Modern Ocean Floor Processes and the Geological Record

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Modern Ocean Floor Processes and the Geological Record

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Marine Studies Group
Geological Society of London

The Marine Studies Group is a specialist group of the Geological Society. It provides a focus for marine geoscientists and promotes the exchange of ideas within the UK community. It exists to develop links between researchers of different disciplines within the marine geoscience field, to strengthen contact with land-based specialist groups and to maintain a high profile for geological progress in the field amongst technologists and industrialists. Conferences sponsored each year include those aimed specifically at undergraduate and postgraduate research topics. The group has strong links with non-Society organizations such as *The Challenger Society* and BRIDGE, and welcomes contact with other marine-minded bodies. The Marine Studies Group can be contacted via the Geological Society.

British Mid-Ocean Ridge Initiative (BRIDGE)
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BRIDGE is a thematic research programme of the UK's Natural Environment Research Council (NERC). Running from 1993 to 1999, BRIDGE investigates the creation of new ocean crust at mid-ocean ridges. The volcanic mid-ocean ridge system is unusually compact and provides an opportunity to understand the oceanographic, geological, chemical and biological aspects of a complete environment. BRIDGE investigates the geological setting of the ridge; the geochemistry of vent fluids and hydrothermal mounds; and ways in which biological communities survive in this apparently hostile environment. Research ranges from regional scale studies mapping unexplored seafloor to microscopic and chemical analyses at individual vent sites. BRIDGE develops novel deep ocean technologies for deployment from surface vessels and manned submersibles, and funds experimental research into the mechanical and chemical nature of the rocks and underlying crust of these active volcanic zones. Contact: BRIDGE Programme Manager, School of Earth Sciences, University of Leeds, Leeds LS2 9JT, UK *or* BRIDGE Programme, Natural Environment Research Council, Swindon SN2 1EU, UK.

The Challenger Society for Marine Science

Founded in 1903 the Challenger Society's objectives are: to advance the study of Marine Science through research and education; to disseminate knowledge of Marine Science with a view to encouraging a wider interest in the study of the seas and an awareness of the need for their proper management; and to contribute to public debate on the development of Marine Science. The Society aims to achieve these objectives by holding regular scientific meetings covering all aspects of Marine Science, by supporting specialist groups to provide a forum for discussion, and by publishing a range of documents dealing with aspects of Marine Science and the Society's programme of meetings. The Society's journal, *Ocean Challenge*, is published three times a year. For details of membership or other Society matters contact: The Challenger Society for Marine Science, Southampton Oceanography Centre (251/20), Southampton SO14 3ZH, UK.

Other Geological Society Special Publications sponsored by these three organizations are:

No. 87 Parson, L. M., Walker, C. L. & Dixon, D. R. (eds) 1995. *Hydrothermal Vents and Processes.*

No. 118 MacLeod, C. J., Tyler, P. A. & Walker, C. L. (eds) 1996. *Tectonic, Magmatic, Hydrothermal and Biological Segmentation of Mid-Ocean Ridges.*

Preface

A multidisciplinary volume bringing together studies of the geologically active sea floor and the ancient record of such activity is long overdue.

With the recent achievements of the BRIDGE and RIDGE programmes, and the successful drilling of oceanic crust and areas of mineralisation, it is timely to test the new models against the wealth of data for similar systems found throughout the geological record.

As our aim is to synthesise knowledge of active and preserved sea floor, we have juxtaposed papers based on the ideas and hypotheses considered, rather than geographical or geological order. Thus the reader is taken from the structure of mid-ocean ridges, through crustal alteration and mineralisation processes to a consideration of faunal communities.

The first five papers all concern crustal configuration. **Gràcia *et al.*** combine evidence from submersible and high resolution side scan sonar to study the relationship between volcanism and tectonism south of the Azores. While the scales of these modes of observation are not wholly compatible, the records do allow segment-scale inferences to be made on the crustal magma system. **Collier & Singh** have carried out a novel seismic inversion technique to allow imaging of a melt lens on the East Pacific Rise and limits to be put on the amount of melt present. Their results also have implications for the segmentation of the crustal magma system, though here at a fast spreading ridge. **Allerton & MacLeod** make inferences of magma transport from Mid-Atlantic Ridge topography and conclude that melt may be channelled through the lithospheric mantle by segment-end faults. They test this hypothesis in the Carrick Luz shear zone of the Lizard Ophiolite, Cornwall, UK where gabbro mylonitic shear zones are observed. **Dilek & Thy** describe detailed observations of the structure and petrology of the Kizildag Ophiolite, Turkey in the light of observations from the Troodos Ophiolite, Cyprus. This section ends with **Minshull *et al.*** revisiting a question posed by Hess in the 1960s – 'Is the oceanic Moho a serpentinisation front?' They argue succinctly and convincingly that this hypothesis holds in areas of thin crust at fracture zones.

Crustal alteration is addressed by the next four papers. All the convincing evidence from modern seafloor settings comes from Ocean Drilling Program results. **Teagle *et al.*** record fluid evolution through the crust from secondary mineral strontium isotope composition during recharge and discharge at the site of ODP hole 504B in 6 Ma old crust on the East Pacific Rise. Such records are vital to our understanding of crustal evolution and fluid fluxes. **Hunter *et al.*** record the petrology of low-temperature alteration of the upper crust on the Juan de Fuca Ridge, again providing new insights into fluid flow through crust of medium spreading rate. **Bickle *et al.*** and **Wells *et al.*** describe studies from the Troodos Ophiolite. Bickle *et al.* use strontium isotope systematics to study the extent of crustal alteration and highlight the difficulty in reconciling the degree of alteration of Troodos sheeted dykes with the inferred fluid fluxes over time. Wells *et al.* study alteration on a more localised scale and use novel laser ICPMS measurements to identify the timing of reaction in an alteration pipe beneath a mineralisation zone, again highlighting the importance of the low temperature overprint on the geochemical budgets for Troodos.

Both high and low temperature mineralisation at mid-ocean ridges are addressed in the next four papers. Ocean Drilling Program sampling of sediment-hosted massive sulphides on the Juan de Fuca and Gorda Ridges is discussed by **James *et al.*** The authors couple sulphide petrological studies with pore fluid analyses to describe the mode of formation for the two deposits drilled. The interaction of fluids with mineralised material is addressed by **Goulding *et al.*** in the study of ochreous sediments from the active TAG hydrothermal mound. Basalt replacement and redox zonation of metals are the important controls on the geochemistry of such sediments. **Robertson & Degnan** review manganese-rich hydrothermal sediment occurrences from the modern oceans and use models of formation to infer the origin of Jurassic Mn-cherts from Southern Greece. Moving back through the geological record, **Herrington *et al.*** describe superbly preserved vent chimney structures from Silurian deposits in the Urals, Russia. Again, models of modern chimney formation explain the features observed in these ancient deposits.

The final two papers in the volume bring together biological studies from modern sea floor systems and the ancient palaeontological record to focus on community structure. **Little *et al.*** describe fossiliferous deposits from the Urals and test the refuge hypothesis posed from studies of modern systems. **McArthur & Tunnicliffe** also address this hypothesis and surmise that hydrothermal vent environments may provide protection from certain causes of extinction through geological time.

The challenges to scientists now are to take the ideas presented forward, to test the hypotheses constructed and to integrate more thoroughly studies of the deep ocean with studies of the deep past. The focus of such studies will necessarily move away from mid-ocean ridges, not the best analogues of ophiolite settings, and move to back-arc basins and areas of crustal convergence. Recent discoveries of high-grade, base metal-rich deposits in the Manus Basin demonstrate that our understanding of processes from mid-ocean ridges is applicable to other oceanic environments. Discovery of mineral deposits within Exclusive Economic Zone limits and at relatively shallow depths brings the potential for exploitation much closer. Before commercial factors overwhelm scientific objectives, the community should apply its new found expertise and common interests to these areas.

This volume arises from a meeting held in May 1997 under the sponsorship of the Geological Society's Marine Studies Group, BRIDGE and the Challenger Society for Marine Science. The enthusiastic response from the community, both in the presentation of new ideas and the interest of the audience, demonstrated the need for a volume recording the output of the meeting. Over the following months, authors have fleshed out the ideas presented in London, argued the detail during the review process and here present papers that focus on the interface between modern and ancient sea floor processes.

We are indebted to the referees who gave their time to review the manuscripts and who made so many valuable observations. Thanks go to Jeff Alt (Michigan), Tim Barrett (British Columbia), Derek Briggs (Bristol), Joe Cann (Leeds), Gail Christeson (Texas), Bob Detrick (Woods Hole), Rowena Duckworth (James Cook), Aline Fiala-Medioni (Banyuls-sur-Mer), Andy Fleet (Natural History Museum, London), Peter Floyd (Keele), Dan Fornari (Woods Hole), Chris German (SOC), Kathy Gillis (Victoria), Geoff Glasby (cosmopolitan), Mark Hannington (Geological Survey of Canada), Greg Harper (Albany), Bob Hessler (Scripps), Jose Honnorez (Strasbourg), John Hudson (Leicester), Susan Humphris (Woods Hole), Pamela Kempton (NERC Isotope Geosciences Laboratory), Mike Kendall (Leeds), David Needham (IFREMER), Bob Nesbitt (Southampton), William Newman (Scripps), Adolph Nicolas (Montpellier), Hazel Prichard (Wales), Steve Roberts (Southampton), Alastair Robertson (Edinburgh), Peter Rona (Rutgers), Martin Sinha (Cambridge), Norm Sleep (Stanford), Damon Teagle (Michigan), Meg Tivey (Woods Hole), Doug Toomey (Oregon), Paul Tyler (Southampton), Eva Valsami-Jones (Natural History Museum, London), Cindy Van Dover (Alaska), Soterios Varnavas (Patras), Bob Whitmarsh (Southampton) and Bob Zierenberg (California), with apologies to anyone we have missed.

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