Arago Seamount: The missing hotspot found in the Austral Islands

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ABSTRACT

The Austral archipelago, on the western side of the South Pacific superswell, is composed of several volcanic chains, corresponding to distinct events from 35 Ma to the present, and lies on oceanic crust created between 60 and 85 Ma. In 1982, Turner and Jarrard proposed that the two distinct volcanic stages found on Rurutu Island and dated as 12 Ma and 1 Ma could be due to two different hotspots, but no evidence of any recent aerial or submarine volcanic source has ever been found. In July 1999, expedition ZEPOLYF2 aboard the R/V L’Atalante conducted a geophysical survey of the northern part of the Austral volcanic archipelago. Thirty seamounts were mapped for the first time, including a very shallow one (27 m below sea level), located at lat 23°26.4'S, long 150°43.8'W, ~120 km southeast of Rurutu. A nepheline-rich scoriaceous basalt sample from pillow lavas dredged on the newly mapped seamount’s western flank gave a K-Ar age of 230 ± 0.004 ka obtained on pure selected nepheline. We propose that this seamount, already called Arago Seamount after a French Navy ship that discovered its summit in 1993, is the missing hotspot in the Cook-Austral history. This interpretation adds a new hotspot to the already complicated geologic history of this region. We suggest that several hotspots have been active simultaneously on a region of the seafloor that does not exceed 2000 km in diameter and that each of them had a short lifetime (<20 m.y.). These short-lived and closely spaced hotspots cannot be the result of discrete deep-mantle plumes and are likely due to more local upwelling in the upper mantle strongly influenced by weaknesses in the lithosphere.

Keywords: Austral Islands, hotspots, mantle plumes, Pacific plate.

INTRODUCTION

The Cook-Austral volcanic chain is located on the southern part of the Pacific plate, in a region of anomalous shallow seafloor known as the South Pacific superswell (McNutt and Fischer, 1987). This region also corresponds to a broad geochemical anomaly called SO-PITA (South Pacific isotopic and thermal anomaly; Staudigel et al., 1991). The Cook-Austral chain extends to the northwest for >2200 km from Macdonald Seamount, an active submarine volcano, to the island of Aitutaki (Fig. 1). The chain is composed of 11 islands and 2 atolls with little area above sea level (the largest is 70 km²). Although oriented roughly in the direction of present Pacific plate motion (11 cm yr⁻¹ along a N115° direction), the pattern of both the aerial and submarine volcanoes is rather complex. At the southern end of the chain, recent bathymetric and seismic data (McNutt et al., 1997) reveal the complexity of the overlapping volcanism. Morphology and geometry of the island groups suggest the existence of two distinct volcanic alignments: the Aitutaki-Mauke Islands group, Rimatara, Rurutu, Tubuai, Raivavae, and Président Thiers bank form the northeast alignment. Ratonga and Mangia Island, Neilson bank, Rapa, Marotiri, and Macdonald Seamount, the only known active volcano, form the southwest branch.

The age of the oceanic crust along the chain ranges from ca. 35 Ma to 80 Ma (Mayes et...
Figure 1. Shaded view of seafloor topography for Cook-Austral region (see upper inset for location); map projection is made along direction of present motion of Pacific plate (from right to left). White lines correspond to crustal magnetic anomalies, and their corresponding age is in white numerals. Black diamonds represent places where K-Ar or Ar/Ar ages are known. These ages in Ma are printed in black.

Several good K-Ar or Ar/Ar ages have been measured for almost all the islands and on seamounts in the Taukina and Ngatetano chains, but no seamount in the northern Austral region has been dated so far (Fig. 1). In the north of the Cook-Austral region, Rarotonga has a younger age of 1.1 Ma (Duncan and McDougall, 1976). At Aitutaki, a 1.2 Ma age coexists with an 8.5 Ma stage (Turner and Jarrard, 1982). In Rurutu, two different volcanic stages have been identified, an old one at 12 Ma (Duncan and McDougall, 1976), compatible with the progression in ages along the northeastern volcanic alignment, and a young one at 1.1 Ma. Several authors agree that the age progression of these islands is roughly compatible with a hotspot origin, with the present volcanic activity located at the Macdonald Seamount volcano, although it is difficult to explain the jump in space and in isotopic composition between Rapa and Raiavae (Chauvel et al., 1997).

Figure 2. Three-dimensional view of seafloor in vicinity of Arago Seamount, newly discovered hotspot volcano. Its location corresponds to black box in Figure 1.

Turner and Jarrard 1982 suggested that the young radiometric ages reported for Rurutu could be explained by another hotspot located between Rurutu and Tubuai. The existence of this hotspot was also suggested by the differences between isotopic signatures of the recent lavas from Rurutu and those produced at the Macdonald hotspot. We can now test this hypothesis with data from the ZEPOLYF2 expedition. Its first objective was to completely map with a multibeam instrument all the seamounts located by satellite altimetry in this area; 100 000 km² were thus covered, and 10 000 km of geophysical profiles were gathered, including 5000 km of single-channel seismic reflection data. A complete sampling of the 30 seamounts was also planned, and 24 successful dredges were collected.

The initial construction stage of Rurutu can be linked to the magmatic source that formed Tubuai, because it presents the same petrologic and geochemical characteristics and the distance between the two islands is compatible with the absolute Pacific plate motion at that time. What is the source of the later 1.1 Ma volcanic event on Rurutu? The ZEPOLYF2 cruise surveyed a seamount 130 km southeast of Rurutu that could be a good candidate (Fig. 2). It was already known under the name of Tinomana by Polynesians who fish there in shallow waters above its summit. It has been called Arago Seamount after the name of the French Navy ship that discovered it in 1993. Numerous cones exist between Rurutu and Arago in this 4500-m-deep basin, but no clear crustal swell seems to be associated with this axis. Arago is a composite volcano that culminates at a depth of 27 m below sea level. It shows three rift zones with the same directions as the ones observed on Rurutu. The principal orientation of the rift zones is N170°, corresponding to structural discontinuities inherited
from the Farallon Ridge, for example, as already observed on Macdonald and Loihi Seamounts. The other main direction is N70°, corresponding to the nearby Austral Fracture Zone. Other minor directions can also be identified. The edifice is composed of three coalescent volcanoes. The highest, Arago, is a regular cone that overtops the other two edifices. The acoustic imagery does not give much more information on the nature of the lava flow’s surface and in particular cannot be used to distinguish between old and recent lava flows. We have dredged to between 900 and 600 m depth on the southern flank, and we collected 55 kg of pillow-lava basalt. We obtained 20 kg of relatively fresh rock and 30 kg of more altered basalt with a very thin Mn crust. Two different basalt samples have been analyzed: one is a hawaiite, and the other is a nepheline. For the nepheline, we obtained a K-Ar age of 230 000 ± 4000 yr, which was determined on K-rich nepheline crystals with a K content of 2.86%, and a much less precise zero age was obtained on glass samples. If we look at the geochemical signature of this nepheline basalt, the Arago point is in the “young Rurutu” region of a Pb-Pb diagram (Fig. 3) corresponding to the 1.1 Ma event, which is clearly separated from the Macdonald signature.

Owing to its geochemical signature and its young age, we propose that Arago Seamount is the missing hotspot proposed by several authors in the past 20 yr. We can now compare its track on the Pacific plate with what we know of the regional volcanism. To reconstruct the apparent path followed by a hotspot on the seafloor, we have moved its present location back in time by using the set of stage poles proposed by Wessel and Kroenke (1997). This data set represents the most updated synthesis for the absolute Pacific plate motion since 145 Ma. However, the last proposed pole for the interval 0–3 Ma, is questionable. Wessel and Kroenke (1997) considered that the recent southeast trend of the Hawaiian track is representative of the global Pacific plate motion since 3 Ma, but the corresponding stage pole leads to important misfits on all the other volcanic tracks and, for this interval (0–3 Ma), we have chosen to use the pole previously proposed by Yan and Kroenke (1993). The apparent hotspot tracks are now determined for the past 20 m.y. with this set of absolute stage poles (Fig. 4). If we use a 100-km-wide track as representative of the zone of influence of a given hotspot source, we clearly see that the Macdonald hotspot could not have generated the northern Austral Islands. Furthermore, its track fits well with the 19 Ma age of Mangaia and with the K-Ar age of 9 Ma obtained on a seamount during the same cruise. The latter also shows the same Pb isotope ratio as Macdonald Seamount. However, the northern Austral Islands can be well explained by a hotspot source that probably stopped producing magma at Raivavae ca. 6.5 Ma. This solution also has the advantage of linking together islands with isotopic signatures clearly different from those of Macdonald. President Thiers bank to the east is a guyot and probably much older. The ages along the track are not compatible with the Cook Islands’ ages. The Rimutara age of 27 Ma is questionable and will not be used to define any of the tracks. Finally, by using the same stage poles, the Arago track is drawn. It fits quite well with Rurutu’s age and Cook Island ages. Note that volcanoes are often not located exactly on track, which we think indicates the importance of lithospheric control rather than a change in the location of the source.

CONCLUSION

We propose that Arago Seamount is the most recent surface expression of the hotspot responsible for the recent volcanic activity at Rurutu and probably for other volcanoes in the Cook Islands chain. We have also shown that the only possible track for Macdonald hotspot is along a southeastern path and that it could not have supplied the magma for the northern Austral Islands. Thus, for these islands we have to propose an extinct magmatic source close to the Austral Fracture Zone. From this new scheme, added to the already complicated geological history of this region, we can extract two common characteristics of all the hotspot tracks identified so far: (1) a short duration of life (<20 m.y.); and (2) several hotspots are active simultaneously on a region of the seafloor that doesn’t exceed 2000 km in diameter.

Our goal is now to identify the mechanism that could cause this apparent rhythmicity of the volcanism in both space and time. We believe that these short-lived and closely spaced hotspots are not consistent with discrete mantle plumes of deep origin. Our preliminary hypothesis favors a more local upwelling in the upper mantle strongly influenced by weaknesses in the lithosphere.

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Figure 4. Hotspot-track reconstruction for three groups of volcanoes identified (see text). Black numbers indicate time (in Ma) along each track. Note that northernmost track starts at 6.5 Ma for last volcanic event known on this track. Active Macdonald Seamount and recently active Arago Seamount are represented by black stars. New K-Ar ages obtained in present study are in black over white disk.

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