EW0203: US-JAPAN COLLABORATIVE RESEARCH: MULTI-SCALE SEISMIC IMAGING OF THE MARIANA SUBDUCTION FACTORY

EW-0203 has carried out controlled-source wide-angle reflection/refraction, and supplementary multi-channel seismic reflection, imaging of the forearc and active arc of the Mariana island-arc system, at 14° to 19°N. The principal objective is to determine the velocity and density structure of the crust as a proxy for the composition of an intra-oceanic arc, with implications for models of continental growth and crustal recycling to the mantle, and if possibe to image magma chambers below active volcanoes. Our study provides baseline seismic information for the MARGINS Subduction Factory experiment in the Mariana system, and in addition to the science objectives above will provide data to guide future geochemical measurements and proposed ODP drilling to understand the material fluxes output in the forearc and volcanic arc.

The MARGINS Program has identified the Izu-Bonin-Mariana (IBM) system as a focus area for interdisciplinary investigations of the "Subduction Factory". The IBM region is the classic example of an intra-oceanic arc – trench – back-arc system, and hence a good place to study the production rate and composition of arc magmatism. Crustal-structure images of island arcs elsewhere in the world have produced strikingly different results: data from the Izu-Bonin arc are consistent with a tonalitic middle crust, whereas data from the Aleutian arc are consistent with a more basaltic one, so that the parallel geochemical controversy, between an andesitic versus basaltic bulk arc composition, is as yet unresolved by geophysical data. We anticipate that EW-0203 data will provide a definitive answer at least for this segment of the Mariana intra-oceanic arc.

Important questions and aims of our controlled-source wide-angle study

•Is there a thick Vp=6.0-6.4 km/s "tonalitic" layer present at 15°-18°N, >1500 km south of prior observations in the Izu-Bonin arc? Or is there a thick Vp=6.4-6.8 km/s "basaltic" layer as in the Aleutian arc?

•What is the crustal thickness, hence magma production rate along the arc? Is the previous measurement of c. 2 km^3/km/Ma in the Aleutian arc, double the c. 1 km^3/km/Ma typically assumed, also typical of the Mariana arc? If so, we need to find more efficient crustal recycling mechanisms.

•How uniform is the crustal velocity structure of the arc along strike, and hence how uniform is the magmatic process generating arc crust beneath and between the active volcanoes?

•Can we distinguish velocity differences indicative of magma chambers below active volcanoes?

•Can we trace a coherent high-velocity mid-crustal layer in the arc rearward of the arc into coherent back-arc oceanic crust, thereby supporting the view from the Aleutians that such material is still recognizable as an intact density barrier to magma segregation and emplacement?

•Can we recognize "lower-crustal layering" in the Mariana arc, suggesting that the Izu-Bonin-type arc is truly a continental precursor? or is it absent (as apparently in the Aleutian arc) implying that oceanic arcs require additional tectono-magmatic evolution before becoming typical continental material?

•Can we recognize seismic bright spots on or just above subducting slab (in principal to >100 km depth using the 60 s MCS records), similar to the Aleutian bright spots and if so tie

them to velocity anomalies that may indicate overpressured aqueous fluids, or shallow melting of sedimentary rocks?

•How does the Pn velocity of the mantle wedge vary across the arc, and hence how does mantle temperature vary across the arc? Does seismic velocity support the lower temperatures estimated from thermal modelling, or the higher temperatures petrologically inferred from the observed magmatic products of wedge melting.

•What is the extent of serpentinite in forearc crust and mantle, and is there enough present to materially affect the rheology of the forearc crust and upper part of the mantle wedge?

We deployed 53 OBSIP OBSs from Scripps (with 2 Hz vertical sensors and hydrophones) (54 were shipped to ensure we could deploy 50; deploying 3 extra was a bonus) in three arc-parallel lines, along the volcanic arc, along the uplifted fore-arc high, and along the modern forearc midway between the trench and the volcanic arc. Deployment and recovery of 53 OBSs in a single cruise sets a new record for the US fleet. OBS deployments were faster than scheduled, and we used the extra time to land from R/V Ewing on Alamagan and deploy two Reftek seismographs with 4.5Hz 3-component sensors. This deployment supplemented equivalent stations deployed on Tinian, Saipan, Anatahan and Pagan in February by our collaborators from Scripps and the CNMI Emergency Management Office.

We used the 20-airgun array (10,810 c.i. towed at 10.5 m to maximize source energy at low frequencies) of R/V Ewing as our controlled source, firing the array every 200 m (250 m in the deeper water), or about every 90 to 100 secs at c. 4.5 kts. We simultaneously recorded our airgun shots on the standard Ewing MCS 6-km streamer, recording 240 (50-m) channels every 8 ms with a 61.44 sec record length, for a nominal sub-surface penetration of c. 200 km. We recorded 3035 km of nominal 15-fold (and 12-fold) data, shooting along the three OBS deployment lines, along an additional arc-parallel line west of the active arc, and along 6 arc-crossing lines.

At the end of EW-0203, OBS retrieval operations were scheduled to end 24 hours before we begin our return transit to Guam, as a contingency against delay in OBS recovery. The remaining time is being used to recover two OBEMs deployed by our Japanese collaborators on a previous cruise; to attempt to recover three Reftek seismographs from the island deployments; and to take as many as four gravity cores as a test of penetration, in a prelude to possible future heat-flow measurements in this area.

EW-0203 follows the successful EW-0202 MCS cruise in the same area, which also extended its coverage east to the Mariana trench and west to the West Mariana Ridge (remnant arc). EW-0203 will be followed by a Japanese-led cruise in January 2003 to shoot a 100-OBS profile across the trench-active arc-remnant arc system. The final cruises of this US-Japanese collaboration will be the deployment in summer 2003 and retrieval one year later of a 50 OBS array for passive seismic recording.