On-going uplift rate of the Saint Peter Saint Paul Peridotite Ridge, Equatorial Atlantic Ocean, base on geomorphologic analyses of wave-cut bench and ^{14}C dating for coral fossils

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Abstract

The Saint Peter Saint Paul Islets is situated at the Equatorial Atlantic Ocean on the top of the morphologic elevation of 90km in length, 25km in width, and 3800m in height constituted by abyssal mantle peridotite. The submarine morphology around the islets is highly accidental characterised by steep slopes and subvertical cliffs. The morphological features and the absence of large coral reef suggest that the islets are formed by recent tectonism that may continue up to the present. It is considered that the peridotite ridge top was present at the ocean bottom and it has just reached to the present sea level. The summit level map shows a wave-cut bench of 7~9 m above sea level. Based on the correlation of this bench to the Flandrian Transgression, the uplift rate in recent 6000 years is calculated as 1.5 mm/year. The ^{14}C datings for the coral fossils also indicate the same uplift rate. If the peridotite ridge corresponds to a tectonically deformed megamullion, total uplift is 1500 to 3000m and the tectonism started at 1 to 2Ma. On the other hand, if the ridge is originated directly from subcrustal mantle, the total uplift becomes about 9000m and tectonism is active in recent 6 million years.

Introduction

The Saint Peter Saint Paul Islets is situated at the coordinate of 00º55.1'N and 29º20.7'W in Equatorial Atlantic Ocean, approximately 1010km to the north-east of the Natal city, Brazil (Figure 1). The total area is approximately 13 thousand m^2 and the maximum altitude is 18m.

The islets are located on the Saint Paul Transform Fault Zone, which is of E-W direction, 630km of length, and right-lateral displacement. The fault zone has morphologically well-defined three intertransform ridge segments. The spreading rate is about 1.5 cm/year for each side. The upper mantle below this area is of relatively low-temperature, called cold-spot (e.g. Gurnis et al., 1998; Ritzwoller et al., 2003; Sichel et al., 2008).

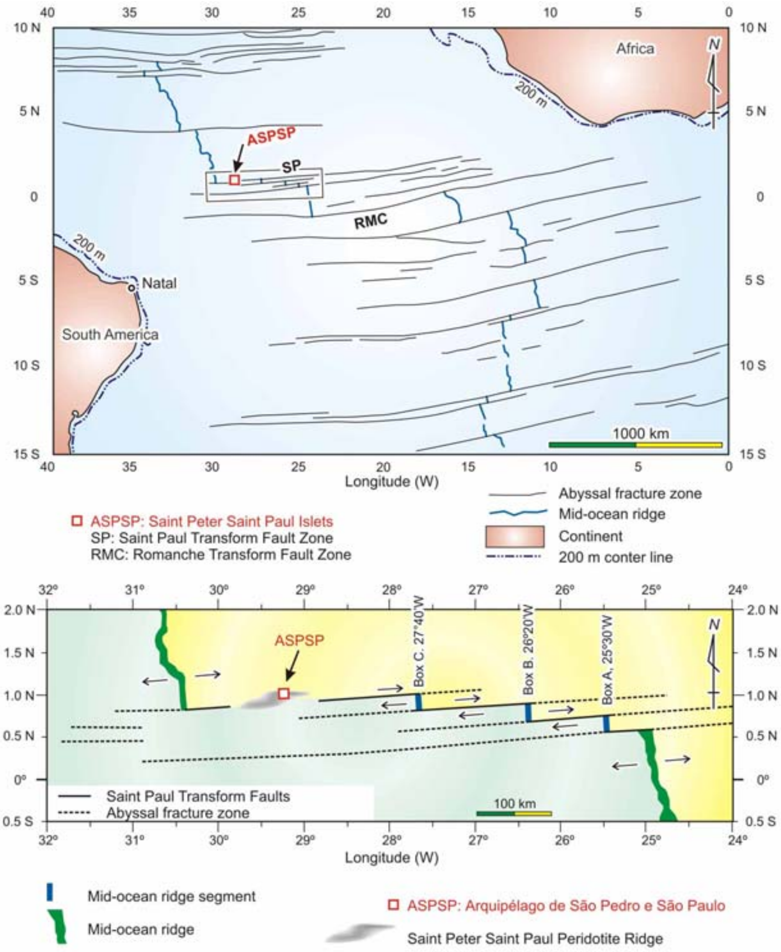

Figure 1. Mapa de localização do Arquipélago de São Pedro e São Paulo situado no Oceano Atlântico Equatorial e seu ambiente tectônico na zona de falha transformante São Paulo.

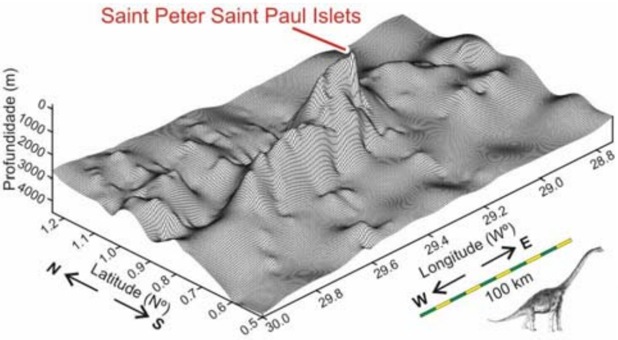

Figure 2. New three-dimensional view for the abyssal morphology around the Saint Peter Saint Paul Islets according to the predicted bathymetry of the version 2007 with resolution of 1.85km (Motoki et al., 2009).

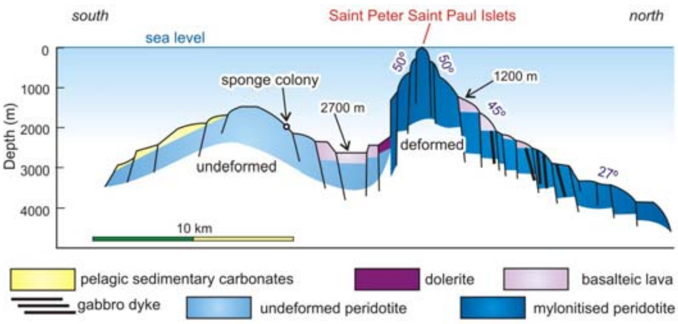

Figure 3. N-S abyssal cross section for the Equatorial Atlantic Ocean around the Saint Peter Saint Paul Islets (Hekinian et al., 2000).

The islets are constituted by abyssal mantle peridoite with various degree of serpentinisation, being the only know abyssal mantle exposure in oceanic region above sea level (e.g. Campos et al., 2003; Sichel et al., 2008). The ultramafic rocks are intensely fractured cutting the mylonite foliation of plastic deformation, suggesting that a strong brittle-mode tectonism took place in recent geologic time and may be active up to the present.

Submarine morphology

The Saint Peter Saint Paul Islets are located in the deepest region of the Atlantic Ocean, with abyssal of 3800m below sea level, in spite of oceanic plate spreading zone. The ridge-transform interactions of this area are about 5000m deep (Hekinian et al., 2000).

Motoki et al. (2009) presents a three-dimensional abyssal morphology view based on the predicted bathymetry (Figure 2). The islets are present on the top of a tabular morphologic elevation of 90km in length, 25km in width, and 3800m in height, namely Saint Peter Saint Paul Peridotite Ridge. Sichel et al. (2009) interpreted that this ridge is a tectonically deformed megamullion.

The slopes of the peridotite ridge are steep, especially southern one. At certain localities, the steepness is higher than 50º. The deep dives performed by the scientific submersible Nautile revealed the existence of many vertical walls of hundreds meters of height (Hekinian et al., 2000; Figure 3). The morphologic characteristics indicate that the peridotite ridge was formed, and still in formation, by recently started active tectonism. The absence of large coral reef corroborates to this idea.

Wave-cut bench

The islets and rocks are scattered in an area of 400 x 300 m, but their altitude is relatively leveled. That is, 27% of the whole area are present in a range of 4 to 10 m above sea level and 10% in 7 to 9 m. This table-like morphology is considered to be wave-cut bench (Sichel et al., 2009), originated from sea wave erosion. To reconstruct the original form of the wave-cut bench summit level map (seppômen) is useful, a technique for reconstruction of virtual palaeogeomorphology from present topographic map filling valleys and drainages (Motoki et al., 2008). The authors adopt the topographic map of 1:500 (Moraes et al., 1997) of the Brazilian Geological Survey (*CPRM*) and mesh interval of 5 m for the summit level work.

The summit level map for Belmonte, Challenger, and Nordeste islets detects tow platforms at the altitude of 4 to 5m and 7 to 9m (Figure 4). The altitude ranges of the platforms are the same in these three islets indicating that no tilting and differential uplifting occur after the formation of the platforms.

On-going uplift rate

Wave-cut bench is formed generally during transgression events, the period in which the seal level is high and stable. The latest transgression took place at 6000 years old, called Fladrian Transgression (e.g. Shackelton, 1987), and during this period the sea level was 5m higher than the present.

The upper platform is higher than 5m and now out of the wave influence. This surface is covered by fine biogenic carbonate sediment of about 1m of thickness with coral fossils (Campos et al., 2005). Correlating this platform to the Flandrian Transgression, which took place during 11000 to 6000 years ago, an uplifting rate of 1.5mm/year is calculated for recent 6000 years.

The ^{14}C ages for coral fossils have a good correlation to altitude. The ages become older according to the altitude and the fossils on the upper platform show ages of about 6600 years (Figure 5). The results support the opinion that the upper platform was formed during the Flandrian

Transgression and later the sea level relative to the islets descended up to the present level. The on-going uplift rate is calculated to be 1.5mm/year.

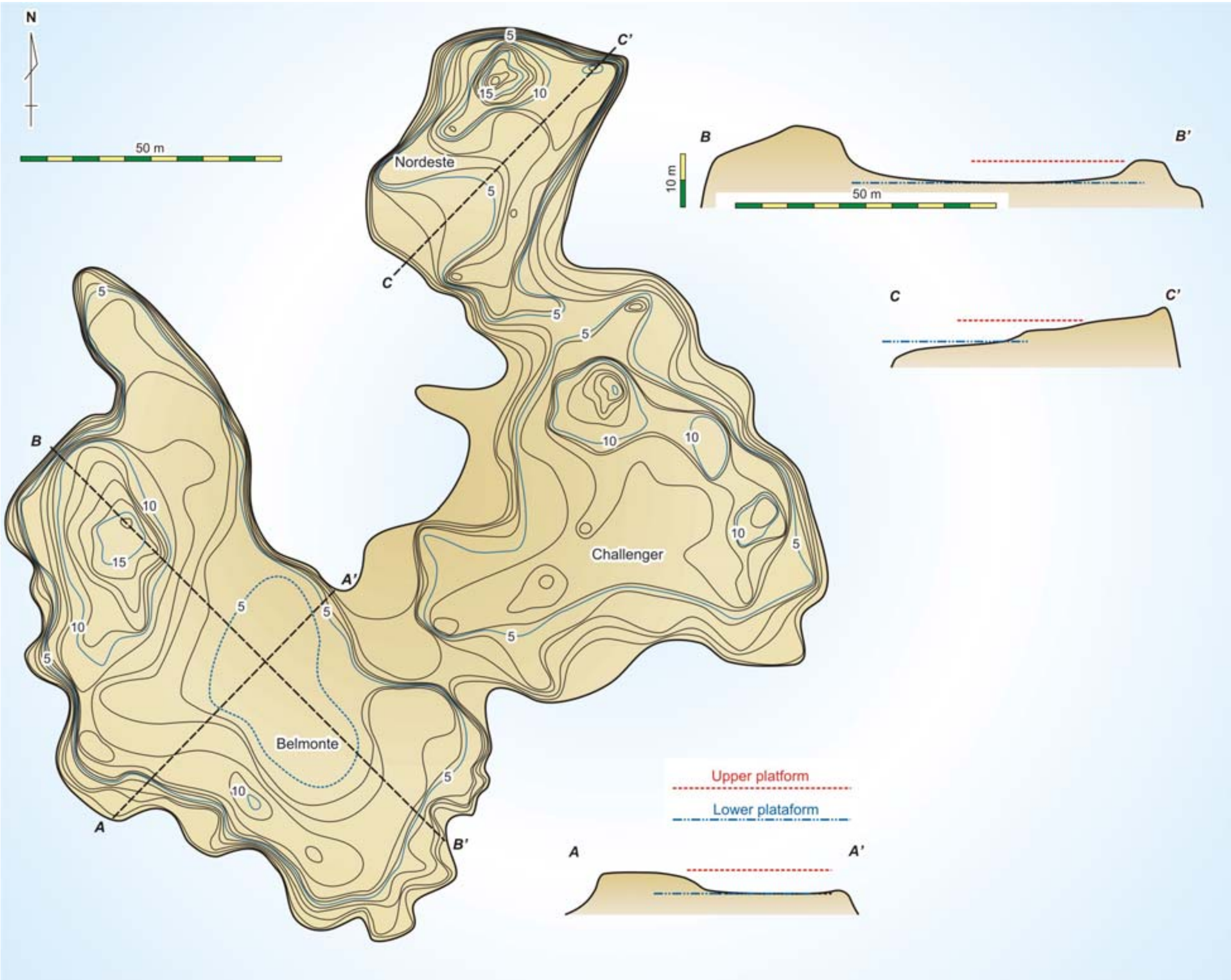

Figure 4. Summit level map for Belmonte, Challenger, and Nordeste islets with mesh interval of 5m (Motoki et al., 2009).

Tectonic movement

The Saint Peter Sainte Paul Peridotite Ridge was interpreted to be a megamullion deformed by recent tectonism (Sichel et al., 2009). If so, the peridotitic rocks were once exposed on the ocean bottom by amagmatic spreading at ridge segment and total uplift of the recent tectonism becomes 1500 to 3000m. Based on the rate of 1. 5mm/year, it takes 1 to 2 million years for the uplifting.

However, the peridotite ridge is made up predominantly of abyssal mantle ultramafic rocks lacking gabbroic mass, which is not according to the megamullion model. The dominance of the peridotite suggests that the materials of the peridotite ridge are originated directly from subcrustal oceanic mantle, being squeezed along the Saint Paul Transform Fault by recent compression tectonism. In this case, total uplift is about 9000m that takes 6 million years.

Conclusion

The geomorphological analyses of abyssal morphology and ^{14}C datings for the coral fossils present the following conclusions:

1. The Saint Paul Saint Peter Islets are situated at the top of the peridotite ridge of the same name, of 90km of length, 25km of width, and 3800m of relative height.
2. The submarine morphology around the islets is highly accidental characterised by steep slopes and vertical cliffs of hundreds to thousand meters of height.
3. The summit level map for three main islets reveal the existence of wave-cut bench, 7 to 9m above sea level.

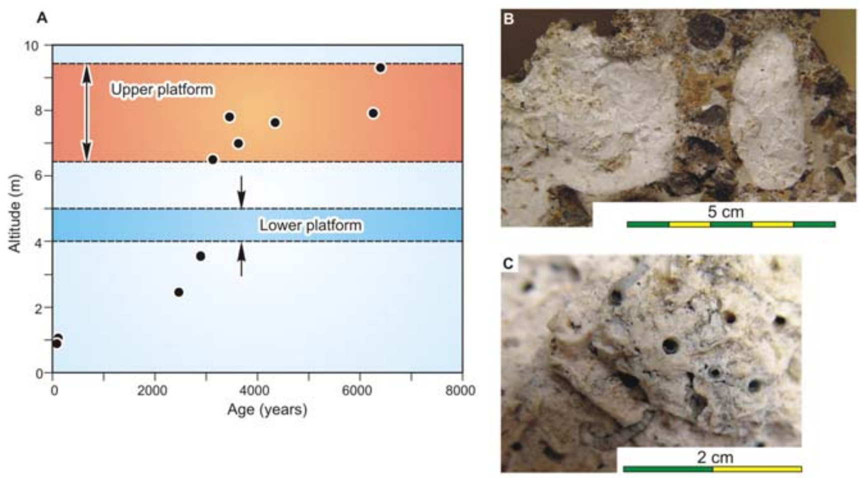

Figure 5. Correlation between the ^{14}C ages of coral fossils, *Melobesia*, collected from the Belmonte Island and its occurrence altitude relative to the wave-cut bench (A), according to Motoki et al (2009).

4. The wave-cut bench is observed in the three islets at the same altitude. This fact indicates that no notable tilting and differential uplift took place between the islets.
5. Considering the wave-cut bench to be formed during the Flandrian Transgression event, the on-going uplift rate is calculated to be 1.5mm/year in last 6000 years.
6. The ^{14}C datings for the coral fossils of also show the on-going uplift rate of 1.5mm/year in last 6600 years.
7. Interpreting the Saint Peter Saint Paul Peridotite Ridge as a tectonically deformed megamullion, the total uplift is 1500 to 3000m and the tectonism takes place in recent 1 to 2 million years.
8. If the peridotite is originated directly from subcrustal oceanic mantle squeezed along the Saint Paul Transform Fault by recent compression tectonism. The total uplift is about 9000m that takes 6 million years.

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