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## Possible causes for structural variation where the New Hebrides island arc and the d'Entrecasteaux zone collide

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### ABSTRACT

A major submarine mountain chain called the d'Entrecasteaux zone (DEZ) collides with the central part of the New Hebrides arc. Three migrated multichannel seismic sections obtained across this collision zone show considerable structural variability within slope rocks. The subducted top of the north ridge of the DEZ can be traced beneath the accretionary wedge. Strata forming this wedge could be uplifted remnants of a wedge that predated collision, or they could have been accreted from rocks that form the ridge crest. Large slope anticlines and major vertical-offset faults are absent from the vicinity of this ridge; therefore, such structures do not necessarily form in collision zones. Between the two ridges of the DEZ, rocks forming the accretionary wedge dip toward the trench and terminate obliquely downward at the decollement between arc and subducted rocks. This attitude is unique to the collision zone and probably records the progradation of a flood of sediment eroded from nearby islands that underwent rapid uplift during the late Quaternary. Near the south ridge, deep-ocean sedimentary rock curve upward and form the west and south faces of the Bougainville spur, a peak that towers over the rest of the lower arc slope. An accreted guyot may underlie this spur. Fragmentary geologic and geophysical evidence suggests that the north ridge, from which mid-ocean-ridge basalt has been dredged, may be denser and stiffer than the south ridge, which appears to be made up mainly of volcanoclastic rocks. These differing physical properties of the two ridges probably determined the type of structures that developed within lower-slope rocks.

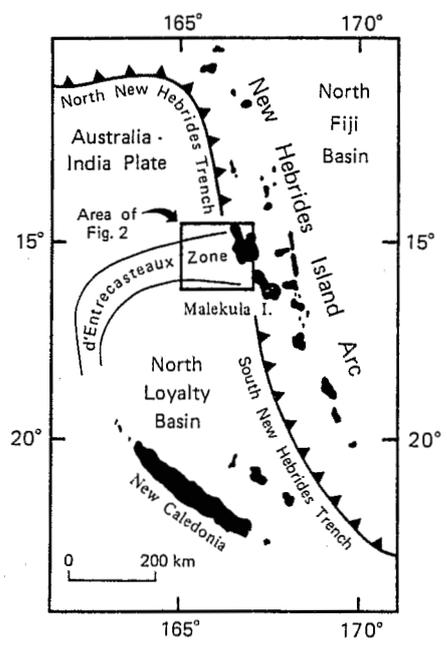


Figure 1. Index map of study area.

### INTRODUCTION

The New Hebrides island arc and its associated trench mark the juncture between the subducting Australia-India plate on the west and the North Fiji Basin on the east (Fig. 1). During 1982 and 1984, Australian, British, French, New Zealand, and United States scientists participated in expeditions aboard the U.S. Geological Survey ship *S.P. Lee* to investigate the geology of the New Hebrides island arc. An important facet of this research has been to decipher what effect is exerted on arc structure by the collision of the arc and the d'Entrecasteaux zone (DEZ), an east-trending submarine mountain system formed by two subparallel ridges (Figs. 1 and 2). Seismic reflection data obtained over the collision zone show a highly diverse structure in lower-slope rocks. In this report we illustrate the main elements of this structure and propose some tectonic processes that may have caused this diversity.

During cruises to this arc, 24-fold seismic reflection data were collected by using a 24.4-l airgun array and a 2400-m, 24-channel streamer. These data were processed through veloc-

ity analysis, common-depth-point (CDP) stack, and migration with a finite-element algorithm.

### MAIN STRUCTURAL FEATURES

#### Slope Structure Near the North Ridge of the DEZ

Bathymetric contours of the arc slope bulge westward where the north ridge of the DEZ enters the subduction zone (Fig. 2). The nearly flat top of the north ridge stands 1-2 km above the surrounding ocean floor.

Seismic line 104 extends along the crest of the DEZ north ridge (Fig. 2). Ridge-forming rocks show considerable structural relief as they dip and thicken westward toward a fault marked by a sea-floor scarp and by terminated reflections (Fig. 3). The reflection from the top of the subducted ridge can be traced beneath the lower arc slope for 15 km with only minor discontinuities. Above the subducted ridge top, strata within the accretionary wedge are subhorizontal. Reflections from deep below the toe of the accretionary wedge suggest that rocks forming the ridge foundation are stratified and dip generally west.

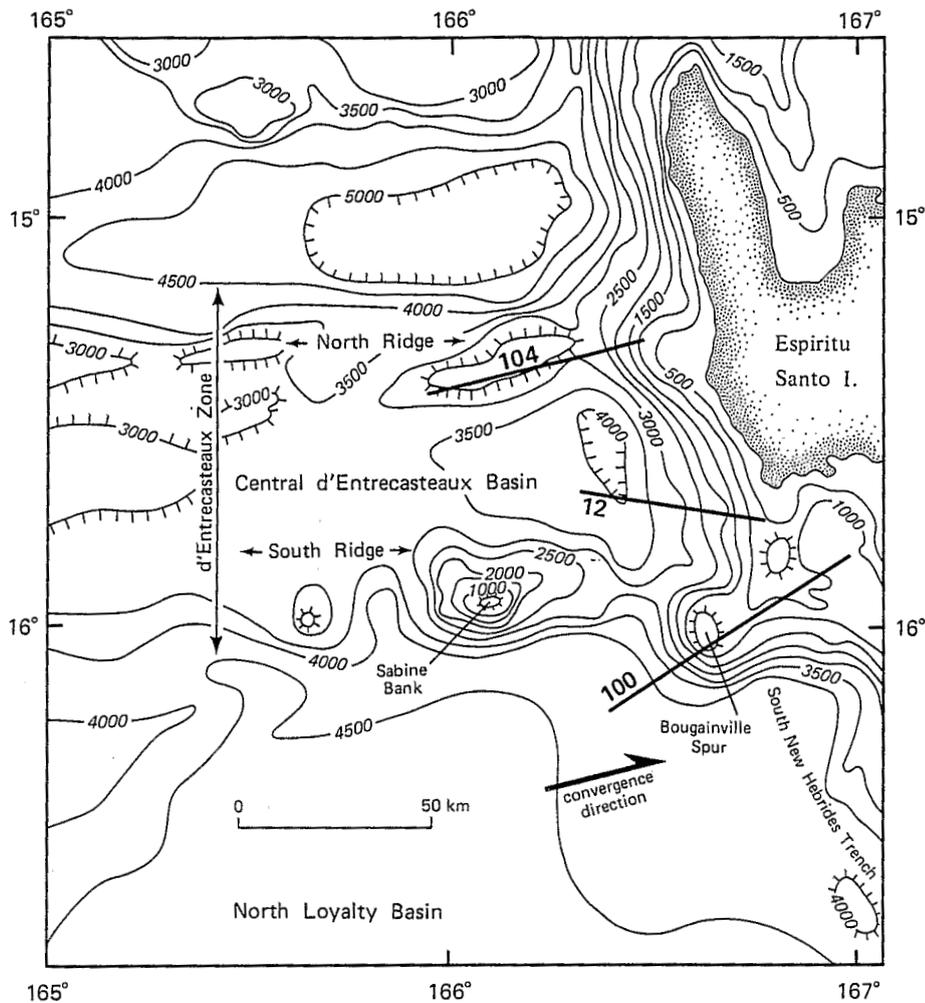
#### Slope Structure Between the Two Ridges of the DEZ

Seismic line 12 shows the structure of rocks that lie between the two ridges of the DEZ (Figs. 2 and 4). Strata within the central d'Entrecasteaux basin are parallel bedded and highly reflective, and they can be traced for 30 km beneath the slope. These parallel-bedded rocks are separated by an abrupt dip discordance from overlying strata, which dip west, away from the arc. This discordance marks the decollement separating downgoing from accreted rocks. Numerous thrust faults appear to merge at depth with the decollement.

#### Slope Structure Near the South Ridge of the DEZ

Bathymetric contours near the south ridge of the DEZ outline the Bougainville spur, a sharp peak that juts above the lower slope of the arc,



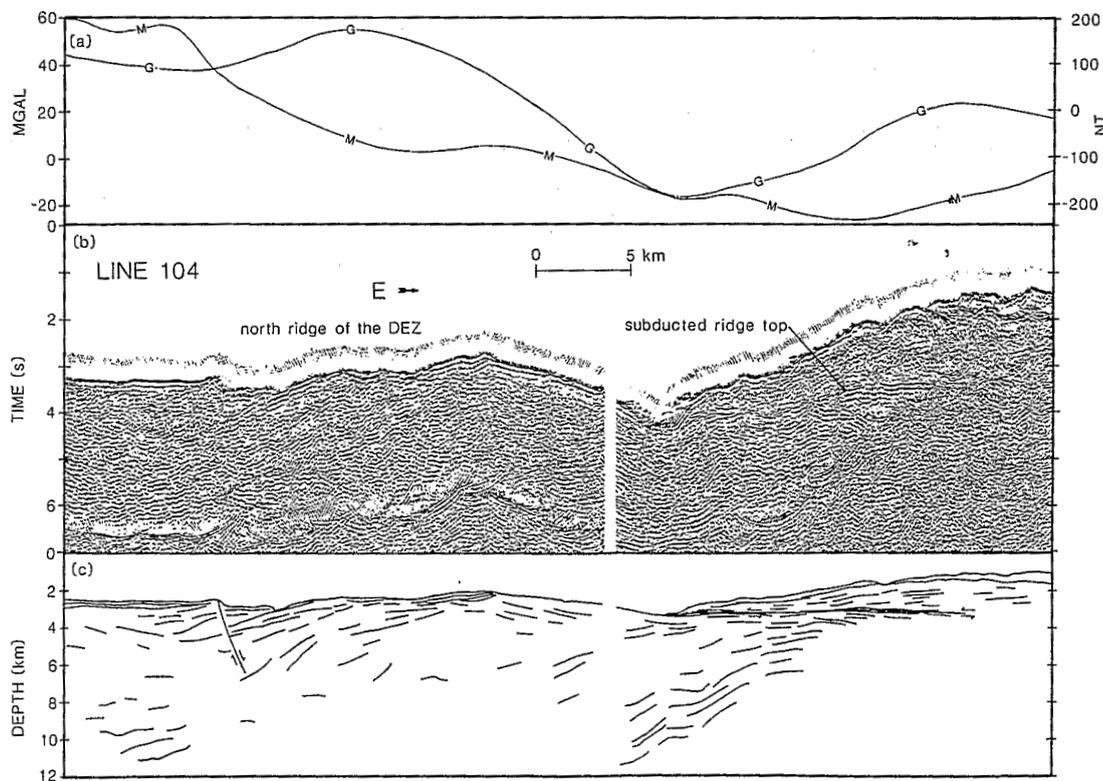


in a position that elsewhere is occupied by the trench and accretionary wedge (Fig. 2). West of this spur the south ridge is a low swell that stands barely 800 m above the surrounding ocean floor. Farther west, however, Sabine Bank surmounts the ridge and towers 4000 m above this floor.

Seismic line 100 does not reveal unequivocally the location of the decollement separating the oceanic plate from the arc. Collet et al. (1985) proposed that this decollement be identified with the fault (below location A, Fig. 5) that forms a sea-floor scarp with a relief of about 800 m.

Flat-lying, parallel-bedded rocks west of the spur thicken gradually toward the spur, curve upward to dip west at 10°–15°, and form the west face of the spur. Preliminary results of prestack migration indicate that a thick, well-bedded section of these rocks extends upward to the peak of the spur. East of this peak lies a sequence of reflective rocks that can be divided into two units (Fig. 5). The deeper unit is composed of weakly reflective rocks that thicken eastward, toward the fault below location A. In contrast, rocks in the shallower unit are strongly reflective and dip east, but are parallel

**Figure 2. Geography and tracklines near collision zone of d'Entrecasteaux zone and New Hebrides arc. Lines with bold numbers are seismic lines referred to in text. Bold arrow shows direction of convergence of Australia-India plate and island arc (Pascal et al., 1978; Isacks et al., 1981).**



**Figure 3. (a) Gravity and magnetic data obtained along seismic line 104; (b) migrated seismic section; (c) depth-converted drawing shown with no vertical exaggeration.**

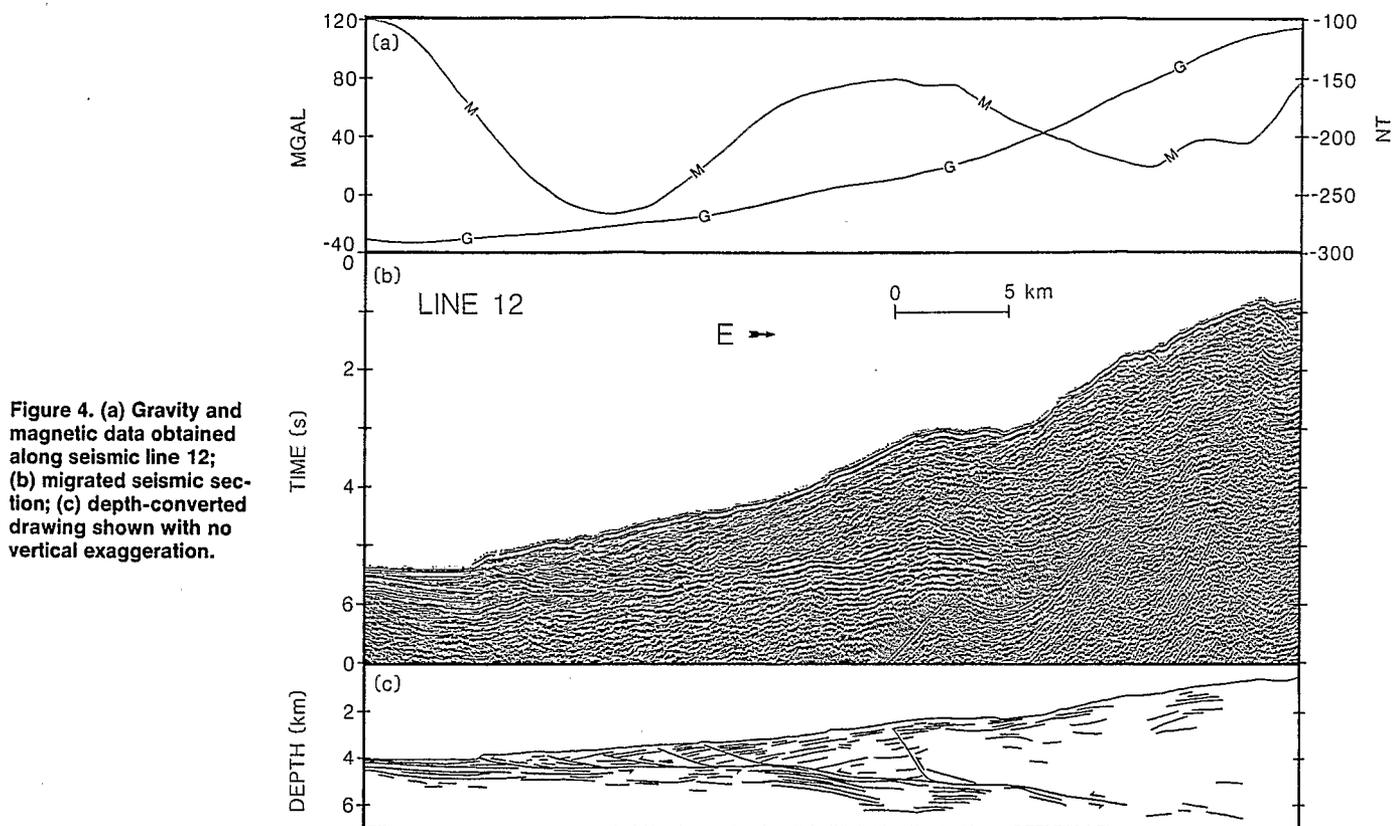


Figure 4. (a) Gravity and magnetic data obtained along seismic line 12; (b) migrated seismic section; (c) depth-converted drawing shown with no vertical exaggeration.

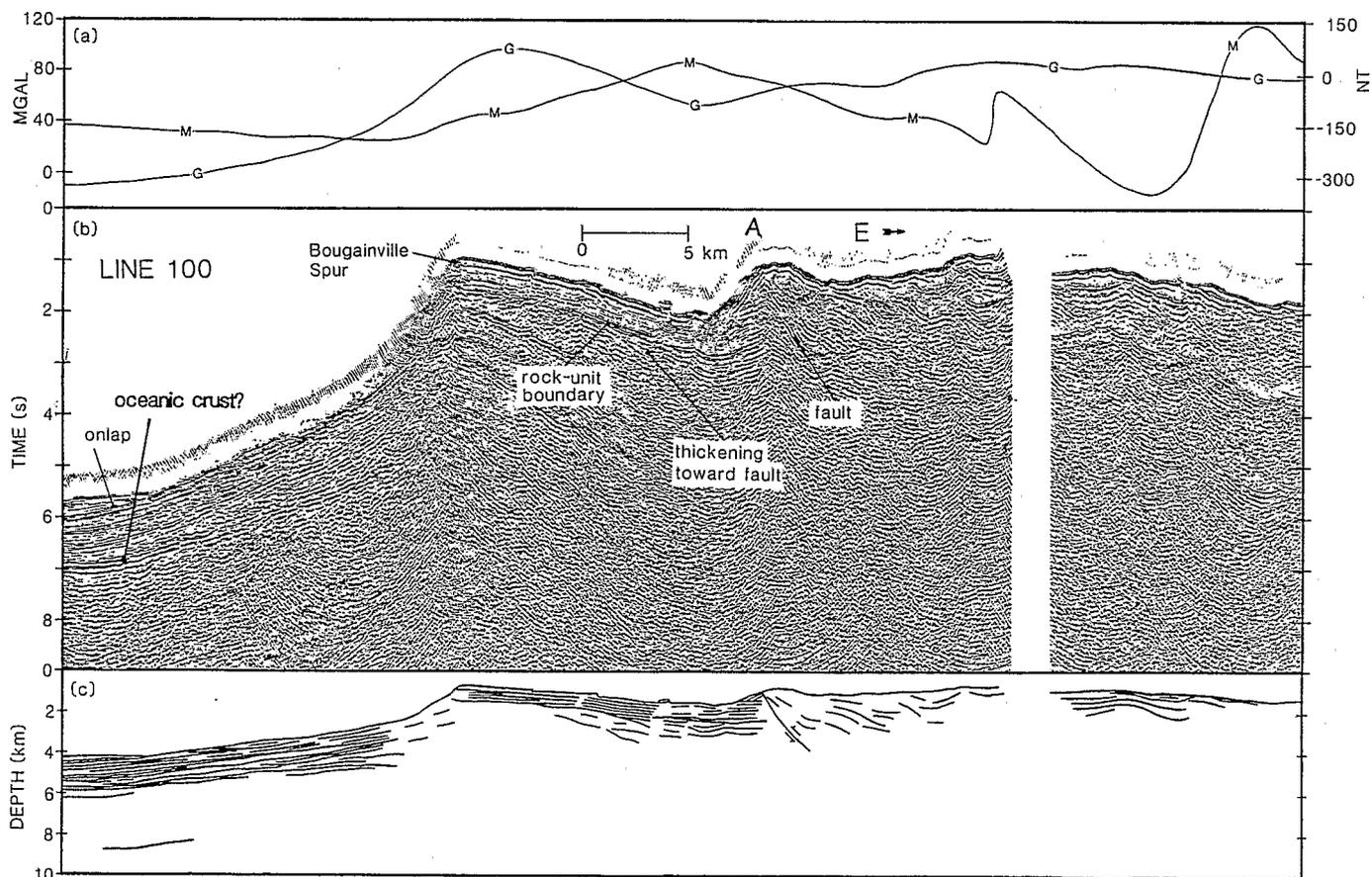


Figure 5. (a) Gravity and magnetic data obtained along seismic line 100; (b) migrated seismic section; (c) depth-converted drawing shown with no vertical exaggeration.

bedded; they neither thin toward the spur's peak nor thicken toward the fault that delimits the sequence on the east.

## DISCUSSION AND CONCLUSIONS

The variety of structures that deform slope rocks in this collision zone suggests that each ridge of the DEZ has interacted differently with the arc. In the following section we describe some processes that may have governed these interactions.

The westward bulge of bathymetric contours where the north ridge is being subducted could have resulted either from overriding of the ridge by an accretionary wedge in place before collision or from accretion of rocks capping this ridge. The absence of large slope anticlines and major vertical-offset faults shows that such structures do not necessarily characterize collision zones.

The direction of convergence at the New Hebrides Trench is N76°E (Pascal et al., 1978; Isacks et al., 1981); hence, the DEZ is being subducted at an oblique angle (10°–15°), and so it creeps slowly north along the trench. Seismic line 12 (Fig. 4) should reveal the tectonic aftermath of subduction of the north ridge. Slope rocks below this line dip consistently toward the trench and extend obliquely downward to end at the decollement at the top of subducted rocks. This trenchward dip is not evident in seismic data from outside the collision zone (Fisher, 1986). This attitude may record progradation of a flood of sediment eroded from Espiritu Santo Island, which was uplifted rapidly during the late Quaternary (Taylor et al., 1980, 1985).

The north ridge is being consumed by the subduction zone (Fig. 3), as is the central d'Entrecasteaux basin (Fig. 4). If some part of the DEZ is not being subducted, it is limited to the structurally complex area encompassing the south ridge and Bougainville spur. Rocks overlying the ocean plate curve up the west face of the spur, and other seismic data show that the same relation holds for the south face. Rocks underlying the Bougainville spur have an indeterminate origin—they may be uplifted arc foundation or subducted south-ridge rocks. Evaluating whether the spur is underlain by uplifted-arc-foundation rocks can only be accomplished by detailed examination of rock samples.

If the Bougainville spur is composed of south-ridge rocks, then one possible interpretation is that the spur was once a guyot, perhaps similar to Sabine Bank, that is being incorporated into the accretionary wedge, as suggested

by Daniel and Katz (1981). If so, south- and west-dipping strata that form the spur faces (Fig. 5) may be a sediment apron deposited around this guyot when it was far from the arc, and the highly reflective, parallel-bedded rocks capping the spur may have been deposited in shallow water as the guyot subsided. These rocks would have been tilted while entering the subduction zone. The fault near location A (Fig. 5) could be either the decollement between oceanic and arc-foundation rocks or an inactive strand of this decollement. The main problem with the interpretation that the spur is an accreted guyot is the small magnetic anomaly recorded over this feature—Sabine Bank causes a much larger anomaly (Collot et al., 1985).

Ridge topography, density, cohesiveness, and elasticity relative to the nearby oceanic plate could all affect how ridge material behaves in a subduction zone. As for the south ridge, seismic data (Fisher, 1986) show that this ridge is composed mainly of discontinuously stratified, presumably sedimentary rocks, and the conical shape of Sabine Bank suggests that most of these rocks are volcanoclastic. In contrast, mid-ocean-ridge basalt has been dredged from the north ridge (Maillet et al., 1983), and only parts of this ridge contain rocks sufficiently well stratified to return coherent reflections (Fig. 3). This fragmentary evidence can be interpreted to mean that the two ridges vary significantly in physical properties—the north ridge may be denser and stiffer than the south ridge. In addition, judging by the exposed part of the DEZ, we think that the south ridge is more likely than the north ridge to bear sharp peaks that could clog the subduction zone. Hence, not only the morphology but also the physical properties of the subducting ridges account for the structural variation within this collision zone.

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### Reviewer's comment

The conclusion that underthrusting ridges do *not* disrupt the forearc region (beyond simple uplift) is surprising and runs counter to the generally held impression.

Stephen Box

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