GeoPRISMS Science Goals in the Havre Trough Back-Arc Basin

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The Havre Trough is an ultra-slow opening (~15-20 mm/yr, *Ruellan et al.*, 2003) back-arc basin undergoing active extension in a broad zone proximal to the arc volcanic front. This appears to be a distinct style of seafloor spreading specific to back-arc basins. We suggest that it facilitates the study of intrinsic melt generation and chemical patterns in the mantle wedge by minimizing 2-D plate-driven advection components while sampling mantle wedge melts over a broad zone. These conditions make the Havre Trough well suited to address GeoPRISMS science objectives:

How do volatile release and transfer affect the rheology and dynamics of the plate interface, from the incoming plate and trench through to the arc and back-arc? At mid-ocean ridges the extraction of water from the mantle by melting has been proposed to greatly strengthen the residual mantle leading to the formation of a strong anhydrous "compositional" lithosphere [*Hirth and Kohlstedt*, 1996; *Phipps Morgan*, 1997] and perhaps helps focus deformation and volcanism to narrow plate boundary zones [*Macdonald*, 1982]. At back-arc basins, mantle water content increases by over an order of magnitude as the volcanic arc is approached [*Kelley et al.*, 2006] resulting in a several orders of magnitude weakening of mantle material [*Hirth and Kohlstedt*, 2003]. Near the arc, lithospheric mantle may not be able to dehydrate because the subducting slab is a continual source of new water and because melts produced near the volcanic front are so hydrous that residual mantle in equilibrium with these melts retains appreciable water [*Hirth and Kohlstedt*, 2003]. Thus, the plate boundary zone at arc-proximal back-arc spreading centers may be exceptionally weak and broad relative to mid-ocean ridges. Observations at the southern end of the Lau basin [*Martinez and Taylor*, 2006; *Watanabe et al.*, 2010; Fig 1] show a pronounced change in character of the plate boundary zone: a narrow zone of volcanic crustal accretion abruptly transitions to a broad, deep zone of volcanic extension consisting of small volcanic cones and ridges. This morphology continues into the Havre Trough for ~1500 km to New Zealand (Fig. 2). Originally, this narrow-to-broad plate boundary transition was interpreted as organized magmatic spreading replacing tectonic "rifting" [*Parson and Wright*, 1996], but more recent observations indicate both stages are fundamentally magmatic [*Martinez and Taylor*, 2006; *Wysoczanski et al.*, 2010]. If this interpretation is correct then the Lau-Havre Trough transition exhibits a fundamental change in the nature of seafloor spreading from a mid-ocean ridge-type, with a narrow plate boundary zone, to a back-arc style of a broad plate boundary zone, probably linked to high water content and its effects on mantle wedge and lithospheric rheology.

How are volatiles, fluids, and melts stored, transferred and released though the subduction system? The ultra-slow opening rates of the Havre Trough permit the pattern of melt generation in the mantle wedge to be expressed in crustal volcanism (Fig.2). The Havre Trough exhibits contemporaneous volcanism in distinct bands extending basinward along slab trajectories from arc volcanoes [*Wright et al.*, 1996; *Wysoczanski et al.*, 2010]. These volcanic bands appear to be surface expressions of mantle wedge "hot fingers" postulated by *Tamura et al.* [2002]. We suggest that ultra-slow extension facilitates the volcanic expression of melt generation in the mantle wedge by minimizing the 2-D mantle advection components imposed by plate spreading. Unlike ultra-slow spreading at mid-ocean ridges, where mantle is commonly exhumed, in arc-proximal back-arc settings the crust appears to be fully magmatic, but modulated in volume in cross-trending patterns. This probably reflects the higher water content in back-arc settings compared to mid-ocean systems, facilitating mantle melting even at ultra-slow opening rates.

What are the geochemical products of subduction zones, from mantle geochemical reservoirs to the architecture of arc lithosphere, and how do these influence the formation of new continental crust? Arc-proximal back-arc spreading centers generate thick felsic crust [*Martinez and Taylor*, 2002; *Dunn and Martinez*, 2010] (Fig. 3) at greater rates than the volcanic arc itself. In the Lau Basin, abrupt changes in the architecture and chemistry of back-arc crust have been documented [*Dunn and Martinez*, 2010] and similar changes are suggested in the Havre Trough. However, unlike the spreading-parallel crustal domains in the intermediate to fast spreading Lau Basin (Fig. 3), the ultra-slow spreading Havre Trough exhibits crustal domains in across-basin bands (Fig. 2), perhaps reflecting the inherent chemical and melt generation patterns in the mantle wedge. These felsic back-arc components suggest significant possible contributions to continental crust formation beyond the volcanic arc itself.

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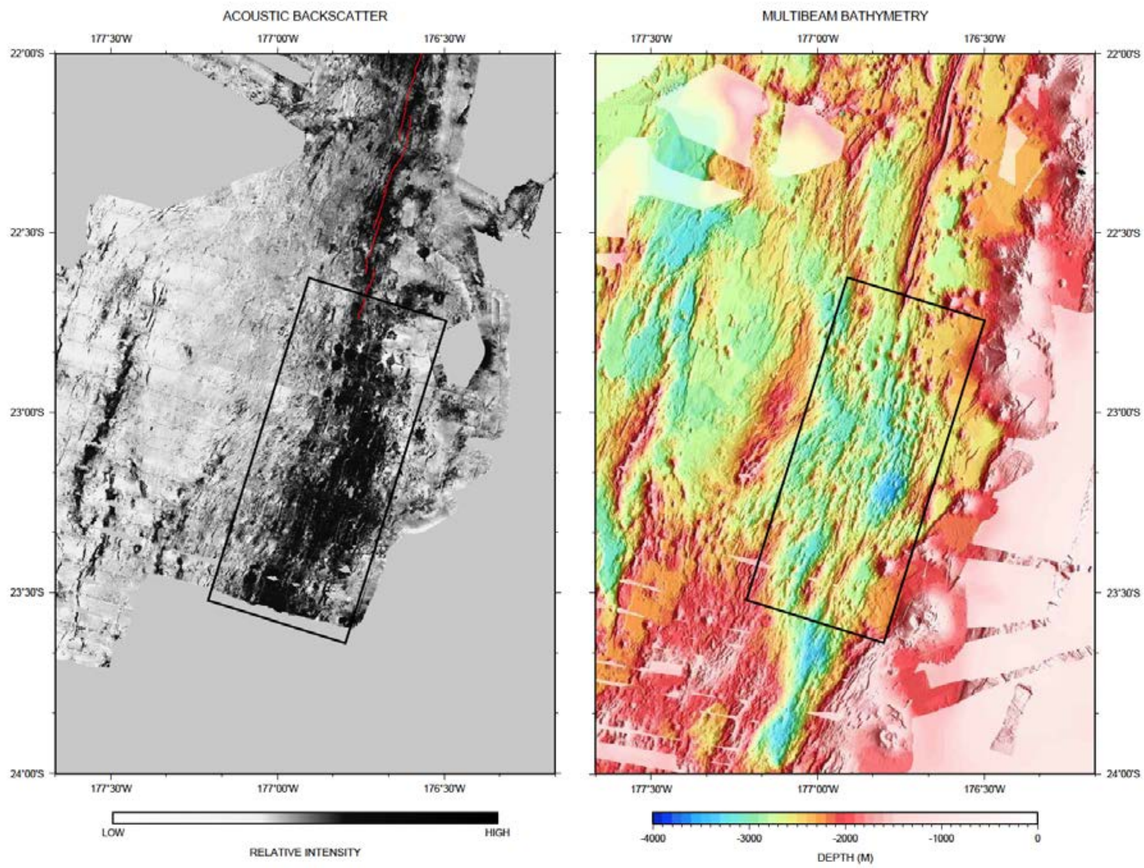

Figure 1. Change in character of the plate boundary zone in the southern Lau Basin. (Left) Acoustic backscatter imagery shows broad distribution of recent volcanism south of the Valu Fa ridge axis (red line). Dark shades = high backscatter. (Right) Bathymetry shows change from peaked narrow Valu Fa Ridge (red line) to deeper and broader terrain consisting of small volcanic cones and ridges. This volcanic morphology of ridges and cones separated along-strike by deeper basins continues in the Havre Trough for 1500 km to New Zealand. It appears to represent a new type of broad plate boundary associated with arc-proximal spreading at slow to ultra-slow rates. Data contributed by K. Okino, U. Tokyo [Watanabe et al., 2010].

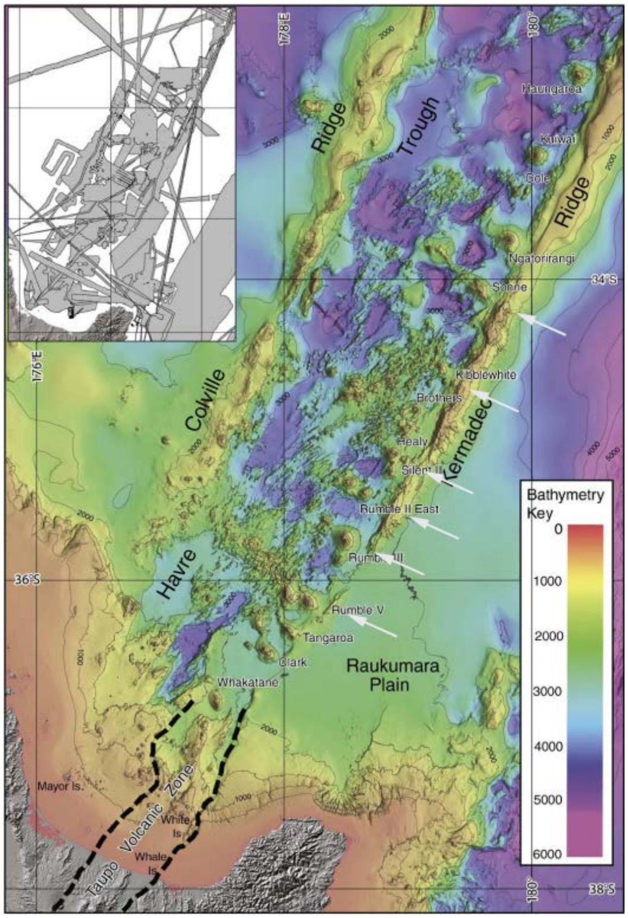

Figure 2. Left) Bathymetry of the Havre Trough showing pattern of crustal accretion. Cross-trending volcanic zones (arrows) are separated by deeper basins suggesting analogies to mantle wedge "hot fingers" postulated by Tamura et al., [2002] . The volcanic terrain may reflect the pattern of melt generation in the mantle wedge more clearly than in other back-arc basins due to the ultra-slow opening rates which minimize plate-driven mantle upwelling and melting components. Figure from Wysoczanski et al., [2010].

Figure 3. Below) Seismic tomography results in the Lau Basin showing large abrupt changes in crustal properties forming distinct domains of thick andesitic crust (Domain II) and thinner basaltic crust (Domain III) with arc separation. A) bathymetry and experiment layout. B) seismic velocity structure. C) silica content of lavas. Havre Trough may reflect similar crustal domains but oriented across-basin due to more pronounced expression of inherent mantle wedge character as a result of ultra-slow opening rates. Figure from Dunn & Martinez [2011].