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TECTONIC FRAMEWORK OF SOUTHERN MEXICO AND ITS BEARING ON THE PROBLEM OF CONTINENTAL DRIFT *

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RESUMEN

La parte meridional de México incluye toda la República al sur de la Zona Volcánica Transmexicana (19° y 20° N), junto con la Península de Yucatán. En esta región la Faja Tectónica Huasteca paleozoica (=Apalachiana=Ouachitana) está unida desde el norte al segmento oaxaqueño del hedreocratón norteamericano del Precámbrico. Las rocas y estructuras dentro de la parte miogeosincilnal de esta faja tectónica están sepultadas por la Sierra Madre Oriental, que constituye la parte frontal miogeosinclinal de la Faja Tectónica Mexicana (=Cordillerana=Laramiana), y su parte eugeosinclinal por los depósitos cenozoicos de la Planicie Costera del Golfo y de la Península de Yucatán. La Faja Tectónica Huasteca rodea al Golfo de México actual y aquí la Sierra Madre Oriental está paralela a ella, siendo ambos arcos cóncavos hacia el norte.

El terreno siálico metamórfico precámbrico de Oaxaca y las rocas muy semejantes al del pre-Carbonífero de la región al oriente del Istmo de Tehuantepec, se extienden hacia el sur, hasta la costa actual del Pacífico donde están en contacto con la corteza oceánica máfica.

Al poniente de Acapulco (100° W), las rocas verdes mesozoicas pre-albianas (Cretácico Inferior) así como toda la secuencia sedimentaria albiana-paleocénica (partes eugeosinclinal y miogeosinclinal de la Faja Tectónica Mexicana, respectivamente) junto con sus estructuras, principalmente pliegues formados durante la Orogenia Hidalguense (Eoceno temprano), siguen un rumbo directamente al Pacífico.

Esta yuxtaposición anómala y abrupta de las rocas y sus estructuras con la corteza océanica a lo largo del segmento mexicano de la Fosa México-Mesoamericana puede explicarse sólo por medio de un fallamiento de gran escala que permitió recortar el extremo meridional del Continente Norteamericano.

Datos geológicos regionales sugieren la posibilidad de considerar aquellas rocas que constituyen la Península de Nicoya (Costa Rica) como las más cercanas que forman la continuación suroriental de la parte eugeosinclinal de la Faja Tectónica Mexicana. Datos geológicos locales de México permiten solamente la consiedración de un fallamiento posterior al Eoceno temprano o, más probablemente, posterior al Mioceno medio. Este fallamiento, tanto lateral como vertical, constituyó una parte del sistema de fracturamiento

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centroamericano que fue originado por los movimientos diferenciales entre Norte y Sud América, durante su proceso de invasión o cabalgamiento sobre la Cuenca del Pacífico.

ABSTRACT

Southern Mexico includes all of the Republic south of the Trans-Mexico Volcanic Belt (19° and 20° N), together with the Yucatan Peninsula. In this region the Paleozoic Huastecan Structural Belt (=Appalachian=Ouachitan) is welded to the Oaxaca segment of the Precambrian North American hedreocraton from the north. The rocks and structures in the miogeosynclinal portion of this structural belt are concealed by the Sierra Madre Oriental, which is the miogeosynclinal frontal portion of the Mexican Structural Belt (=Cordilleran=Laramide), and the eugeosynclinal portion by the Cenozoic deposits of the Gulf Coastal Plain and the Yucatan Peninsula. The Huastecan Structural Belt curves around the present Gulf of Mexico and the Sierra Madre Oriental parallels it, being both arcs concave to the north.

The sialic Precambrian metamorphic terrain of Oaxaca and the very similar metamorphic rocks of pre-Carboniferous age to the east of the Isthmus of Tehuantepec extend southward to the present Pacific coast where they are in contact with a mafic oceanic crust.

Westward from Acapulco (100° W), the pre-Albian (Lower Cretaceous) Mesozoic greenstones as well as all Albian-Paleocene sediments (eugeosynclinal and miogeosynclinal portions of the Mexican Structural Belt respectively) and their structures, chiefly folds resulting from the Hidalgoan Orogeny (early Eocene), run right into the Pacific.

This abrupt and anomalous juxtaposition of the rock sequences and their structures with the oceanic crust along the Mexican segment of the Mexico-Mesoamerica Trench can only be explained by large-scale faulting that permitted the chopping off this southern extreme of the North American Continent.

Regional geologic evidence suggests the possibility of considering the rocks making up the Nicoya Península of Costa Rica, to be the closest southeastward continuation of the eugeosynclinal portion of the Mexican Structural Belt. Local geologic evidence from Mexico permits only the consideration of post-early Eocene and more probably post-middle Miocene faulting. This faulting, both transcurrent and vertical, no doubt formed an integral part of the Central American fracture system that resulted from the differential movements between North and South America during their encroaching process on the Pacific Basin.

INTRODUCTION

One of the basic aims of a geological investigation is the deciphering of the events through which a region or a continent underwent during its geological evolution. The present tectonic make-up of a region provides the answer as to its actual structure, but also poses innumerable questions as to the nature and timing of the past geological events. A final answer cannot be given at once, and even successive answers at consecutive times can only provide a progress report.

The writer has pointed out very discretely more than 15 years ago (De Cserna, 1951) the possibility that continental drift is responsible for the present abrupt structure of Mexico along its Pacific coast, and to his knowledge, this was the first published statement on the subject.

During successive years, geotectonic research, based on field mapping by the writer and his associates of critical areas, on geological field examination of already studied localities, and on reevaluation and compilation of published and unpublished data have led the writer to develop his views on the tectonic evolution of Mexico (De Cserna, 1958, 1950 and 1961). Needless to state

that the theory of continental growth as proposed by Stille (1941), Wilson (1951), and Kay (1951) is thoroughly supported by the Mexican geological evidence.

At present, the writer considers the painting of the gross picture to be concluded insofar as the recognition and depicting of various structural belts that make up Mexico are concerned. Now, a tremendous amount of good quality detailed work is needed to refine the picture with fine and delicate details through detailed geological mapping and related stratigraphic, structural and geochronologic studies.

While the local story is already presented, the writer feels that it is due time to make one step farther and an attempt to relate the continental structure of Mexico to the adjacent ocean basins and land areas. The abundance of geologic data from the southern United States already allowed the establishing of geologic continuity between Mexico and the United States which will be well displayed in many aspects by the masterly compilation of P. B. King on the Tectonic Map of North America. Toward the south, only in recent years are becoming available excellent geologic information on critical areas. Thus, timing is excellent for a first attempt to make such regional considerations.

In the following pages, geological facts will be presented together with their regional interpretation, primarily to show major lateral discontinuities in the geology between southern Mexico and adjacent areas. These discontinuities and offsets certainly call for extensive faulting which are, with all probability, related to continental drift.

STRUCTURAL BELTS OF SOUTHERN MEXICO

The geotectonic make-up of southern Mexico has been discussed previously by the writer (De Cserna, 1958 and 1960). More recently, the concept of "morphotectonic provinces" of Harrington (1956) has been applied with considerable success for discussing the tectonic history of Mexico (Guzman and De Cserna, 1963). Thus, in this paper the previously adopted schemes will be followed primarily to facilitate the integration of the data already published. However, while in previous publications the Precambrian areas and events in Mexico were hardly touched upon, in this paper this important geological feature will also be treated, eventhough briefly.

OAXACAN STRUCTURAL BELT.—A terrain of metamorphic rocks, made up chiefly of gneiss, schist and cipolin marble with related granitic plutons and pegmatites, is clearly recognizable in southern Mexico, east of the 100° W meridian (Figure 1). Several radiometric age determinations gave a Grenville age (900± — 1,100± m. y.) for these metamorphic rocks (Fries *et al.*, 1962; Fries and Rincon-Orta, 1965).

Precambrian age of these rocks has been recently corroborated with the discovery of lower Paleozoic fossiliferous nearshore sediments (Ing. J. Pantoja-Alor, personal communication; Pantoja-Alor and Robinson, 1967).

The structural belt, as a whole, has been studied very little. The scattered information available indicates, however, that the general trend of foliation is roughly N-S and, accordingly had been depicted on the Tectonic Map of

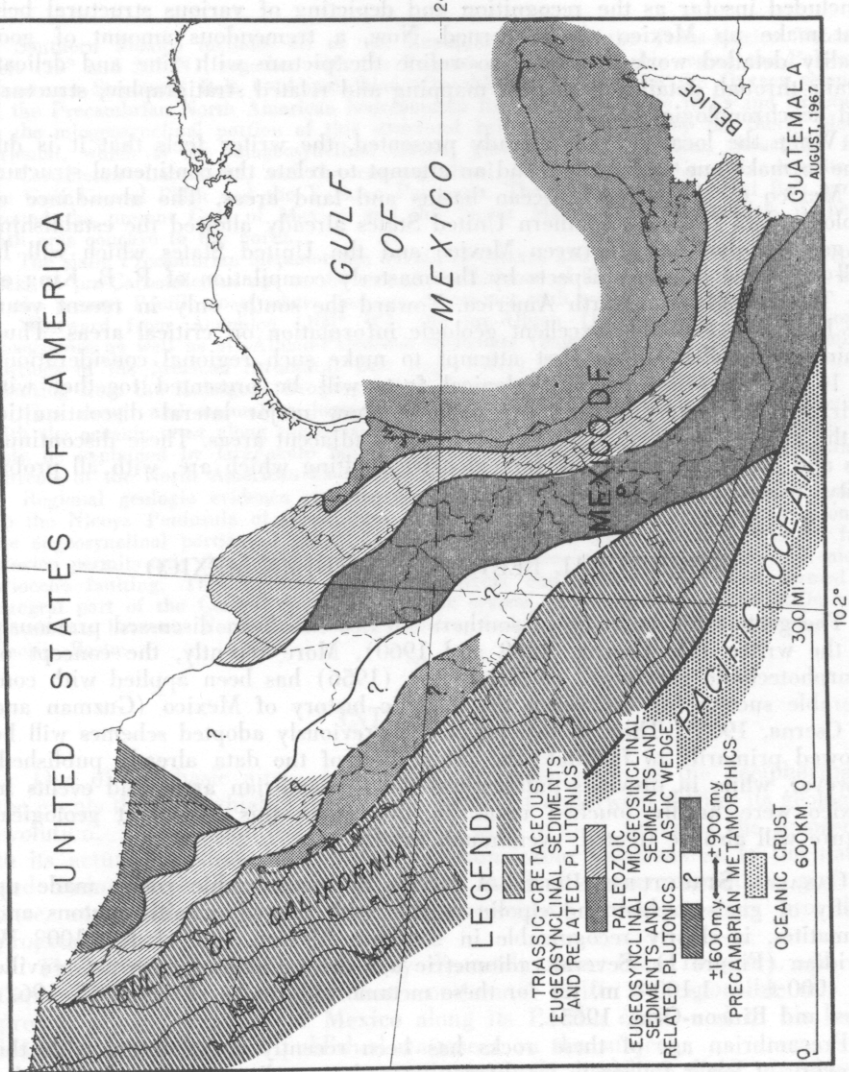

FIG. 1.—Map of Mexico, showing the location of Precambrian-Mesozoic structural belts.

Mexico (De Cserna, 1961). The structures on the south run right into the Pacific Ocean between the 100° W meridian and the Isthmus of Tehuantepec, whereas east of that point, they acquire a NW-SE trend. Toward the north, the metamorphic rocks can the traced into northern and northeastern Mexico, where they were dated as Precambrian, both stratigraphically and geochemically (Fries *et al.*, 1962). On the basis of chronologic and petrologic similarity, Fries proposed a common geotectonic origin for these rocks by considering them to be the results of the Oaxacan Orogeny (*i. e.* the metamorphism). The writer recently applied the term Oaxacan Structural Belt to this feature, which extends from the southeast Pacific coast of Mexico northwestward into northeast Mexico (Figure 1; De Cserna in press).

HUASTECAN STRUCTURAL BELT.—There is a belt of discontinuous outcrops in east-central and southeastern Mexico in which lower Paleozoic near-shore and upper Paleozoic flysch sediments crop out. These sedimentary rocks rest on Precambrian metamorphics against which they are strongly folded. These rocks constitute the miogeosynclinal portion and subsequent clastic wedge of the Paleozoic Huastecan Structural Belt (De Cserna. 1960).

Metamorphic and associated plutonic and volcanic rocks have been encountered in some wells drilled by Petroleos Mexicanos in the Yucatan Peninsula (Ing. E. J. Guzmán, personal communication), beneath the Mesozoic sequence. In the opinion of the author, these rocks were formed in the eugeosynclinal portion of the Huastecan Structural Belt whose presence was suggested or prognosticated carlier by the writer (De Cserna. 1960).

Rocks belonging to this structural belt extend into northeastern Mexico as well as into Guatemala and Belice.

JALISCOAN STRUCTURAL BELT.—In southern Mexico, a structural belt was coined after the State of Jalisco, which extends south to the Pacific Coast, is represented very poorly. There are plutonic rocks and associated metamorphics west of the port of Manzanillo (104° W), which have been dated radiometrically as middle Paleozoic. In an earlier paper (De Cserna, 1960) as well as on the Tectonic Map of Mexico(De Cserna, 1961), the writer has considered the metamorphic rocks in southern Mexico that surround the well-dated Precambrian areas in the State of Oaxaca and extend eastward into Guatemala, to be of similar origin to those rocks that outcrop west of Manzanillo. At present, the writer abandons this carlier interpretation and restricts the plutonic and associated metamorphic rocks west of Manzanillo to be part of the Jaliscoan Structural Belt. This radical change in the interpretation of the geotectonic situating of the terrains resulted from the mapping and examining critical areas by the writer during the past years.

Indeed, the rocks that outcrop in the State of Jalisco, in southwest Mexico, beneath the Lower Cretaceous limestone sequence, are Mesozoic metavolcanic rocks which might, here and there, include small areas of Paleozoics not mapped-out yet in detail.

MEXICAN STRUCTURAL BELT.—Superimposed over practically the entire terrritory of Mexico, one can observe the rocks and the structure that make up the Mexican Structural Belt (De Cserna, 1960). On Figure 1, only the eugeosyn-

clinal portion of the Mexican Structural Belt is shown due to the fact that its miogeosynclinal portion together with the Upper Cretaceous-Paleocene clastic wedge can be encountered practically everywhere in the country. For geotectonic purposes, the eugeosynclinal portion of this structural belt has the outmost significance, in the opinion of the writer, for the deciphering of the tectonic make-up of southern Mexico and adjacent land areas.

The rocks that underlie the fossiliferous Lower Cretaceous (Albian) or Upper Jurassic (Kimmeridgian-Portlandian) facies transitional into the miogeosyncline, consist of black slates, graywackes, lenses of marble, meta-andesites and pillow lavas (Plate 1, fig. 1), and some metarhyolites some of which yielded belemnites indicative to a Late Jurassic age. Included in this sequence are abundant dunite, periodotite and serpentinite with associated asbestos deposits. The entire sequence was very severely deformed during early Eocene time and has a NW-SE general trend which is oblique to the present Pacific coast-line in such a way that the structures run right into the Pacific Ocean (Plate 1, fig. 2). These rocks together with the Upper Cretaceous flysch sediments are intruded by huge stocks of granite or quartz monzonite. These stocks have been dated radiometrically to be of medial Cretaceous age (± 100 m. y.) and are distributed roughly parallel to the present Pacific coast of Mexico (De Cserna, 1960; 1965).

OTHER MAJOR GEOTECTONIC UNITS OF SOUTHERN MEXICO

Aside from the briefly described structural belts, there are two important major geotectonic units in southern Mexico which are the Trans-Mexico Volcanic Belt and the Mexican segment of the Mexico-Mesoamerica Trench.

TRANS-MEXICO VOLCANIC BELT.—There is a belt of Plio-Pleistocene, chiefly rhyodacite olivine basalt volcanic complexes that traverse Mexico in an E-W direction, roughly between latitudes 18° and 20° N (Figure 2). These volcanic complexes constitute the highest elevations of the country and their belt-like distribution was noted by Alexander von Humboldt, more than a century ago.

During the last fifteen years, various authors attempted to relate the Trans-México Volcanic Belt to the Clarion Fracture Zone of Menard (1955). However, to date, no one has presented evidence, based on detailed geologic mapping, that would relate or support such interpretation on realistic grounds. On the other hand, the relationship between this volcanic belt and the Mexico-Mesoamerica Trench was proposed some time ago (Guzmán and De Cserna, 1963; De Cserna, 1965).

MEXICO-MESOAMERICA TRENCH.—This important feature of the Pacific Ocean floor has been studied by various investigators and the most recent account on the subject was presented by Fischer (1961). The trench extends east-southeastward from the 106° W meridian and parallels, more or less, the south coast of Mexico, and then swings in a more southerly direction to terminate in the vicinity of the Nicoya Peninsula of Costa Rica.

Between this trench and the actual Pacific Coast, in 1926 Vening-Meinesz (1948) found a belt of negative gravity anomalies.

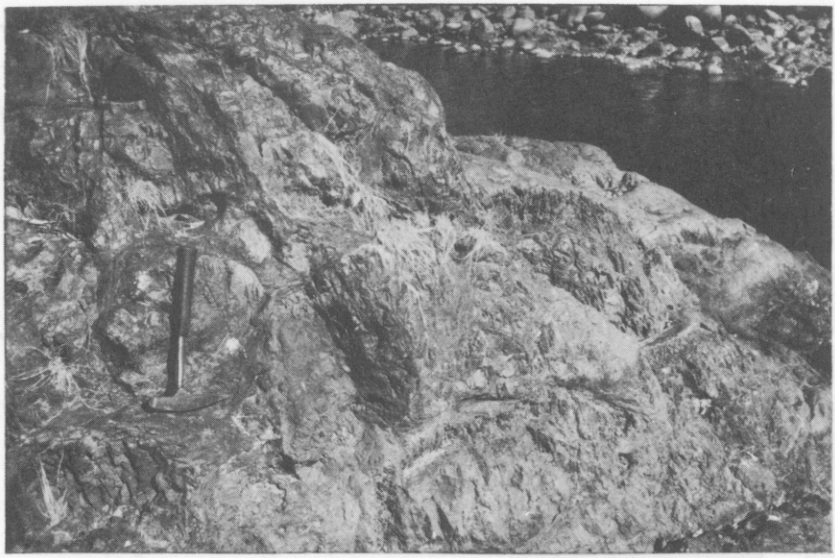

Fig. 1.—Outcrop of basaltic pillow lava in the vicinity of Tecpan, west of Acapulco.

Fig. 2.—View due east of the Pacific coast, in the vicinity of Zihuatanejo, west of Acapulco. Note abrupt termination of roughly N-S trending structure against the sea.

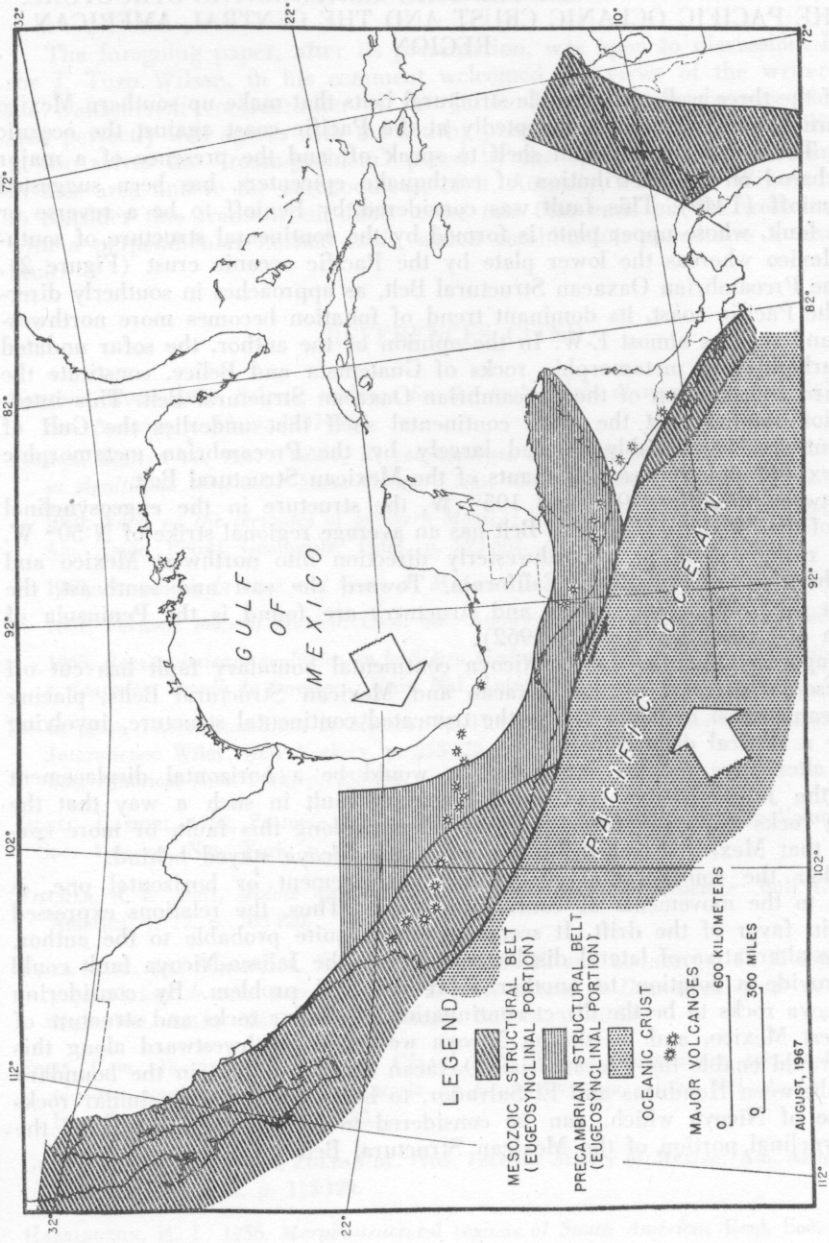

FIG. 2.—Map of Mexico and the Central American region, showing the Precambrian and Mesozoic structural belts that are recognized in Mexico and their continuation into Central America.

INTERRELATION OF THE MEXICAN CONTINENTAL STRUCTURE, THE PACIFIC OCEANIC CRUST AND THE CENTRAL AMERICAN REGION

Of the three well-recognizable structural belts that make up southern Mexico (Figure 1), two terminate abruptedly at the Pacific coast against the oceanic crust. There is no continental shelf to speak of, and the presence of a major fault based on the distribution of earthquake epicenters, has been suggested by Benioff (1949). This fault was considered by Benioff to be a reverse or thrust fault, whose upper plate is formed by the continental structure of southern Mexico whereas the lower plate by the Pacific oceanic crust (Figure 2).

The Precambrian Oaxacan Structural Belt, as approaches in southerly direction the Pacific coast, its dominant trend of foliation becomes more northwesterly and reaches almost E-W. In the opinion of the author, the sofar undated pre-Carboniferous metamorphic rocks of Guatemala and Belice, constitute the eastward continuation of the Precambrian Oaxacan Structural Belt. This interpretation implies that the small continental shelf that underlies the Gulf of Tehuantepec, is probably formed largely by the Precambrian metamorphic complex and superimposed remnants of the Mexican Structural Belt.

Between meridians 99° and 105° W, the structure in the eugeosynclinal rocks of the Mexican Structural Belt has an average regional strike of N 50° W. These rocks extend in a northwesterly direction into northwest Mexico and into the Peninsula of Baja California. Toward the east and southeast, the nearest area where such rocks and structures are found is the Peninsula of Nicoya of Costa Rica (Dengo, 1962).

It appears, that the Jalisco-Nicoya continental boundary fault has cut off a sinusoidal segment of the Oaxacan and Mexican Structural Belts, placing the oceanic crust in contact with the truncated continental structure, involving largely a vertical displacement.

An alternative to this interpretation would be a horizontal displacement along the Jalisco-Nicoya continental boundary fault in such a way that the Nicoya rocks slid away from southwest Mexico along this fault, or more correctly, that Mexico travelled farther west and Nicoya stayed behind.

Either the consideration of vertical displacement or horizontal one, is related to the movements of continental blocks. Thus, the relations expressed speak in favor of the drift. It seems, however, quite probable to the author, that the alternative of lateral displacement along the Jalisco-Nicoya fault could also provide a solution to another sofar unsolved problem. By considering the Nicoya rocks to be the direct continuation of similar rocks and structure of southwest Mexico, and by sliding Nicoya west and northwestward along this fault, would enable the Precambrian Oaxacan Structural Belt in the boundary region between Honduras and El Salvador, to be in contact with similar rocks to those of Nicoya which, can be considered to be the continuation of the eugeosynclinal portion of the Mexican Structural Belt.

CONCLUDING REMARKS

The foregoing paper, after its presentation, was open to discussion. Professor J. Tuzo Wilson, in his comment welcomed the views of the writer as to the transcurrent consideration of the Jalisco-Nicoya Fault, because this, not only perfectly well agrees with the nearby presence of the East Pacific Rise, but it also solves the "room-problem" posed by the spreading of the ocean floor in that area and to the east-southeast of it. Actually, Professor Wilson inclines to consider this transcurrent fault to be one that ends on the west-northwest with a perpendicular normal fault, which combination constitutes a transform fault.

REFERENCES CITED

BENIOFF, HUGO, 1949. *Seismic evidence for the fault origin of oceanic deeps:* Bull. Geol. Soc. America, v. 60, p. 1837-1856.

CSERNA, ZOLTAN DE, 1951 (1953), *El conocimiento actual de la plataforma continental y su significado tectónico:* Mem. Congr. Cient. Mexicano, D. F., v. 3, p. 9-22.

— 1958. *Notes on the tectonics of southern Mexico:* in Habitat of oil; L. G. Weeks, editor. Am. Assoc. Petrol. Geologists, Tulsa, p. 523-532.

— 1960, *Orogenesis in time and space in Mexico:* Geol. Rundschau, v. 50, p. 595-605.

— 1061, *Tectonic map of Mexico:* Geol. Soc. America, New York, scale 1:2.500,000.

— 1965, *Reconocimiento geológico en la Sierra Madre del Sur de México, entre Chilpancingo y Acapulco, Estado de Guerrero:* Univ. Nal. Autón. México, Inst. Geología, Bol. 62, 76 p.

— in press, *The Precambrian of Mexico:* in The Precambrian; Kalervo Rankama, editor. Interscience Wiley, New York, v. p. 253-270.
Soc. America, New York, p. 133-161.

DENGO, GABRIEL, 1962, *Tectonic-igneous sequence in Costa Rica:* Buddington Volume, Geol. Soc. America, New York, p. 133-161.

FISCHER, R. L .,1961, *Middle America Trench; Topography and structure:* Bull. Geol. Soc. America, v. 72, p. 703-720.

FRIES, CARL, JR., SCHMITTER, EDUARDO, DAMON, P. E. and LIVINGSTON, D. E. 1962. *Rocas precámbricas de edad grenvilliana de la parte central de Oaxaca en el sur de México:* Univ. Nal. Autón. México, Inst. Geología, Bol. 64, p. 45-53.

FRIES, CARL, JR. and RINCÓN-ORTA, CÉSAR, 1965. *Nuevas aportaciones geocronológicas y técnicas empleadas en el Laboratorio de Geocronometría:* Univ. Nal. Autón. México, Inst. Geología, Bol. 73, p. 57-133.

GUZMÁN, E. J. and CSERNA, ZOLTAN DE, 1963. *Tectonic history of Mexico:* Am. Assoc. Petrol. Geologists. Mem. 2, p. 113-129.

HARRINGTON, H. J., 1956. *Morphostructural regions of South America:* Geol. Soc. America, Mem. 65, p. xiii-xviii.

KAY, MARSHALL, 1951, *North American geosynclines:* Geol. Soc. America, Mem. 48, 143 p.

MENARD, H. W., 1955. *Deformation of the northeastern Pacific Basin and the west coast of North America:* Bull. Geol. Soc. America, v. 66, p. 1149-1198.

PANTOJA-ALOR, JERJES and ROBINSON, R. A., 1967. *Paleozoic sedimentary rocks in Oaxaca, Mexico:* Science, v. 157, no. 3792, p. 1033-1035.

STILLE, HANS, 1941. *Einführung in den Bau Amerikas:* Borntraeger, Berlín, 717 p.

VENING MEINESZ, F. A., 1948. *Gravity expeditoins at sea 1923-1938, v. 4:* Netherlands Geod. Comm., Delft, 233, p.

WILSON, J. T., 1951. *On the growth of continents:* Papers Proc. Roy. Soc. Tasmania, v. 85.