Submarine Hydrothermal Processes in Volcanic Arcs, Back Arcs and Continental Shelf Settings in the SW Pacific.

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Summary

In the past two years CSIRO scientists have led 6 cruises, totaling 160 days at sea, to investigate hydrothermal ore forming processes in volcanic arcs, fore-arc and triple-junction related submarine volcanoes, and back arc basins associated with convergent plate margins in the SW Pacific region. Additionally, conceptual Mississippi-Valley-type targets associated with possible warm seeps at passive margins have been investigated in the Great Australian Bight. These investigations have resulted in a number of new discoveries of seabed hydrothermal deposits in Vanuatu, Solomon Islands, Papua New Guinea (PNG) and Indonesia; and an unprecedented opportunity to witness and document the earliest stages of ore forming activity and island arc building on the sea floor over a wide range of geographic and geologic settings. Our studies of modern seafloor ore-forming systems provide concepts that lead to improved methods of exploring for ancient mineral deposits on land that originally formed by similar processes.

Introduction

Between April 2000 and April 2002, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Exploration and Mining has led 6 research expeditions, totaling 160 days ship time, in the waters of Papua New Guinea, Vanuatu, Solomon Islands, Indonesia and Australia. Five expeditions were undertaken aboard the Australian research vessel Franklin following successful competitive research proposals, and the sixth used the Indonesian vessel Baruna Jaya VIII. In addition, two CSIRO participants joined JOIDES Resolution for the Ocean Drilling Program Leg 193 in the Manus Basin of PNG.

The major scientific objective underpinning these expeditions was to locate and study present-day seafloor and sub-seafloor hydrothermal ore-forming activity in order to develop improved methods of exploring for ancient mineral deposits on land that originally formed by similar processes. The research has been supported financially by a number of Australian-based mineral companies, by Australian international aid agencies, and by CSIRO funds, and was conducted in collaboration with researchers from other Australian institutions, Indonesia, Portugal, New Zealand, United States of America, South Korea, and the host nations. Building upon earlier successes in the 1986-1997 PACLARK-PACMANUS programs in the Woodlark and Manus Basins of PNG, we have sought to examine a wider range of geological settings, in which ancient orebodies are inferred to have formed, including both volcanic and sediment-hosted environments. We have now visited volcanic arcs, fore-arc and triple-junction related submarine volcanoes, and back arc basins associated with convergent plate margins in the SW Pacific and SE Asia, as well as conceptual Mississippi-Valley-type targets associated with warm seeps at passive margins in the Great Australian Bight (see Figure 1). Survey areas range from northern Sulawesi and the far western Bismarck volcanic arc near PNG-Indonesia border, through the eastern Manus Basin and the Tabar-Lihir-Tanga-Feni chain in PNG, the western Solomon Islands

festoon, the San Cristobal arc, parts of the Vitiaz arc, to the northern and southern New Hebrides arc in the Solomons and Vanuatu.

Key Results

New active hydrothermal vent fields have been discovered both north and south of PACMANUS on andesitic-dacitic Pual Ridge in the eastern Manus Basin of PNG, at Nifonea in the Vate Basin (the northernmost backarc trough in Vanuatu), and with variously andesite-dacite-rhyodacite volcanic edifices at Grover Seamount in the San Cristobal arc and at Stanton and Starfish Seamounts in the northern New Hebrides arc in the eastern Solomon Islands. Stanton Seamount is a particularly interesting discovery because possible intrusive rocks and stockwork veining suggestive of porphyry-copper-gold-style mineralization were recovered from a resurgent dome-crater complex within a larger caldera setting. The arc-related vent field discoveries in the eastern Solomons are associated with quite localized, gas-rich hydrothermal plumes (methane and carbon dioxide) lacking significant concentrations of ferruginous or other hydrothermal particulate matter. Contrary to accepted theories, we have also discovered that the Corolis Troughs in southern Vanuatu and the Vanikoro Trough in the northern New Hebrides arc are magmatically active. The recovery of volcanic samples from these basins that are in the incipient stage of rifting provides an unprecedented opportunity to understand the full spectrum of magmatic evolution during back arc rifting processes.

Potential sediment-hosted settings, including the vicinities of major transfer and extensional faults, were investigated in the Coriolis, Santa Cruz, Utupua and Vanikoro back arc basins in the southern and northern New Hebrides volcanic chain, in the Tomini-Gorontolo basins of northern Sulawesi, and in the western Bismarck Sea, the Manus Basin and nearby St Georges Channel in PNG waters. So far these areas have not yielded an analogue for ancient deposits of this type, though enigmatic, possibly hydrothermal plumes were identified near an intrabasinal volcano (Una Una) in the Tomini Basin and near two fault zones in the western Bismarck Sea.

A highlight of the expedition to northern Sulawesi was a visit to Banua Wuhu, an active volcano (eruption in 1919) whose summit is just exposed at low tide. Gas bubbling, subsurface sonic activity, and venting of hydrothermal fluids with temperatures around 50ºC are known to occur on the summit at around 10 m depth, where ferruginous oxide deposits several mm thick are common. A multibeam bathymetric chart to 1000 m was prepared and when coupled with deeper narrow-beam echo sounding shows that Banua Wuhu is a parasitic feature on the north-western side of adjacent Mahenetang Island, also a volcanic construction, the combined edifice exceeding 3000 m in height. Extensively altered porphyritc andesite containing disseminated pyrite and a carbonate-chlorite-clay mineral assemblage was recovered from around 400 depth on the western flank of Banua Wuhu.

Bikpela and 2-Fluid Model

Among other geological outcomes at PACMANUS was the serendipitous collection from the Roman Ruins field of a particularly large sulfide chimney. Weighing approximately one tonne and 2.7 metres tall, the upper part of this structure named *Bikpela* (Big Fellow) is composed almost entirely of sphalerite –a typical specimen assayed 53 wt%Zn and 0.15 wt%Ag. The lower part contains more pyrite, barite and chalcopyrite. This and smaller recent samples provide key evidence supporting our hypothesis that two hydrothermal fluids with very different compositions are contributing to the PACMANUS mineralising system. This inference is supported by initial post-cruise research arising from ODP Leg 193, which suggests a complex hydrothermal system involving mixing of seawater- and magmatic-fluid dominated end members.

Kavachi and Hydrothermal Plumes

Two visits to the Kavachi submarine volcano in the New Georgia Group, Solomon Islands, have enabled us to witness spectacular Surtseyan eruptions of molten lava from a shallow summit just below sea level in May 2000, to measure significant changes in morphology and to compare hydrothermal plume signatures and alteration assemblages over a two-year period. Repeated visits to SuSu Knolls in the eastern Manus Basin, PNG, have also demonstrated significant secular changes in the intensity and orientation of its hydrothermal plume. Altogether, our recent cruises have identified some 20 previously unknown volcanic seamounts and substantial knolls, and we have visited a similar number of known edifices, most of which proved inactive with the notable exception of Oscostar Seamount in southern Vanuatu.

Geophysical Trials and Biosampling

The program has included two other activities not related to our principal objective. At PACMANUS, we conducted trials of deep-submergence geophysical sensors being developed in CSIRO to facilitate future seafloor mineral exploration and mining. Principal parameters measured included total magnetic intensity, horizontal magnetic gradient, resistivity properties and electromagnetic response of the sub-seafloor, sub-bottom chirped acoustic profiles, system orientation, depth, altitude, and ambient temperature. We also collected a comprehensive suite of samples at actively-venting seafloor hydrothermal sites from which hyperthermophilic microbes were successfully extracted for culturing and use in a new CSIRO multidivisional research initiative involving biological applications in mining and mineral processing.

Acknowledgments

Seagoing expeditions of the kind completed over the past 2.5 years involve too many people to acknowledge individually. However, Ray Binns who has led 3 cruises (and instigated this work at CSIRO commencing in 1986) and was Co-Chief Scientist on Ocean Drilling Leg 193 is acknowledged in particular. Special thanks also to CSIRO management, Neil Phillips, and Graham Carr; CSIRO colleagues, Brent McInnes, Joanna Parr, Stephen Sestak and Chris Yeats; Richard Arculus, ANU; Haryadi Permana, Indonesian Institute of Sciences, Indonesia; industry supporters, Rio Tinto, Phelps Dodge, Newmont and Pasminco; and the host countries for allowing surveys in their waters. The Master and crew of the Australian Research Vessel Franklin are thanked for their tireless efforts and professionalism.

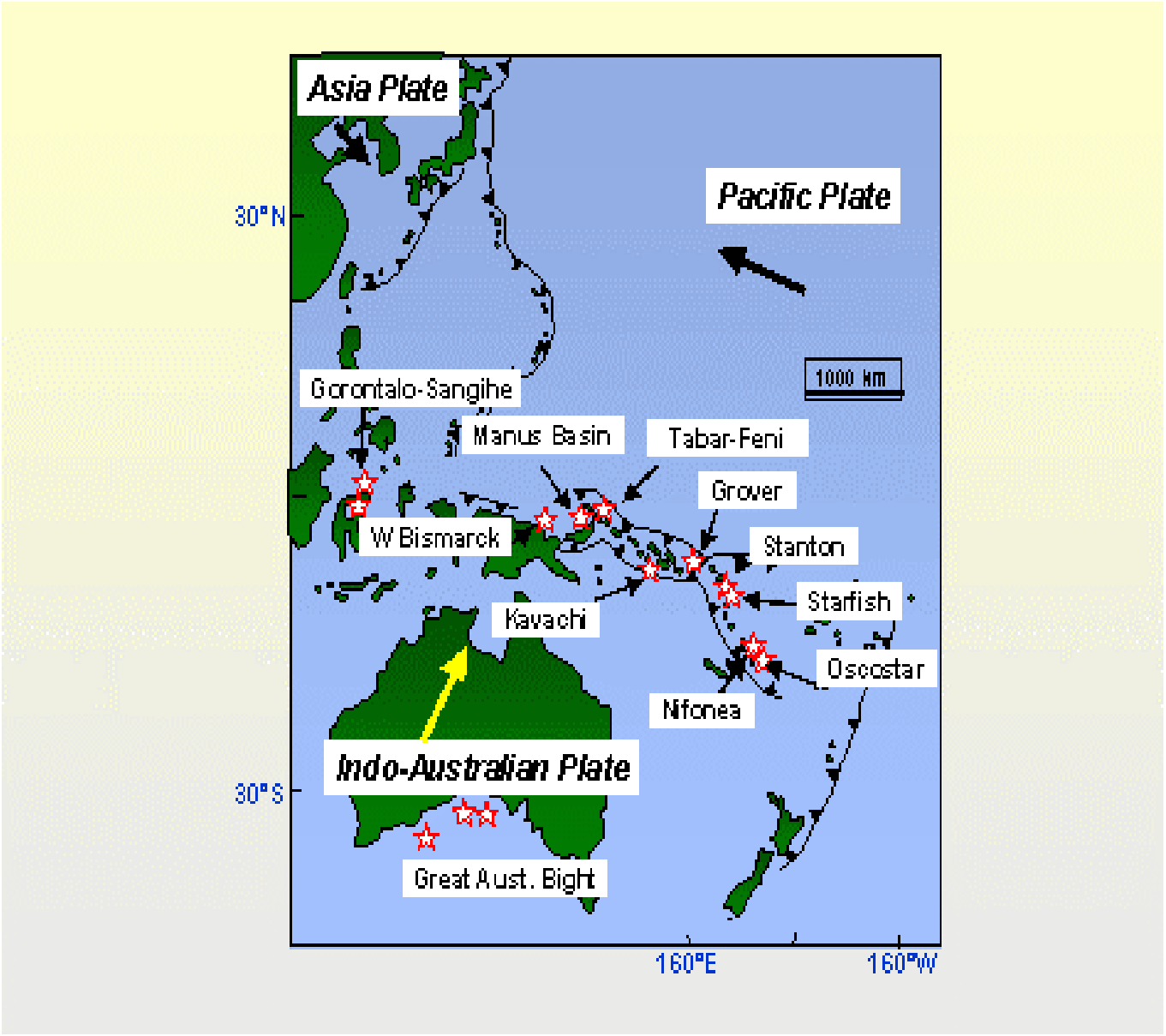

Figure 1 Areas of CSIRO-led Investigations, 2000-2002