[1]Evidence for the Tectonic Segmentation of the Antarctic Peninsula from Integrated ERS-1 SAR Mosaic and Aeromagnetic Anomaly Data

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ABSTRACT

The Antarctic Peninsula (AP) is a Mesozoic-Cenozoic Andean-type magmatic arc resulting from subduction of Pacific Ocean lithosphere beneath its western margin. During the past 60 million years discrete segments of the Pacific-Phoenix spreading ridge have successively collided with the western margin of the AP diachronously from south to north in a series of ridge-crest collision episodes. Previous work suggested that the AP (upper plate) was tectonically segmented due to subduction of discrete ridge-crest segments, with segments bounded by the projection of oceanic fracture zones (OFZ). An ERS-1 SAR mosaic was created over the Graham Land-Palmer Land Transition Zone (TZ) and combined with aeromagnetic anomaly and mapped geologic data to study how the process of OFZ subduction modified AP structure. Good correlation of SAR lineament trends and mapped fault trends on Alexander Island provide evidence that some of the SAR lineaments are structurally controlled. Correlation between the SAR and aeromagnetic lineaments suggests both mark crustal structures in the TZ. A model invoking distributed left-lateral fault motion can produce that tight dextral curvature across the TZ and explain the lineament patterns. Correlation between lineament trends and OFZ traces suggests that faulting reflects the response of the AP crust to OFZ subduction.

INTRODUCTION

The S-shaped AP (Fig. 1) is nearly 1500km long extending from the eastern end of Palmer Land northward toward South America. It is made up of a continuous, narrow, and snow covered plateau ranging in height between 2500 and 1500m and is severely dissected by deep coastal glaciers [1]. Physiographically the AP is separated into two sections, Graham Land to the north and Palmer Land to the south (Fig. 1). The zone between Graham Land and Palmer Land was termed the Transition Zone [1], defined where the exposed width of the peninsula dramatically thins, the curvature changes from sinistral to dextral, and there is significant dissection by glaciers.

OBJECTIVES AND METHODS

The primary objectives of this research were to investigate what new information could be obtained from high resolution SAR imagery in order to better understand how the process of OFZ subduction modified the AP structure and to investigate geologic and tectonic processes that occurred at the Graham Land-Palmer Land TZ. To test the hypothesis that the unique structure of the TZ formed in response to OFZ subduction, the TZ was examined in detail. SAR lineament trends were compared with detailed aeromagnetic lineament trends and trends in structural geologic data. To model the dominant lineament trends, a Riedel Model for left-lateral faulting was utilized. To explain the lineament patterns and the tight dextral curvature of the AP across the TZ, a model for oroclinal bending [2] was examined.

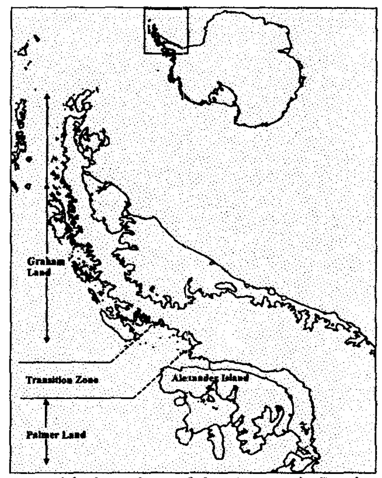

Fig. 1. Geographic location of the Antarctic Peninsula.

DETAILED SAR MOSAIC

Because SAR produces high-resolution imagery, it provides the opportunity to focus in more detail on areas of interest relevant to past tectonic events. The detailed SAR mosaic (Fig. 2) provides a comprehensive view of the TZ bounded by the Adelaide Fracture Zone (FZ) to the north and the Tula FZ to the south.

There is heavy dissection of glaciers in the TZ. Such glacier swarms are first indicators that major faulting may have occurred. The Adelaide FZ crosses onto the AP in the vicinity of Neny Glacier. Wyeth [1] noted that the Neny-Gibbs glacial trough marks a fault line based on geologic evidence of NW trending faults in the vicinity of Kenyon Peninsula. If this is true, then the Neny-Gibbs glacial trough may mark the onshore extension of the Adelaide FZ.

[1] Sponsored by NSF Office of Polar Programs

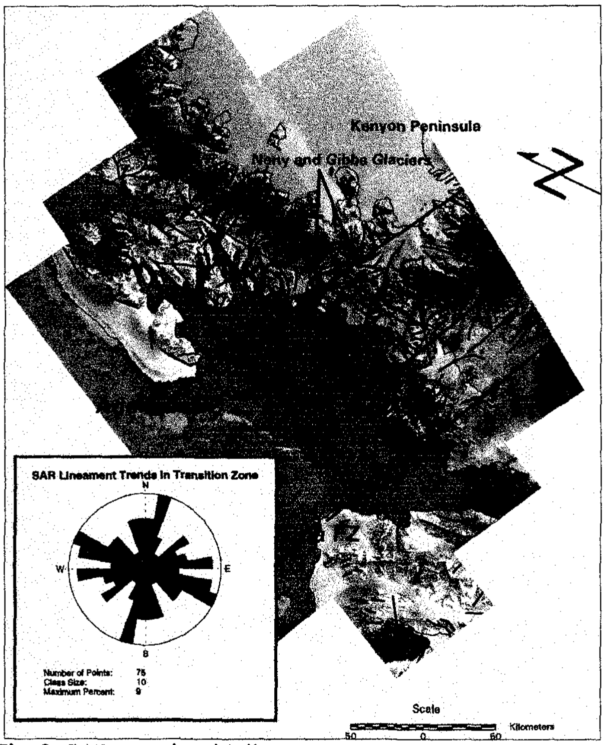

Fig. 2. SAR mosaic with lineament map and rose diagram.

SAR LINEAMENTS AND TRENDS IN STRUCTURAL GEOLOGIC DATA

A lineament map was derived from glacial drainage patterns visible on the SAR mosaic (Fig. 2). A rose diagram reveals three main trends in the SAR lineaments (Fig 2, inset) To determine whether linear features visible on the SAR mosaic correlate with structural bedrock features, the SAR lineament trends were compared with trends in structural geologic data.

Fault, dyke, bedding, and rock cleavage trends within the TZ were measured directly from the BAS Geological Maps and compiled into rose diagrams (Fig. 3). Due to the limited number of mapped faults (four), fault trends are inconclusive. However, dyke trends show a prominent N-NW (330°-360°) clustering as do the bedding (350°-360°) and rock cleavage trends (330°-350°). The N-NW trends correspond with one cluster of SAR lineament trends. There is a lesser E-W (270°-290°) clustering of dyke trends.

Due to the lack of mapped faults in the TZ, rose diagrams were constructed to compare mapped fault trends measured on Alexander Island with SAR lineament trends. Alexander Island is an area where detailed ground-derived information is readily available, making it an ideal location for a comparative study. Mapped fault trends (Fig. 4, left) show a prominent 350°-360° trend with a lesser 290°-300° trend in the NW quadrant. SAR lineament trends (Fig. 4, right) agree well with the mapped N-S fault trends providing evidence that SAR lineaments mark faults in this region.

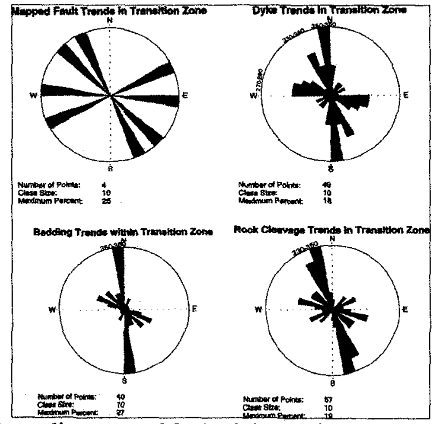

Fig. 3. Rose diagrams of fault, dyke, bedding, and rock cleavage trends within the TZ.

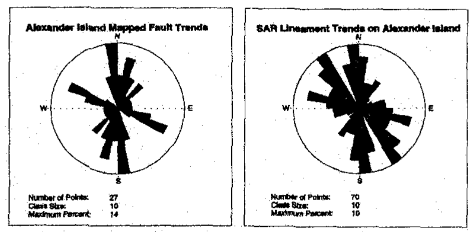

Fig. 4. Rose diagrams of mapped fault and SAR lineament trends on Alexander Island.

AEROMAGNETIC LINEAMENTS

The aeromagnetic anomaly map and aeromagnetic lineaments (Fig. 5) were derived from a detailed (3km grid spacing) aeromagnetic survey of the TZ [3]. There is an over all NW-SE trend in the magnetic fabric as evident in an elongate positive anomaly extending into Marguerite Bay (Fig.5A) trending NW-SE. Johnson and Swain conclude that: (1) the prominent NW-SE (315°) trend of the magnetic fabric supports a link between the magnetic lineations and extrapolated OFZ (Fig. 5C, D). (2) The apparent left-lateral offset of the western side of the Pacific Margin Anomaly (PMA) suggests the OFZ are faults with a component of left-lateral strike-slip motion. (3) The area of subdued anomalies west of the PMA is a down-faulted block (Fig. 5C) believed to be the result of ridge-crest arrival at the trench.

A rose diagram of the onshore aeromagnetic lineament trends (Fig. 5, inset) shows a prominent 300°-320° trend corresponding well with the aeromagnetic observations.

COMBINED LINEAMENT MAPS

The correlation between the two types of lineaments strongly suggests that both SAR and aeromagnetic lineaments mark crustal structures. Rose diagrams of the SAR and onshore aeromagnetic lineament trends were intercompared with a Riedel Model for left-lateral faulting with a main shear trend of 305° to demonstrate more clearly the angular relationships (Fig. 6). The main shear trend of 305° is a best-

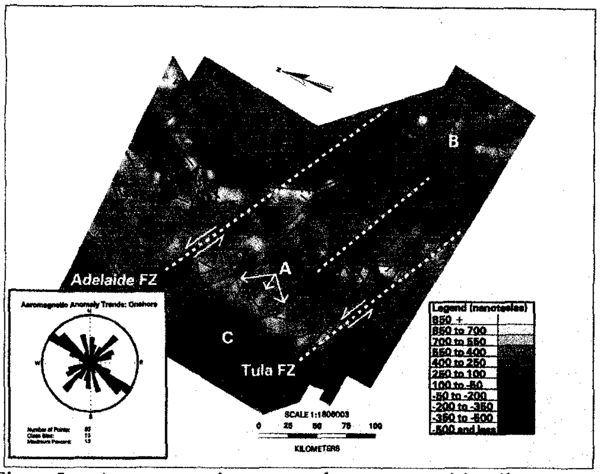

Fig. 5. Aeromagnetic anomaly map with lineaments (modified from [3]).

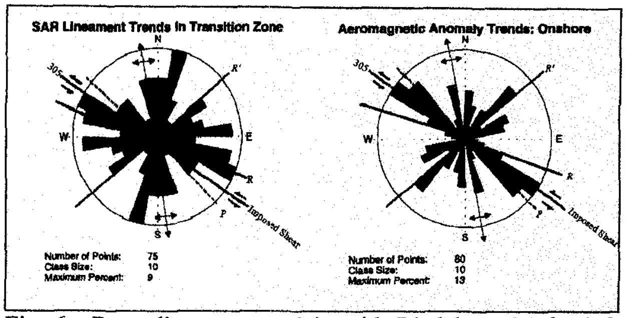

Fig. 6. Rose diagrams overlain with Riedel Model for left lateral faulting.

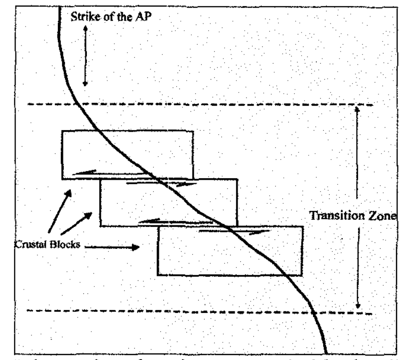

Fig. 7. Schematic showing crustal block displacement westward producing apparent offset of AP and dextral curvature across the TZ.

fit estimate between the prominent SAR and aeromagnetic lineament trends. The good angular match between the Riedel Model and the SAR lineament trends (Fig. 6) suggests a viable model for the lineament patterns in the TZ invoking left-lateral fault motion. The onshore aeromagnetic lineament trends (Fig. 6) also have a reasonably good angular relationship with the Riedel Model. The correlation of the SAR and aeromagnetic lineament trends with the Riedel Model support a model for left-lateral faulting in the TZ in response to subduction of OFZ.

STRIKE-SLIP BENDING MODEL

Cunningham [2] proposed a left-lateral strike-slip model to explain the curvature of the southernmost South America. This model is based on the existence of regional strike-slip faulting, rotation and translation of southernmost Andes crustal blocks, and relative plate motions through time. He integrated field data and existing paleomagnetic data with the existence of widespread lineaments that were statistically consistent in orientation with the Riedel Model for left-lateral faulting. A similar model could explain the tight dextral curvature of the AP in the TZ. The SAR and aeromagnetic lineament patterns are compatible with left-lateral fault motion associated with an extensional environment. Distributed left-lateral faulting could offset the AP axis and produce a dextral curvature across the TZ by crustal block displacement (Fig. 7).

CONCLUSIONS

The strongly dissected nature of the TZ, defined by SAR lineaments, led to the hypothesis that the exposed portion of at least some SAR lineaments represent faults from the good correlation between mapped fault trends on Alexander Island and SAR lineament trends. The hypothesis that SAR lineaments mark crustal structures is also confirmed by correlation between the SAR and aeromagnetic lineament trends. Based on previous interpretations for the TZ, a hypothesis that SAR lineaments in the TZ record left-lateral faulting was developed. The good angular relation between lineament trends is compatible with left-lateral the Riedel Model for left-lateral faulting and SAR and aeromagnetic strike-slip shearing across the TZ. These relations are in agreement with previous evidence that the apparent left-lateral offset of the PMA was the result of left-lateral strike-slip motion. Correlation in the dominant trends of the SAR and aeromagnetic lineament trends (290°-330°) with OFZ trends (315°) suggests that left-lateral faulting was in response to OFZ subduction. A model for distributed left-lateral faulting was presented as a mechanism for the block displacement.

REFERENCES

[1] Wyeth, R. B., 1977. "The Physiography and Significance of the Transition Zone between Graham Land and Palmer Land". British Antarctic Survey Bulletin, No. 46, 39-58.

[2] Cunningham, W. D., 1993. "Strike-slip Faults in the Southernmost Andes and the Development of the Patagonian Orocline". Tectonic, Vol. 12, No. 1, 169-186.

[3] Johnson, A. C., and C. J. Swain, 1995. :Further Evidence of Fracture-Zone Induced Tectonic Segmentation of the Antarctic Peninsula from Detailed Aeromagnetic Anomalies". Geophysical Research Letters, Vol. 22, No. 14, 1917-1920.