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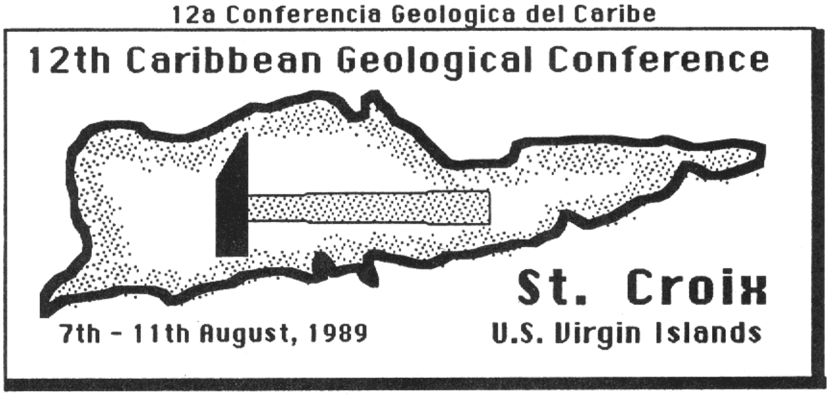

12me Conference Geologique de Caraibes

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NEOTECTONICS OF THE PUERTO RICO TRENCH: EXTENSIONAL TECTONISM AND FOREARC SUBSIDENCE

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ABSTRACT

Study of multichannel seismic-reflection profiles indicate underthrusting in the Puerto Rico Trench diminishes from east to west. GLORIA sidescan studies suggest that strike-slip tectonism is more predominant toward the west. Faults present along the north and south walls of the trench slope are extensional. The south-dipping 19^o latitude Fault on the trench slope break probably has a history of both normal and strike-slip motion. This fault juxtaposes a metamorphic terrane found beneath the lower trench slope and the arc massif complex. The arc massif near the 19^o lat Fault has differentially subsided about 4 km since the Late Miocene, with the hinge line near the present shoreline of Puerto Rico. This subsidence may have occurred during: 1) a tectonic erosion event beneath the trench slope; 2) 'folding' accompanying compression of the arc massif platform; 3) rollover associated with normal movement on the 19^o lat Fault.

Overall, the Puerto Rico Trench represents a transtensional environment. The history of the trench has been complicated by subduction of buoyant oceanic crust ca. 40 mybp, accompanied by plate margin truncation, and deformation, rotation and uplift of the arc massif on the order of 2-4 km. About 9 mybp, the arc massif of Puerto Rico rotated an addional 20^o counterclockwise, such that many of the features observed today are relict from that event.

INTRODUCTION

The Puerto Rico Trench is located in a corner zone, where the orientation of the Caribbean-North America plate boundary abruptly changes from east-west to north south (Fig. 1). Study of multichannel seismic-reflection profiles of the Puerto Rico Trench and surrounding areas reveals an extremely complicated structural evolution since the Miocene. Three important features we recognize are 1) the lateral and temporal transition from underthrusting to strike-slip deformation; 2) 4 km of subsidence of the arc massif platform near the trench slope break since the Late Miocene; and 3) a plate margin erosion event in the trench, probably of Late Eocene age .

REGIONAL GEOLOGY

In this paper we will present information about the Puerto Rico Trench from the area north of the Virgin Islands, to the Mona Passage (Fig. 1). North of the Puerto Rico Trench is Atlantic oceanic crust, which passes laterally eastward to attentuated continental crust or thick oceanic crust of the Bahama bank (Uchupi and others, 1971; Freeman-Lynde and Ryan, 1988). The Puerto Rico Trench east of the northern Virgin Islands curves toward the south, as shown by both bathymetric and gravity data, into the north-south oriented Lesser Antilles subduction zone (Bowin, 1972). West of the Mona Passage, the Bahama bank is probably colliding with Hispaniola at the Puerto Rico Trench (Dolan and others, 1989). The exact nature of this collision zone, whether mostly thrust, strike-slip, or both, is uncertain. However, a steeply inclined seismic zone exists at least in eastern Hispaniola (Schell and Tarr, 1978; McCann and Sykes, 1984), indicating that subduction is occurring. The Hispaniola basin lies west of the collision zone and is being underthrust beneath Hispaniola (Austin, 1983; Dillon and others, this volume).

Hispaniola is cut by a number of strike-slip faults; two important ones, the Septentrional and South Samana Bay faults, are shown in Figure 1 (Mann and Burke, 1984). As shown in this study, these faults can be traced eastward using bathymetry, dredge sample compositions, and seismic reflection studies, into what is defined here as the 19^o lat (latitude) Fault. The 19^o lat Fault can be traced further east, where it nearly coincides with the Escarpment Fault. North of the 19^o lat fault and east of the Mona Canyon are a series of basins and ridges on the southern wall of the Puerto Rico Trench. Unlike most ridges in subduction zone settings, these ridges and basins locally do not parallel the strike of the trench, and trend northeast (Anomalous Block) and northwest (Main Ridge).

Profound tectonic subsidence (approximately 4 km) occurred between the island of Puerto Rico and the 19^o lat Fault in the Neogene. Evidence for this is discussed below, but consists of dredge hauls and submersible observations of in-place shallow-water carbonates of Miocene age along the 19^o lat Fault and in the walls of the Mona Canyon. To the south of Puerto Rico, a second subduction zone is observed, the Muertos Trough or Trench (Ladd and Watkins, 1978; Ladd and others, 1977; Ladd and others, 1981; Biju-Duval and others, 1982). The Virgin Island basin, between Puerto Rico and St. Croix, probably formed as a pull-apart (Case, 1975; Jany and others, 1987), or as interpreted here, is mostly extensional.

Tectonic Evolution of the Eastern Greater Antilles

The eastern Greater Antilles consists largely of a suite of rock types thought to have formed in oceanic island arc and trench settings. Arc-related rocks of Cretaceous to Eocene age occur in central Hispaniola, Puerto Rico, and the Virgin Islands (Joyce, 1985). North of the Septentrional fault in Hispaniola (Fig. 1) is a complicated terrane containing both arc-related lithologies and high-pressure, low-temperature metamorphic rocks (Nagle, 1974; Eberle and others, 1980; Joyce, 1980). Such metamorphic rocks are thought to represent products of

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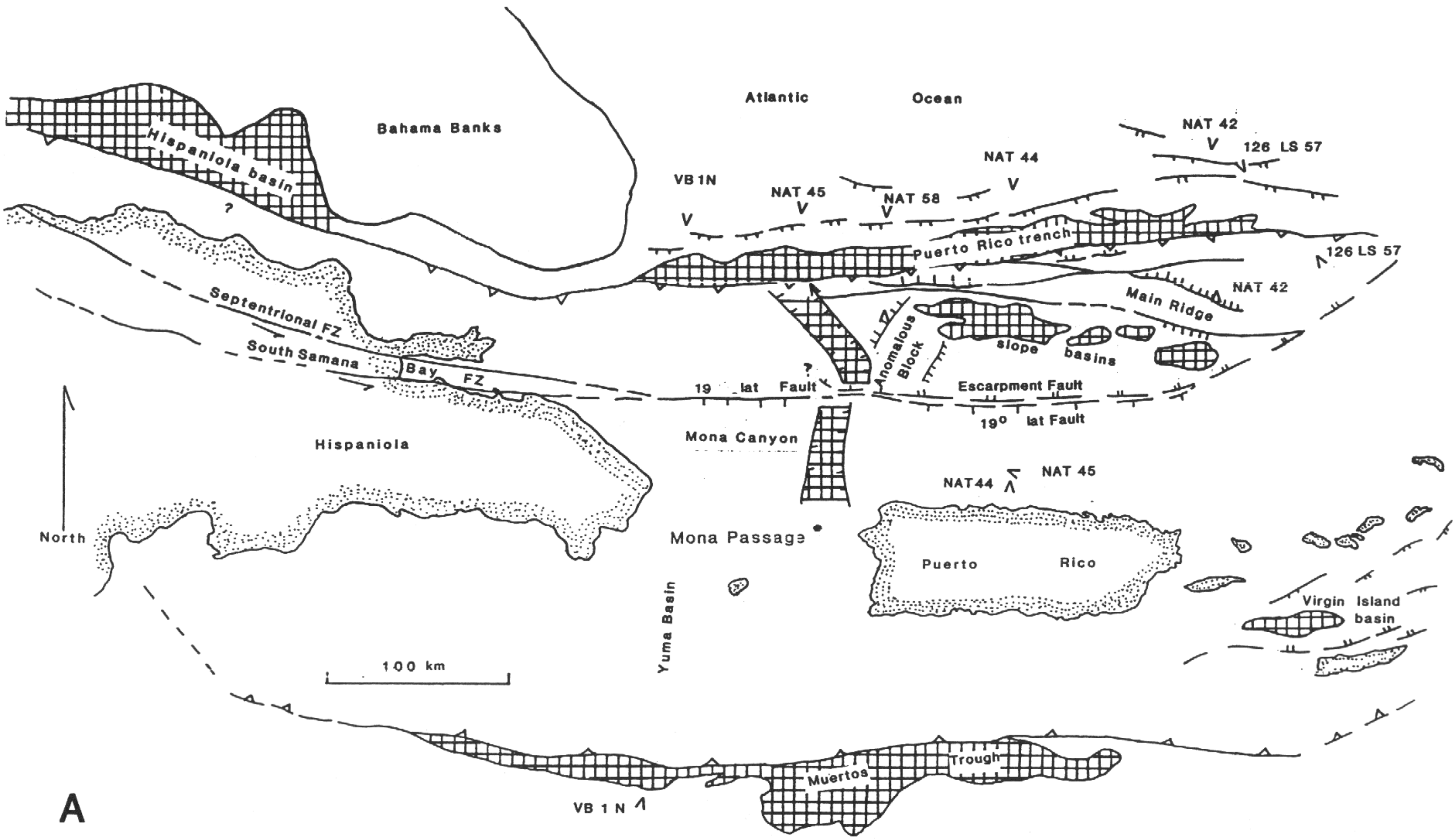
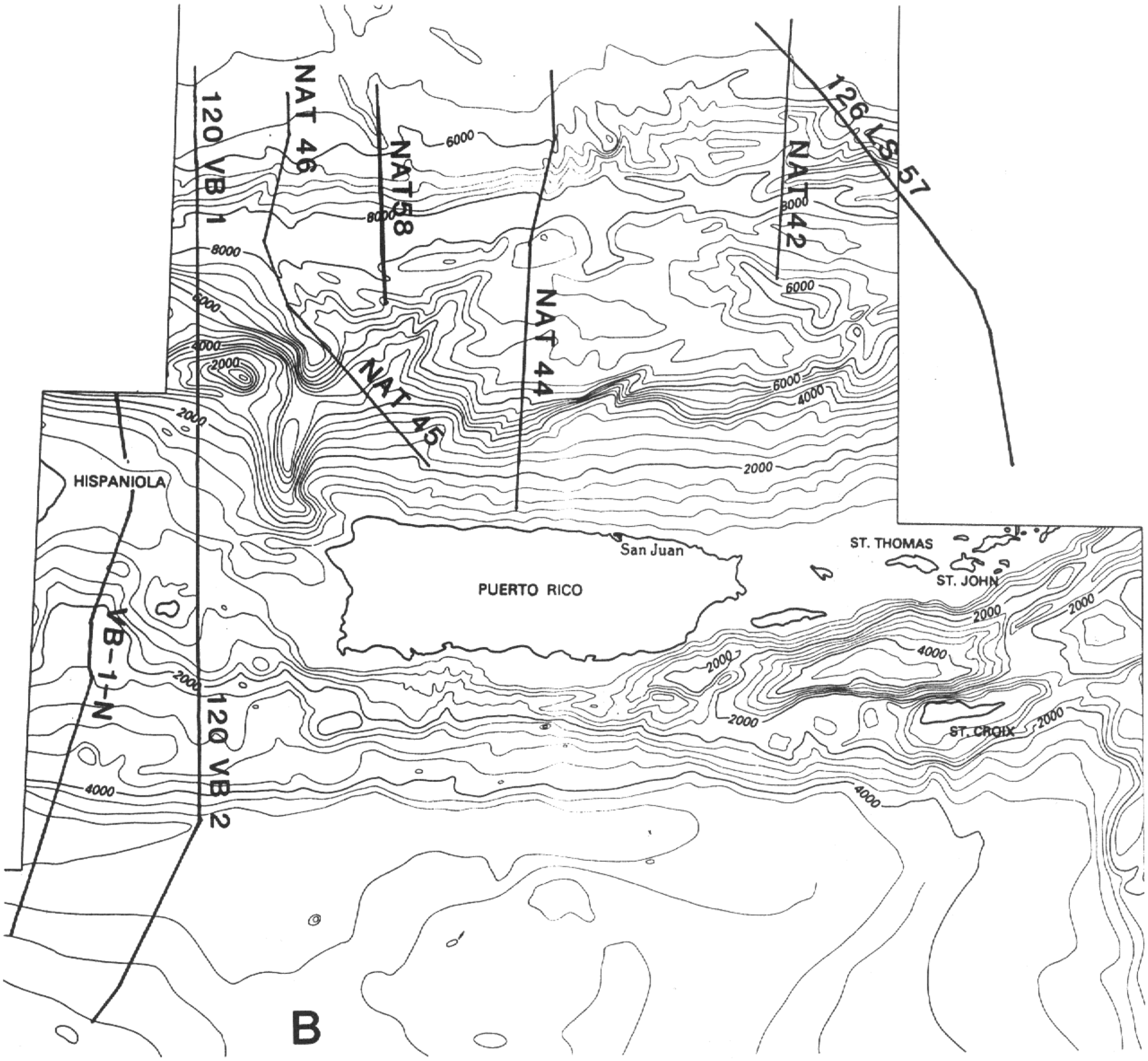


Figure 1. Location map of features of geologic interest in the area around Puerto Rico, with location of seismic lines of Figure 4.



recrystallization in a subduction zone setting. South of the Septentrional fault in central Hispaniola is the Cordillera Central, where Cretaceous arc volcanism was pronounced (Lewis, 1980).

During the Late Eocene, a poorly understood event resulted in the end of arc magmatism and uplift of subduction-zone rocks. Earlier studies proposed that, like Cuba, the eastern Greater Antilles collided with the Bahama bank in the Early Tertiary (Pindell and Dewey, 1982). However, that does not explain the presence of over 250 km of slab subducted below eastern Hispaniola since the middle Tertiary (McCann and Sykes, 1984). That is, if true collision occurred with the Bahama bank, further subduction would be inhibited.

The Oligo-Miocene history of Hispaniola is characterized by subduction and accretion in southern Hispaniola (Biju-Duval and others, 1982) and the formation of carbonate banks and strike-slip basins toward the north (Lewis, 1980). On Puerto Rico, Oligo-Miocene basins were apparently formed through extensional processes (Birch, 1986; Moussa and others, 1987).

PUERTO RICO TRENCH

The Puerto Rico Trench is a flat-lying submarine valley, filled with turbidites (Connolly and Ewing, 1967) surrounded by great topographic relief (Figs. 1, 3). North of the trench, the Atlantic Ocean crust is broken into a number of blocks by normal faulting, as indicated by offsets in seismic stratigraphy (Fig. 4).

The south wall of the trench also exhibits extreme relief, the most profound associated with the Puerto Rico scarp (Ewing and Heezen, 1955; Ewing and others, 1965), which is shown here to be a fault scarp (that is, the 19° lat Fault and Escarpment Fault) associated with the continuation of the Septentrional and Samana Bay fault zones.

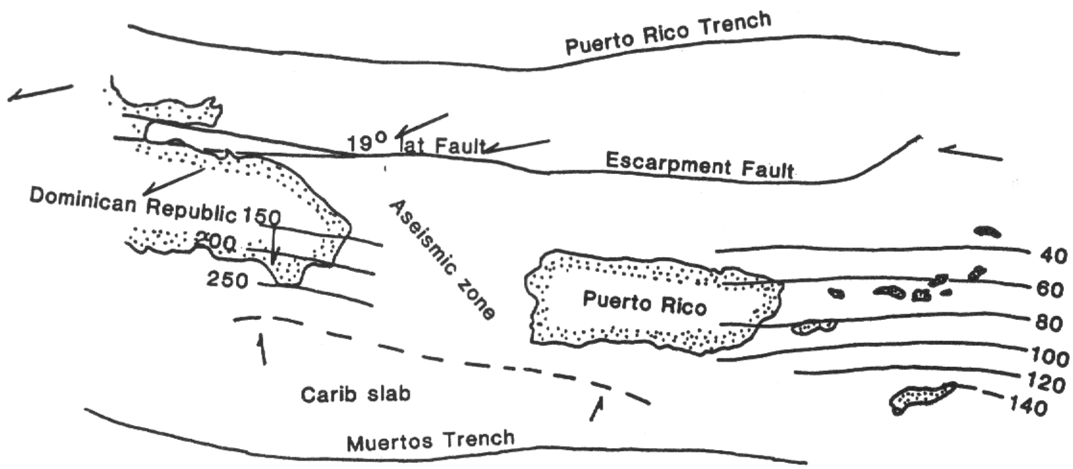


Figure 2. Summary of information concerning inclined seismic zones beneath Puerto Rico and the Virgin Islands. Focal mechanisms give motion of lower plate (arrows). From Molnar and Sykes (1969), Bracey and Vogt (1970), Schell and Tarr (1978), Sykes and others (1982), McCann and Sykes (1984), Byrne and others (1985) and Ascencio (1980). "Carib slab" in the Muertos trough is based on earthquakes located and focal mechanisms done by Ascencio (1980) and Byrne and others (1985) and based on seismic reflection studies by Ladd and Watkins (1978) who noted the presence of inclined reflectors below the Yuma basin (located in Figure 1).

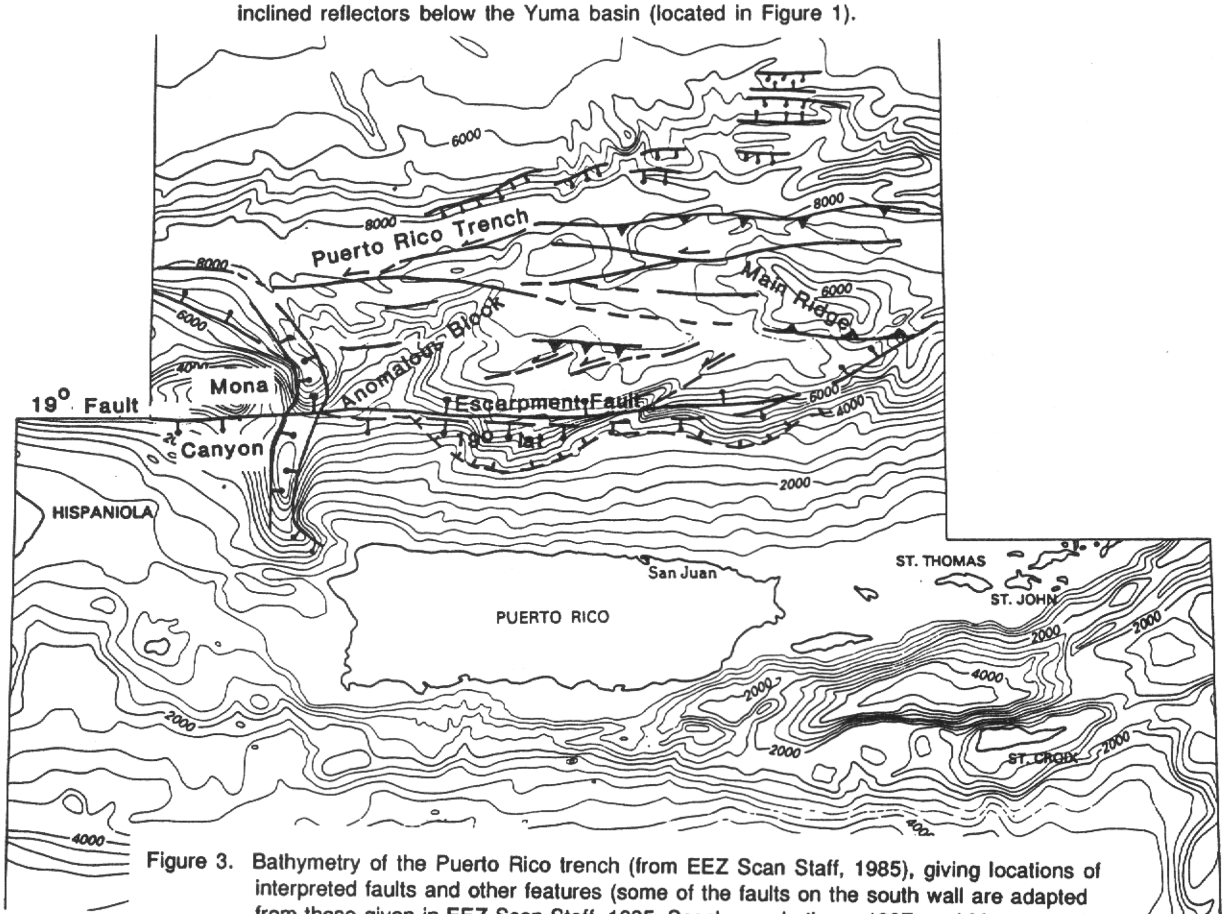


Figure 3. Bathymetry of the Puerto Rico trench (from EEZ Scan Staff, 1985), giving locations of interpreted faults and other features (some of the faults on the south wall are adapted from those given in EEZ Scan Staff, 1985, Scanlon and others, 1987, and Masson and Scanlon, in press; all faults on the north wall of the trench are from EEZ Scan Staff, 1985).

BENIOFF ZONE AND SUBDUCTION DIRECTION

An inclined seismic zone below Puerto Rico has been documented by Sykes and Ewing (1965), Schell and Tarr (1978), Ascencio (1980) and McCann and Sykes (1984). Fault plane solutions show mostly left-lateral strike-slip faulting parallel to the trench on inclined planes (Molnar and Sykes, l969) (Fig. 2). From central Puerto Rico to eastern Hispaniola, the inclined seismic zone is discontinuous, which indicates that the steeply-dipping slab is detached at it's eastern end(McCann and Sykes, 1984)(Fig. 2). The origin of this slab is debatable: McCann and Sykes (1984) suggested that the detachment occurred during an earlier collision/accretion event with the Bahama banks. Bracey and Vogt (l970), suggested it was a small subduction zone, which Schell and Tarr (1978) and Mann and others (1984) related to a strike-slip restraining bend in Hispaniola.

The rate of underthrusting can be estimated from the direction and rate of relative plate motion, presuming that the motion is all taken up along the Puerto Rico Trench. Estimates of Caribbean plate motion relative to North American plate motion range from N 65° E (Sykes and others, 1982) to ESE (Jordan, 1975; Stein and others, 1988). To generalize these two different vectors, the plate motion is about east-west with an uncertainty of about 25°. Estimates of rates of relative plate motion range from approximately 1.5 to 4 cm/yr (McCann and Sykes, 1984; Jordan, 1975; Stein and others, 1988). From this, one can conclude that present day rates of underthrusting on the Puerto Rico Trench are well under 1 cm/yr.

DREDGE HAULS, SUBMERISBLE OBSERVATIONS AND PISTON CORING IN THE PUERTO RICO TRENCH AREA

On the north wall of the Puerto Rico Trench, Bowin and others (1966), Chase and Hersey (1968), Nalwalk (1969) and Perfit and others (1980) described dredged rocks attributed to an origin at a mid-ocean ridge spreading center, later covered by pelagic sediments. Dredge samples containing oceanic crustal rocks such as serpentinites and serpentinized peridotites support the presence of normal faults imaged seismically, that have up to several kilometers of throw.

Perfit and others (1980; see also Fox and Heezen, 1974; Weaver and others, 1975; Heezen and others, 1985; Le Pichon and others, 1985) noted two principal basement rock lithologies on the south wall of the trench: arc-related rocks and metamorphic rocks similar to blueschist grade metamorphic rocks identified on the north coast of Hispaniola (see Perfit and others, 1980; Joyce, 1985; Joyce and Aronson, 1987) . The boundary between these two basement rock lithotypes north of Puerto Rico is the 19° lat and Escarpment Faults (Fig. 1,2,3). On Hispaniola, the Septentrional and South Samana Bay Faults separate a dominately metamorphic complex to the north from an arc terrane to the south. Both basement rock types are overlain by Tertiary limestones.

Intact Miocene shallow-water limestone sequences at water depths of greater than 4 km, are present on the south wall of the Puerto Rico Trench (Moussa and others, 1987). The Puerto Rico slope extends from the island of Puerto Rico to the 19° lat and Escarpment Faults. Apparently, in the Miocene, the Puerto Rico shelf extended 50 km further to the north, and subsided since that time (Meyerhoff and others, 1983; Birch, l986; Moussa and others, l987). Birch (1986) and Moussa and others (1987) argued that the subsidence was Pliocene or younger. However, based on review of dredge haul and piston core data the conclusion is reached that subsidence probably began in the Late Miocene. For example, piston core number V3-2 is a foraminiferal lutite of Late Miocene age (Ewing and Heezen, 1955), and dredge samples 5, 11 and 23 (Perfit and others, 1980), both indicate open marine deposition in the Late Miocene. Interesting, at 9 ma, a change in North American plate motion occurred toward more southerly motion (Pollitz, 1988), which may have caused flexure in the Puerto Rico arc massif platform, with resulting subsidence.

Heezen and others (1985) described an intact coral reef in the Mona Passage near the 19° lat Fault at a depth of 3652 m of post-Pliocene age based on paleontologic data, and older than 700,000 yrs based on U/Th studies. The rapid subsidence indicated by this submerged reef is perhaps related to the 19° lat Fault or perhaps Mona Canyon subsidence, and not directly to the regional subsidence of the Puerto Rico slope.

GLORIA STUDIES

Studies of the Exclusive Economic Zones off Puerto Rico by the U.S. Geological Survey using GLORIA reveal pronounced continuous lineations in the Puerto Rico Trench, possibly related to strike-slip faulting (EEZ Scan Staff, 1985; Scanlon and others, 1987, Masson and Scanlon, in press). Unfortunately, the 19° lat and Escarpment Faults, were not observed by the GLORIA scans because the ship tracks converge and parallel 19° (thus 19° is a zone of no data collection). Given that the Puerto Rico Trench is undergoing left-lateral shearing accompanying E-W motion of the Caribbean plate relative to the North American plate, the lineations are presumed to be left-lateral shear zones (Fig. 3). The orientation of the Escarpment Fault near the Main Ridge indicates it may be a releasing bend along the primary strike-slip fault zone. The fault at the base of the Main Ridge is probably a reverse or thrust fault based on its orientation and on the pronounced topography on the south side of the lineation. Using the above assumptions, the slope basins (Figs. 1,3) to the west of the Main Ridge therefore represent pull-apart or fault-wedge basins, relative to the releasing bend and the complex system of faults on the landward wall of the trench (nomenclature after Mann and Burke, 1984).

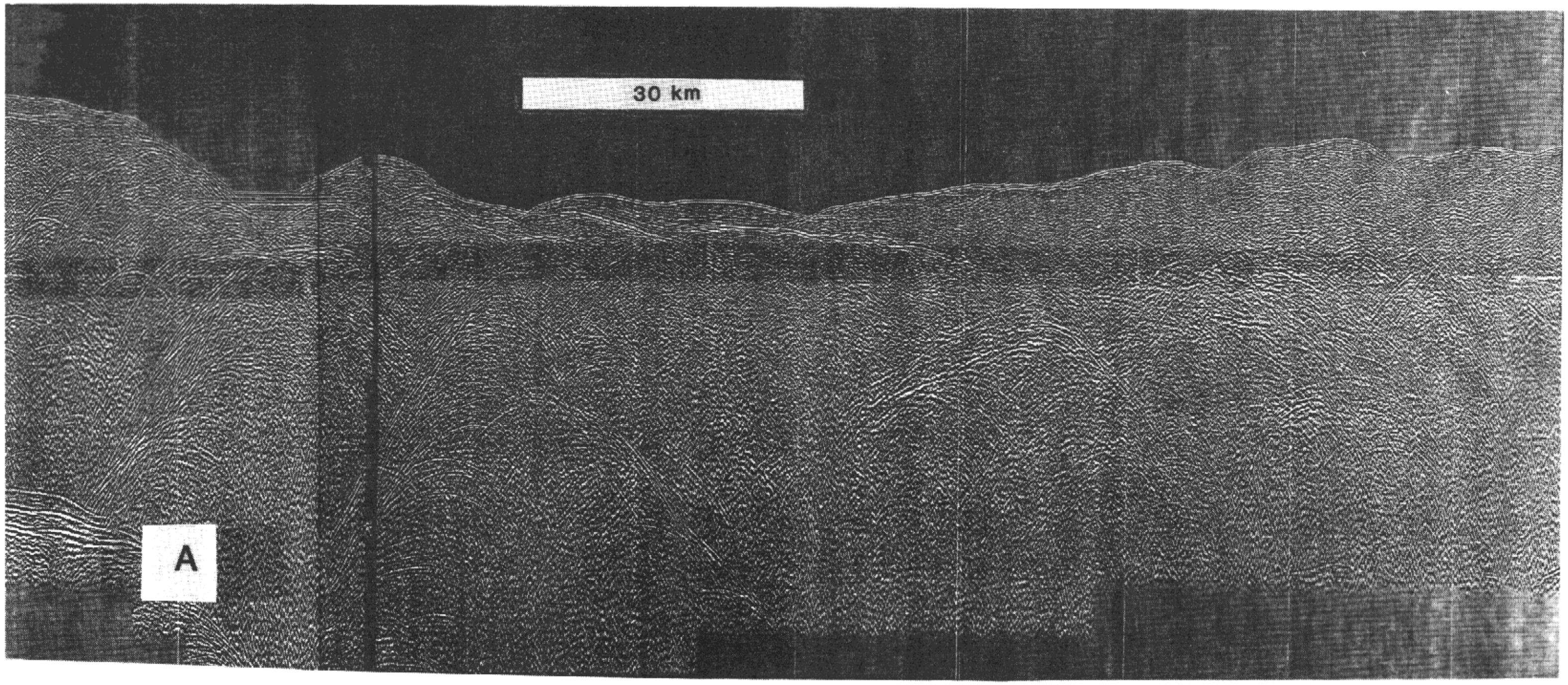
Folding is not prevalent in the GLORIA data from the Puerto Rico Trench, although folds and a well-developed deformation front is observed in the Muertos Trough to the south on the same data set. The lack of folds in the Puerto Rico Trench is puzzling, but may reflect the occurrence of indurated rock in the trench slope, and absence of accreted sediment. One fold associated with a probable reverse fault (Fig. 4F) was imaged in multichannel seismic profile at the base of the Puerto Rico scarp, and that fault is shown in Figure 3.

SINGLE AND MULTICHANNEL SEISMIC LINES CROSSING THE TRENCH

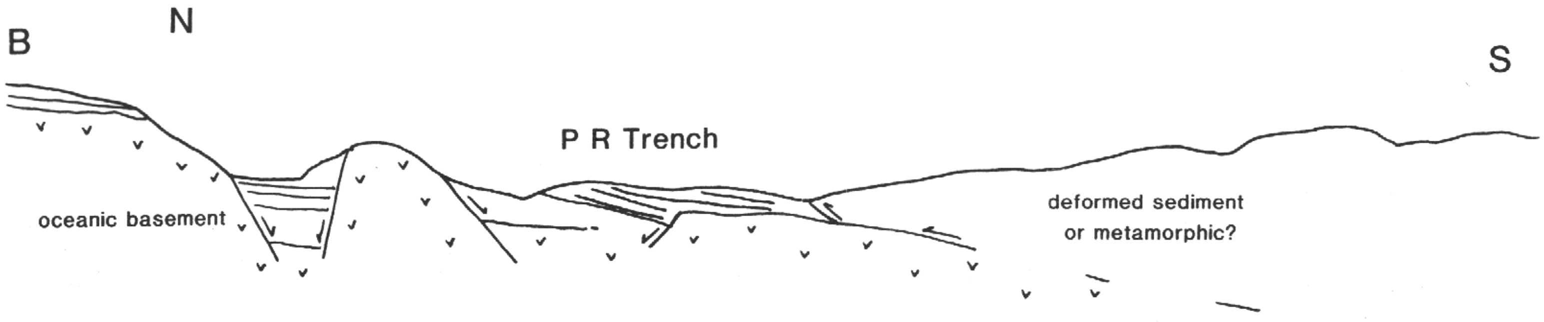
A number of studies have used single channel data to study the Puerto Rico Trench (most recently, McCann and Sykes, 1984; and EEZ staff, 1987). The present study relies on multichannel data (see Fig. 1) owned by the Texas Institute of Geophysics, and reprinted with their permission here.

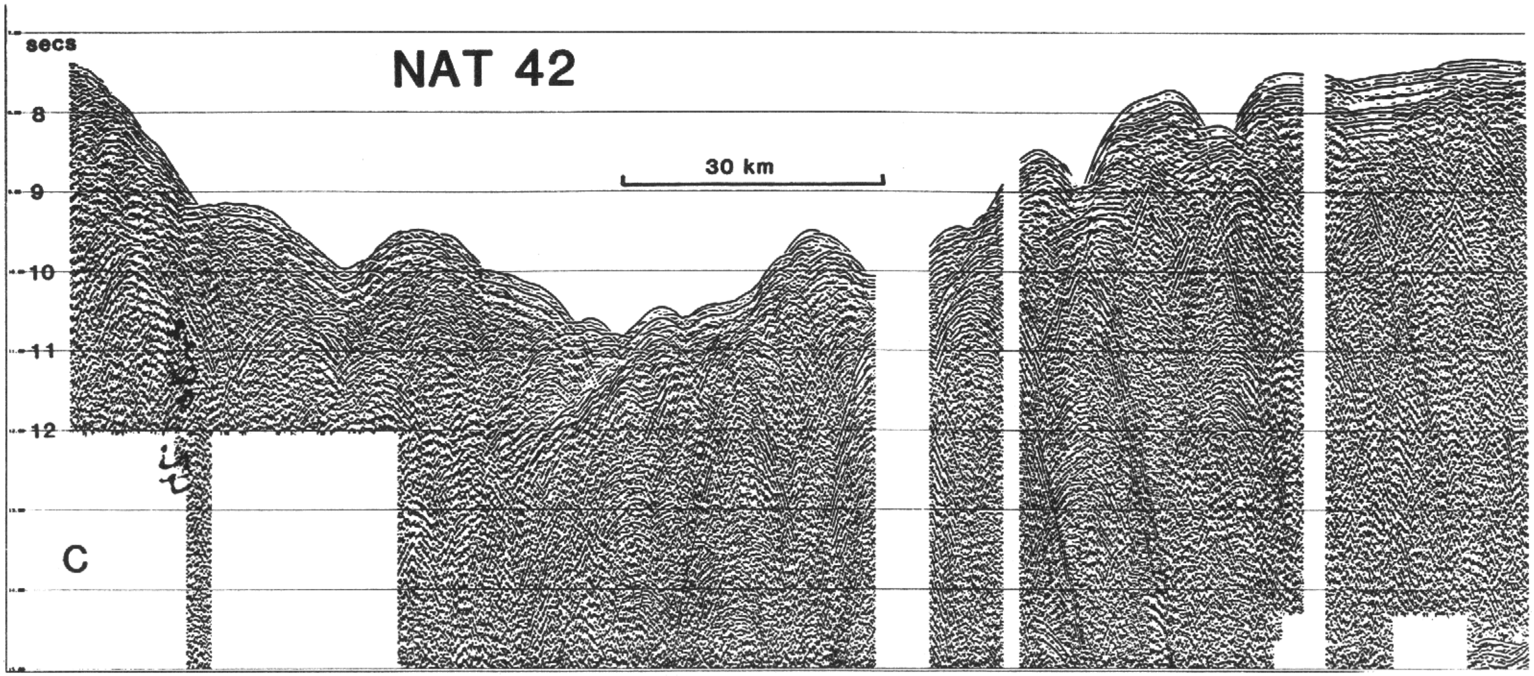
Figure 4A-J show unmigrated seismic lines and interpretations. The 19° lat and Escarpment Faults are imaged as transitions from parallel-layered reflectors over acoustic basement to acoustic basement exposed at the seafloor (Figs. 4 E,F,G,H,K,L). The south-dipping 19° lat Fault is separated from the north-dipping Escarpment Fault by an inferred horst block.

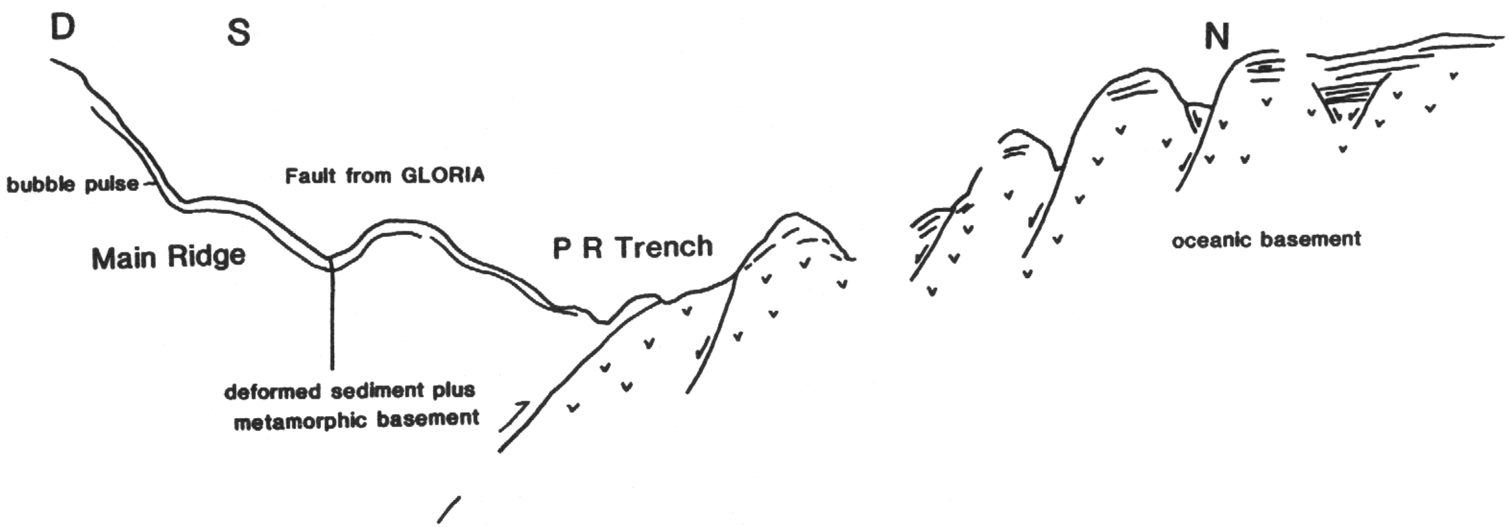
The Mona Canyon graben (Fig. 1) is over 100 km long, and several kilometers deep. The graben is segmented by the 19° lat fault, yet is not appreciably offset laterally, indicating no lateral movement on the fault since the graben formed.

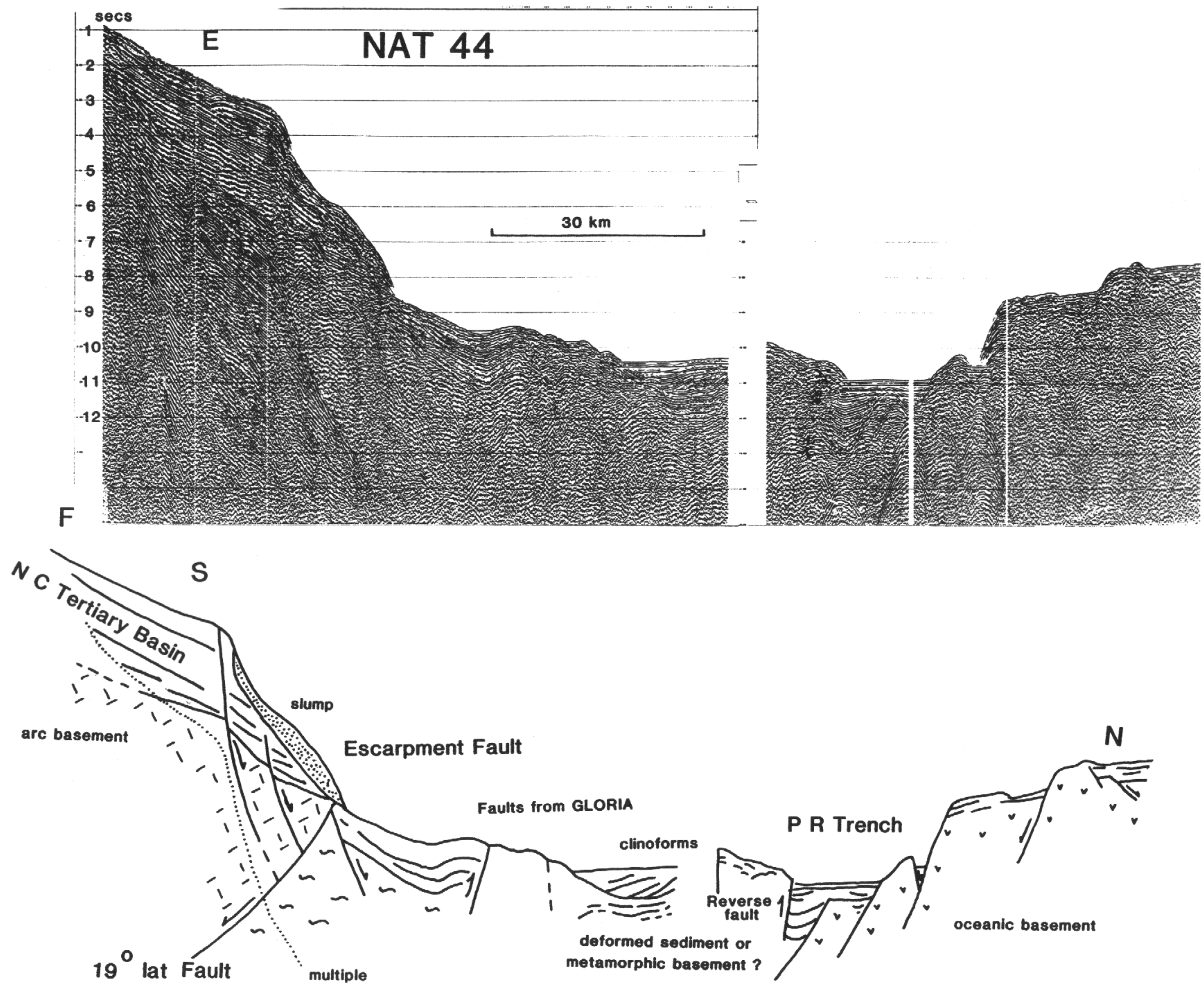

30 km
A

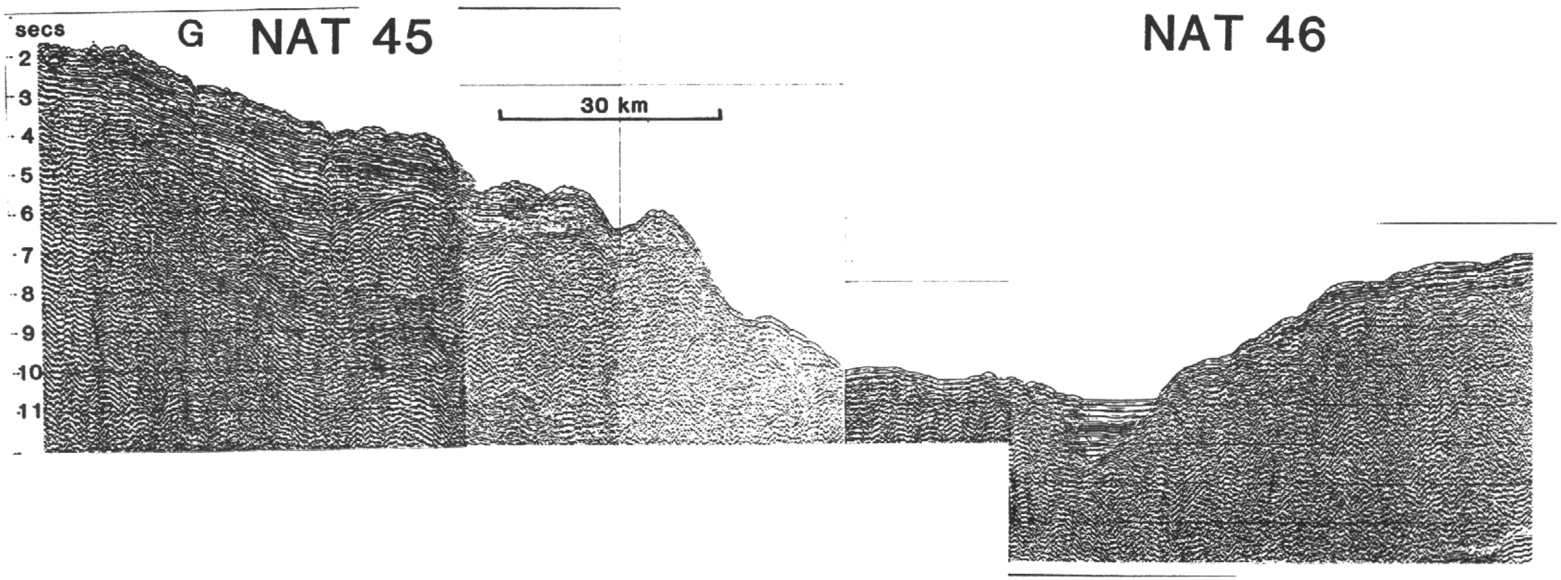
126 LS 57


B
N
S
P R Trench
oceanic basement
deformed sediment
or metamorphic?

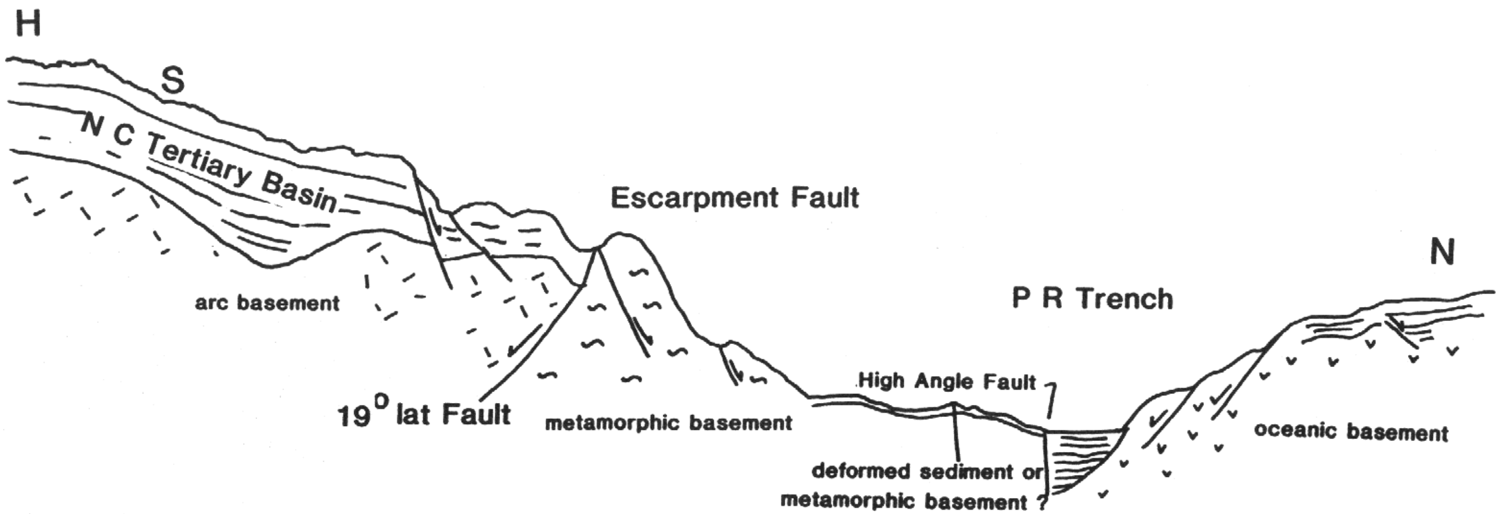

secs
NAT 42
8
9
10
11
12
30 km
C


D
S
N
bubble pulse
Fault from GLORIA
Main Ridge
P R Trench
oceanic basement
deformed sediment plus
metamorphic basement

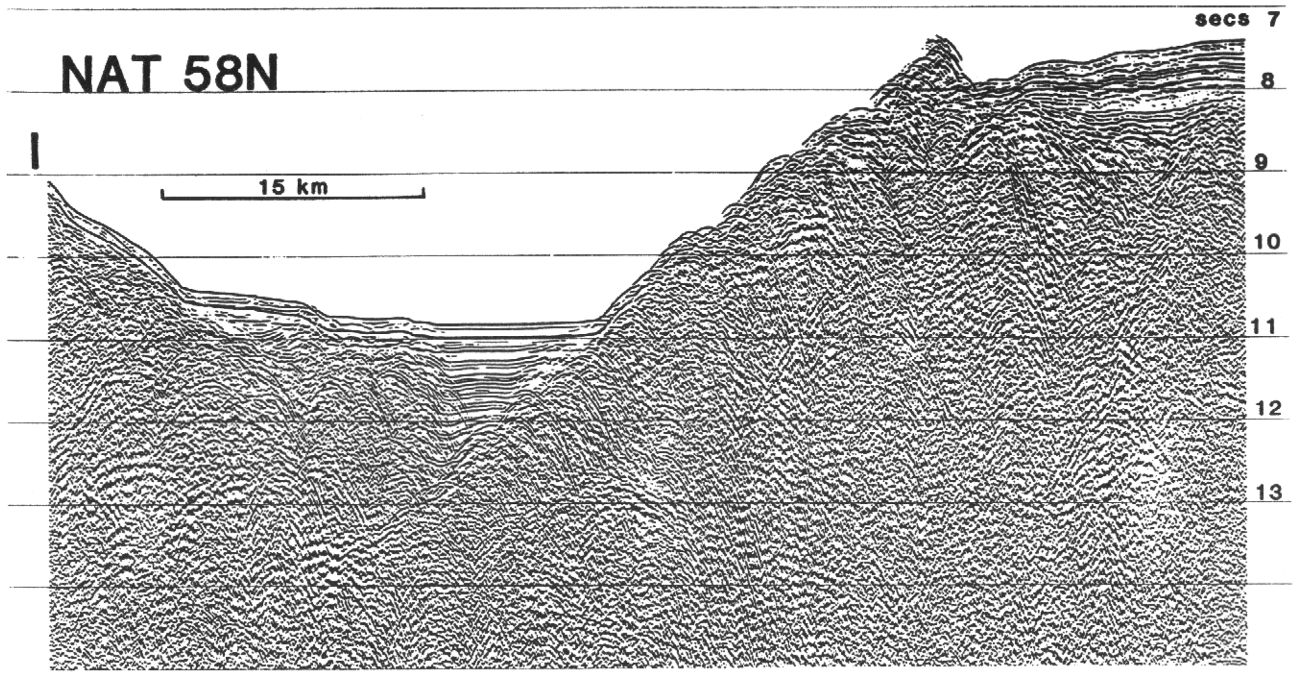

secs
1
2
3
4
5
6
7
8
9
10
11
12
E
NAT 44
30 km
F
S
N C Tertiary Basin
slump
arc basement
Escarpment Fault
N
Faults from GLORIA
clinoforms
P R Trench
Reverse fault
oceanic basement
deformed sediment or
metamorphic basement ?
19° lat Fault
multiple

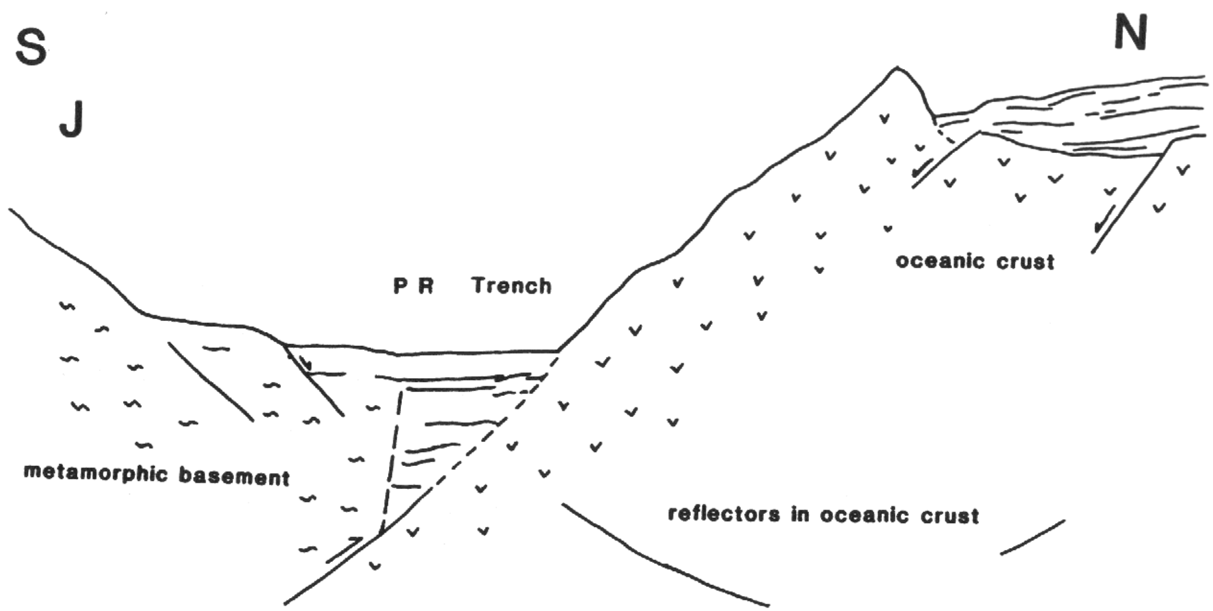


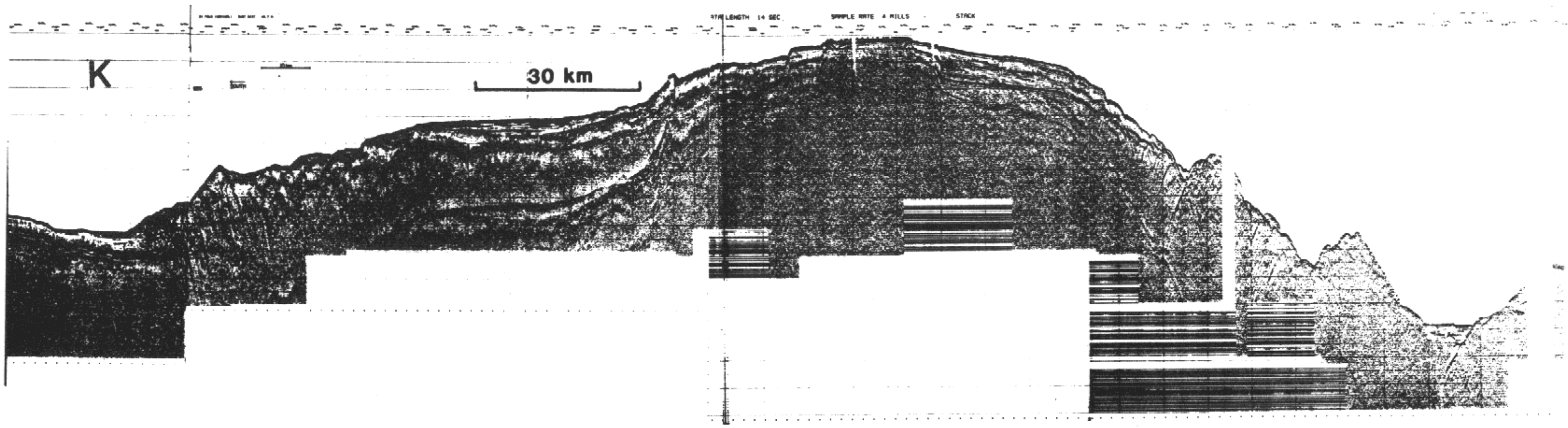
secs
2
3
4
5
6
7
8
9
10
11
G
NAT 45
30 km
NAT 46



H
S
N C Tertiary Basin
Escarpment Fault
N
arc basement
P R Trench
High Angle Fault
19° lat Fault
metamorphic basement
oceanic basement
deformed sediment or
metamorphic basement ?


NAT 58N
I
15 km
secs 7
8
9
10
11
12
13


S
J
N
P R Trench
oceanic crust
metamorphic basement
reflectors in oceanic crust



L

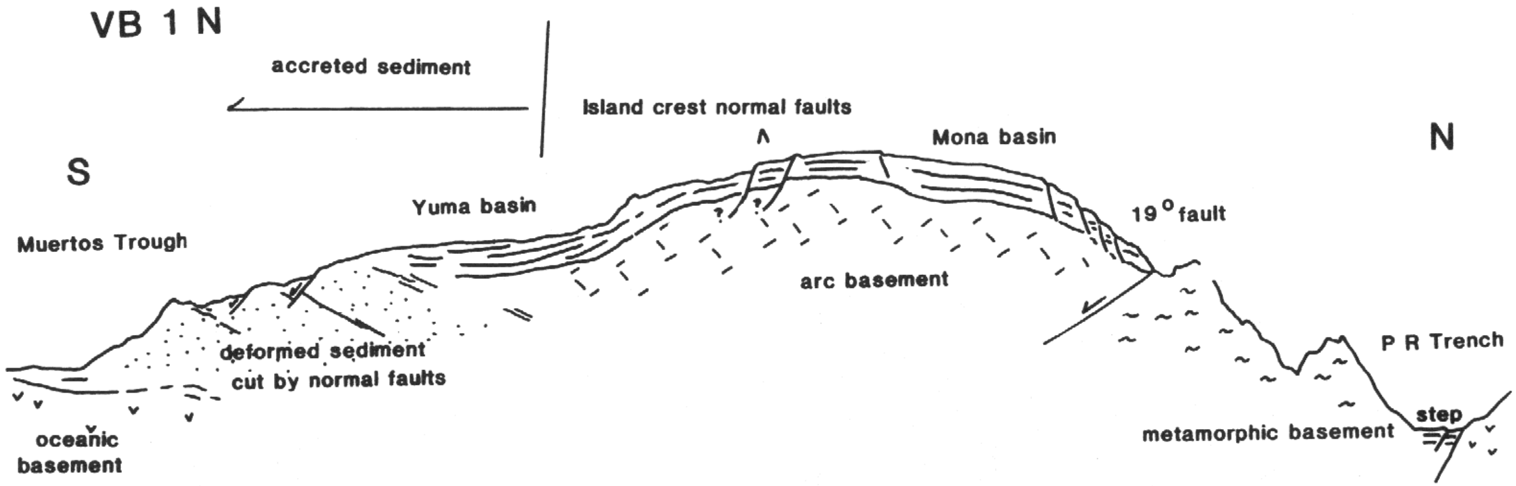


Figure 4. Seismic reflection profiles, located in Figure 1. Property of the Texas Institute of Geophysics and reprinted here with permission. See text for discussion. Figures A,C,E,G,I,K show data and B,D,F,H,J,L show interpretations. Important note: some of the interpreted faults are based on crossing of presumed faults shown in Figure 3, but can not be observed on the seismic lines. Dip of frontal fault in Puerto Rico Trench in F and H are from other lines (not shown here) with less vertical exaggeration. Dip of 19° lat Fault is from migration of K (Larue and Ryan, work in progress).

Migration of seismic profile VB-1-N (line interpretation shown in Fig. 4 K,L) suggests that the 19° lat Fault is a south-dipping normal fault (Larue and Ryan, work in progress). The antiformal strata above this south-dipping fault (Fig. 4L) is proposed to result from rollover accompanying motion on a listric fault (see also, Speed, 1989). However, the floor of the Mona Canyon is characterized by a downward step to the north at 19° lat based on bathymetric data. Because the anticlinal rollover can be traced by bathymetry and seismic reflection profiles along 19° latitude to longitudes slightly east of Puerto Rico, it seems that the 19° lat Fault has to exist in this area as a south-dipping listric normal fault. The topographic steps toward the north (floor of Mona Canyon and steep south trench slope) are thus associated with the inferred Escarpment Fault, which is thought to be separated from the 19° lat Fault by a narrow horst block (Fig. 4 E,F,G,H). The western edge of the Escarpment Fault crosses the Mona Canyon (as shown by a downward step to the north down the axis of the canyon), and perhaps loses displacement further west, as it is not imaged well by bathymetry. The eastern part of the 19° lat Fault is defined by the disappearance of the rollover structure described herein. Possibly the rollover is progressively truncated by the Escarpment Fault, or the 19° lat Fault loses displacement toward the east.

The layered reflectors south of 19° (for example, Fig. 4 E,F,G,H) can be traced via other seismic lines (unpublished data, University of Puerto Rico in Mayaguez) to the island of Puerto Rico, and correlated with formations in outcrop and in borehole (for example, Moussa and others, 1987).

The multichannel lines show that the Puerto Rico Trench contains about 1 or 2 seconds of trench facies strata (Ewing and others, 1965). Well-developed thrust faults are only imaged on the easternmost lines (Fig. 4A,B,C,D,E,F), and length of the imaged thrust zone diminishes toward the west. West of Puerto Rico in the trench, there is little evidence for significant amounts of underthrusting (Fig. 4 G,H,I,J,K,L). Linear features interpreted as faults on the GLORIA scans are not obvious on most of the multichannel seismic lines; these faults are shown in the interpreted seismic profiles to document their relative positions. If the linear features from the GLORIA studies are indeed mostly strike-slip faults, it is well-known that strike-slip faults are not easily imaged using seismic reflection techniques (for example, Sylvester, 1988).

The slope basins of Figure 1 are not clearly imaged in Figure 4E,F,G,H (see also, Figure 4 of Murphy and McCann, 1979). Thus it cannot be proven based on seismic data that the slope basins are indeed strike-slip related, related to pull-aparts and fault divergence, and not solely related to accretion as was previously suggested (McCann and Sykes, 1984). A strike-slip origin to the slope basins is therefore based on bathymetric patterns, GLORIA scan studies, and inferences based on directions of plate motion.

Line 45 (Fig. 4C,D) shows the North Coast Tertiary basin, north of Puerto Rico. Birch (1986) argued that the basin contains two sequences: an older extension-related sequence (Late Eocene through Oligocene) followed by a sequence deposited during cooling of the magmatic arc (Oligocene-Miocene). Recently it has been shown through drilling on the north coast of Puerto Rico that lower series of reflectors in the basin is of Lower to Middle Eocene age (Larue, 1990). The north side of the basin is truncated by the 19° lat Fault, however, clear northward stratigraphic thinning and onlap onto basement south of the fault is indicated.

Line VB-1-N (Fig. 4K,L) shows a complete seismic reflection record from the Muertos Trough to the Puerto Rico Trench. The southern part of this line was described by Ladd and Watkins (1978) who noted the presence of inclined reflectors in sedimentary rock beneath the Yuma basin. Here, it is concluded that from these inclined reflectors beneath the Yuma basin to the Muertos Trough, all rocks are accreted (Fig. 2), and thus the northern limit of the subducting Caribbean plate is given. From the Yuma basin to the 19° lat Fault, the arc massif has a bowed appearance, with an anticlinal drape of sedimentary rocks over arc basement. Based on studies on land on Puerto Rico, on dredge hauls in the Mona Canyon and along the Puerto Rico scarp and limited information on the south slope of Puerto Rico, it is concluded that a platform of shallow water carbonates was flexed into this anticlinal orientation (that is, these are not depositional slopes). Age of this flexure, based on the above, is assumed to be approximately Late Miocene.

DISCUSSION

Evidence for Plate Margin Truncation

The Puerto Rico Trench underwent one or perhaps two plate margin truncation events. The metamorphic rocks exposed beneath the south trench wall formed at pressures of 3 to 7 kb (burial of 12-25 km) and temperatures of 400 to 550° C (Perfit and others, 1980). If such conditions apply to a subduction zone setting, as suggested by Perfit and others (1980), the original trench was probably located 50 to 100 km north of its position prior to uplift of the metamorphic rocks. That is, metamorphism occurred 50-100 km down slab, in the hanging wall of the original trench. Uplift probably occurred in the Early Tertiary, possibly the Eocene or Oligocene, as indicated by a few K-Ar dates, shut off of volcanism, and regional geologic relations (Joyce, 1985). Figure 5A shows one such means in which plate margin truncation can occur during and accompanying subduction of oceanic topography (von Huene, 1986; Lallemand and Le Pichon, 1987). According to these workers, margin truncation follows subduction of the tail of the the anomalous topography.

A second period of margin truncation may have occurred in the Miocene to Pliocene, and is indicated by shallow water facies strata deposited at least as far north as 19°, only 70 km from the present trench.

Faulting in the Puerto Rico Trench region

The north and south walls of the Puerto Rico Trench are characterized by normal faults with cumulative vertical diplacements of several kilometers. Relative plate motions indicate that left-lateral strike-slip faulting is important as well. Although dominantly normal faults bound the walls of the Puerto Rico Trench, the trench floor appears to be dominated by thrust-faults in the east that progressively change to strike-slip faults in the west. Although the Puerto Rico Trench is not characterized by active underthrusting (as revealed by seismic reflection profiles), an inclined seismic zone exists below Puerto Rico. In summary, the Puerto Rico Trench is essentially an inclined strike-slip fault in transtension (supporting the plate motion vectors of Jordan, 1975).

The Main Ridge is probably a fragment of the metamorphic complex that has been uplifted along a reverse or thrust fault. The slope basins to the south and west of the Main Ridge are probably related to the releasing bend of the 19° lat and Escarpment Faults, and thus are pull-apart (or fault wedge) basins (nomenclature of Mann and Burke, 1984).

The Mona Canyon is not visibly offset by the 19° lat Fault using bathymetric data (and if it is offset, it's offset is right-lateral). There is a topographic step of approximately 2 km in the Mona Canyon as it crosses the 19° lat fault, thus some

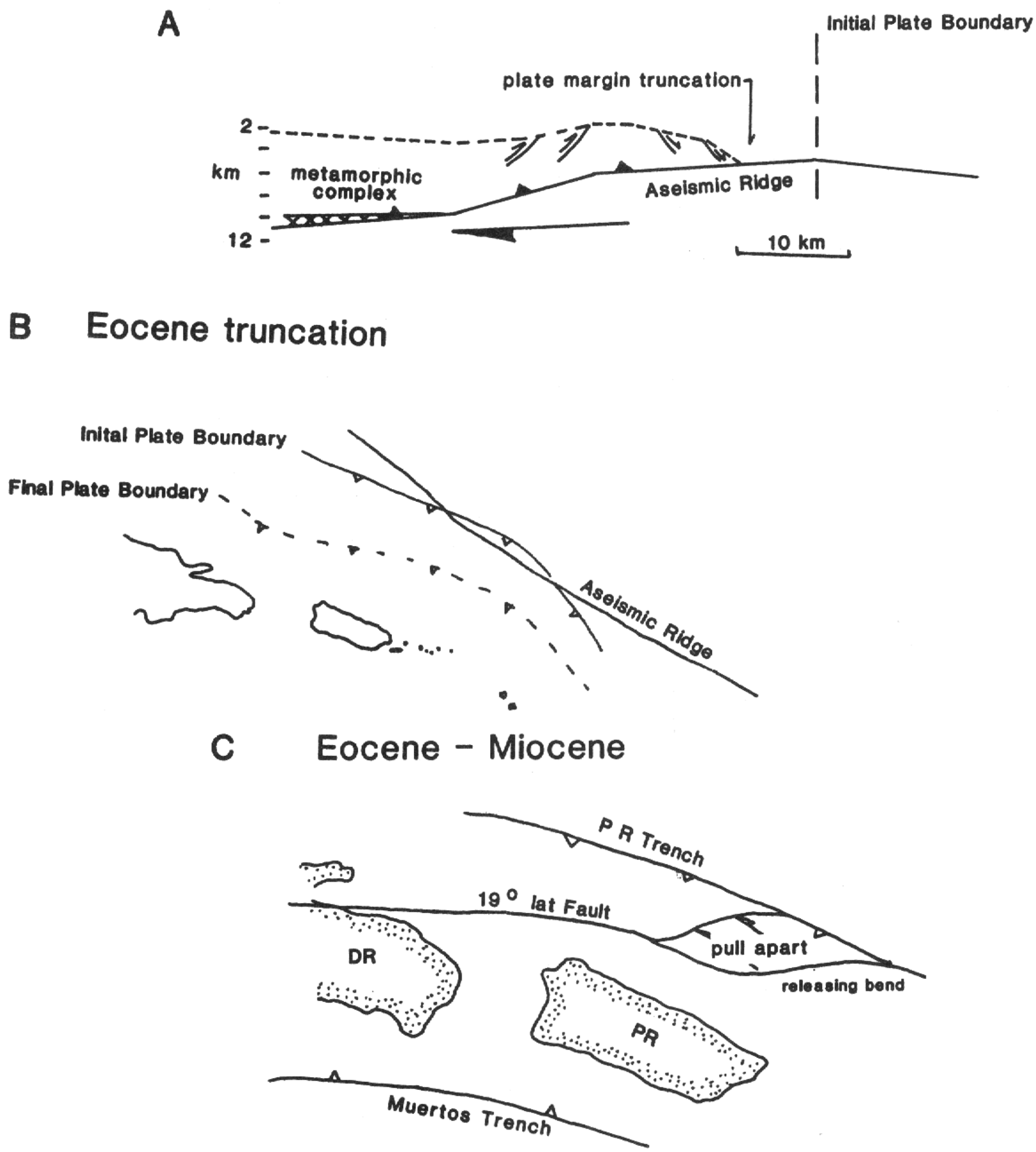
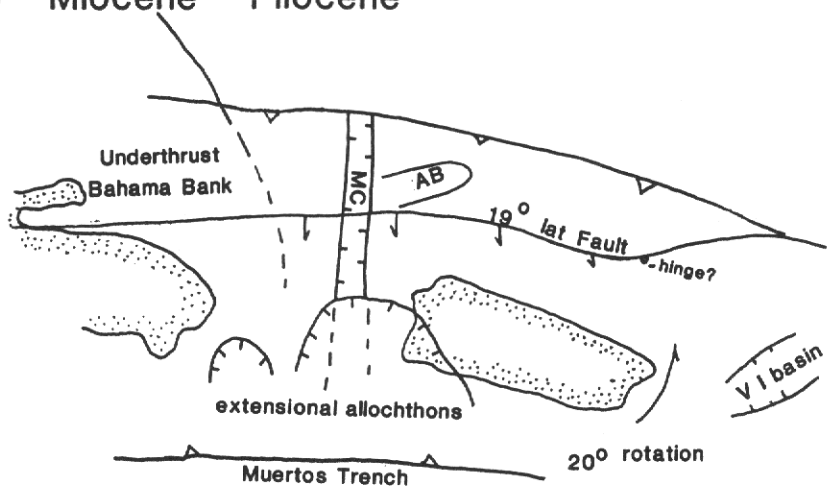
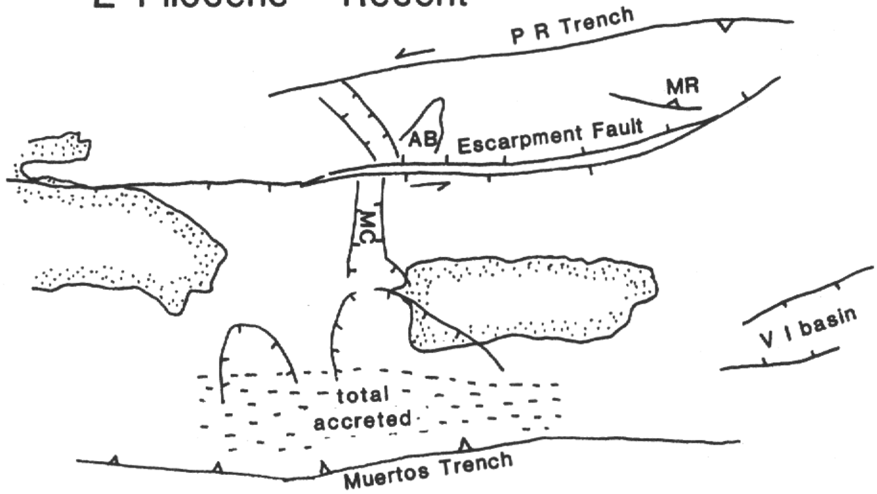


Figure 5. A. Model from Lallemand and Le Pichon (1987) for plate margin truncation associated with subduction of anomalous seafloor topography. Diagram has been modified, showing upper limit of metamorphic rocks now present in the Puerto Rico Trench wall. Subduction of the ridge is thought to have caused uplift and exposure, mostly through extensional processes, of the metamorphic complex in the present day trench wall. B. Subduction of an aseismic ridge in the Eocene (to perhaps Oligocene) results in a plate margin truncation event. C. Oblique subduction in the Eocene through Miocene results in formation of a pull-apart region on the 19° lat Fault, with attendant formation of slope basins (see Fig. 1). The Muertos Trench is located closer to Puerto Rico prior to formation of accretionary complex. D. Miocene through Pliocene events: 20° counter clockwise rotation of Puerto Rico (from Reid and others, 1988), opening of Virgin Island, Whiting, St. Croix, and other basins southeast of Puerto Rico. 19° lat Fault is hinged on the east and moves normally on the west (that is, displacement increases to west), probably also associated with rotation of Puerto Rico block. Mona Canyon graben opens because Hispaniola moves more slowly than Puerto Rico owing to underthrust Bahama Bank (a drag effect). Rotation of Puerto Rican block is taken up in Puerto Rico trench by overthrusting Atlantic crust, and overthrusting in Muertos

D Miocene - Pliocene



E Pliocene - Recent



Trench, and rotation on the 19° lat Fault. Extensional allochthons form between Hispaniola and Puerto Rico (Larue, 1989), obscuring location of the Puerto Rico block boundary. E. Pliocene to Recent reconstruction. North America-Caribbean plate motion is nearly pure East-West, with overthrusting in Puerto Rico trench associated with rotation of the Puerto Rico block. Main Ridge (MR) is uplifted on a splay thrust. Mona Canyon (MC) north of 19° lat Fault and anomalous block (AB) rotate by simple shear into northwest-trending structure. Muertos Trough has developed significant accretionary complex. Extensional allocthons cut older accreted material (Larue, 1989).

vertical motion is indicated. It is concluded that strike-slip motion along the 19° lat Fault must have occurred prior to formation of the Mona Canyon, if the Mona Canyon formed as a continuous feature across the 19° lat Fault. The change in orientation of the Mona Canyon from N-S, south of the 19° lat Fault to NW-SE, north of the 19° lat Fault could conceivably be due to rotation of the Mona Canyon accompanying shear between the 19° lat Fault and the Puerto Rico Trench, or alternatively, the Canyon could have formed in this kinked position.

Forearc Subsidence

The shelf north of Puerto Rico once extended to the 19° lat fault, and this shelf subsided approximately 4 km in the Late Miocene to form a slope environment. Birch (1986) has shown that this forearc subsidence is best modelled using flexural isostasy of an elastic plate subject to a small upward load in the south and a large downward one in the north, and suggested several tectonic mechanisms to accomplish such flexure. One obvious means in which tectonic subsidence could occur is through tectonic erosion (for example, Scholl and others, 1980). Alonso and others (1987) suggested the interesting hypothesis that subduction may have been initiated in the trench at about the same time as subsidence, such that the downbowing of the Puerto Rico shelf was in response to the formation of the trench. Such an hypothesis is acceptable and could explain the detached slab of McCann and Sykes (1984); that is, a period of nonsubduction was followed by continued subduction and formation of the trench.

The hypothesis favored here for forearc subsidence is that subsidence occurred during extension on the 19° lat Fault, and the flexure is due to extensional rollover. This hypothesis indicates that the change in plate motion at 9 m.y.b.p. (Pollitz,1988) did not cause relative compression between North America and the Caribbean plate, but extension.

CONCLUSIONS

A summary of the neotectonic history of the Puerto Rico Trench area is as follows (Fig. 5B-F, 6). 1)The metamorphic complex was uplifted to its position on the south trench wall during extension associated with subduction of an aseismic ridge, probably in the Late Eocene (Fig. 5B). This aseismic ridge could have formed as a transform boundary separating older rocks to the southeast from younger more buoyant rocks to the northeast, during the opening of the Atlantic Ocean (Pindell and others, 1989). 2) Deposition of shallow water Oligocene through Middle Miocene carbonates as far north as 19° latitude, accompanied strike-slip motion on the 19° lat Fault including motion around a releasing bend (Fig. 5C). Oblique subduction occurred in the Puerto Rico Trench. 3) Motion on the 19° lat Fault in the Late Miocene (Fig. 5D) was normal oblique, with accompanying extensional rollover and subsidence of shallow-water Oligocene-Miocene strata south of the fault. Normal movement was hinged in the east, increasing toward the west, indicating counter-clockwise rotation. Paleomagnetic data onland Puerto Rico indicates nearly 20° of counter-clockwise rotation during this period (Reid and others, 1988). Also associated with the rotation of the Puerto Rico block was the opening of basins southeast of Puerto Rico (Whiting basin, Virgin Island basin, St. Croix basin) and overthrusting in the eastern Puerto Rico Trench. The Mona Canyon Graben formed as the Puerto Rico block rotated and moved away from Hispaniola. 4) In the Pliocene to Recent (Fig. 5F), as Puerto Rico rotated into its present position, faults north of Puerto Rico in the Puerto Rico Trench which previously showed a component of shortening became strike-slip faults. Distributed shear between the 19° lat Fault and the Puerto Rico trench, caused rotation accompanying shear of the Mona Canyon graben north of 19° latitude. Further down-dropping of the trench region occurred associated with normal motion on the trench slope walls (including Escarpment Fault), associated with transtensional tectonism in the Puerto Rico Trench.

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