Offset across the Polochic fault of Guatemala and Chiapas, Mexico

Burke Burkart
Department of Geology, University of Texas at Arlington, Arlington, Texas 76019

ABSTRACT

Polochic fault is seen on LANDSAT imagery to continue its westward path from northwestern Guatemala across the Chiapas massif to the Pacific coastal plain. The fault has had 132 ± 5 km of left-lateral displacement that is recorded in the offset of Cenozoic fold and thrust belt structure and stratigraphy. The trace of the Polochic fault has been folded into what approximates a sinusoidal curve of about 130-km wave length and 7-km amplitude by an essentially east-west compressive stress. The curious similarity in displacement and fold wavelength results in a premovement reconstruction that reveals not only a match across the fault in geology, but an almost perfect fit of one block against the others. Some segments of the fault across which recorded slip took place are probably locked and not active. Strain has shifted to other shears in western Guatemala and Chiapas and to the Motagua fault. Parts of the Polochic and the newer shears may be alternating with the Motagua as the Caribbean-North American plate boundary. With the 132 km of slip removed, segments of the now fragmented Cenozoic fold belt can be brought into coincidence in a clear-cut arcuate trend that is convex southwest. The major fault displacement is believed to have occurred within the interval from middle Miocene to middle Pliocene time. Eastern Guatemala has undergone a counterclockwise rotation of about 25° that reoriented the fault trace and all other structural fabric from due east to the present east-northeast azimuth.

INTRODUCTION

The Polochic fault has been thought to be the boundary between the Caribbean and North American plates (Kesler, 1971; Muehlberger and Ritchie, 1975). The Polochic, which was initially described by Walper (1960), is placed by most writers in the company of two other prominent faults, the Motagua and the Jocotán. All three fault zones appear to enter the Caribbean on an east-northeast azimuth and have been interpreted to be associated with Cayman Trench structure. Hess and Maxwell (1953, Fig. 2) first inquired into the apparent left-lateral offset on Cayman Trench structures and implied that this offset might extend across Guatemala. A study of basement-rock relationships on either side of the Polochic led Kesler (1971) to suggest that not more than 150 km of left slip has occurred and that a more likely magnitude would be from 100 to 120 km.

POLOCHIC EXTENSION IN MEXICO

The Polochic fault is traceable from the Chixoy and Polochic valleys of north-central Guatemala across western Guatemala where it crosses the frontier as a westward extension of the Cuilco River segment of the Cuilco-Chixoy-Polochic fault of Kesler and others (1970; see Fig. 1). Although the fault has not been mapped in Mexico, LANDSAT imagery (Fig. 2) clearly shows that the fault continues in a westward direction into Mexico across the Chiapas massif on a roughly sinusoidal trend. It probably continues across the coastal plain into the Pacific. LANDSAT imagery also shows a myriad of essentially east-west shears across a zone at least as far north as the Chiapas-Oaxaca state boundary and as far south as the latitude of Volcán Tacaná (Fig. 2A). The shears run in a northwest-trending belt parallel to the coast. Stream offsets of about 1 km indicate left slip across these shears. The northern splay is a band of shears that appears relatively straight on LANDSAT imagery. This northern zone appears as a concentration of east-west faults across which there is an offset of drainage on the order of 1 or 2 km. The zone is younger than the main splay and very likely has never been a zone of major offset. This interpretation of Polochic fault structure differs from that of Muehlberger and Ritchie (1975, Fig. 1), who, working with Skylab IV orbital photographs, showed several faults that I suggest are not part of the fault system across which a major displacement occurred. Skylab photographs do not reveal the main splay, northern shear zone, or broad zone of shears discussed above.

Lopez-Ramos's (1975) geologic map of Chiapas, Mexico, shows a band of Paleozoic metamorphic rocks that terminates about 7 km southeast of Mapastepec, Chiapas (Fig. 1). At this same location the contact between Quaternary sediments and igneous rocks turns abruptly from its general trend parallel to the coast to a west trend. These two geologic discontinuities coincide with the extension of the main splay as described above.

ACTIVITY OF THE MAJOR FAULTS

The Jocotán fault is not active as is shown by crosscutting graben structures (Clemons, 1966; Muehlberger and Ritchie, 1975). The Motagua fault definitely has left-slip activity, as was demonstrated by the February 4, 1976, earthquake (Plafker, 1976). The case for activity on the Polochic fault is not so clear,

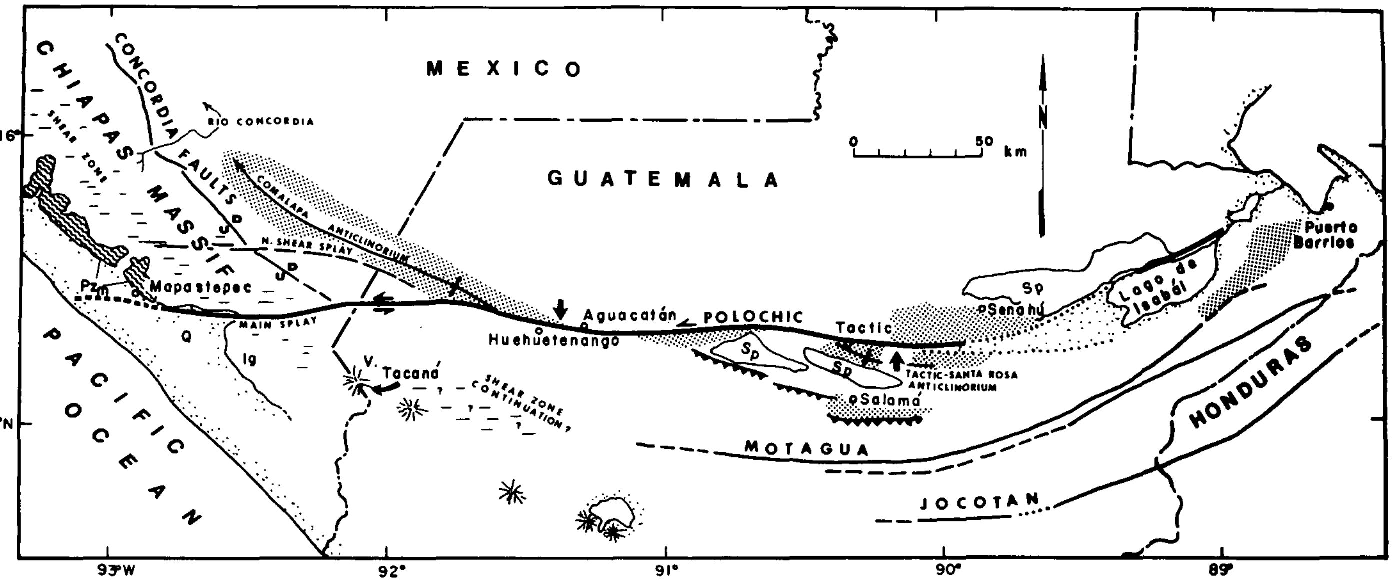

Figure 1. Map of western Guatemala and southern Chiapas showing trace of Polochic fault and its relationship to exposed Paleozoic sedimentary core (shaded) of fold belt of northern Guatemala. Arrows indicate match-up points on reconstruction shown in Figure 3. Concordia faults are probably correlative with reverse faults near Salamá on the southern block.

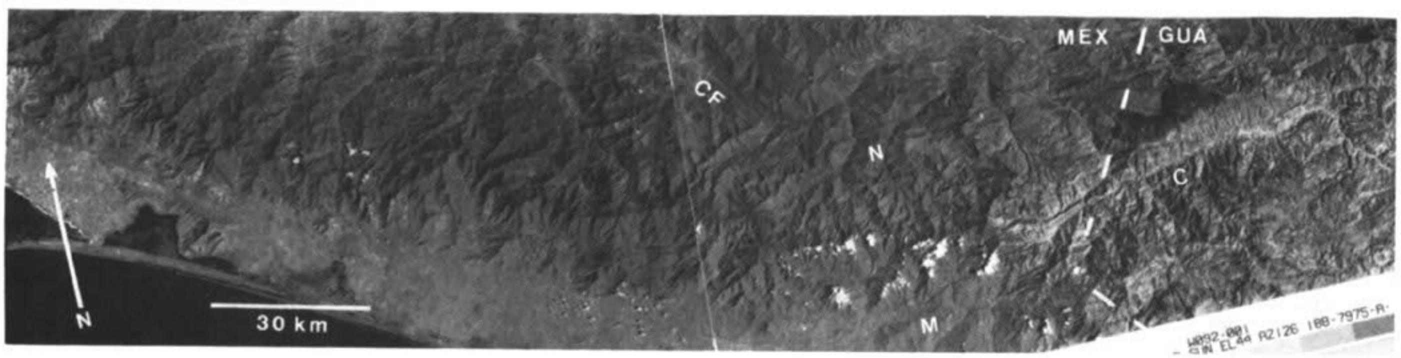

Figure 2A. LANDSAT imagery of western extension of Polochic fault across western Guatemala and southern Chiapas. Southern part of Concordia faults is labeled CF. Older main splay M extends from Cuilco segment C to coastal plain. Northern shear splay N offsets river left laterally near frontier. East-west shears are pervasive as far north along coast as Chiapas-Oaxaca boundary. Scan lines, which are also almost east-west, are particularly strong in these images. Mosaic of two ERTS images, Nos. E-1572-15561 (on east) and E-2317-15524 (on west).

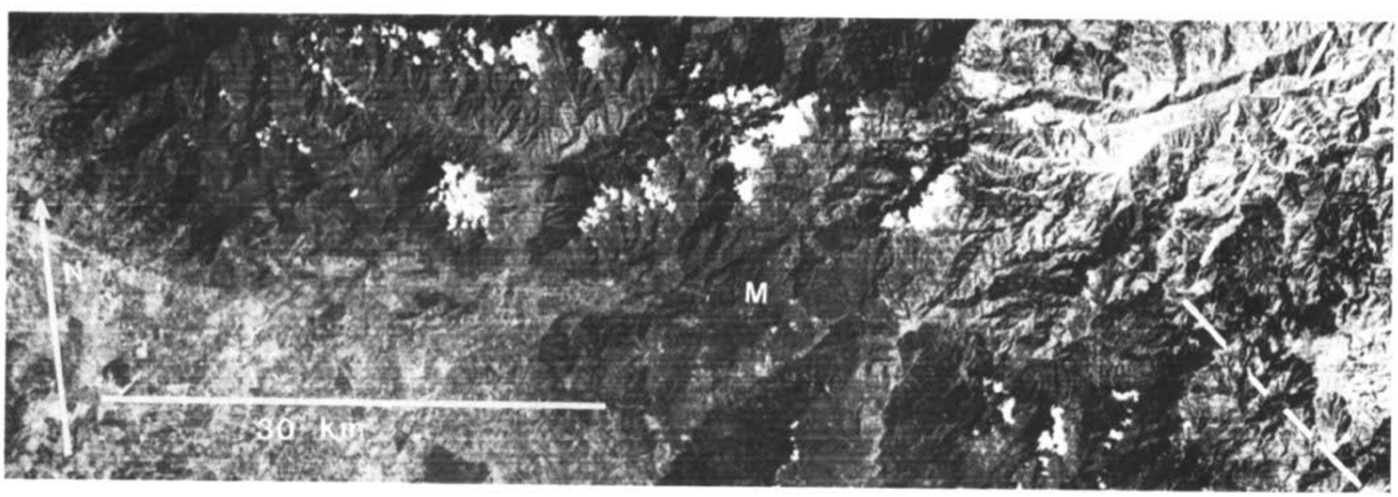

Figure 2B. Enlargement of the main splay (M).

however; the overall sinuous fault trace would suggest zones of locking in contrast to the Motagua, whose fault trace is a relatively smooth, gentle arc. Bonis (1967, p. 79) found no evidence of offset on the Polochic in the Alta Verapaz fold belt near Senahú. The fault appears to be inactive in eastern Guatemala. In western Guatemala where the Polochic has offset recent river valleys (Kupfer and Godoy, 1967; Anderson and others, 1973), there are at least some segments of relatively recent activity. The northern shear splay may be developing to cut off a locked segment in western Guatemala and Chiapas. Extensive east-west shears in the Chiapas massif (see above) may be associated with locking of the Polochic. The curved main splay of the Polochic in Chiapas is probably a now-dormant segment.

OFFSET ON THE POLOCHIC FAULT

If the block north of the Polochic fault trace is moved eastward a distance of 132 ± 5 km, there is a unique match in the geology across the fault (Fig. 3) that restores to coincidence the Cenozoic and older structures and pre-Cenozoic stratigraphy. The Polochic is defined here as (1) the generally west-trending, continuous, sinusoidal trace that is depicted on the geologic map of Guatemala (Bonis and others, 1970), (2) the westward extension of the Cuilco or main segment of the fault (see above), and (3) a partially buried segment in eastern Guatemala which runs north of Lake Isabál in a generally east-northeast direction.

With the reconstruction suggested here, there is an unusually good match of map outcrop patterns, orientation of structural fabric, and major Cenozoic structures. Major structures of northwest Guatemala and Chiapas (B. Burkart, 1977, unpub.) coincide with structures across the fault mapped by Walper (1960), McBirney (1963), and van den Boom and others (1971). The southernmost of two anticlinoria with wavelengths of 30 to 35 km, centered in northwestern Guatemala on the Rio Ocho and Río Chanjón, is shown in structure section B–B′ in Anderson and others (1973, Fig. 2). This major structure I have designated the Comalapa anticlinorium (Fig. 1) after a village in adjacent Chiapas; it is discernible from map outcrop patterns (Lopez-Ramos, 1975). On the reconstruction it matches the Tactic–Santa Rosa anticlinorium of Walper (1960).

The Polochic fault does not cut across the Cenozoic fold belt of eastern Guatemala, but runs parallel to fold axes. Displacement would be very difficult to measure there for this reason. By employing the geologic map trace (Bonis and others, 1970) that runs just north of Lago de Isabál to restore the same sense and amount of slip as before, the Paleozoic rocks near Puerto Barrios on the southern block are positioned due south of the Senahú area Paleozoic exposures on the northern block (Fig. 4). This restoration would bring together discontinuous and separated segments of the Paleozoic core of the fold belt and would leave only the Isabál graben (Bonis, 1967) as a gap.

The match of Figure 3 is made with a point on the fault 7 km west of Aguacatán on the northern block in contact with a point on the fault on the southern block 21 km east of Tactic. This match is made on the contact between the Chochal and Esperanza Formations on the northern block and Chochal Formation and Upper Tactic Formation on the south. The contact is faulted on the north and must be extrapolated to the Polochic. Vertical displacement and possible drag add an uncertainty estimated at ±5 km.

One of the most convincing features of this reconstruction is in stratigraphic correlation across the fault. The correlation chart

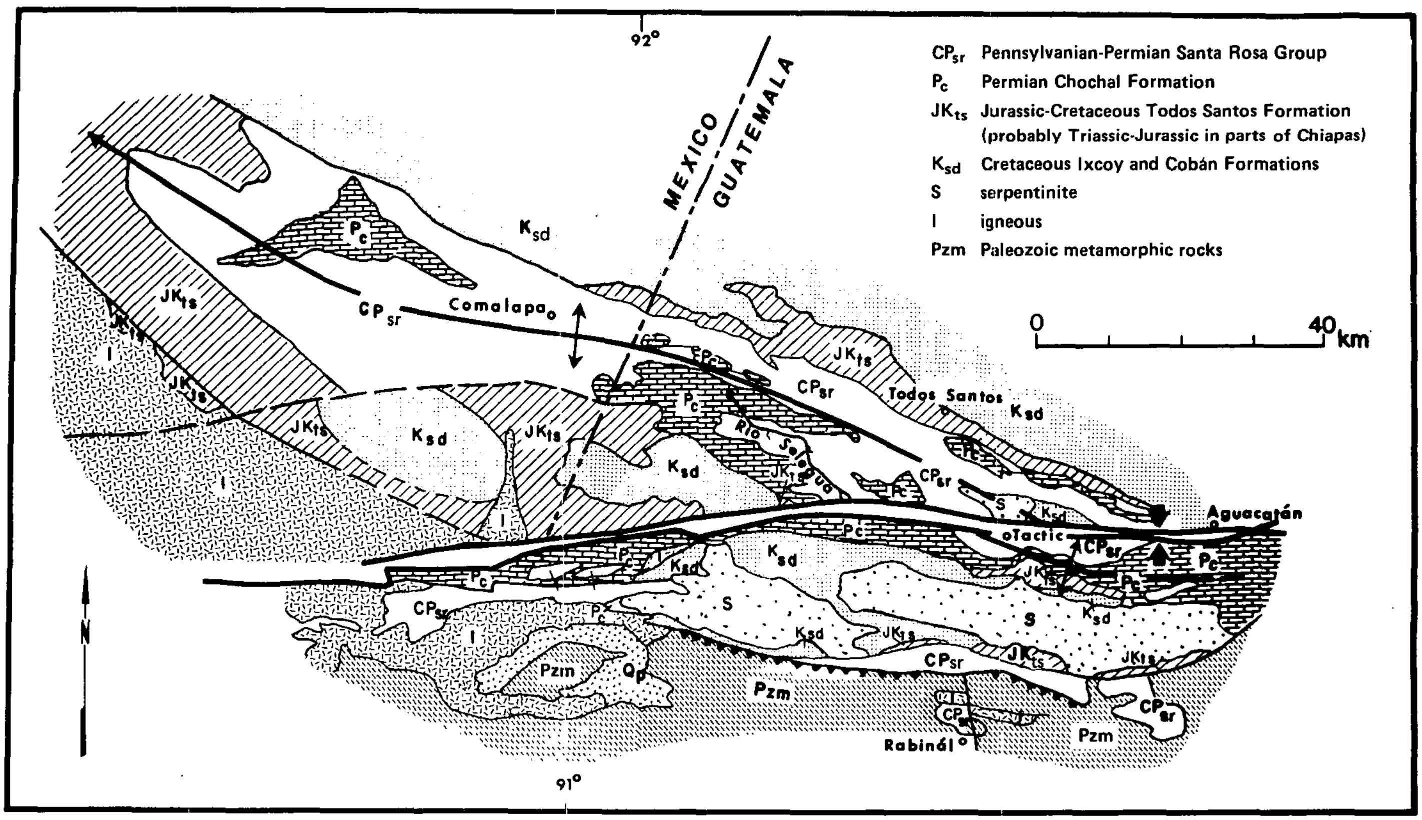

Figure 3. Geologic map showing reconstruction across Polochic fault after left slip of 132 ± 5 km has been eliminated. Each block is bounded by its own present-day segment of Polochic fault. Space is left between blocks. Geology in Mexico is from Lopez-Ramos (1975) and my 1968 and 1976 field study. Geology in Guatemala is from Bonis and others (1970) and Walper (1960). Formation names are from Bonis and others (1970).

presented in Anderson and others (1973, Fig. 4) summarized the stratigraphic terminology between northwestern Guatemala and central Guatemala south of the Polochic. Formation names and time ranges of Anderson and others (1973) and van den Boom and others (1971) are almost identical for the entire stratigraphic section. Workers in northwestern Guatemala have been able to employ stratigraphic nomenclature from central Guatemala south of the Polochic with little difficulty, whereas in areas that are closer but within the Cuchumatanes Mountains to the north and northeast, facies problems (especially in the Pennsylvanian-Permian Santa Rosa Group) have made correlation of individual formations impossible.

The reverse faults mapped by McBirney (1963, Map 1), depicted on the geologic map of Guatemala as though they were splays of the Polochic fault (Bonis and others, 1970), correlate with a system of generally northwest-trending faults in Chiapas that I am calling the Concordia fault system after the Río Concordia. Some of these faults appear on the geologic map of Chiapas (Lopez-Ramos, 1975) as normal faults across which basement rock of the Chiapas massif is juxtaposed to the Cenozoic fold belt to the east. Faults of this system are older than the left-slip offset on the Polochic; however, there is evidence of further fault movement in Skylab photographs and LANDSAT imagery. The Concordia faults may have undergone offsets between segments that would account for the zigzag pattern. In LANDSAT imagery (Fig. 2), one can see the southern end of the Concordia fault system and its intersection just west of the frontier with the main splay of the Polochic (see above). This is believed to match a point on the southern block determined by northwestward extension of McBirney's (1963, Map 1) reverse faults to intersect with the Polochic. This translation distance is about 130 km as measured along the present fault trace.

In the reconstructed position, the Polochic fault trace and structures on the southern block run crosswise to those on the

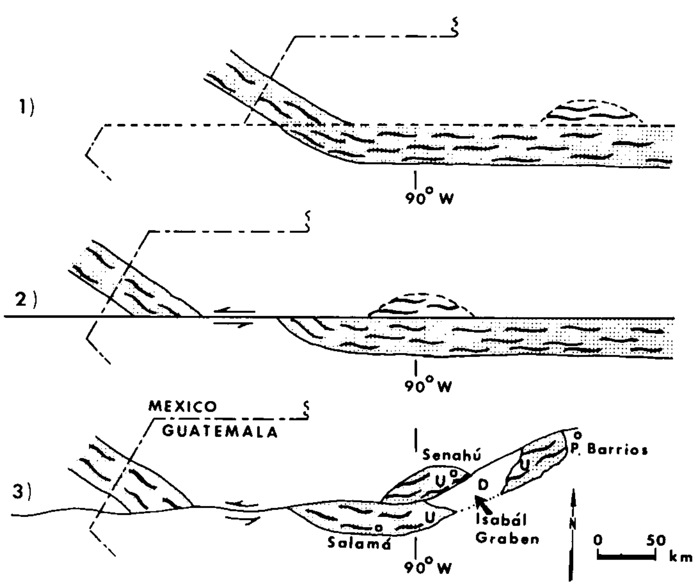

Figure 4. Diagrammatic representation of stages of deformation of Cenozoic fold belt of southern Chiapas and northern Guatemala. Shaded areas represent exposed Paleozoic core (which may not have been exposed in Senahú fold belt in stages 1 and 2). Wavy symbols indicate fold trends. The following stages are represented: (1) preslip; (2) after most of the 132 km of slip was effected; (3) present configuration after 25° counterclockwise rotation of eastern Guatemala. The long. 90°W line applies to stage 3 and southern (fixed) block of stages 1 and 2.

northern block, and severe overlap exists. It would require a 25° clockwise rotation of southern block structures east of long. 90°W to make them parallel and remove overlap. Counterclockwise rotation of eastern Guatemala by about 25° must have occurred after measured slip of the Polochic. By the time of rotation, the previously adjacent northern block had moved sufficiently to the west to be out of the way of serious effects of this rotation. There is no imprint of this event on rocks that were adjacent at the time. The present-day ubiquitous, progressively northeast-trending fabric east of long. 90°W on both blocks appears to be a reorientation of a previously west-trending fabric. The fault and general fabric of nuclear Central America and the Cenozoic fold belt ran east-west in eastern Guatemala. Muehlberger and Ritchie (1975) proposed such a rotation on the basis of structures in Honduras and southeastern and south-central Guatemala. D. W. Curran and W. D. MacDonald (1977, unpub. abs.) in a paleomagnetic study of Tertiary volcanic rocks of the Siguatepeque area of Honduras, reported that there has been a 30° counterclockwise rotation since mid-Tertiary time.

SINUOSITY OF THE POLOCHIC FAULT TRACE

In western Guatemala and Chiapas, the trace of the Polochic fault approximates a sinusoidal curve with a wavelength of about 130 km and 7-km amplitude (Fig. 1). The reconstruction proposed here moves the northern block back to a position about one full wavelength away from its original position. The best fit of the geology across the fault is also the best geometric fit for the two fault blocks (Fig. 3).

Sinuosity of Polochic fault was probably caused by east-west compression that folded the originally straight fault trace. This would suggest a stress field that would affect the entire region from at least as far east as present-day north-central Guatemala to the Middle America Trench. The relatively small ratio of amplitude to wavelength suggests that this folding would not be detected in mapping studies of limited areas. However, strong east-west compression is suggested by large structural trends on the geologic map of Guatemala (Bonis and others, 1970) such as deflection of fold axes north of the Polochic in the vicinity of the Chiapas frontier; by structures in Alta Verapaz, Guatemala, in the vicinity of the Río San Simón; and in Central Chiapas by sinusoidal left-slip faults near Tuxtla, Chiapas (Bonis and others, 1970; Lopez-Ramos, 1975). On a smaller scale, the near-vertical folds with north-trending axial planes discussed by Kesler (1971) for western and central Guatemala may be of this same generation. After folding of the Polochic, continued strain may have shifted to one or both of the other major faults, the Jocotán and Motagua, or to other splays in Chiapas and northwest Guatemala.

AGE OF DISPLACEMENT

Most of the displacement that has been measured on the Polochic fault occurred during recent Cenozoic time. It is succeeded by the postulated 25° or so of counterclockwise rotation of eastern Guatemala described above and by movements on the northern shear splay and active faults such as the Motagua. If one assumes that (1) a 2-cm/yr average strain rate existed across the North American and Caribbean plates (Plafker, 1976) throughout the time of movement of the Polochic fault, (2) the fault is still active, and (3) all strain was taken up on this particular fault, its first movement would have occurred 6.5 m.y. B.P. or during middle Pliocene time. An age two or three times older would apply if the strain had been shared with the Jocotán or Motagua faults or both; thus, the age of inception could be as early as middle Miocene. Considering the rotation that is believed to have begun in Honduras and eastern Guatemala in about mid-Tertiary time (D. W. Curran and W. D. MacDonald, 1977, unpub.) and the fault model presented above, I would suspect that major fault movement was complete before Pliocene time.

Considerably older fault movement has been suggested by Anderson (1969) and Bonis (1969). The results of my study do not rule out pre-Cenozoic movement in the same zone or parts of it. But in southern Chiapas and northwestern Guatemala, as Kesler (1971) has demonstrated, the pre-Late Pennsylvanian orogenic belt can be made continuous by the same direction and about the same amount of slip on the Polochic that is suggested here. Important slip did not occur in the interval from Late Pennsylvanian time to the time of the Cenozoic offset.

THE CARIBBEAN-NORTH AMERICAN PLATE BOUNDARY

The Polochic fault across which the 132 km of offset took place was an earlier plate boundary. It appears that this fault has been augmented and partly supplanted in this capacity by a much more complex set of faults. Plafker (1976) suggested a shift of strain from the Motagua fault to the Polochic in western Guatemala as one possible reason for the ill-defined path of the Motagua to the west. The three models he presented project the Motagua fault westward to intersect the Middle America Trench, and he suggested that there is a continuous plate boundary. Because activity has been demonstrated on the Motagua and recent offset on the western Polochic, it would appear that the plate boundary was complex and discontinuous. Even if only the two subparallel faults are involved, sharing the strain alternately, there would be a discontinuous plate boundary. But at this plate margin, there may be many more faults in the form of the shears of the Chiapas massif that probably continue southeastward into western Guatemala (Fig. 1). If they do continue and are active, plate movement could be distributed to these east-west shears, obviating the requirement for a discrete Motagua fault zone in western Guatemala. In the context of this 200-km-wide zone of shear faults, the northern shear splay of the Polochic and other active segments in western Guatemala appear to be relieving only a little more of the strain than other visible faults of the shear zone, and they are doing that only because of the existence of older zones of weakness. A widely distributed or smeared-out plate margin such as is suggested here would lead to a very indefinite triple junction.

REFERENCES CITED

Anderson, T. H., 1969, Pre-Pennsylvanian and later displacements along Chixoy-Polochic fault trace, northwestern Guatemala: Geological Society of America Special Paper 121, Abstracts for 1968, p. 6-7.

Anderson, T. H., Burkart, B. Clemons, R. E., and others, 1973, Geology of the western Altos Cuchumatanes, northwestern Guatemala: Geological Society of America Bulletin, v. 84, p. 805-826.

Bonis, S. B., 1967, Geologic reconnaissance of the Alta Verapaz fold belt, Guatemala [Ph.D. dissert.]: Baton Rouge, Louisiana State University, 146 p.

——1969, Evidence for a Paleozoic Cayman Trough: Geological Society of America Special Paper 121, Abstracts for 1968, p. 32.

Bonis, S. B., Bohnenberger, O. H., and Dengo, G., 1970, Mapa Geologico de la Republica de Guatemala: Guatemala Instituto Geografico Nacional, scale 1:500,000.

Clemons, R. E., 1966, Geology of the Chiquimula quadrangle, Guatemala, Central America [Ph.D. dissert.]: Austin, University of Texas, 123 p.

Hess, H. H., and Maxwell, J. C., 1953, Caribbean research project: Geological Society of America Bulletin, v. 64, p. 1-6.

Kesler, S. E., 1971, Nature of the ancestral orogenic zone in nuclear Central America: American Association of Petroleum Geologists Bulletin, v. 55, p. 2116-2129.

Kesler, S. E., Josey, W. L., and Collins, E. M., 1970, Basement rocks of western nuclear Central America: The western Chuacús group, Guatemala: Geological Society of America Bulletin, v. 55, p. 2116-2129.

Kupfer, D. H., and Godoy, J., 1967, Strike-slip faulting in Guatemala [abs.]: American Geophysical Union Transactions, v. 48, p. 215.

Lopez-Ramos, E., 1975, Carta Geologica del Estado de Chiapas (second edition): Instituto de geología de la Universidad Nacional Autonoma de Mexico, scale 1:500,000.

McBirney, A. R., 1963, Geology of a part of the central Guatemalan Cordillera: University of California Publications in Geological Sciences, v. 38, no. 4, p. 177-242.

Muehlberger, W. R., and Ritchie, A. W., 1975, Caribbean-American plate boundary in Guatemala and southern Mexico as seen on Skylab IV orbital photography: Geology, v. 3, p. 232-235.

Plafker, G., 1976, Tectonic aspects of the Guatemalan earthquake of 4 February 1976: Science, v. 193, p. 1201-1208.

van den Boom, G., Müller, A., Nicolaus, H. J., and others, 1971, Geologische Übersichtskarte 1:125,000, Baja Verapaz und Sudteil der Alta Verapaz (Guatemala): Hanover, Bundesanstalt für Bodenforschung.

Walper, J. L., 1960, Geology of Cobán-Purulhá area, Alta Verapaz, Guatemala: American Association of Petroleum Geologists Bulletin, v. 44, p. 1273-1315.

ACKNOWLEDGMENTS

Reviewed by R. E. Clemons and W. R. Muehlberger. Supported by University of Texas at Arlington Graduate School Organized Research Grants 15-670 and 15-672. Field support in Guatemala was by the Instituto Geografico Nacional. In Mexico the Instituto Mexicano del Petroleo gave assistance in the field. The following offered aid or suggestions: S. B. Bonis, J. D. Boon, O. H. Bohnenberger, Z. de Cserna, G. Dengo, J. F. Fischer, J. T. Kirkland, J. Godoy, R. Malpica, D. H. McGibbon, D. F. Reaser, E. Rodriguez, and O. Salazar.

MANUSCRIPT RECEIVED DECEMBER 19, 1977

MANUSCRIPT ACCEPTED MARCH 24, 1978