TECTONICS, VOL. 6, NO. 4, PAGES 411-422, AUGUST 1987

TECTONIC WEDGES AND OFFSET LARAMIDE STRUCTURES ALONG THE POLOCHIC FAULT OF GUATEMALA AND CHIAPAS, MEXICO: REAFFIRMATION OF LARGE NEOGENE DISPLACEMENT

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Abstract. Fault wedges along the Polochic fault of northern Guatemala and Chiapas, Mexico record left-lateral slip of from 20 to 65 km that accompanied documented Neogene slip of 130 km across this North American—Caribbean plate boundary fault. Wedges can be correlated to source areas consistent with left-lateral displacement along the Polochic fault. They occur adjacent to restraining bends in three areas where changes in strike of the fault have been mapped. These wedges, which have been previously interpreted as allochthons emplaced along low-angle reverse faults, are bounded by high-angle faults. Folds that terminate against the Polochic fault are part of a regional fold belt that originated during the Campanian through Paleocene (Laramide) orogenic event. A previous contention that some of these major folds are secondary and related to fault movement is shown to be incorrect. The 130 km model of left-lateral offset across the Polochic fault is reviewed along with evidence for and against a Neogene time of major displacement. Additional evidence for the model is presented: (1) Late Cretaceous granitoid rocks from near Motozintla, Chiapas, Mexico (northern fault block), are correlated with granitic rocks of the Santa Maria Batholith in the region of Huehuetenango, Guatemala (southern block), (2) mineralization at the contacts of the granitoid intrusives of the two areas is correlated, (3) points of deflection of Laramide structural axes are correlated across the fault, (4) a major thrust sheet similar to that of the Sierra de Santa Cruz in eastern Guatemala is reassembled by reversing 130 km of left-lateral slip which has offset serpentinites north of the fault in western Guatemala and those south of the fault in central Guatemala.

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Paper number 7T0329.
0278-7407/87/007T-0329$10.00

INTRODUCTION

The Polochic fault was regarded by Muehlberger and Ritchie [1975] as one of three major faults in a distributed boundary between the North American and Caribbean plates, the Motagua and Jocotan faults constituting the remaining major structures. The Polochic fault extends from the Motagua fault zone westward across northern Guatemala into southern Chiapas and across the Gulf of Tehuantepec to the Middle America trench [Burkart, 1983]. Evidence for 130 km of sinistral displacement across the Polochic presented by Burkart [1983] and Deaton and Burkart [1984] suggested that this major displacement began at around 10 Ma. Estimates of aggregate Cenozoic offset across this plate boundary have been as high as 1100 km [Wage and Burke, 1983]. Anderson et al. [1985] argue for a total offset across the Polochic fault of no more than several kilometers since early Tertiary.

This study describes three areas along the Polochic fault where fault-bounded blocks occur whose origin most workers have attributed to strike-slip faulting. Yet a different interpretation is that these blocks are allochthons that were emplaced across the Polochic fault by northward directed gravity sliding during the Laramide, such that the time of major offset was restricted to pre-Laramide [Anderson et al., 1985].

We present new evidence for the fault wedge (strike slip) origin of these blocks and review previous studies that suggest the same or similar origin. The 130 km model of Burkart [1978, 1983] and chronology of fault activity of Deaton and Burkart [1984] are reviewed, along with questions as to their validity raised by Anderson et al. [1985]. Special attention is paid to the structures on the northern fault block that terminate against the Polochic fault. One of these breached structures, the Comalapa anticlinorium, has been correlated with the Tactic Santa Rosa anticlinorium south of the fault in central Guatemala [Burkart, 1978].

The three areas studied lie along the Polochic fault zone from central Guatemala to 35 km west of the frontier in Chiapas, Mexico (Fig. 1). We have designated the areas as follows: area 1, the frontier area of Guatemala and Mexico (Canibal quadrangle westward beyond Motozintla, Mexico), area 2, between San Sebastian Huehuetenango and Aguacatan, Guatemala, area 3, between Chiantla and Tactic, Guatemala. These are the first published results of a several-year mapping study of area 1. We have mapped much of area 2 in detail and noted results in the work by Dengo [1982, 1986] and Deaton and Burkart [1984]. Although we have made numerous reconnaissance studies of area 3 during which the faults bounding the tectonic blocks have been examined, most of the data are from quadrangle mapping studies by workers from Louisiana State University (LSU) under the direction of S. E. Kesler (see below) and from the German Geologic Mission to Guatemala [van den Boom, 1971].

NATURE OF FAULT-BOUNDED BLOCKS ALONG POLOCHIC FAULT

In each of the three areas studied, fault-bounded blocks of disputed origin are found within a zone no farther than 4 or 5 km from the Polochic fault trace (Figure 1). Blocks are mostly elongate, parallel to the Polochic fault, and bounded by generally west trending faults. Even on small-scale regional geologic maps the blocks in area 1 [Burkart, 1986] and area 3 [Bonis et al., 1970] stand out in strong lithologic contrast to surrounding rocks. In each of the three areas the blocks, which are internally faulted (or are block aggregates), measure from 4 to 10 km in width and 40 to 50 km in length (Figure 1). Discussion of the three areas follows.

Area 1: Canibal-Motozintla, Mexico-Guatemala Frontier

We have mapped structures of the Polochic fault zone across area 1 from the Guatemala-Mexico frontier to the Pacific coastal plain (Figure 1) and have delineated the boundary faults of a block which we call the Motozintla fault wedge. Although this wedge is one of several in area 1 associated with a major restraining bend [Crowell, 1974] of the Polochic fault located near the coastal plain of Chiapas, Mexico (Figure 1), it is the most prominent and the only one we will discuss in detail. This wedge of Late Cretaceous pink granitoid and older sedimentary rocks extends from Canibal quadrangle of westernmost Guatemala across the frontier past the town of Motozintla to within 20 km of the Pacific coastal plain in Mexico (Figure 1). An excellent section is exposed along the Rio Motozintla, where a deep NE trending gorge cuts diagonally across the granitoid wedge, exposing zones of high-angle (greater than 70^0) faults along the northern and southern contacts between the wedge and adjacent blocks (Figure 1). Within the wedge, pink granite (sensu latu) intrudes red beds of the latest Jurassic—earliest Cretaceous Todos Santos Formation, exposed as a roof pendant along the main (southern) boundary fault. Carfantan [1977] estimated a Late Paleozoic age for the pink granite, however, we obtained a 68.4 $\pm$ 3.4 Ma (Late Cretaceous) K-Ar age from K feldspar from this granite (Table 1). Granitoid rocks of the wedge are part of an intrusive body which we have called the "Motozintla pluton," the southernmost of at least eight intrusive centers of Late Cretaceous granitoid rocks which run along the backbone of the Sierra de Soconuzco. We refer to the intrusive centers collectively as the "Soconuzco intrusives". Intrusive rocks of this age have not been reported previously in the Chiapas massif [Burkart et al., 1986]. The granitoid rocks intrude Paleozoic metamorphics and the Todos Santos Formation in the Sierra de Soconuzco of the Chiapas massif but are not present south of the main splay of the Polochic fault in area 1. Roof pendants of contact-metamorphosed Todos Santos are found within the fault wedge (Figure 1). Sulfide mineralization has been found at intrusive contacts with the Todos Santos Formation at several localities to the north (see below).

Anderson et al. [1985] interpret the pink granitoid rock to be in one of the multiple thrust sheets lying astride the Polochic fault where it crosses the frontier. Their interpretation is based upon reconnaissance mapping of eastern Canibal quadrangle and reinterpretation of a study by Carfantan [1977] of the Motozintla area of Chiapas, Mexico. In the strictest sense fault wedges could be defined as allochthons, but we find no evidence in either the Motozintla or Canibal areas of allochthons of the type suggested by Carfantan [1977] and Anderson et al. [1985], namely, thrust blocks that have moved long distances on low-angle faults. Anderson et al. [1985] map the Polochic

TABLE 1. Data Used in Radiometric Age Calculations, Sample MP-PSC8

Run	Volume Ar^{40}Rad per g Sample, (cm/g)	$\%^{40}K$	%K	Radiometric age (Ma)
1	2.89	84.2	10.8	68.4 ± 3.4
2	2.99	85.3	10.9	68.4 ± 3.4

Analyses by Teledyne Isotopes, Westwood, N.J. on microcline perthite separate prepared by the authors. Analytical error within 5% of the 68.4 Ma average, or ± 3.4 Ma. Constants for age calculation: $\lambda_e = 0.581 \times 10^{-10}$ yr^{-1}; $^{40}K = 1.167 \times 10^{-4}$ atom per atom of natural K. (Convention on decay constants, Subcomission on Geochronology, 25th International Geological Congress, 1976.)

fault (CCP) as an "inferred fault" across the entire Canibal quadrangle but terminate it near the Mexico frontier. Our mapping in western Canibal confirms the location of the Polochic fault of Anderson et al. [1985] which, as Erdlac and Anderson [1982] note, separates "igneous and metamorphic rocks from distinctive pinkish-orange quartz porphyry and volcaniclastic rocks" across Canibal quadrangle. We have found that the Anderson et al. [1985, Figure 4] Polochic fault continues westward into the Motozintla River Valley where, as to the east, it separates the pink Motozintla granitoid rocks from metamorphic basement complex to the south. Carfantan [1977, Figure 2] correctly maps the Polochic main splay in the Motozintla Valley but places the trace 1 km north of its actual position at the frontier, a discrepancy noted by Anderson et al. [1985].

We disagree with the interpretation of Anderson et al. [1985] that the Polochic fault extends beneath an allochthon in the Motozintla area. The interpretation evidently stems, in large part, from the fact that Carfantan [1977, Figure 2] mapped rocks of several different lithologies and ages together as a single, unnamed, allochthonous assemblage, described as a "volcano-plutonic complex" of "metaandesite," "metarhyolite," "metagraywacke," and "metatuff" of greenschist facies. Our field study of area 1 (Figure 1) reveals that lithologies mapped by Carfantan [1977, Figure 2] as the "volcano-plutonic complex", can be correlated with and are, in fact, contiguous with well-known stratigraphic units of western Guatemala. The "volcano-plutonic complex" consists of the following units: (1) granitoid rocks of the Motozintla pluton (above), (2) Todos Santos Formation [Anderson et al., 1973] and Todos Santos metamorphosed by Motozintla pluton, and (3) Paleozoic metamorphic rocks, equivalent to the Western Chuacus Group of western Guatemala [Kesler et al., 1970]. Indeed, Carfantan [1977, Figure 2] maps the three units individually north of the Polochic fault zone but does not recognize them along and adjacent to the Motozintla segment of the Polochic fault. An exception is the Todos Santos, which Carfantan [1977] mapped in a few areas near the fault without, however, recognizing its contact relationship with the Motozintla granite and thus misinterpreting the metamorphic facies. In area 1, Todos Santos Formation and Motozintla granite are found only north of the main splay of the Polochic fault, yet they are mapped together by Carfantan [1977, Figure 2] with the Paleozoic metamorphic rocks that are the dominant lithology adjacent to the south of the fault (Figure 1). Aside from the stratigraphic problems generated by combining these disparate lithologies, mapping them as one unit obscures the strong lithologic contrast that actually exists across this segment of the fault (Figure 1).

In their statement, "The granite likely extends westward across the border into Mexico" (which, clearly, it does), Anderson et al. [1985] signal a lack of familiarity with the critical rocks and contacts of the Motozintla area. On the map composite of Anderson et al. [1985, Figure 2] the Polochic fault (or its alluvial valley) is shown, quite correctly, to separate the pink granitoid rock on the north from Paleozoic metamorphic rocks on the south. These authors do not, however, adequately address the problem that this relationship was not noted by Carfantan [1977, Figure 2] in the Motozintla area, just across the frontier in Chiapas. As stated above, Carfantan [1977] mapped the "allochthon," on both sides of the Polochic main splay, yet no contact is shown by Anderson et al. [1985] between the "allochthon" and the Paleozoic metamorphic rocks that they map south of the Polochic fault across all of Canibal quadrangle. Instead, on the map composite of Anderson et al. [1985, Figure 2], the unnamed "allochthonous units" stop at the frontier in México and the Paleozoic metamorphic rocks stop near the frontier in Guatemala. Paleozoic metamorphic rocks along the southern contact of the main splay in Mexico (above) are lithologically identical to those in Canibal quadrangle, mapped as "metagranite and augengneiss" by Anderson et al. [1985]. We have remapped (Figure 1) as "Paleozoic metamorphic rocks" the presumed allochthonous sequence of Carfantan [1977]. An excellent section of about 1500 m of the Paleozoic metamorphic rocks extends southward from the main splay of the Polochic fault along the road from Motozintla to the frontier at Niquivil village (Figure 1). Throughout this section, foliations strike about N60°W in augengneiss, metaquartzite, black phyllite, mica schist, and a wide range of metaigneous rocks, whose outcrops are continuous with the Western

Chuacus Group of Guatemala, studied by Kesler et al. [1970] in Cuilco quadrangle just east of Canibal, Guatemala. Lithologies are comparable and foliation trend directions are the same in the Cuilco and Motozintla areas.

We have found no structural evidence for the low-angle thrust fault described by Carfantan [1977], who describes the fault from outcrops 2 km east of Mazapa at the crossing of the Rio Becantun and the road that runs east from Motozintla. This locality is on our cross section A-A' (Figure 1). At this locality, several relatively minor faults have juxtaposed unmetamorphosed and metamorphosed Todos Santos Formation. Carfantan [1977] describes metaandesites above and separated from red clays of the Todos Santos Formation by a near-horizontal thrust fault, "marked by a crushed zone several decimeters in thickness" (our translation from Spanish). We identify Motozintla granite and metamorphosed Todos Santos beneath the zone of crushed rock and unmetamorphosed Todos Santos above the zone. We conclude that the zone of crushed rock, shown in the of Carfantan's [1977, Figure 3] photograph, lies along a minor fault. Carfantan [1977, Figure 2] extends the presumed thrust fault 12 km west of Rio Becantun along the Motozintla wedge. We find this to be the intrusive contact of the Motozintla granite and the Todos Santos Formation and not a thrust fault (Figure 1).

Recent activity along the main Polochic splay is indicated in the Motozintla River Valley by primary geomorphic features such as offset and deflected drainages, truncated or faceted spurs, and spectacular shutter ridges. Valley fill there contains ash deposits dated by Damon and Montesinos [1978] at 1.62 Ma. In easternmost Canibal, Guatemala as in east bordering Cuilco quadrangle, the main splay is buried beneath Rio Cuilco valley fill of Neogene tuff, breccia and alluvium [Erdlac, 1979; Erdlac and Anderson, 1982]. These young glass-bearing deposits are likely of comparable age to the above 1.62 Ma ash deposits in the Motozintla River Valley [Deaton and Burkart, 1984].

The Amatenango fault (northern splay) is marked by a zone 500 m wide of near vertical foliation (resembling slaty cleavage) in calcmylonite at Amatenango de la Frontera village at the frontier in Mexico. The Amatenango fault maintains a consistent N87°E trend from the frontier to about 35 km west where it is cut off by the main splay. To the east in Canibal quadrangle, Guatemala, the trace bends southward to form the leading edge of the granite-wedge salient (Figure 1). As Anderson et al. [1985] note, this fault dips steeply to the south in eastern Canibal quadrangle, whereas in Mexico we have found the Amatenango fault to be near vertical at the following localities: Amatenango de la Frontera, SE of El Zapotillo, north of El Carrizal, and Llano Grande (Figure 1). It is consistent with our fault wedge interpretation that the Amatenango splay appears to have a thrust component across Canibal quadrangle, where the eastern limit of the granite is at the leading edge of the eastward tapering granite-wedge salient (cf. our Figure 1 and Anderson et al., 1985, Figure 4). The proposed multiple thrust sheets in area 1 [Anderson et al., 1985] can be more logically interpreted as elements of a positive flower structure produced by strike-slip movement that created the fault wedge.

Offset of the easternmost exposures of granitoid rocks on the fault blocks separated by the Amatenango splay suggests an approximate left-lateral slip of 30 km across that fault.

Area 2: San Sebastian Huehuetenango to Aguacatan, Guatemala

In area 2 the generally west trending faults within 4 or 5 km of the Polochic fault have been ascribed to strike-slip faulting, and cross sections show them to be near vertical [Blount, 1967, Plate X; Anderson 1969, Plate 2; Anderson et al., 1973, Figure 2; Dengo, 1982, Plate 1). Anderson et al. [1985] present these faults as low-angle thrusts. One of these faults, the Taluca (Figure 1), was determined by Dengo [1982, 1986] to be an abandoned, high-angle splay of the Polochic that was active in the Tertiary. Left slip on the Taluca has been as much as 20 km (Figure 1). Dengo [1982, 1986] presents the following evidence for a strike-slip origin for the Taluca fault: (1) contacts along the fault between serpentinite and Paleozoic rocks are near vertical, (2) foliation planes within the serpentinite are near-vertical and subparallel to the Taluca, (3) finite strain analysis of stretched limestone clasts and porphyroclasts from fault zone calcmylonites indicates left-lateral slip for the fault, (4) additional petrofabric data such as preferred orientation of calcite c axes, superimposed fractures, and pressure-solution seams in the calcmylonites indicate left-lateral shear across the Taluca fault plane.

Along with the main splay the Taluca fault outlines the Taluca wedge, a block with the same general shape and dimensions as the Motozintla wedge. Dengo [1982, 1986] notes that this wedge is located at a restraining (convergent) bend that separates two west trending, right-stepping segments of the Polochic fault.

Area 3—Chiantla to Tactic, Guatemala

In area 3 we have identified a fault wedge or composite of narrow wedges which we refer to as the Sacapulas wedge complex. A similar origin was proposed earlier by McRee [1968], Forth [1971], and Josey et al. [1975], who mapped high-angle faults within the block complex and at the block boundaries. The narrow blocks west of Cunen village (Figure 2) were believed to have resulted from rotation and convergence during movement within a major strike-slip fault zone. Forth [1971] determined a dip of 75° for one of these long faults (Figure 2) on the basis of the geometry of the fault trace over the rugged terrane. The major faults bounding wedges in

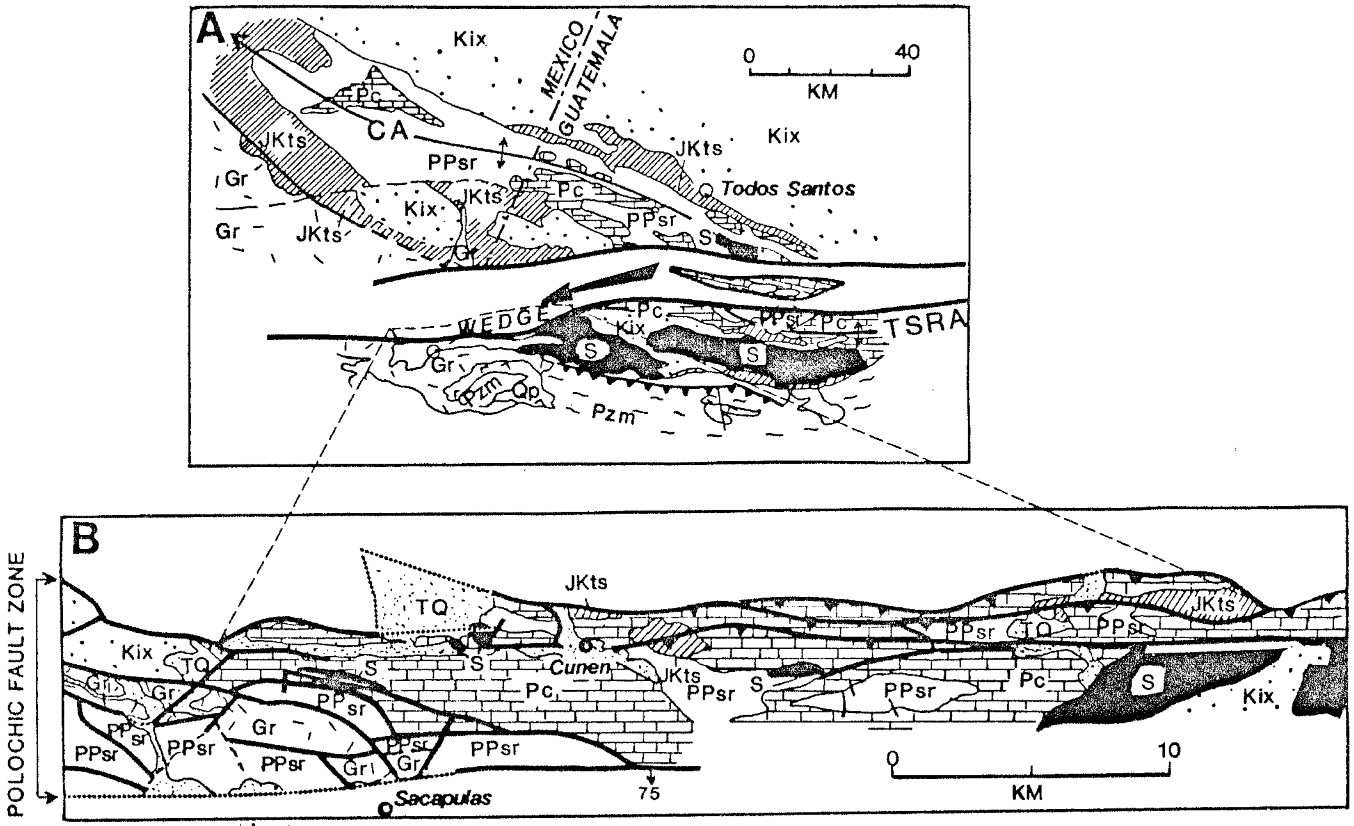

Fig. 2. (a) Reconstruction (130 km left slip restored) from Burkart [1978] showing Sacapulas fault wedge in present position (with dashed outline and labeled "wedge") and position before offset. Wedge contains fault-bounded elements referred to as "allochthons" by Anderson et al. [1985]. CA, Comalapa anticlinorium; TSRA, Tactic—Santa Rosa anticlinorium; Pzm, Paleozoic metamorphic basement rocks; Gr, granite; PPsr, Pennsylvanian-Permian Santa Rosa Group; Pc, Permian Chochal Limestone; JKts, Jurassic-Cretaceous Todos Santos Formation; Kix, Cretaceous Ixcoy (northern block) and Coban-Campur equivalent (southern block); S, serpentinite; TQ, Tertiary-Quaternary volcanics and alluvium; Qp, Quaternary pumice. Figure 2. (b) Expanded view of wedge area of Figure 2. Faults and lithologic units are as mapped by Forth [1971], McRee [1968] and Josey et al. [1975] for area west of Cunen and by Bohnenberger and Blount [1966] for area to the east.

Figure 2 were alternately interpreted by Anderson et al. [1985] to be low-angle thrusts. Several observations independent of the original study confirm the interpretation that blocks are fault wedges, namely: (1) only high-angle faults were encountered in our field studies of these blocks; (2) fault-bounded blocks are elongate parallel to the main west trending Polochic fault zone, and are separated by deep, steep-sided river valleys; they are geomorphologically similar to blocks between anastomosing faults in other strike-slip fault zones [Crowell, 1974]; (3) linearity of faults bounding the narrow blocks in this mountainous terrain is too great for low-angle faults; faults shown on the map in Figure 2 cut across a region where relief is approximately 1400 m [Josey et al., 1975]; (4) Van den Boom et al. [1971] show the faults to be almost vertical in their cross section of the fault zone just east of the map area of Figure 2; the eastern part of Figure 2 was mapped in an early reconnaissance study by Bohnenberger and Blount [1966], who referred to these as reverse but not low-angle faults; (5) there is no known place of origin for the allochthons proposed by Anderson et al. [1985], whereas rocks of the fault wedge (or composite of wedges) that we propose (Figure 2) correlate to two possible areas adjacent to the Polochic fault.

The Sacapulas wedge complex is almost exactly midway between two outcrop areas of Chochal Limestone, the dominant rock that makes up the wedge. About 65 km west of the wedge the Chochal is exposed in the Comalapa anticlinorium (see below) north of the fault. About 65 km to the east, Chochal Limestone crops out south of the Polochic fault in the Tactic—Santa Rosa anticlinorium. Both Chochal outcrop areas are adjacent to the Polochic fault zone. Chochal Limestone exposures in the Tactic-Santa Rosa anticlinorium are the only ones known south of the Polochic fault.

Rocks within the Sacapulas wedge complex are quite different from those north and south of the faults that now bound the wedge complex. This wedge area, which is composed almost entirely of Permian Chochal Limestone, is also a mismatch to adjacent lithologies on the 130 km reconstruction of Burkart [1978], shown in our Figure 2. Anderson et al. [1985] point to this mismatch as evidence against the 130 km reconstruction. It should be noted that without the Chochal outcrops the stratigraphic match is virtually perfect. The fault wedge hypothesis that we propose is consistent with the present-day position in the fault zone of this out-of-place block and explains the mismatch on the 130 km reconstruction. Being equidistant from equivalent Chochal rocks on the northern side of the Polochic fault in the Comalapa anticlinorium (now 65 km west) and on the southern fault block in the Tactic—Santa Rosa anticlinorium (now 65 km east) suggests a left-lateral slip of about 65 km (half the total slip) across each of the two major faults bounding the wedge complex to the north and to the south. The wedge probably "dropped off" at this intervening position, having faulted from one or the other of the principal fault blocks during the time interval of major offset. Strike-slip faults mapped within the existing wedge complex (see above and Figure 2) may be the result of postemplacement deformation of a single block or sequential accretion of three or four small, narrow wedges.

Previous workers (above), who mapped the complex structures of area 3, ascribed major (100 km) slip to the Polochic fault without defining a single, throughgoing structure. Anderson et al. [1985] cite lack of a throughgoing structure as evidence that the Polochic fault lies beneath and is obscured by younger allochthons. The alternative hypothesis proposed here, that this area is a complexly structured strike-slip fault wedge, obviates the need for a throughgoing fault because displacement can be distributed along faults bounding the wedge or within it. Bally [1983] presents five seismic profiles across strike-slip faults. In each profile a flower structure is formed by a high-angle master fault that splays upward into several faults that outline wedges, some of which display a component of thrust in addition to a probable strike-slip component, while other blocks are seen to have a normal-fault component relative to adjacent blocks. If a sufficiently deep horizon is mapped, a throughgoing master fault trace will emerge, otherwise a fault zone of anastomosing, perhaps discontinuous fault traces will be mapped, as appears to be the case for area 3.

AGE AND ORIGIN OF STRUCTURES TRUNCATED BY THE POLOCHIC FAULT

A Neogene time of major offset across the Polochic fault [Burkart, 1978, 1983; Deaton and Burkart, 1984] has been disputed by Anderson et al. [1985], who postulate a post Late Jurassic—pre-Turonian sinistral displacement of unspecified magnitude. Central to the issue of age of offset is the mode of origin of folds and reverse faults that terminate at the Polochic fault across northern Guatemala. Burkart [1978, 1983] proposed that the fault truncates and offsets Laramide age structures, while Anderson et al. [1985] argue that in western Guatemala north of the Polochic fault, NW trending structures are, for the most part, secondary—generated during fault movement in the pre-Turonian Cretaceous.

The Comalapa anticlinorium of northwestern Guatemala is one of the most prominent of the disputed structures. It and the Tactic—Santa Rosa anticlinorium of north central Guatemala (Figure 1) are interpreted by Burkart [1978, 1983] to be offset segments of the same Laramide structure. The Laramide age and correlation of the two structures are disputed by Anderson et al. [1985], and a post Late Jurassic—pre-Turonian age is postulated instead for the Comalapa anticlinorium. The older age would fit their contention that the Comalapa was one of the secondary fault structures.

Age of the Fold Structures

Lack of angular unconformity within the sedimentary sequence of the Comalapa anticlinorium is evidence that there has been only one significant folding event. That event would have to postdate Campanian-Maastrichtian because beds of uppermost Ixcoy Formation of that age are part of the fold [Anderson et al., 1973]. Lack of angular unconformity between Permian Chochal Limestone and Late Jurassic—Early Cretaceous Todos Santos Formation was demonstrated by Anderson [1969] and was also noted by Burkart and Clemons [1972] and Anderson et al. [1973]. The contact between Todos Santos and overlying Ixcoy Formation is described by Anderson [1969] as "probably conformable" and by Anderson et al. [1973] as "conformable." Angular unconformity is absent within the Ixcoy or its equivalents in adjacent Mexico [Chubb, 1959] and central Guatemala [Vinson, 1962] and is unreported in the Comalapa anticlinorium area. The fact that there is no angular unconformity at any stratigraphic level makes the scheme of Anderson et al. [1985] unworkable. The proposed pre-Laramide folding of the Comalapa anticlinorium would have to have taken place during the time of deposition of pre-Turonian Cretaceous Ixcoy carbonates, which constitute much of its northern limb (both limbs in far western Guatemala and Mexico). The requisite profound unconformity in the Mesozoic section, the expected siliclastic facies wedge in the Ixcoy Formation and the required foreshortened section of Ixcoy do not exist. Only minor pre-Cretaceous structures could have existed before Cretaceous folding along the same axes to have left no discernible record, and only minor folding could have accompanied contemporaneous deposition of Ixcoy carbonates.

The Tactic—Santa Rosa anticlinorium (Figures 1 and 2) is also of Laramide age as indicated by Ixcoy and Sepur formations of Campanian-Maastrichtian age within the fold. McBirney [1963] also notes lack of angular unconformity between Paleozoic and Mesozoic sedimentary rocks in that region. The two structures are coeval and of Laramide age.

Origin of Structures Terminated by the Polochic Fault

There have been 2 proposals for the origin of the structures terminated by the Polochic fault: (1) they are part of the Laramide orogenic belt of Chiapas and Guatemala [Dengo and Bohnenberger, 1969], as suggested by Burkart [1978, 1983], and (2) they originated as secondary structures caused by strike-slip displacement along the Polochic fault [Anderson et al., 1985].

The Tactic—Santa Rosa anticlinorium, the proposed offset equivalent of the Comalapa anticlinorium, is in north central Guatemala south of the Polochic fault (Figure 1). Anderson et al. [1985] contend that the Tactic—Santa Rosa structure is a southward-dipping homocline, and that such a structure is not a match to the Comalapa anticlinorium. Walper [1960], who named the structure, and McBirney [1963, Map 2 cross section] show this anticlinal structure to be complete. The van den Boom [1971] cross section, cited by Anderson et al. [1985] as evidence of the homocline, cuts the NW trending structure close to the Polochic fault, where its northern limb has been removed. This cross section interpretation virtually requires the "homocline" to be the southern limb of an anticline because that limb is shared with a syncline to the south.

The en echelon, left-stepping arrangement of folds and faults that should be observed in map view if such structures are related to left-lateral strike-slip deformation [Wilcox et al., 1973] is not observed north of the Polochic fault. Instead, the structures have a parallel or relay pattern and consistently diverge from the fault. Dengo [1986] discusses one of the presumed secondary structures of Anderson at al. [1985], the Rio Ocho fault, noting that it cuts Cretaceous rocks that did not exist at the postulated pre-Turonian time of Polochic fault activity.

Folds that terminate against the Polochic fault are of a length and wavelength that cannot be attributed to strike-slip faulting. One in particular, the Comalapa anticlinorium (discussed above), has a wavelength of about 60 km and an axis that extends 120 km from the Polochic fault into Mexico. It is a regional structure sharing limbs with other regional structures that can be followed northward into Chiapas for several hundred kilometers and eastward to the Motagua Valley. Because these are latest Cretaceous-Early Tertiary structures (see above) it is reasonable to relate them to the Laramide regional folding event [Dengo and Bohnenberger, 1969] and not to strike-slip faulting.

The Polochic fault cuts a secant path across the otherwise regionally continuous, arcuate Laramide fold belt. It truncates NW trending structures west of the Cuchumatanes and NE trending folds east of the mountains (e.g. Senahu anticlinorium). In between it runs parallel to west trending fold axes in the area of Nebaj (Figure 1). A strike-slip fault with a single sense of displacement cannot produce such a contradictory set of secondary structures. There are no NW trending folds or reverse faults east of the Cuchumatanes Mountains. Instead, the Polochic fault cuts NE trending structures in surface rocks of the same Late Cretaceous age as to the west, where the NW trending secondary structures are postulated by Anderson et al. [1985].

REAFFIRMATION OF THE 130 KM MODEL

Previous Correlations

With reference to the faults of northern Central America, Anderson et al. [1985] state "no geologic features are known which can be unambiguously shown to be offset more than a kilometer." We point out that at least 19 pairs of features with 130 km of left offset have been correlated across the Polochic fault [Burkart, 1978, 1983; Deaton and Burkart, 1984]. Features correlated include belts of Pb-Zn mineralization, stratigraphic outcrop belts and contacts, major structures such as the anticlinoria (above) and boundary faults between sedimentary and basement provinces, nuclear Central America and the Chiapas massif, the two segments of the Miocene volcanic belt, displaced segments of the Middle America trench, rivers and drainage divides, and conglomerates from one of the rivers and their provenance. These correlations are independent of the existence or nonexistence of allochthons in the Polochic fault zone.

Burkart [1983] suggested that major drainages and drainage divides across the Polochic fault could be brought into juxtaposition by a restoration that removed about 130 km of left slip. Disagreeing that these geomorphic features are useful in determining offset, Anderson et al. [1985] state, "The match of rivers and divides is subjective and is viable only if the drainage systems can be shown to have developed prior to fault activity." The recognition of a match or correlation between two sets of displaced drainages and divides carries with it the discovery that the matching geomorphic features did exist prior to displacement. Clearly, the earliest rivers had to postdate emergence of northern Central America from the Cretaceous seas. Because there are marine sedimentary rocks of Maastrichtian age on both sides of the Polochic fault, that emergence was everywhere post earliest Tertiary. Dengo and Bohnenberger [1969] suggest that the time of this regional emergence was late Eocene-Oligocene, which is very consistent with the post Campanian-Maastrichtian age of folds truncated by the fault and the Late Miocene time of initial activity postulated for the Polochic fault [Burkart 1978, 1983; Deaton and Burkart, 1984].

As important as the specific correlations discussed above is the continuity in lithology and structure across northern Central America on the 130 km reconstructions [Burkart, 1983]. Structural elements of the northern Central American orogen are continuous on these reconstructions, which is not so today. To achieve this with the same model that restores paleodrainage systems suggests that the model is correct.

New Correlations

Additional evidence for the 130 km model of Neogene left-lateral slip comes from the correlation of rocks of the Motozintla pluton (above) with those of the Santa Maria batholith [Stevens, 1969], the probable offset equivalents to the east in the region between Huehuetenango and Sacapulas, Guatemala [Blount, 1967; Stevens, 1969; Burkart et al., 1986; Metal Mining Agency of Japan, unpublished report, 1978]. Where subtended by the fault, centers of the two granitoid rock outcrop areas are approximately 130 km apart with a left sense of offset (Figure 1). Rocks from these two areas, subjects of an ongoing study by us, are petrographically comparable, consisting not only of the distinctive pink granites but also of monzonites, granodiorites, and tonalites cut by dikes of aplite, andesite and diabase [Burkart et al., 1986]. Five K-Ar ages, 85, 83, 74, 62, and 58 Ma (Late Cretaceous-Paleocene) from granitoid rocks in the Chiantla to Sacapulas area were reported by Metal Mining Agency of Japan [unpublished report, 1978]. These compare favorably to the 68.4 Ma age we obtained for the Motozintla pluton. These granites are absent north of the fault in Guatemala where they terminate as abruptly at the Polochic fault as the Motozintla granite does in Mexico. Penetrative rocks of this type are not likely to disappear entirely owing to erosion or thrusting [Anderson et al., 1985]. The intrusives of both areas are coarse grained at the fault contact which along with other field evidence, makes it unlikely that the fault was an original intrusive contact. These correlations are additional evidence for post Late Cretaceous sinistral slip of 130 km across the Polochic fault.

Skarn-type mineralization (Cu, Pb, Zn, and Fe) found along the northeastern contact of the Santa Maria batholith of Guatemala (Metal mining Agency of Japan, unpublished report, 1978] has a counterpart in a mineralized contact zone (Cu, Pb, and Fe) along the corresponding northeastern margin of the Motozintla pluton and the other Soconuzco intrusives. We have observed sulfide mineralization at the contact of these granitic rocks with Todos Santos Formation (see above) or Paleozoic metamorphic rocks at several localities north of the Polochic fault in area 1 (Figure 1) and near San Nicolas and Cuxtepec villages, 55 and 75 km northwest of Motozintla (beyond map area of Figure 1). E. Montesinos [personal communication, 1980] reported similar contact mineralization at two localities between Motozintla and San Nicolas.

There is good evidence that the arcuate Laramide orogenic belt was offset by sinistral displacement across the Polochic fault. Both the Comalapa and Tactic Santa Rosa anticlinoria are NW trending as they approach the fault, but on the southern fault block the Tactic-Santa Rosa structural axis changes to west and then ENE as it progresses eastward (Figure 1), reflecting the arcuate, concave northward structural geometry seen on both fault blocks [Dengo and Bohnenberger, 1969]. Such an arcuate pattern must have a zone of west trending structural fabric. North of the Polochic fault the regional change from NW to west occurs near the fault just north of the village of Aguacatan, while on the southern block this change in strike occurs about 25 km east of Tactic. The map (Figure 1) shows linear bands within which the loci of regional strike of folds changes from NW to west. These bands intersect lengths of the fault the centers of which are about 130 km apart, conforming to previous measurements of displacement.

The reconstruction (Figure 2) brings together pieces of a probable serpentinite allochthon. We do not consider this union to be "ad hoc" as Anderson et al. [1985] claim, but see the resulting allochthon as a possible analog to the Santa Cruz ophiolite thrust sheet of northeastern Guatemala [Rosenfeld, 1980], as it compares well in size and tectonic setting.

SUMMARY

Each of the three areas of proposed fault wedges is at or adjacent to a major bend in the Polochic fault. Wedges lie within the Polochic fault zone no more distant than 5 km from the fault trace. Boundary faults to the blocks have been studied in each area and found to be high angle (greater than 70°), except along the leading edge of the fault wedge in area 1 where a flower structure is indicated. All wedges can be correlated to exposures adjacent to the fault zone and in the proper direction to have been emplaced by left strike-slip movement. Previous field studies in each of these areas have concluded that the blocks are strike-slip fault related.

There is complete compatibility in the hypothesis of Laramide thrusting in northern Guatemala and our interpretation of fault wedges for the fault-bounded blocks. Several studies have discussed the probability of thrusts and several have documented Laramide thrusts in central and eastern Guatemala across the region of the Polochic fault [Anderson et al., 1985]. Some of the slivers that Anderson et al. [1985] classify as allochthons may have been transported northward to that latitude as part of larger Laramide thrust sheets but such a history does not preclude subsequent Neogene breakup and translation along the Polochic fault. The 130 km reconstruction juxtaposes the only documented low-angle reverse fault in western Guatemala (Chochal Limestone above younger Todos Santos red beds along the southern margin of the Cuchumatanes Plateau north of Chiantla village [Blount, 1967]) with the region of likely thrusts east of area 3 near Tactic and Salama.

New correlations supporting 130 km of sinistral offset across the Polochic fault have been made, as follows: (1) Late Cretaceous granitoid rocks of the Sierra de Soconuzco of the Chiapas massif are correlated with those of the Santa Maria batholith of western Guatemala. (2) Sulfide mineralization at the contact with the above rocks is correlated between the two areas. (3) Change of strike (from NW to west) of regional structural fabric adjacent to the Polochic fault is correlated across the fault. (4) Serpentinites correlate north and south of the Polochic fault.

Aside from evidence for a Tertiary time of displacement provided by offset of such specific features as Laramide structures, Early Tertiary rivers and divides, Late Miocene river conglomerates [Deaton and Burkart, 1984], and Soconuzco intrusives of Chiapas and the Santa Maria batholith of Guatemala, the following general observation is an important constraint on the time of major activity across the Polochic fault. Despite its bends or buckles, the Polochic fault zone has unusually straight segments, and where studied in detail [Dengo, 1982, 1986], exhibits near-vertical, planar structural elements. The Laramide collision which produced folding, thrusting, uplift, doming, and obduction of ophiolites, [Donnelly and Lopez-Ramos, in press] would have deformed such elements of a pre-Laramide Polochic fault. It is inconceivable that the Polochic fault zone would survive as a continuous, essentially vertical, west trending structure, while all other structures and formation contacts of the Laramide orogenic belt emerged in a regionally arcuate pattern.

Acknowledgements. We are most grateful for critical suggestions made by W. R. Muehlberger and one anonymous reviewer. C. I. Smith and R. C. Finch reviewed and commented on an earlier version of the manuscript for which we are very appreciative. The help of R. E. Denison, who advised at all stages of the K-Ar determination, was indispensable.

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(Received January 30, 1987;
revised March 27, 1987;
accepted March 27, 1987.)