MEXICAN VOLCANIC BELT

PART 1

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PREFACE

The Mexican Volcanic Belt (MVB) is a 20 - 70 km-broad structure which extends roughly east-west from Veracruz on the coast of Gulf of Mexico to near Puerto Vallarta in the west (Mooser, 1972). Its present location and tectonic setting are given in Fig. 1 (Atwater, 1970; Demant and Robin, 1975; López-Ramos and Sánchez-Mejorada, 1976). Worth noticing is the fact that although the MVB presumably belongs to the circum-Pacific volcanic chain, it is not parallel to the subduction zone (Middle America Trench, MAT) but makes an angle of about 20 degrees with it (Molnar and Sykes, 1969).

Alexander von Humboldt (Humboldt, 1808) provided the first scientific explanation for the alignment of volcanoes in the MVB. He proposed the existence of a crustal fracture disecting the continent along the 19th parallel from the Atlantic to the Pacific Ocean. The volcanic features of the Revillagigedo Islands in the Pacific, some 800 km to the west of the MVB (from Puerto Vallarta), were believed to belong to the same giant fracture. This pioneer hypothesis has been revived ever since with different kinds of modifications.

MVB is probably underlain by Precambrian and Paleozoic metamorphic rocks and Mesozoic igneous (granitic and granodioritic) intrusive bodies. Cretaceous sedimentary rocks also outcrop in some areas and have been encountered during drilling. Oligocene to Miocene rhyolitic and ignimbrite rocks of Sierra Madre Occidental (see Fig. 1) must also occur beneath the Mio-Pliocene to Recent volcanic rocks of the MVB province.

Plate tectonics is a unifying theory which combines surface geology with planetary evolution. In this broad concept, the MVB is a highly complex continental arc whose origin is presumably related to the subduction of the Cocos plate beneath the North American plate along the MAT (Fig. 1; see also Arwater, 1970; Handschumacher, 1976; Lynn and Lewis, 1976; Menard, 1978). Their convergence rate has been estimated as 6 to 7 cm a^{-1} (Minster and Jordan, 1978; Nixon, 1982). Towards the north of the Cocos plate, aseismic subduction of the Rivera plate also influences volcanism in the western portion of the MVB.

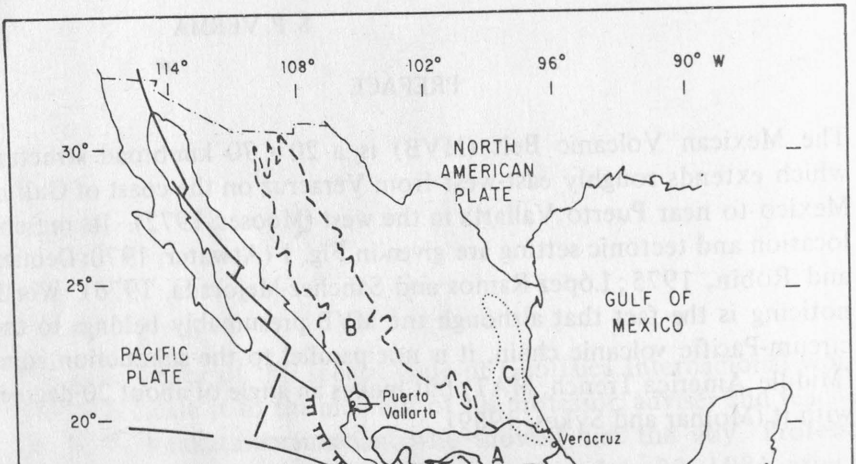

Fig. 1.- Location and tectonic setting of the Mexican Volcanic Belt (modified after Atwater, 1970; Mooser, 1972; Demant and Robin, 1975; López-Ramos and Sánchez-Mejorada, 1976).
A = Mexican Volcanic Belt; B = Sierra Madre Occidental;
C = Eastern Cordillera; EPR = East Pacific Rise;
MAT = Middle America Trench.

At present, a major complication arises because the Cocos plate is being subducted beneath the North American plate along the northwestern part of the trench and beneath the Caribbean plate in the southeast (see Figs. 1 and 2). Jordan (1975) has estimated the present-day motions of the Caribbean plate. He has found that this plate may actually be almost fixed in the hot spot reference frame. In this connection, Sykes *et al.* (1982) have shown that the relative motion between the North American and Caribbean plates is probably close to 4 cm a^{-1}.

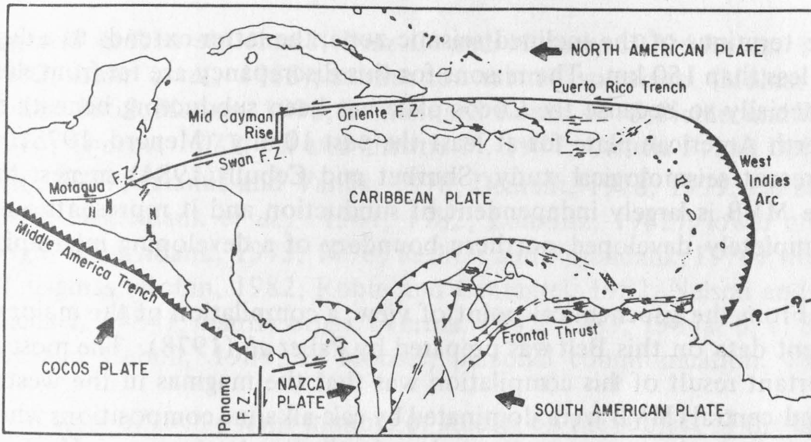

Fig. 2 - A simplified tectonic map of the Caribbean region showing plate boundaries and late Cenozoic tectonic features. Bold arrows give the direction of plate velocities with respect to the Caribbean (after Jordan, 1975).

Small- or large-scale fragmentations of the Cocos plate have been proposed by several workers (Stoiber and Carr, 1973; Isacks and Barazangi, 1977; Burbach *et al.*, 1984). For this plate, the seismic activity suggests a shallower mode of subduction in the north (corresponding to the MVB) than to the south (Central America; e.g. Molnar and Sykes, 1969). On the other hand, the existence of seismic gaps has been confirmed through relocation studies of large events by Singh *et al.* (1981). Thus, one important seismic gap - the Michoacan gap - may very well exist but its possible relation to the volcanism in the MVB is not known.

The results of driling near MAT (Glomar Challenger IPOD-DSDP Leg 66) by Moore *et al.* (1979) as well as those of magnetic (Karig *et al.*, 1978) and seismic reflection (Shipley *et al.*, 1980) studies indicate that the Mesozoic to Precambrian basement approaches within 35 km of the trench axis and this limits the width and the volume of the off-scraped material. However, it appears that part of the continental margin has in some way been removed during the process of subduction (Karig *et al.*, 1978).

Nixon (1982) makes a very intriguing observation that the majority of volcanoes making up the MVB are located more than 50 km beyond the terminus of the inclined seismic zone; the latter extends to a depth of less than 150 km. The reasons for this discrepancy are far from clear, especially so because the Cocos plate has been subducting beneath the North American plate for at least the past 10 m.y. (Menard, 1978). In a recent seismological study, Shurbet and Cebull (1984) suggest that the MVB is largely independent of subduction and it represents an incompletely developed northern boundary of a developing micro-plate.

From the geochemical point of view, a compilation of the major element data on this Belt was prepared by Pal *et al.* (1978). The most important result of this compilation was that the magmas in the western (and central) MVB were dominated by calc-alkaline compositions whereas those in the eastern part were largely alkaline in character. However, in the light of the presently available data, the picture is not that simple. Another compilation is very much desirable and is, in fact, underway at present (Aguilar-y-Vargas, B. Eng. Thesis, in preparation). There are several studies involving trace elements, but not many attempts (such as Verma, 1984a) to use these data quantitatively for testing petrogenetic models.

The studies of radiogenic isotopes ($^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, etc.) in the MVB are very scanty (Whitford and Bloomfield, 1976; Moorbath *et al.*, 1978; Cantagrel and Robin, 1978; Carmichael and DePaolo, 1980; Verma, 1981a, b, 1982, 1983; Reid, 1983). The available isotopic data seems to be compatible with the derivation of the magmas in the studied areas of the MVB from the upper mantle with rather small contribution from an altered oceanic crust, subducted sediments or sialic continental crust.

K-Ar dates have been obtained by several workers (e.g., Watkins *et al.*, 1971; Steele, 1971; Cantagrel and Robin, 1979; Mahood and Drake, 1982; Ferriz and Mahood, 1984). It appears that most volcanic centers are associated with rather young dates (generally less than 1 m.y.) but the history of this volcanic province should be traced back to at least several million years.

The present hypotheses for the origin of the MVB are many and quite diverse: fracture-models (Humboldt, 1808; Mooser and Maldonado, 1961; Mooser, 1969); extension of the East Pacific Rise (Mooser *et al.*, 1970 cited in Mooser, 1972); ancient zone of weakness (Mooser, 1972); strike-slip displacement (Gastil and Jensky, 1973); local rifting and graben structures (Díaz C. and Mooser, 1972; Robin, 1976, 1982; Luhr *et al.*, 1985); subduction related volcanism (Molnar and Sykes, 1969; Mooser, 1972; Demant and Robin, 1975; Pichler and Weyl, 1976; Thorpe, 1977; Pal and Urrutia F., 1977; Urrutia F. and Del Castillo, 1977; (Hanuš and Vaněk, 1978; Demant, 1978, 1979; Pal *et al.*, 1978; Negendank *et al.*, 1981, 1982; Lomnitz, 1982); lower crustal origin (Negendank, 1973, 1976; Richter and Negendank, 1976); mixing of magmas (Robin, 1982; Robin and Cantagrel, 1982; Nelson and Carmichael, 1984); mantle origin (Verma, 1982; 1983, 1984a, b, c; Shurbet and Cebull, 1984; F. Mooser, personal communication, 1984).

In spite of such a large number of studies on the subject of the MVB, we still lack an adequate knowledge of many of its important aspects, problems and solutions. Further, a large population of Mexico lives here as many important cities are located in the MVB (Mexico, Guadalajara, Puebla, Toluca, Querétaro, Pachuca, Cuernavaca, Veracruz, Colima and so on). Thus, there exist innumerable problems associated with this densely populated area. Finally, this volcanic Province is also very important from geothermal and economic-mineral points of view. Therefore, a systematic effort is very much needed: one possibility could be to start with a compilation of the present thoughts and prospects by bringing together all the interested members of the scientific community in order to analyze the local, regional or global problems.

THIS SPECIAL ISSUE

This issue presents the first part of a collection of original papers concerned with different aspects of the MVB. It contains a total of nine papers written by eighteen authors from ten different institutions. Three of them are written in Spanish whereas the others are in English. Although these papers deal with a wide variety of topics and cover different areas of North American and Cocos plates, all of them are related to scientific problems of the MVB. We hope that this series of special issues of the Journal will give us a better perspective of problems and prospects of this important, Circum-Pacific, presumably continental volcanic-arc Province.

In the first paper, Allan reports the results of a gravity survey carried out within the northern part of the Colima graben. The modeling of the data indicates a sediment depth of about 900 m and a vertical offset of about 2.5 km within this graben. These results have important bearing on the tectonics of the western MVB.

In the second paper, Verma, López-Martínez and Terrell present a geochemical study of Miocene, calc-alkaline, basaltic to andesitic flows from north-east Jalisco to show that the volcanic activity in the MVB province should not be limited to Plio-Quaternary but be taken back to at least 11 Ma. They also present Sr isotope data to support a sub-crustal origin for these magmas.

The third paper by Venegas S., Herrera F. and Maciel F. (in Spanish) gives an account of the relationship of regional geology with geothermal resources. They present a compilation of K-Ar dates in the MVB. Their final considerations in this paper are concerned with the existing, better explored, potentially geothermal areas of the Belt.

In the fourth paper, Lugo Hubp, Ortiz Pérez, Palacio Prieto and Bocco Verdinelli (also in Spanish) use the existing geologic maps of the central part of the MVB to derive a kind of spatial frequency-distribution of volcanic cones in the region and delineate the areas with different levels of concentration of these cones and point out their implications in terms of future volcanic activity and risk.

The fifth paper by Ferriz (also written in Spanish) gives a detailed account of the geochemistry and mineralogy of Los Humeros caldera - a geothermally important silicic volcanic center. From the mineral associations and their abundance in the different rock types studied. he concludes that there existed a chemical zonation as well as thermal and volatile-compositional gradients in the subsurface magma chamber.

The sixth paper is by Steele and concerns with the volcanic history of Iztaccihuatl in central MVB. He uses the normal magnetic polarity encountered in all lava flows studied, to put a maximum age constraint on them and supports his interpretation from recent K-Ar dating. The author then discusses his paleomagnetic data in terms of models for the secular variations of the magnetic field.

In the seventh paper, Gilbert, Mahood and Carmichael present an excellent account of the volcanic stratigraphy of the Guadalajara area (Jalisco). They report new data on K-Ar dates which go back to about 8

Ma. They combine their age data with the geology and geochemistry of the area to point out how the volcanic activity has migrated within the studied area from one point to the other.

In the eight paper, Sandoval Ochoa presents a brief review of some of the published papers on the continental margin in southern Mexico and proposes the existence of a N 17^{O} E trending fault that runs from the inner slope of the MAT to the MVB. This work is an excellent example of combining land and marine features into one single working hypothesis.

The last paper by Luhr and Carmichael reports an extremely interesting and unique observation of contemporaneous eruption of both alkali and calc-alkaline magmas at two different locations in western and central MVB and point out that this observation can not be easily reconciled with the general models for subduction-related volcanic arcs.

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