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Cenozoic volcanism of the Capel-Faust Basins, Lord Howe Rise, SW Pacific Ocean

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New bathymetry, geophysical data and samples were acquired in 2007 during a marine reconnaissance survey using the R.V. *Tangaroa* in the frontier Capel and Faust basins, Lord Howe Rise (LHR) by Geoscience Australia as part of the Australian Government's Offshore Energy Security Program. This survey identified a number of volcanic features including cones, flows and sill-related features on the seafloor. Based on analysis of seismic data and swath bathymetry, there are at least two distinct ages of volcanism exposed on the seafloor; Late Miocene–Pliocene cones with a largely unmodified conical shape and Eocene–Oligocene volcanic features. The Middle Miocene Gifford Guyot, part of the Lord Howe seamount chain was included in the survey area. Volcanic features are common on the seafloor of the LHR and in the neighbouring Tasman Basin, with two identified north–south seamount hotspot chains to the west of the Capel-Faust region that have been active from the Miocene to recent. The previously completed ZoNéCo 5 swath-mapping, seismic and sampling survey also identified a few small conical seamounts on the northern LHR, along a roughly north-northwest trend, dated as Early Miocene. The younger Capel-Faust seamounts are aligned with these and the age relationships suggest they could be part of a single seamount chain. The older cones do not show any preferred alignment within the survey area and are too old to be related to the current hotspot activity in the region. Samples are variably altered but trace element abundances of all dredged mafic rocks indicate they are alkalic basalt. Samples from the younger cones can be differentiated from each other and from the Gifford Guyot on a plot of Ti, Sr and Tb/Yb reflecting different source depths or degrees of partial melting. A comparison of pyroxene from the older more altered cones and the younger cones shows that these most likely represent two distinct magmatic events and that the younger cones are similar to the ZoNéCo 5 seamounts.

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1. Introduction

The Lord Howe Rise (LHR) region (Fig. 1) forms one of Australia's largest unexplored offshore frontiers, extending 1600 km from southwest of New Caledonia to the Bellona Trough, west of Mount Cook in New Zealand. Pre-existing geologic data coverage of the area is sparse, with many unknowns and data gaps throughout the region. Programs by Geoscience Australia have focussed on acquiring new data and filling these gaps initially with the Big New Oil Program (2003–2007) and subsequently the Offshore Energy Security Program (2007–2011).

As a part of these programs, new geologic and geophysical data were acquired over three surveys in the area. The joint Australian–French AUSFAIR MD153 (Australia–Fairway Basin bathymetry and sampling) Survey in 2006 focussed on acquiring swath bathymetry, sub-bottom profiler, gravity and magnetic data, as well as rock dredge samples and giant CALYPSO piston cores (Colwell et al., 2006). The Capel-Faust GA-302 seismic survey by Geoscience Australia in 2006–2007 acquired approximately 6000 km of 106-fold 2D data (Kroh et al., 2007) over the Capel and Faust basins of the northern Lord Howe Rise (NLHR). The Tangaroa GA-2436 survey in late 2007 aimed to investigate both petroleum prospectivity and seafloor environments in the Capel-Faust area, successfully acquiring piston core and dredge samples, as well as approximately 24,000 km2 of multibeam bathymetry and 11,000 line km of shipboard gravity and magnetic data with a line spacing of 3–4 km (Heap et al., 2009).

A number of previously unknown volcanic features were mapped and sampled during the Tangaroa GA-2436 survey (Fig. 1). Volcanic features previously identified in the LHR region include two oceanic north-south seamount chains, one to the west of the Lord Howe Rise, the Tasmantid seamount chain (McDougall and Duncan, 1988) and the Norfolk Ridge seamount chain to the east (Exon et al., 2004). The ZoNéCo 5 survey (1999, RV L'Atalante) also revealed a few small conical seamounts on the NLHR, along a roughly north-northwest trend, and sampled two of them (Exon et al., 2004). During the GA-2436 survey,

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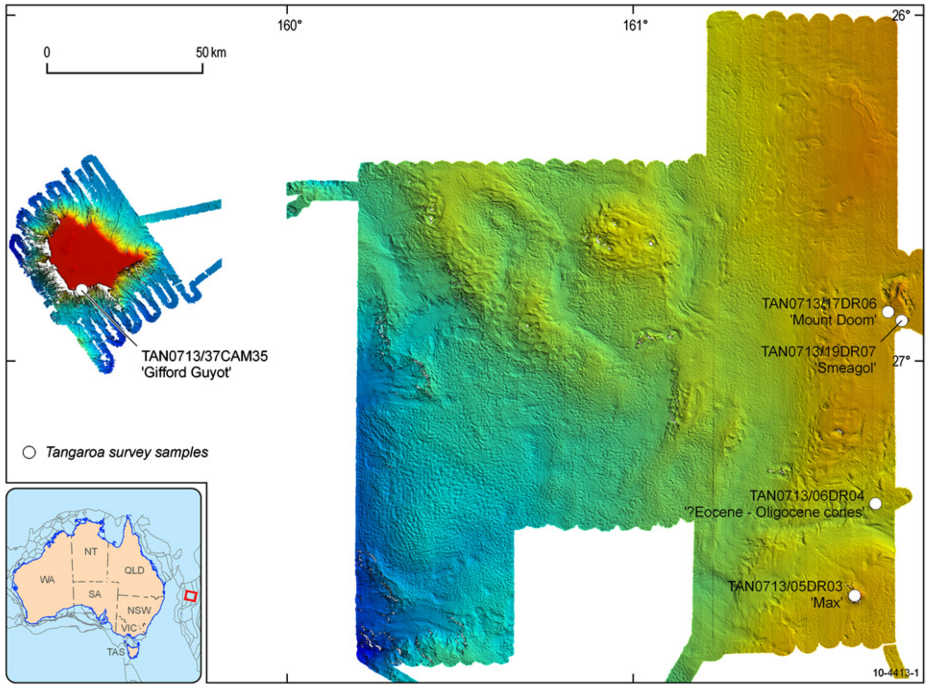

Fig. 1. Regional setting and location of sample sites used in this study from the Tangaroa GA-2436 survey. The swath bathymetry data shown was also acquired during this survey.

sampling targets were identified on the basis of previously acquired seismic data (GA-302) coupled with bathymetry data acquired during the survey.

In this paper we provide a description of the morphology of the volcanic edifices in the Capel-Faust basins, a petrographic description of the samples dredged during the survey and the results of geochemical analysis of whole rock samples and pyroxene grains. This work will allow correlation of these volcanoes with others identified on the LHR. The age range of volcanism will be outlined and correlated with that of other volcanoes in the LHR region, thus providing an insight into the tectonic setting of the Cenozoic volcanic activity in the Capel-Faust basins.

2. Regional setting

The Capel and Faust basins are located in water depths between 1500–3000 m on the NLHR (Fig. 1). This region was originally part of the eastern margin of Gondwana, characterised by convergent tectonics in the Palaeozoic and Mesozoic (Gaina et al., 1998; Sdrolias et al., 2001; Veevers, 2000; Crawford et al., 2003; Lafoy et al., 2005; Schellart et al., 2006; Collot et al., 2009). Subsequent oblique rifting starting in the Early Cretaceous, associated with the break-up of Gondwana and the formation of the Tasman Sea, separated the continental fragment from the rest of Australia. Rifting continued until the latter part of the Late Cretaceous, producing a number of basins along the length and width of LHR with likely petroleum potential (Stagg et al. 1999; Blevin 2001; Willcox et al., 2001; Van de Beuque et al., 2003; Exon et al., 2007). The thickest sediments and largest structures were identified in the Capel-Faust basins and have been the focus of data acquisition in the region.

The LHR is dominated by a thick cover of marine ooze, resulting in a paucity of rock exposures from which to obtain samples. A continental origin for the LHR has largely been inferred from crustal thicknesses of 29–34 km (Zhu and Symonds, 1994; Shor et al., 1971). A number of igneous rocks have been sampled across the LHR. The 2006 AUSFAIR Survey dredged along the Vening-Meinesz fracture zone on the LHR and recovered volcanic and plutonic clasts within conglomerate (Colwell et al., 2006/05). These samples represent at least two episodes, or a long-lived and continuous phase, of Late Cretaceous alkalic volcanism, dated at 97 and 74 Ma, likely to be associated with rifting. DSDP Hole 207 (1000 km to the south) also encountered Cretaceous volcanic activity with samples of rhyolite dated at 93.7+1.1 Ma (McDougall and van der Lingen, 1974). Seismic data analysis of the Capel-Faust basins has also identified a number of probable rift-related volcanic units that have not been validated by sampling (Cowell et al., 2010).

Hotspot volcanoes occur over areas of continental crust and in the adjacent ocean basins. There are three main chains of such volcanoes, the Tasmantid, Lord Howe and Norfolk Ridge seamount chains that parallel other hotspot chains on the nearby Australian continent. Exon et al. (2004b) also suggested that seamounts surveyed during the ZoNéCo 5 survey over the NLHR were also part of a seamount chain, erupted through continental crust.

3. Morphology, distribution and ages of the volcanic features

The Tangaroa GA-2426 survey mapped and sampled three distinct sets of volcanic edifices, grouped by age. The oldest set was identified on previously acquired seismic data (GA-302) and is typically associated with the Paleocene–Eocene and Eocene–Oligocene unconformities interpreted from the DSDP 208 well data to the north. The edifices can be seen on seismic profiles to build upward from these horizons or basement highs, through a blanket of marine ooze, to be exposed on the seafloor (Fig. 2). The detailed shape of the summits is evident on recently acquired bathymetry data (Fig. 3A). Each cone is surrounded by a moat where the currents have eroded sediment. These volcanoes do not have any preferred alignment within the surveyed area, similar to some other groups of seamounts in the southwest Pacific (Finn et al., 2003).

The youngest set of cones can be seen clearly on the bathymetry data and on the seismic sections and have their bases close to the modern sea floor. These volcanic cones are likely Late

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