# VOYAGE SUMMARY SS01/2003

**Title**
Subduction east of Australia from 120-45 Ma: search for the missing evidence in the eastern Lord Howe Rise, New Caledonia Basin, Norfolk and Three Kings Ridge Region.

**Itinerary**
Departed Hobart 1400 hrs, Friday 21 Feb, 2003
Arrived Auckland 1000 hrs, Thursday 13 March, 2003

**Principal Investigator**
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**Scientific Objectives**
The tectonic history of the eastern edge of the Australia plate during the Cretaceous (~130 million years ago (Ma) to 50 Ma), currently involves a major paradox. Global plate kinematic models demand that there was subduction of the Pacific oceanic crust westward beneath the Australian plate throughout much of the Cretaceous, whereas arc-type rocks characteristic of such subduction are unknown across the region. To attempt to solve this problem, comprising

- The nature of the plate boundary east of Australia during the Cretaceous-Palaeocene, and
- The existence, location, longevity and composition of the missing arc,

we propose a research voyage to sample the southern section of the Norfolk-New Caledonia Ridge, Norfolk Basin, and Loyalty – Three Kings Ridges.
Dredging of scarps (rather than just the later volcanic peaks) of these ridges should yield Cretaceous subduction-related volcanic rocks, and perhaps even fragments of the hypothesized most easterly continental crust of Australia rifted from the Lord Howe Rise in the Cretaceous.

**Voyage Objectives**
Key objectives in the original proposal were for carrying out 30 deepwater reconnaissance-type dredge hauls, and up to 12 gravity cores from seafloor sediment sections in the proposed study area. No other technical work was planned. Subsequently, before the voyage, we revised the number of possible dredge hauls to 35, and decreased to 6 the proposed gravity cores, on the basis that the gravity cores did not directly address the scientific objectives of the voyage, but were more 'add-on' science.

**Voyage Track**

The voyage track, and 35 dredge stations, are shown on the attached Figure 1. Following departure from Hobart to the southern end of the Norfolk Ridge, the voyage followed a roughly clockwise circuit around and occasionally into the Norfolk Basin, bounded by the Norfolk and Three Kings Ridges, completing the voyage in Auckland.

**Results**

The prime voyage objective was to sample old rocks on the seafloor of the Norfolk Ridge, the Norfolk Basin and the Three Kings Rise, with 35 carefully planned dredges in water depths mainly between 1000m and 3500m. Despite often very difficult sea conditions, we successfully carried out 35 dredges over the region, recovering useful rocks in all but 3 dredge deployments. It was discovered before deployment of the gravity corer that there were some major technical problems with this facility, and it was not deployed at all. This did not impact on the results of the voyage, because, as noted, above, the gravity cores were to be 'add-on' science not directly addressing the scientific objectives of the voyage.

A number of key scientific results were apparent from the dredged rocks even before shore-based detailed laboratory studies. These are summarized below:

1: The great overthrust ophiolite sheet that dominates New Caledonia, and represents the forearc crust of the extinct Loyalty island arc emplaced westward on to the Norfolk Ridge around 40-35 million years ago, was traced hundreds of km further south almost as far as offshore Northland in New Zealand. Distinctive ophiolitic peridotites, representing upper mantle of the Loyalty forearc, were dredged from seamounts south and east of the Cagou Trough, and provide a major regional constraint on the tectonic evolution of the SW Pacific region.

2: An upthrust block of volcanic rocks exposed on the seafloor in a major scarp at the northern end of the Norfolk Ridge was successfully dredged, yielding diverse broadly andesitic or trachyandesitic volcanics of unknown age. Interpretation of available seismic sections across this scarp area do not rule out the possibility that these lavas are Cretaceous or even older volcanics. If this is so, these lavas may well represent lavas from the 'missing volcanoes' that were the focus of this voyage. Dating studies are in progress.

3: Basaltic lavas representing crust of the Norfolk Basin were dredged at a number of locations, and will provide the first glimpse of the composition of this essentially unknown mid-Tertiary backarc basin. A current problem of great interest to geochemists and geodynamicists is the distribution and longevity of upper mantle domains with 'Pacific-type' isotopic signatures, versus those with 'Indian-type' signatures. Until recent studies showed that the Indian-type isotopic fingerprint had appeared in the last 5 million years in the Lau Basin behind the active Tonga-Kermadec arc, it was presumed that the boundary between the Pacific and Indian mantle domains lay along or close to the Antarctic-Australia Discordance, south of the Nullabor coast of southern Australia. The basalts dredged from the Norfolk Basin will enable testing of the distribution of the Indian domain back to around 30 million years ago, when this crust is hypothesized to have formed.

4: The southernmost seamount volcano of the Loyalty arc was dredged, and although primitive arc tholeiites were expected, the dredged volcanics were biotite-bearing andesites with likely shoshonitic affinities. Similar lavas were dredged from a large bathymetric high south of this seamount, on the other side of the massive Cook Fracture Zone. This high is believed to represent strongly extended crust of the forearc and arc of the Eocene Loyalty arc, but the presence of rocks with apparent shoshonitic affinities provides an important new constraint on regional tectonic development. Again, dating of these rocks will test whether these old arc volcanoes represent the 'missing arc volcanoes' or not.

5: A dredged seamount on the western side of the South Norfolk Trough yielded unusual rhyolitic quartz-phyric pumice breccias of unknown age. These bear many similarities to felsic pyroclastic rocks of Cretaceous age occurring in the Whitsunday Province of coastal central Queensland, and may represent a southern extrapolation of the Whitsunday Province rafted eastward during opening of the Tasman Sea between about 85 and 52 Ma. Dating of these rocks to better constrain their tectonic significance is in progress.

6: Limestones and fossiliferous sandstones were recovered from about half the dredges, including some dredges dominated by volcanics. Microfossils in these sedimentary rocks will provide valuable data for an investigation of the immersion and uplift history of the Norfolk Ridge and Three Kings Ridge.

**Voyage Narrative**

The voyage, the maiden voyage of the refitted R/V Southern Surveyor left Hobart around midday February 19th, and proceeded on a northeasterly course through fairly rough seas for over 4 days to the first dredge site on the eastern side of the southern end of the Norfolk Ridge. The rock dredge was a chain-bag type, and was deployed from the port trawl warp. The weight to hold the dredge at the seafloor was attached to the dredge wire 25m above the dredge itself. We planned a series of 35 dredges addressing diverse targets on seamounts, uplifted blocks and scarps on the Norfolk and Three Kings Ridges and in the Norfolk Basin itself. Palaeontological determinations of microfossil assemblages were made by Dr Pat Quilty for each relevant dredge within a day or so of that dredge being brought on board. The dredge was snagged on the bottom numerous times during the voyage, requiring great skill by the bridge and dredging personnel to bring the vessel around and back over the dredge without breaking or catching the wire. No dredge was lost during the entire voyage, but several were seriously deformed, requiring rebuilding in the ship workshop, and in one case, welding back in Auckland.

**Dredge 1** recovered only nanno ooze and a few very small fragments of coral and vesicular basalt.

**Dredge 2**, on a seamount representing an uplifted block at the northwestern end of the Vening Meinesz Fracture Zone immediately east of the southern end of the Norfolk Ridge, yielded a single small chunk of metadolerite or amphibolite. Weather continued to produce rough, confused seas with swells to 3m, making dredging more difficult, but not impossible.

**Dredge 3** attempted a second dredge at this uplifted block on the Vening Meinesz Fracture Zone, but wind and current conditions did not allow the dredge to reach the seafloor at the chosen location, so we moved on to the next site.

**Dredge 4** targeted a relatively low ridge in the central part of the South Norfolk Basin, never before dredged. This yielded only some fawn muddy ooze, managanese chips, and a few pumice fragments.

**Dredge 5** was targeted on the same ridge slightly further north, and produced 30kg of pillow basalt and dolerites, with fresh glassy rinds on the basalts.

**Dredge 6** took place further north in the Norfolk Basin, focusing on a scarp at the eastern end Nepean Saddle. This yielded only fawn abyssal mud and small pumice chips.

**Dredge 7** located nearby Dredge 6 at the lower slopes of a large volcano produced around 80 kg of boulders and cobbles of olivine basalt, and minor limestone or chalk infilling cavities in the basalt. Sieving of mud in the pipe dredge produced abundant chips and fragments of apparently fresh volcanic glass, almost certainly of basaltic composition.

**Dredge 8** targeted the southern slope of a large E-W orientated volcano at the western end of Nepean Saddle, not far from the eastern scarp of the Norfolk Ridge. This dredge yielded 30kg of cobbles and boulders of olivine basalt, and sieving of mud in the pipe dredge produced abundant chips and fragments of apparently fresh basaltic glass. Moderating sea conditions improved the efficiency of deploying the dredge.

**Dredge 9** sampled the scarp of a projection extending eastward from the Norfolk Ridge, and yielded 150 kg of yellow sandstones, along with some cherts and limestones.

We steamed past the eastern side of Norfolk Island on the evening of 2/3/2003, with the sea conditions the calmest they had been so far on the voyage.

**Dredge 10** targeted a well-defined scarp on the western side of the northern end of the Norfolk Ridge. It yielded some 30 kg of reddish-brown lavas with plagioclase and subordinate mafic phenocrysts, resembling andesitic to trachyandesitic lavas, including some obvious clasts in volcanic conglomerate, but also around 40 kg of shallow and deepwater limestones, and 20 kg of yellow muddy sandstones.

**Dredges 11, 12 and 13** were targeted at a ridge between the Norfolk Ridge and Cook Fracture Zone**.** **Dredge 11** yielded 8kg of basalt, along with minor limestone, whereas **Dredge 12** did not reach the seafloor due to strong currents and adverse wind a sea conditions in this area. **Dredge 13** recovered around 15kg of bioclastic limestone and minor altered tuff, along with abundant manganese crusts.

**Dredge 14** attempted to sample the southern end of the Loyalty Ridge, but recovered only fawn mud/ooze with a few pumice chips.

**Dredge 15** sampled the eastern slope of the southernmost volcano defining the Loyalty Ridge north of the Cook Fracture Zone. It yielded around 30kg of arc-type andesites with plagioclase and pyroxene phenocrysts.

It was planned to dredge several sites along the well-defined scarp of the Cook Fracture Zone, but weather and sea conditions ruled against this unfortunately. As a result, we selected several targets in the immediate area with slopes amenable to dredging given the ambient wind and sea conditions.

**Dredge 16** was from a broad submarine high just south of the Cook Fracture Zone and west of the extrapolated extension of the Loyalty Ridge. It recovered in excess of 200kg of andesitic lavas, volcaniclastic sandstones and some dolerites, and is interpreted to be a strongly extended arc volcano, originally part of the Loyalty arc.

**Dredge 17** targeted a small ridge considered to be a possible extinct spreading ridge in the Forster Basin near the Cook Fracture Zone. This dredge produced only mud and manganese nodules, along with a few small pebbles, including one of basaltic appearance.

**Dredge 18** targeted a small ridge on the north side of the Cook Fracture Zone considered to be a possible extinct spreading ridge. Again unfortunately, this dredge recovered only fawn foram nanno-ooze and a few small pumice fragments.

**Dredge 19** attempted to sample the southern side of the Cook Fracture Zone adjacent to the Three Kings Ridge, but the dredge yielded only foram nanno ooze and a few small volcanic pebbles.
**Dredge 20** targeted the scarp of the eastern side of the Cagou Trough, and recovered around 300kg of rocks representing an oceanic crustal section dominated by basalts and dolerites, but also containing gabbros and possible pyroxenites.

**Dredge 21** targeted the scarp of the eastern side of the Cagou Trough further south than dredge 20, and despite the dredge snagging and being strongly deformed during unsnagging operations, it recovered around 10 kg of greenschist facies metabasalts, hyaloclastites and minor basaltic volcaniclastic sandstone. This dredge was 'retired' from operation and rebuilt during the Auckland lay-over.

**Dredge 22** targeted a volcano at the northern end of the Three Kings Ridge, and yielded around 0.5kg of soft, weathered volcanic breccia and minor volcaniclastic sandstone.

**Dredge 23 and 24** also attempted to sample rocks constituting volcanoes at the northern end of the Three Kings Rise, but both yielded only bioclastic limestones of presumed reef facies on the sides of these submerged cones.

**Dredge 25** sampled the eastern scarp of the southern Cagou Trough, but recovered only chalk and some pumice.

**Dredge 26** was taken on the western scarp of the southern Cagou Trough, and it yielded 2 boulders (17kg and 1 kg) of altered igneous breccia and some nanno ooze.

**Dredge 27** sampled the same slope as Dredge 26 but higher up the slope. It yielded around 15 kg of volcaniclastic sandstone & siltstone, some metabasalts, and some limestone pebbles.

**Dredge 28** targeted a N-S ridge on the SE corner of Bates Plateau, Norfolk Basin. It produced around 250 kg of massive blocks of brecciated and bioturbated conglomerate in which the main angular clasts are blocky siltstone and shale with small sandstone dykes, along with a small amount of white grainstone and pinkish packstone. The dominant rocks may have formed as a result of a debris flow.

**Dredge 29** was deployed on a seamount south of the Cagou Trough. It yielded around 300 kg of massive and cataclasized chert with calcite? veins.

**Dredge 30** targeted a seamount south of, and on the same trend as the Cagou Trough, south of dredge 29. It produced ~ 200kg of harzburgite, serpentinised harzburgite, ultramafic breccia, plagiogranite, and gabbro.

**Dredge 31** sampled another seamount immediately south of that dredged for Dredge 30, and it yielded 250 kg of serpentinized harzburgites, pyroxenites, and some microgabbros and dolerites. These rocks in Dredges 30 and 31 are strikingly similar to those making up the major part of the New Caledonian ophiolite.

**Dredge 32** sampled a seamount well south of, and to the west of the Cagou Trough trend. It produced around 100kg of unusual quartz-phyric pumice breccias and less abundant massive felsic lavas.

**Dredge 33** dredged a seamount close to the Vening Meinsez Fracture Zone northwest of Northland. It produced about 100 kg of sandstone, siltstone, breccia and minor carbonates.

**Dredge 34** targeted a N-S scarp on the Cagou Trough trend near Vening Meinesz FZ. It yielded around 100 kg of sandstone, siltstone, breccia, carbonates, and minor hyaloclastite.

**Dredge 35** sampled a seamount near the Vening Meinesz FZ, S of Three Kings Ridge. It yielded around 100 kg of siltstone, breccia, and basalt.

Following Dredge 35, a one-day long transit took the vessel to Auckland, NZ.

**Summary**

Despite often difficult sea conditions, we successfully dredged 'useful' rocks from all but 3 of 35 dredge deployments. As noted in the list of dredge results above, these dredges included some extremely exciting and unpredicted discoveries that will impact strongly on our understanding of the tectono-magmatic evolution of the SW Pacific region. Scientifically, therefore, we regard this voyage as highly successful.

**Personnel**

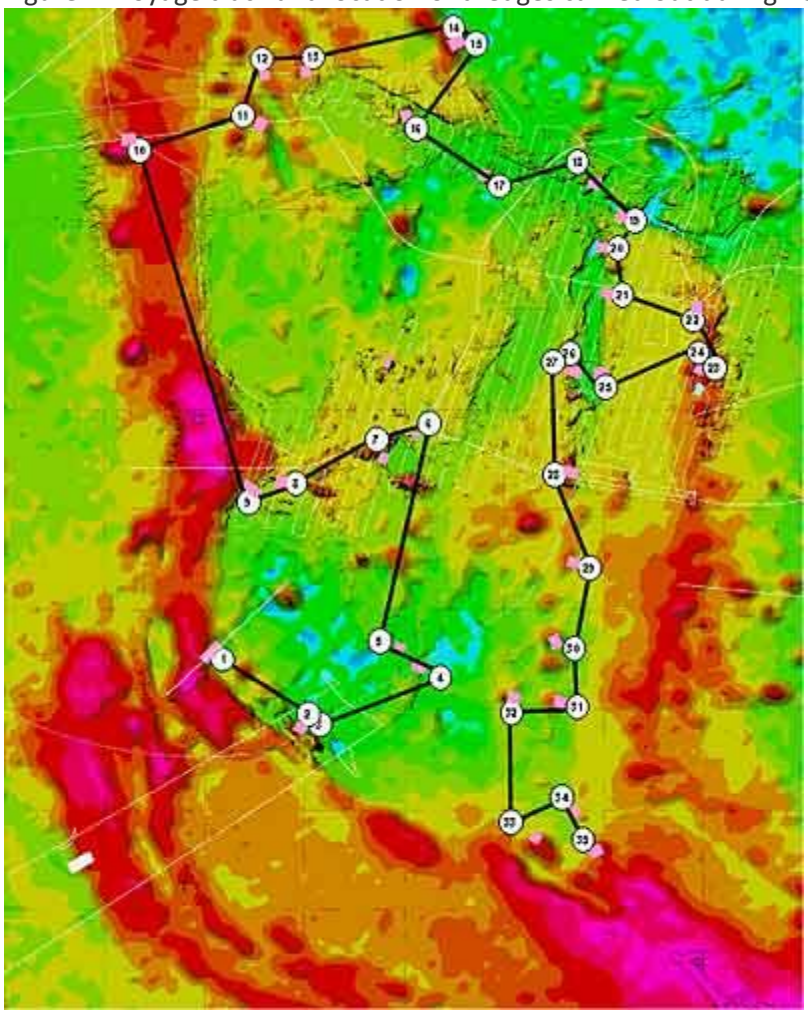
Scientific Crew
Tony Crawford, Utasmania, Chief Scientist, Petrology, tectonics
S ebastien Meffre, Utasmania, Petrology/tectonics
Patrick Quilty, Utasmania, Micropalaeontology
Michael Baker, Utasmania, PhD student
Phil O'Brien , Geoscience Australia, Marine geology
John Stratton, Geoscience Australia, Dredging specialist
Lyndon O'Grady, Geoscience Australia, Dredging and tech support
Andrew Hislop, Geoscience Australia, Engineering tech support
Michel Allenbach, UNew Caledonia, Sedimentology
Rick Herzer, IGNS, NZ, Marine geophys/tectonics
Jeff Cordell, CSIRO Marine and Atmospheric Research, Voyage Manager/Electronics
Bob Beattie, CSIRO Marine and Atmospheric Research, Computing

Marine Crew
Ian Taylor, Master
Arthur Staron, Chief Officer
Roger Pepper, Second Officer
John Morton, Chief engineer
David Jonker, First Engineer
James Hickie, Second Engineer
David Willcox, Chief Steward
Garry Phillips, Chief Cook
Angela Zutt, Second Cook
Malcolm McDougall, Bosun
Manfred Germann, IR
Tony Hearne, IR
Darren Henderson, IR
Rebecca Brown, Greaser

**Acknowledgments**
This voyage was essentially a shake-down voyage for the refitted Southern Surveyor, and problems were to be expected. Although numerous small and not so small technical/engineering problems required attention from the ship crew, including problems with air conditioning, drinking water, leaking seals, electronics, and others, these were dealt with extremely efficiently and effectively by the ship's crew, and did not impact adversely on the scientific program. The bridge team and GA dredging team worked together with the scientific crew with great professionalism and commitment to ensure deployment of 35 dredges despite often extremely trying weather conditions. I am particularly grateful to Ian Taylor and his crew, voyage manager Jeff Cordell, and John Stratton and his Geoscience Australia technical support personnel, for their unstinting support and commitment, without which this voyage would not have been so successful.

**Prof Anthony J Crawford**
**Chief Scientist**

Figure 1: Voyage track and location of dredges carried out during Voyage SS01/2003.



Updated: 22/04/04