

The Izu-Bonin-Mariana (IBM) Arc System: Outstanding Natural Laboratory for the Studies of Convergent Plate Margins

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Arc systems are composed of all crustal and lithospheric elements that form at convergent margins. This includes forearc regions, magmatic arcs, actively rifting back-arc basins, and fossil elements such as remnant arcs and extinct back-arc basins. Intra-oceanic arc systems promise to yield insights that are unobtainable by studying Andean-type arcs. Intra-oceanic convergent margins are built on oceanic crust, where original crustal thicknesses are known. With suitable geophysical studies, we can easily track crustal growth rates and processes. Intra-oceanic convergent margins are built on refractory oceanic crust, thus minimizing problems associated with crustal contamination of arc magmas. Because intra-oceanic convergent margins are far-removed from terrestrial sediment sources, forearc architecture is largely exposed, and we can study the composition and structure of the earliest subduction-related rocks, and use this to understand how subduction zones begin. This same lack of sediments allows us to directly sample and more readily interpret subduction-related fluids venting through the forearc, and it also means that back-arc rifting can be more easily studied. Because back-arc basin basalts reflect a hybrid melting process that is intermediate between melting due to adiabatic decompression and melting due to hydrous fluxing like that forming arc magmas, studying back-arc basin basalts offers insights into how both arc and MORB magmas form. The formation of

hydrothermal ore deposits in arcs and back-arc basins has obvious implications for scientific and economic endeavors. The IBM Arc system manifests the 2500 km long convergent margin that extends south from Tokyo, Japan, to Guam, U.S.A. This intra-oceanic arc system is a natural laboratory for understanding convergent plate margin processes and products, for both scientific and political reasons: it is one of the simplest of all arc systems with a well-known geologic history and modern geodynamic setting. Political jurisdiction is shared between the Japan and U.S., indicating that favorable logistical and political considerations exist and are likely to continue.

A IBM workshop intended to stimulate and co-ordinate studies of the IBM arc system was supported by the Japan Society for the Promotion of Science (JSPS) and the U.S. National Science Foundation (NSF) and held July 27 to August 1, 1996, at the Shonan Village Center, Hayama, outside of Yokohama, Japan. The workshop was divided into 2 parts. The first four days involved scientific presentations and discussion of problems that need to be resolved, along with a visit to the Japan Marine Science and Technology Center (JAMSTEC) in Yokohama. This was attended by 10 US. and 75 Japanese scientists along with one scientist each from Germany, Britain, and Australia. The last two days were spent in the Miura Peninsula

and the Tanzawa Mountains examining IBM arc crust exposed by continuing collision between the northernmost IBM arc and Honshu.

During the first part of the workshop, four working groups (Tectonics & Geophysics, Magmatic Evolution, Subduction Fluxes, and Hydrothermal Activity & Mineralization) discussed the important research priorities and hypotheses that should be addressed by multi-national efforts and made recommendations as to how these objectives could be met. It is impossible to do justice to the complete range of issues that need to be addressed to fully utilize the IBM arc system as a natural laboratory for understanding convergent margin processes. Instead, highlights of the 4 working groups' recommendations are presented below. These recommendations are presented in greater detail along with a short bibliography in "IBM Arc System Workshop - Working Group Reports", which is available as a web page (<http://www.utdallas.edu/rjstern/IMB-ArcSystem.html>).

Tectonics and Geophysics:

This group was particularly impressed by three recent scientific developments concerning the IBM arc system: 1) New models for how subduction began about 45 million years ago; 2) New, high resolution images of crustal and upper mantle structure, based on BS refraction experiments; and 3) New appreciation of the continuing 'edge-on' collision of the IBM arc with Honshu, Japan. The first item is of global interest because the IBM arc system is an outstanding place to understand general processes of subduction zone initiation. This working group emphasized the need for more research to test and refine these models. Subduction initiation models require a better understanding of Cenozoic plate kinematics as well as more detailed understanding of the physics of

subduction initiation. It is also important to understand how the crust of the forearc forms during subduction initiation, and what part of this story is preserved in ophiolite on land.

Recent high-resolution refraction images of the IBM crust and upper mantle constrains rates and processes for the formation of continental crust and has revealed a mid-crustal tonalitic layer, necessitating critical re-evaluation of the bulk composition of arc crust. At present only a single profile has been carried out and several more are needed positioned across the arc to image structures associated with different tectonic settings. A particularly exciting possibility is to image the crust near where crustal structures can be sampled, for example in the trench wall adjacent to the Challenger Deep. Similar techniques promise to help us better understand how the transition from rifting to spreading occurs in back-arc basins. Finally, the IBM-Honshu collision zone was recognized as an outstanding region to study terrane accretion and reconstruct the crustal structure of an intra-oceanic arc cross-section.

This working group also articulated the need of the scientific community to obtain existing bathymetric and magnetic data, now in the archives of the US Navy and the Japan Hydrographic Department.

Magmatic Evolution:

This group dealt with both short-term and long-term aspects of magmatic evolution. Efforts to understand long-term magmatic evolution address a long-standing controversy regarding whether or not arcs evolve with time through tholeiitic, calc-alkaline, and shoshonitic stages; resolving this controversy is expected to constrain our understanding of mantle wedge replenishment rates and processes of arc magma genesis. Specific research objectives focus on how magma sources have changed

over the past 45 million years of IBM arc history, what we know about unmodified mantle sources, and how these have been affected by fluids and melts released from subducted crust and sediments. Efforts to understand short-term magmatic evolution focus on the nature of primitive magmas and how these fractionate. Recent appreciation of the importance of felsic magmatic components in the form of tephra and glass inclusions in phenocrysts, in tandem with recognition of the mid-crustal tonalite layer, warrants further efforts to understand the generation of felsic melts in the IBM arc system.

Subduction Fluxes:

This group emphasized the importance of quantifying fluxes to and from the IBM convergent margin 'factory'. Input fluxes include subducted sediments, altered oceanic crust, and convecting asthenosphere. Output fluxes include fluid flow from the trench and forearc, serpentinization of the forearc lithospheric mantle, alteration of the convecting asthenosphere, and magmatic outputs from the arc to the back-arc basin. A controversy continues as models emphasizing mantle controls on arc magmas compete with those emphasizing control by subducted crust and sediments. The IBM arc system is a good place to test these hypotheses because of the strong variations in lava compositions observed along and across it. This controversy needs to be resolved before the ultimate goal - developing and testing a

quantitative flux model for the IBM arc system - can be realized. The presence on the subducting plate of thin (<500m) sediments showing simple facies variations indicates the IBM arc system is among the best arc systems on earth for developing and testing convergent margin flux models. Both Magmatic Evolution and Subduction Fluxes working groups called for implementation of a petrologic-geochemical-isotopic database for IBM lavas.

Hydrothermal Activity and Mineralization:

Hydrothermal systems in Western Pacific convergent margins are increasingly being studied, and it is important to continue discovering IBM hydrothermal sites. Variations in tectonic style and melt composition and temperature may lead to very different types of hydrothermal systems: arc, intra-arc rift, and back-arc basin; mafic, felsic, and shoshonitic. A few representatives of each hydrothermal system 'type' should be carefully scrutinized. This scrutiny should include estimating the dimensions of the convection cell, periodicity of fluid flow, its relationship to seismic and volcanic activity, the role of phase separation, and effective water-rock ratios. This should lead to the determination of hydrothermal fluid end members and of hydrothermal fluxes for the IBM arc system.

Establishing firmer links between interested US. and Japanese scientists is the next step in studying the IBM Arc System.