several terranes composed of Precambrian, and Paleozoic rocks, and by Mesozoic arc-complexes (Campa *et al.*, 1981). The WNW-ESE trend of the present southern Mexican coast, which interrupts the Cordilleran trends, is due to lateral movements occurred intermittently between late Cretaceous and late Miocene times. Accretion phenomena are suggested to be restored along Meso American trench since late Miocene (Karig *et al.*, 1978).

Sierra Madre Oriental is a paleogeographic element belonging to Mesogean system,

extending to the whole Caribbean area until late Cretaceous. This belt consists of a folded and embricately thrust-folded foreland with respect to the above-mentioned Pacific orogenic belts. It is mainly built up by Mesozoic carbonatic rocks. The belt was deformed during the Laramide orogenic phase, as a consequence of the Cordilleran orogenic system formation. Late distensive movements are responsible for the formation of graben structures, considered as a south-eastern prosecution of the Basin and Range Province, developed in Coahuila and Zacatecas States (Córdoba *et al.*, 1980).

MORPHO-STRUCTURAL ANALYSIS

On the basis of morpho-structural analysis the MVB results to be characterized by the presence of peculiar tectonical and morphological features, assuming a great prominence in the central southern Mexico physiographical framework. The association of these features allowed to distinguish several morpho-structural units as represented in Figure 1. Moreover, the regional units conterminous to MVB are considered in the present paper.

MVB UNITS

Western sector

1) Tepic-Guadalajara and Colima Grabens

Plio-Quaternary volcanoes of this sector lie enclosed in a graben system extending along NW-SE trends among Tepic, Guadalajara and Colima. The border fault-scarps of the depressions show an advanced erosional stage pointing out, together with the presence of Pliocene volcanoclastic deposits (Pasquare and Zanchi, 1985), an early activation during Pliocene, followed by an interruption of sinking in Quaternary.

At present these grabens are overflowed by epiclastic and volcanoclastic materials coming from the Quaternary volcanic centers present in the area. The main Pleistocene volcanoes present in the Tepic-Guadalajara depression appear to be connected with the NW-SE fault system. In the Colima graben N-S trends interact with NW-SE regional trends. Here distensive movements seem to go on along the main marginal faults also during Quaternary times.

Central sector

2) Central depression

This unit is represented by a tectonic depression extending for 200 km from E to W between Valle de Santiago and Chapala lake and bordered by ENE-WSW active faults. The bottom is filled with lacustrine and fluvial sediments, and is still occupied by lakes. The average height of the depression is around 1 800 m a.s.l. The Chapala lake shows a further collapse of more than 300 m.

The eastern side of the depression is interrupted by a NNW-SSE fault system, forming the Querétaro fracture zone, known in literature as Taxco-San Miguel de Allende line (Demant, 1978).

3) ENE-WSW faulted blocks

The central depression is limited by ENE-WSW faulted blocks composed by Plio-Quaternary volcanic sequences connected with the MVB activity. Many volcanic centers are present along the faults edging the blocks. Southward facing cuestas characterize the unit. The faulted blocks interact with the above mentioned Querétaro fracture zone, forming a complex system of variously oriented horsts and grabens.

4) León-Guanajuato Plateau

Mexican Central Plateau is flanked along its southern border by a huge plateau placed at a height varying between 1 800 and 2 000 m a.s.l. The escarpment dividing the two units results on the whole extended in E-W direction, but in detail it is strongly segmented. The plateau western side shows a dense dendritic pattern, hollowed in Tertiary volcanoclastic rocks.

The unit is crossed by a N-S and NNE-SSW fault system, along which small recent volcanic centers grew up.

5) Tarascan Plateau

This unit consists of a huge plateau crossed by ENE-WSW and WNW-ESE faults, marked by the alignment of small Quaternary volcanic cones. The average height of the plateau is 2 400 m a.s.l. Inside the plateau and along its margin under the recent volcanic products; Sierra Madre Occidental volcanic sequences sporadically outcrop forming the relative basement of the MVB centers.

Eastern Sector

6) Eastern Plateau

The main eastern plateau extends for hundreds of kilometers from the Querétaro fracture zone to the Cofre de Perote-Pico de Orizaba N-S fracture lineament. This lineament constitutes the eastern boundary of the MVB.

The plateau is characterized by the presence of very extensive plains, placed among recent volcanic ridges and ancient Sierra Madre Occidental volcanics. The depressions are flooded by recent volcanoclastic deposits coming from the largest strato-volcanoes of the MVB. The height of the plateau is generally above 2 000 m a.s.l., and reaches 2 700 m near Toluca and Puebla.

The basement of the plateau is mainly made up by Oligo-Miocene volcanics belonging to Sierra Madre Occidental volcanic province, and filling up a roughly NW-SE trending tectonic depression developed during volcanic activity. A borehole near Mexico City, Pozo Texcoco, intersected the Sierra Madre Oriental sedimentary rocks after traversing 2 060 m of volcanic materials (Mooser *et al.*, 1974).

From the structural point of view, this unit shows a lower tectonic control compared to the recent intensive faulting affecting the western and central sectors of the MVB. Therefore, near the Querétaro fracture zone, the plateau is crossed by ENE-WSW faults, forming recent grabens. Also in other sectors the presence of small grabens was recognized.

The plateau is subdivided in minor compartments by N-S and NNE-SSW Quaternary fault systems, covered by recent volcanoclastic deposits. Along the former fault family the Popocatepetl-Iztaccshuatl and Pico de Orizaba-Cofre de Perote volcanic chains have grown, while along the latter La Malinche center has developed.

In the western part of the plateau poorly tectonized Oligo-Miocene volcanics belonging to Sierra Madre Occidental outcrop forming isolated ridges. The central part is characterized by the presence of Plio-Quaternary volcano-sedimentary sequences, forming the relative basement of the large strato-volcanoes. In the eastern part, extending beyond a line passing through Atlixco, La Malinche volcano and Zacatlán, the folded complexes of Sierra Madre Oriental outcrop forming isolated ridges, mainly developed in the south-eastern end of the unit.

7) Pre-Pliocene relict volcanic centers

West of Mexico City several ridges consisting of Sierra Madre Occidental Oligo-Miocene volcanics were recognized (Negendank, 1972; Mooser *et al.*, 1974). They are made up by acidic lava flows and domes poorly affected by tectonics. The absence of marginal fault-scarps suggest that this unit cannot be included in horst and graben structures, but it consists of old still preserved volcanic centers. They are aligned along NW-SE and N-S trends.

CONTERMINOUS UNITS

a) Coastal plains

In this unit the coastal plains, connected with the transcurrent opening of the Gulf of California and with the evolution of the divergent Atlantic margin of the Gulf of Mexico, were included.

b) Intermontane Plains

These plains consist of alluvial and lacustrine basins, filling sinorogenic tectonic depressions of Sierra Madre Oriental and Sierra Madre del Sur.

From the structural point of view, they are generally placed on huge sinclinoria and on regional fold axis saddles. Their average height ranges from 900 to 1 200 m a.s.l.

c) Cordilleran orogenic belts

In this unit Sierra Madre Occidental and Sierra Madre del Sur orogenic belts, forming the Pacific Cordilleran system outcropping in western Mexico, were included. This unit is on the whole characterized by a long morphogenetic evolution and shows a strong erosional dissection.

The areal distribution of the Cordilleran units results to be scattered because of the presence of the wide Oligo-Miocene volcanic cover of Sierra Madre Occidental and of a strong tensional dismembering. Therefore, also inside the central part of the MVB, horsts composed by the orogenic basement of Sierra Madre Occidental outcrop near León and Zitácuaro.

d) Sierra Madre Oriental folded belt

Sierra Madre Oriental is a folded and emblicated foreland mainly composed of Mesozoic carbonatic rocks, forming Eastern Mexico orographic framework. The morphology of this belt is characterized by the great longitudinal development of basins and ridges, extending in NW-SE direction and crossed by NE-SW probably transcurrent fault systems.

In the extreme eastern part of the MVB, Sierra Madre Oriental ridges emerge from the volcanic plateau near Orizaba.

e) Sierra Madre Occidental volcanic plateau

This unit includes the thick Oligo-Miocene volcanic and volcanoclastic sequences which cover extensively the previously described orogenic belts.

Single volcanic landforms were recognized only in a few cases. However the general morpho-structural framework is typical of lava-flows and volcanoclastic plateau sequences, strongly dissected by normal erosion.

f) Sierra Madre Occidental tectonic depressions

The Oligo-Miocene volcanic sequences of Sierra Madre Occidental are dissected by N-S tectonic depressions filled up by late Miocene lavas and tephra (Pasquare and Zanchi, 1985). These depressions are coheval with the opening of the Protogulf of California (Colletta and Angelier, 1983), and are to be considered as a southern prosecution of Basin and Range province. They are locally reactivated in Quaternary times between Guadalajara and Durango.

g) Sierra Madre Occidental horsts

North of the MVB Sierra Madre Occidental volcanics show well developed horst structures, usually associated with previously described grabens (*f*). Strongly dissected units (1) were distinguished from well preserved ones, with still surviving structural surfaces (2). The dip of these surfaces is generally east-facing.

STRUCTURAL ANALYSIS

A simplified map including the whole investigated area is shown in Figure 2. The

structural provinces represented in the figure were recognized by the association of the previously described morpho-structural units.

Five structural provinces are recognizable in Central Mexico. Their evolution result to be tightly connected with the geological history of the southern part of the North-American Plate. In this chapter their areal distribution and mutual relationships are discussed and clarified focusing on MVB.

Basin and Range Province

The Basin and Range Province represents the southern end of the homologous unit of south-western U.S.A. It is characterized by N-S and NNE-SSW block-faulted structures developed within Sierra Madre Occidental volcanics.

The disjunctive tectonics is particularly developed in the Guadalajara-Durango area, while further east less intensively faulted structures give rise to Mexican Central Plateau.

North of Guadalajara the main phase of tectonic splitting was followed by an important volcanic phase during late Miocene (Watkins *et al.*, 1971; Gastil *et al.*, 1979; Pasquaré and Zanchi, 1985). Recent reactivation of the above mentioned structures causes the sinking of isolated grabens.

Californian Province

The southern part of Sierra Madre Occidental Cordilleran belt is largely intersected by NE-SW disjunctive fault systems, with minor transversal NE-SW fracture lineaments. The most deformed and collapsed part of this province is constituted by a graben system developed between Tepic and Colima. It contains the Pliocene and Quaternary volcanic centers representing the western sector of MVB.

These structures are clearly connected with the opening of the Gulf of California, activated since Pliocene (Colletta and Angelier, 1983).

MVB Central Province

The MVB central part develops as a continuous structural province, showing tectonic lineaments clearly distinguished from the conterminous ones.

This province is characterized by the presence of the Quaternary Chapala-Cuitzeo depression, bordered by rigid compartments forming the Tarascan and Guanajuato plateaus. The disjunctive lineaments show a rather complex pattern. In the Tarascan Plateau the main fracture systems follow NNW-SSE and NE-SW directions, while the Chapala-Cuitzeo depression is controlled by a very close system of WSW-ENE tensional faults. An impressively great amount of monogenetic volcanic centers, mainly Quaternary in age, is associated with the above-mentioned fracture lineaments.

North of the Chapala-Cuitzeo depression, the Guanajuato plateau shows an intermediate structural position with respect to Basin and Range Province. In this sector N-S lineaments probably related to Basin and Range structures are associated with small Quaternary MVB volcanic centers.

The MVB central province is bounded along its eastern side by a complex grid of faulted blocks, markedly extending in NNW-SSE direction, forming the Querétaro fracture zone. This important lineament, acting as a hinge between the MVB west-central sector and the eastern one, is here interpreted as the tectonic boundary between the Pacific Cordilleran system and Sierra Madre Oriental, buried under Tertiary and Quaternary volcanic sequences and reactivated until very recent times.

Sierra Madre Oriental province

The Sierra Madre Oriental belt represents a structural province dominated by a folded sedimentary Mesozoic sequence. It is characterized by a marked NW-SE trend.

The eastern part of MVB deeply intersects the Sierra folded structures, according to a WNW-ESE elongated shape. This trend probably corresponds to a huge tectonic depression in which Oligo-Miocene Sierra Madre Occidental volcanics accumulated (Mooser *et al.*, 1974).

The disjunctive tectonic lineaments controlling this sector during Quaternary are covered with a thick volcanic and volcanoclastic sequence forming the MVB eastern plateau. They seem to correspond to N-S and NNE-SSW fracture systems displayed by the alignment of the large stratovolcanoes present in this province. These fracture systems might represent Quaternary activation of typically N-S trending Basin and Range Province tensional structures, present further north in Sierra Madre Oriental belt (Córdoba *et al.*, 1980).

Sierra Madre del Sur province

Between the central-eastern part of MVB and Sierra Madre del Sur Cordilleran belt, a strongly collapsed sector develops. Its northern margin is characterized by the presence of huge depressions and tectonic collapses mainly according to NW-SE and NE-SW tensional faults, which sharply interrupt the development of MVB.

Southward the WNW-ESE Río Balsas fault system separates this collapsed sector from the Sierra Madre del Sur belt.

STRUCTURAL EVOLUTION

Oligo-Miocene

The first tensional movements recognized in the studied area may account for the formation of the tectonic depression developed within Sierra Madre Oriental, filled up by Oligo-Miocene volcanic sequences (Mooser *et al.*, 1974). These rocks, presently forming the basement of MVB eastern plateau may be considered as the extreme south-eastern sector of Sierra Madre Occidental volcanic sequences, on the basis of their similar characteristics and age.

The above mentioned stage may be considered coeval with the tensional movements linked with Oligo-Miocene Sierra Madre Occidental volcanic activity, which preceded the following extensional events connected to the Basin and Range Province (McDowell and Clabaugh, 1979).

Late Miocene

In late Miocene the Sierra Madre Occidental Oligo-Miocene volcanics were generally splitted in N-S and NNE-SSW faulted blocks. These horst and graben structures represent the southern prosecution of western U.S.A. Basin and Range Province.

During the same age the tectonic splitting was followed by an important volcanic activity in the Guadalajara-Durango area with partial filling of grabens (Pasquaré and Zanchi, 1985). During this phase the Mexican Central Plateau acted as a more stable block, although it split up in minor N-S trending tilted blocks.

Pliocene

Between late Miocene and early Pliocene the Gulf of California opened along NW-

SE trends. These lineaments entered the Sierra Madre Occidental southern sector, forming the Tepic-Guadalajara and Colima graben system.

During this phase MVB early volcanic activity began. In the western sector it was connected with the previously described graben system. In the central and eastern ones collected data do not allow to recognize yet the structures along which Pliocene MVB developed.

During Quaternary in the western MVB sector Pliocene structural setting still controls volcanic activity, especially in the Tepic-Guadalajara depression. In Colima graben N-S structures, probably connected with Basin and Range Province were reactivated. In the MVB central sector a new structural pattern develops. It consists of a bundle of WSW-ENE tilted blocks, forming together the Cuitzeo-Chapala depression. Tarascan and Guanajuato plateaus represent its highest steps. In Guanajuato plateau the presence of N-S fracture systems is probably connected with the reactivation of old Basin and Range structures.

Beyond the Querétaro fracture zone in the eastern sector N-S and NNE-SSW disjunctive lineaments dominate, controlling the development of the main central volcanoes of MVB.

In the same period the southern collapsed margin of MVB develops, according to NW-SE and NE-SW trending faults. Further south the activation of Río Balsas ENE-WSW fault system may have occurred contemporaneously.

CONCLUSIONS

The morpho-structural and structural analyses presented in this paper allowed to recognize the crustal structures conditioning the rise of magmas which gave origin to MVB. The evolution of these structures appear generally to be linked with conterminous structural provinces and shows a clear connection with the geological evolution of the regional units making up the North-American Plate.

As a consequence of this process MVB does not represent an homogeneous structural element but appears to be sharply divided in three main sectors.

The western part of the MVB is linked with the opening of the Gulf of California. The connection is shown by the Tepic-Guadalajara and Colima graben systems.

The central sector is characterized by ENE-WSW trending faults, and constitutes an autonomous structural province, whose geodynamical meaning is still unclear. The MVB central sector is separated from the eastern one by the Querétaro fracture zone, probably representing a recent reactivation of the buried boundary existing between Cordilleran orogenic belts and Sierra Madre Oriental folded foreland.

The eastern sector is entirely developed within Sierra Madre Oriental. The volcanic centers are conditioned by N-S and NNE-SSW tectonic lines, and lie enclosed in an Oligo-Miocene depression. The geodynamical meaning of these lineaments might be linked with a recent activation of Basin and Range structures, but the relationships with this structural province are not as clear as in the other sectors. In the whole this unit shows a lower structural control compared to the recent and close faulting affecting the other sectors. This different structural development is probably caused by the presence of the rigid basement of Sierra Madre Oriental under the eastern sector, while the MVB western and central areas are underlied by the intensively fractured Cordilleran belts.

Moreover, in these two sectors the clearly recognizable reactivation of late Miocene N-S trends belonging to Basin and Range structures demonstrates the important relationships existing between MVB and the evolution of the Cordilleran belts.

All the previously described structures are sharply interrupted by the Río Balsas fault system, probably representing an important shear zone connected with the Meso American trench-Sierra Madre del Sur convergent system.

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