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Evidence for sinistral strike-slip deformation in The Solomon Island arc

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Abstract During the SOPACMAPS 2 crusie carried out by IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) and ORSTOM (Institut Français de Recherche Scientifique pour le dévelopement en Coopération) on the *R/V L'Atalante*, in the Central Solomon Arc area, multibeam bathymetric and imagery data and single-channel seismic reflection profiles were collected from an area of about 3500 km^2, to evaluate regional tectonics. Structural data geophysical profiles interpretation provide evidence for left-lateral transtensional tectonics on the southern edge of the Central Solomon Trough. This transtensional deformation is represented by faulting, block tilting, and rhombohedral deformation. The regional geology and the analysis of the sedimentary cover allow us to demonstrate that this tectonic occurred in two different phases during Oligocene to Miocene and Pliocene to Pleistocene times.

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Introduction

Plate motion reconstructions of the Southwest Pacific based on magnetic lineation analysis (Minster et al. 1974) and hot spot reference frame for the Cretaceous and Cenozoic times (Stock and Molnar 1982, 1987; Gordon and Jurdy 1986; Engebretson et al. 1985) lead to the conclusion that the double islands chain of the Solomon Island arc results from complex subduction–collision interactions between the Australian and Pacific plates (Fig. 1) (Coleman and Packham 1976; Wells 1989).

The relative motion between the Australian and Pacific plates is trending northward at a rate of 70 mm/yr (Minster and Jordan 1978; DeMets et al. 1990), and Australia is being consumed beneath the Pacific plate along a succession of trenches that flank the Solomon Islands arc to the south. During the Pliocene to Pleistocene time, the northeastward dipping subduction has generated a volcanic chain that extends along the southern islands of the Solomon arc southeastward to Guadalcanal Island (Fig. 1). The volcanic products associated with this volcanic line range in composition from calc-alkaline to alkaline basalts (Colwell and Vedder 1986), suggesting the probable existence of extensional tectonics in the area. The Pacific plate has a northwestward absolute rate of motion of 107 mm/yr (Minster and Jordan 1978). This rapid oblique motion is accommodated by both subduction and left-lateral strike-slip deformation along the Solomon Islands plate boundary. Evidence for large-scale strike-slip deformation has been provided by regional studies including global scale plate kinematics (Vedder and Coulson 1986) and earthquake focal mechanisms (Cooper and Taylor 1984; Wells 1989).

The recent SOPACMAPS 2 cruise, carried out in August 1993 with the French research vessel *L'Atalante*, provides evidence, at a kilometric scale, for extensional strike-slip deformation of the Solomon Islands arc. In this paper, we focus on the detailed morphology and structure of the Mborokua Basin, a basin that extends across the southern part of the central Solomon Trough (Fig. 1). This

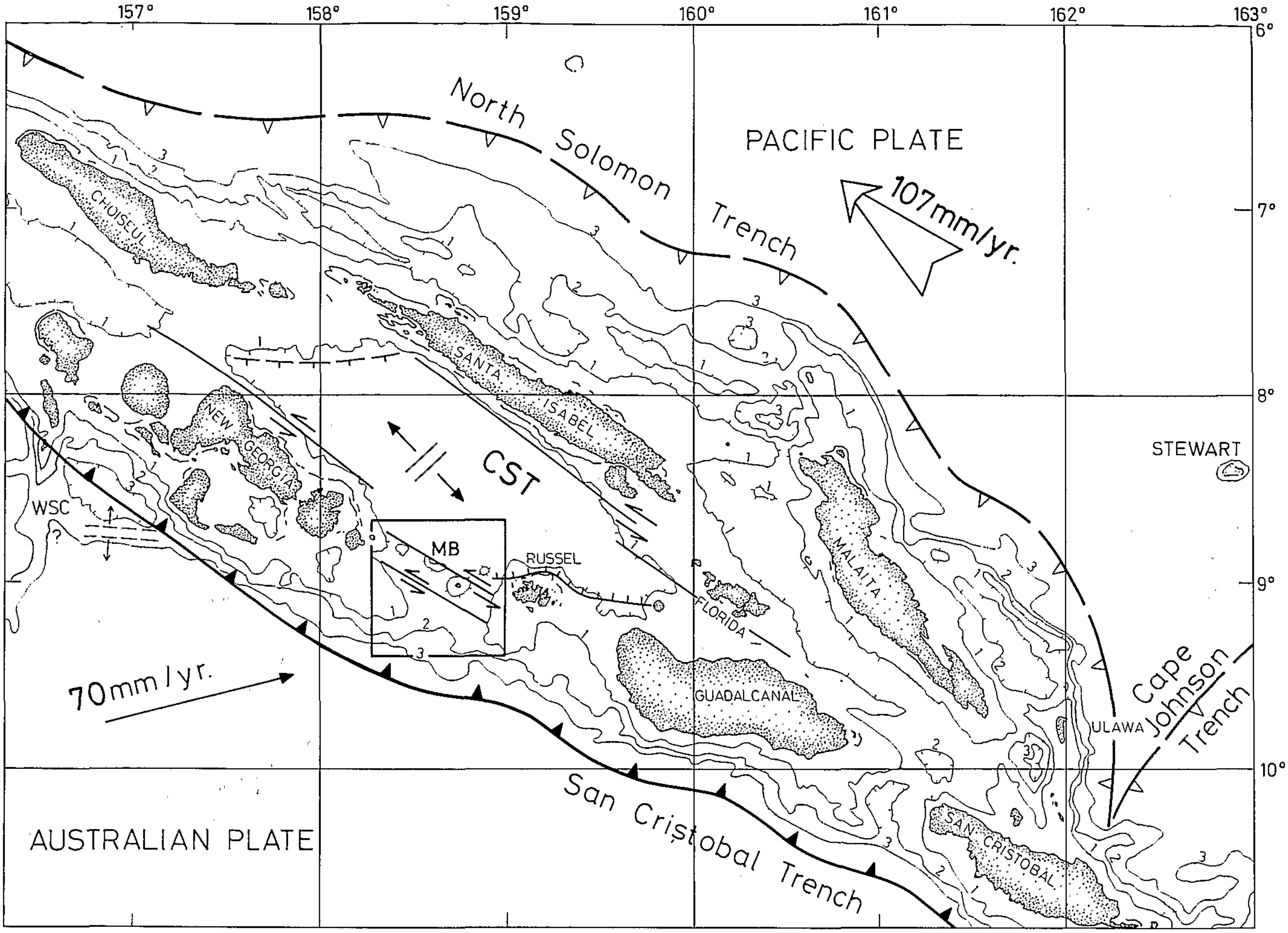

Fig. 1 Simplified geodynamical setting of the Solomon Islands arc. The inferred extensional zones are represented with arrows showing the direction of extension. Left-lateral strike-slip faults are shown in Mborokua Basin and Central Solomon Trough. The vector of the relative motion of the Australian plate and Pacific plate is from Wells (1989). The white arrow corresponds to the absolute motion of the Pacific plate. Fossil (white triangles) and active (black triangles) subduction zones are indicated. The box corresponds to the detailed coverage of SOPACMAPS 2 cruise and includes the Mborokua Basin. CST = Central Solomon Trough; WSC = Woodlark Basin spreading center; MB = Mborokua Basin

basin was selected because it is located at the subduction boundary between the Australian plate represented to the south by the Woodlark Basin and the Russel Basin, which was interpreted to be a recently opened basin inside the Solomon Island arc (Wells 1989).

Data acquisition

L'Atalante was precisely positionned by the use of two GPS receivers, providing an accuracy of better than 100 mA. SIMRAD EM-12 dual multibeam echosounder/side-scan sonar system was used to collect bathymetric and sea-floor imagery along a swath width of about five to six times the water depth in shallow water (less than 3000 m deep), and more than 20 km in depths greater than 3000 m. Two GI airguns, fired at a 10-s shot, were used to obtain seismic reflection data. These data were acquired at a 500-Hz sampling rate, using a 300-m-long, six-channel streamer. Magnetic and gravity data were also collected along the ship's tracks.

Results

The Mborokua Basin is the area located between Russell and New Georgia Islands linking the Central Solomon Trough to the north (Russell Basin) with the Woodlark basin to the south. It is characterized in its central part by an emerged small volcano named Mborokua. Existing bathymetric data on the area are scarce, especially in the southeastern area. Seismic profiles were conducted across the Mborokua Basin during the Tripartite Project (Bruns et al. 1986). They indicate that significant sediment accumulations are present in the south of Mborokua Basin. The Mborokua Basin lies beneath about 1500 m of water and is about 60 km long and 30 km wide. The basin contains

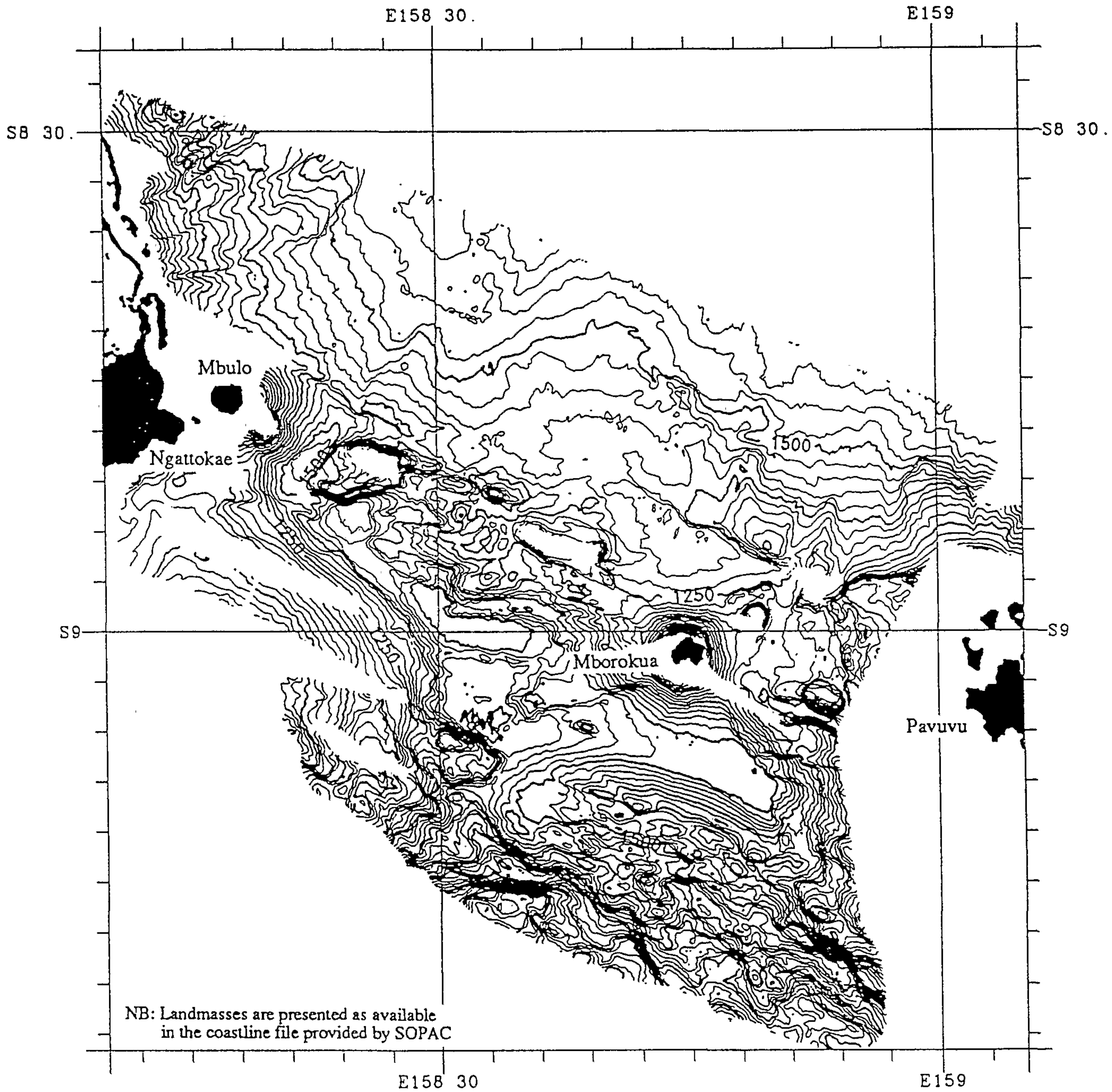

Fig. 2 MultiBeam (SIMRAD EM12) map of the Mborokua Basin. Isobath interval = 50 m. In black, the emerged lands

strata as much as 1 km thick. The sequence thins seaward and is cut by small normal faults (Bruns et al. 1986). The south side of the basin is about 0.5–1 km higher than the north side, and basin strata dip landward, indicating uplift of the south edge of the basin. Dredged rocks from the east edge of the basin indicate that part of the section is Pleistocene (Colwell and Vedder 1986). Uplift of these strata indicates active late Cenozoic uplift of the slope south of the Russell Islands.

Based on the variations of the structural grain of the sea floor given by the multibeam survey (Fig. 2), we recognize three main structural provinces within the Mborokua Basin (Fig. 3): a smooth sea-floored northern province, a horst- and grabenlike central province, and a highly tectonized southern province. These provinces are separated by well-delineated fault zones, trending N120°–130°E, parallel to the overall strike of the island arc.

The northern province shows a sea floor that slopes gently northward from a water depth of 1300 m near latitude 8°55′S to 1800 m in the Central Solomon Trough. This slope appears to be cut by two main conjugate, structural lineaments trending N130°–140°E and N70°E, thus forming a large-scale, V-shaped pattern. Minor sea-floor irregularities such as north-trending, 20- to 100-m-high ridges and subcircular bumps also disrupt the northern province.

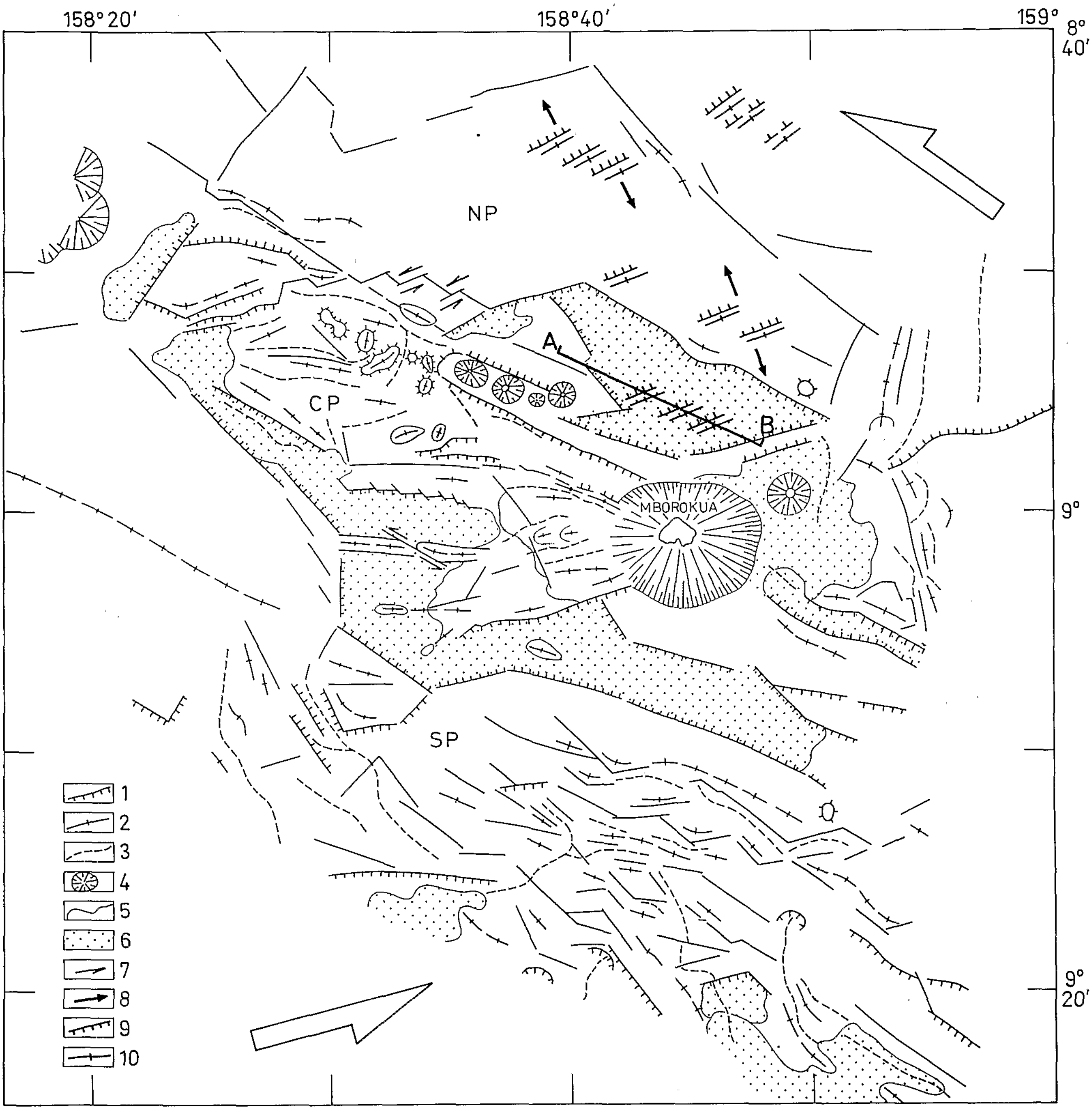

Fig. 3 Structural map of Mborokua Basin established from bathymetry, imagery, and seismic reflection. The stippled areas trending N30 in the middle of the map and the areas between them form the Mborokua Basin. NP = Northern Province; CP = Central Province; SP = Southern Province; 1 = normal fault; 2 = high; 3 = low; 4 = volcano; 5 = limit of volcanic flows; 6 = sedimentary infilled graben; 7 = strike-slip fault; 8 = extensional axis; 9 = normal fault deduced from seismic data; 10 = ridge crest deduced from seismic data. Southern white arrow corresponds to the relative motion between Pacific and Australian plates and northern white arrow to the absolute motion of the Pacific plate. AB = location of the seismic profile of Fig. 4

Single-channel seismic reflection data indicate that the northern province is underlain by a 2-km-thick sedimentary section. According to the seismic refraction data by Cooper et al. (1986, 1989), this sediment sequence reaches up to 6 km in thickness beneath the Central Solomon Trough. Our data show that in the Mborokua Basin the sediment sequence locally overlies a highly irregular acoustic basement. This basement consists of domed structural highs separated by lows filled with fan-shaped stratified sediment (Fig. 4). The structural highs are interpreted as buried tilted blocks of island arc rocks.

The central province is a 30-km-wide graben, extending WNW and intruded by magma associated with the present-day volcanic line. This province lies under a water depth of 1300–1700 m and is characterized by a series of

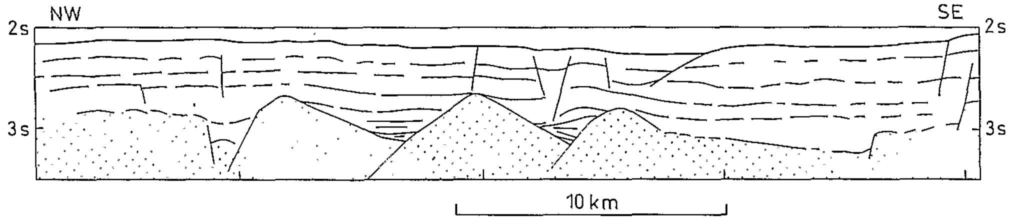

Fig. 4 Example of seismic profile (location given by AB on Fig. 3) showing northwest facing buried tilted basement blocks. The basement is indicated by dotted area. Vertical exaggeration is about 5

flat-bottomed, steep-sided troughs pierced by intrusions and volcanic edifices including the Mborokua Volcano. North of this volcano, the central province shows a rhombhedral trough bounded to the north by a south-facing, 100-m-high, scarp fault trending N120°E. This scarp becomes north-facing in the western part of the province, where it is locally offset left-laterally by short N70°E-trending faults. Several 100- to 300-m-high domes or elongated edifices, interpreted as submarine volcanoes, are aligned along the N110°E-trending ridge that bounds the rhombic trough to the south and terminates at the Mborokua Volcano. In the center part of the province, the Mborokua Volcano appears to have been emplaced where a set of parallel N120°E-trending faults converge with N70°E directions. South and west of the volcano a series of flat-bottomed troughs are bounded by scarps and faults trending N110°–130°E and N70°E. These troughs are bounded to the south by smooth slopes gently rising southward from 1500–1700 m to 1100–700 m. Seismic reflection sections extending N–S across the trough located south of the Mborokua Volcano show that this slope marks the roof of a major stratified block that is tilted northward (Colwell and Vedder 1986).

The southern province represents the upper part of the fore-arc slope, deepening southward from 1100 m to 2900 m in the study area. Here the sea floor is highly tectonized and shows outcropping blocks that are tilted north. The southern province also shows a structural grain dominated by two sets of faults trending N120°–140°E and N70°–80°E, respectively. These faults delineate a small-scale rhombic pattern indicative of strike-slip tectonics.

Discussion and conclusions

The bathymetric and geophysical data presented in this paper provide evidence for extensional tectonics with a left lateral strike-slip component. This deformation may have affected the arc summit at two periods of time: the first period, during the Oligocene to Miocene, may have controlled the development of the Central Solomon Trough, whereas the second one, during the Pliocene to Pleistocene period, may have been related to the emplacement of the New Georgia volcanic line (Vedder and Burns 1989).

The evidence for the first period of extensional tectonics is derived from the observation of tilted crustal blocks beneath the northern province of our study area, i.e., along the southern flank of the Central Solomon Trough. The observed N120°E and N70°E structural trends and V-shaped topography, together with structural correlations between seismic reflection lines suggest that the buried blocks were tilted toward the northwest, indicating that extensional tectonics occurred in a NW direction. This direction is oblique to the general trend of the arc, suggesting that rifting occurred in a left-lateral transtensional tectonic environment. The tilted blocks are buried beneath 500 to 1000 m of sedimentary fill. Based on ages provided by Bruns et al. (1986), the sedimentary fill is dated as Pliocene to Pleistocene, suggesting that rifting may have occurred during Late Oligocene to Early Miocene time. This phase of rifting is in good agreement with the hypothesis of Wells (1989), who suggested that the Central Solomon Trough formed as an early Tertiary pull-apart basin during oblique subduction of the Pacific plate.

Evidence for the second period of sinistral transtensional tectonics is derived from the analysis of detailed bathymetry and seismic reflection data in the central and southern provinces of our study area. Elongated, narrow, flat-bottomed troughs and ridges bounded by well-delineated scarps trending N120°E across the Mborokua Basin as well as the two large tilted blocks flanking the central province to the south provide evidence for a major rift zone. Rhombic depressions, left-laterally offset faults, and small-scale crustal blocks tilted northwestward together with the small-scale rhombic tectonic pattern clearly expressed in the southern province support a sinistral strike-slip component of the deformation. Although the two large blocks appear to be tilted to the north, small-scale buried blocks are tilted northwestward.

We speculate that the arc swell and the left-lateral transtensional rift zone extend westward along the arc summit and that the volcanic edifices of the New Geogria Group were emplaced along transtensional fault zones in a leaky transcurrent transform fault context. The arc swell may be due to the subduction of the hot Woodlark basin spreading center (Cooper and Taylor 1984) beneath the New Georgia Islands, whereas the sinistral component of the rifting is related to the oblique convergence motion between Australia and Pacific plates.

The transtensional geodynamic context, may account for the alkaline component of the lavas emitted from the New Georgia volcanoes, while the calc-alkaline lavas are related to the subduction processes along the San Cristobal trench.

Acknowledgments The goal of the SOPACMAPS project was to establish a detailed understanding of the geology and geodynamics of the areas mapped and provide information on their economic potential. The survey was carried out by SOPAC (South Pacific Geosciences Applied Commission) in the waters of Fiji, Solomon

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