Petrological & geochemical insights into subduction initiation- the case of Izu-Bonin-Mariana volcanic arc

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Convergent margins mark sites of plate destruction and are unique to Earth among the terrestrial planets. However, currently we lack clear understanding of why and how they are initiated. Among a number of hypotheses that have been proposed, the so-called "spontaneous subduction initiation" model appears particularly relevant (Stern, 2004; Arculus et al, 2015) to the initiation of one of the largest, nominally intra-oceanic subduction zones in the W. Pacific-the Izu-Bonin-Mariana (IBM) system. Spontaneous subduction initiation occurs when a change in plate motion allows the gravitationally unstable lithosphere to founder along an existing plate boundary. The IBM system (Fig. 1A) represents an example of arc initiation wherein subsidence of relatively old Pacific lithosphere began along a system of transform faults/fracture zones adjacent to relatively buoyant lithosphere. The initial record on the overriding plate during the spontaneous subduction commences with rifting, spreading, and formation of magmas such as highly depleted, low-K tholeiites and boninites (Hickey-Vargas et al., 2007; Ishizuka et al., 2011; Arculus et al., 2015; Brandl et al., 2017).

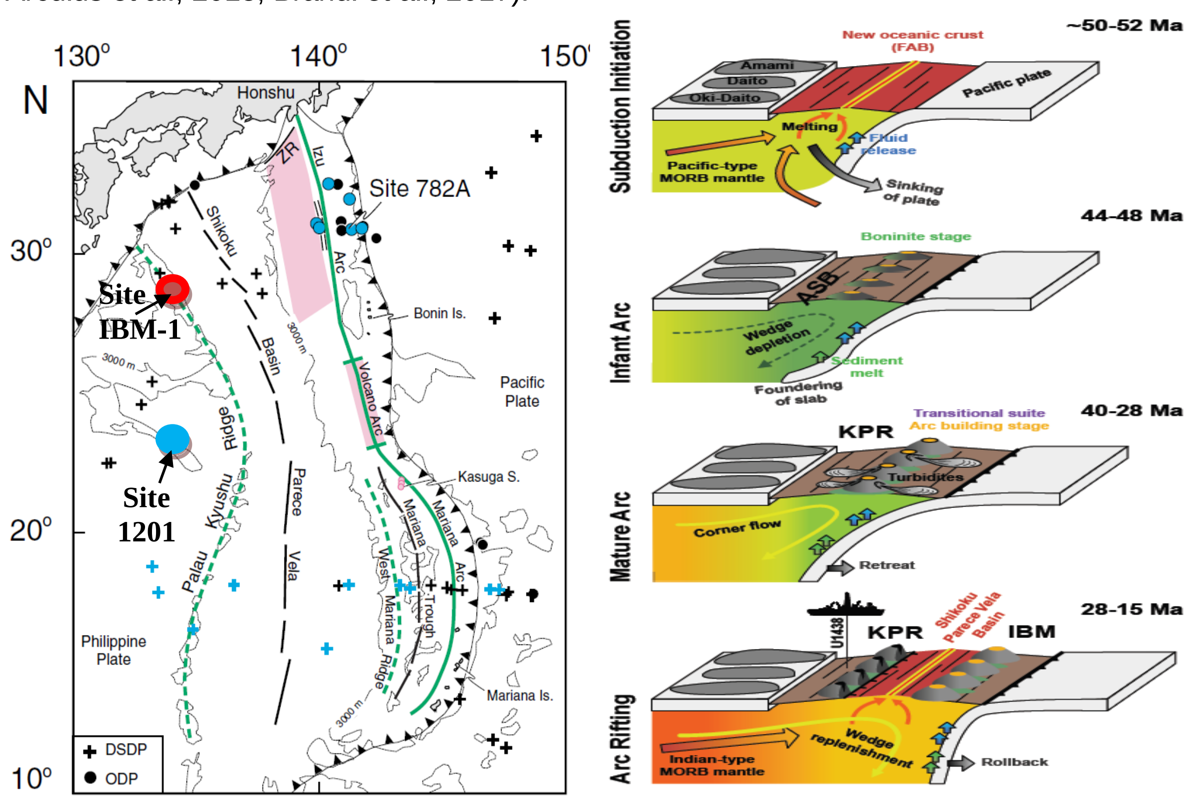

*Figure 1A (left): Regional geology of the IBM arc-basin system south of Japan. Currently active volcanic arc front (thick green solid line), back arc basin rifts (thick black solid lines) and remnant (early) arcs (thick green stippled lines) are shown. Filled circles are ODP drill sites, and crosses are DSDP drill sites. The sites from which fallout tephra is recovered are highlighted in blue. Also shown is the location of the IBM-1 cite (red circle; this proposal). Figure 1B(right) Cartoon showing the possible creation and evolution of the Izu-Bonin-Marianas (IBM) arc-basin crust since subduction initiation (52-50 Ma) through stages of arc infantry (48 to 44 Ma), maturation (44 to 28 Ma) and finally arc death (28- 15 Ma). Such insights can only be possible after core recovery from the recent IODP expeditions 351 (see Brandl et al., 2017). **The IBM arc- basin system is a spring of truly fascinating insights into the temporal evolution of the subarc mantle feeding arc volcanism!***

Following subduction initiation, further igneous development is fundamental to the creation of arc volcanic chains, which in turn is essential to the formation and evolution of continental crust. Testing models of subduction initiation and subsequent arc evolution requires identification and exploration of regions adjacent to an arc, where pre-arc crust (basement) is directly overlain by undisturbed arc-derived materials. The IBM system is globally important because we have clear evidence for the age (~52 Ma; Ishizuka et al., 2011, Arculus et al., 2015; Brandl et al., 2017) and exact site of inception, (Kyushu-Palau Ridge; Fig 1A), the duration of arc activity, and changes in magmatic composition and volumes through time through extensive drilling (ash & pyroclast records) and dredging (Fig. 1A).

Dr. I.Savov sailed as shipboard scientist on IODP Exp. 351, which successfully drilled site IBM-1 at the Amami Sankaku Basin (ASB), just south of Japan and west of the KPR proto-arc (Fig. 1A). The site penetrated the pre-arc IBM basement (Early Eocene) and the overlying 1400m of volcaniclastic sediments. Studying the volcano-sedimentary cover is crucial to decipher the geochemical and petrological evolution of the post-arc inception volcanism in the entire IBM region. The primary target of this PhD studentship is to sample and subsequently study the arc- derived volcaniclastic sediments directly overlaying the basement at site IBM-1. In analogy to the previously drilled site 1201 (where Dr. Savov also sailed as shipboard scientist; see Savov et al., 2006; Hickey-Vargas et al., 2007), these sediments should preserve the explosive ash and pyroclastic fragmental records for at least the first 25 M.yrs. of the developing nearby volcanic arc (KPR). To date, the geochemical data available for such materials recovered from the fore-arc regions of the IBM system (site 782, see also Fig. 1A) are concentrated in the Neogene (e.g., Straub, 2003, 2004) and only limited Paleogene record of volcaniclastics and ash material that is well-dated AND appropriate for geochemical study is available from any of the existing DSDP/ODP Sites (incl. 291, 292, 294, 446-447 & 1201; Savov et al., 2006; Hickey-Vargas et al., 2007; Ishizuka et al., 2011; Brandl et al., 2017; see Fig. 1A&B). Increasing the resolution of the IBM post-arc inception records will allow geochemical modelling aiding the quantification of the volumes of sediment, slab crust and/or mantle involved in the developing of the early stages of arc magmatism.

In detail, the PhD student will construct geochemical profiles across the entire Cenozoic, with emphasis on the Paleogene volcaniclastics. The student will analyse the volcanic ash and the most unaltered volcaniclasts for Sr, Nd, Pb and B isotopes in the TIMS Lab at the Univ. Leeds. These isotope systems, in addition to major and trace element variations, have been shown to be a powerful tool for resolving provenance (Pb, Sr), as well as uniquely trace the sedimentary and/or crustal (slab) and mantle contributions (Sr, B and Nd) to arcs (Straub, 2004; Savov et al., 2006; Hickey-Vargas et al.,2007). Using a combination of elemental and isotope tracers will allow the PhD student to uniquely quantify the volumes of fluids/melts involved in the sources of the earliest volcanic eruptions that took place at the IBM.This task is critical for the subduction initiation modelling and also for better understanding of the causes of the modern along-IBM major element and isotope variations (Stern, 2004; Ishizuka et al., 2011). After examination under polarized microscope and with the help of the state-of-the-art SEM and EPMA Facility at Univ. Leeds, the student will be able to identify up to 20 unaltered volcaniclasts and ash samples. These, in addition to the ages derived from the nanofossil and paleomagnetic record (shipboard data), will allow the student to constrain very precisely the temporal evolution of volcanism at Site IBM-1. Once this is known, the student will connect the anticipated results with the existing (mostly Neogene) ash and volcaniclasts datasets from other parts of the IBM (see Fig 1B; Bryant et al., 1999; Straub et al., 2004) and other W. Pacific sites (Savov et al., 2006; Hickey-Vargas et al., 2007;Ishizuka et al., 2011). Together, the combined age and isotope results are expected to be a major step toward the more complete understanding of the temporal chemical and petrological evolution of the arc volcanism after subduction initiation, which is an issue remaining largely unknown.

Desirable (but not required) background:

Students with experience in the fields of geochemistry, volcanology and petrology are encouraged to apply.

Potential for high impact outcome

A recently published *Nature Geoscience* paper involving Dr.Savov (see Arculus et al., 2015) reported only the limited shipboard major and minor element geochemical data from Exp. 351. Building an insights from 3 additional radiogenic (Sr-Nd and Pb) and one novel stable isotope system (boron) and their power to uniquely decipher high temperature processes such as magma sources and volumes, is an excellent sign that the contributions from this studentship will be able to deliver publications in high impact journals . The processes of subduction zone initiation are identified as Challenge 11 of the Science Plan of IODP (www.iodp.org/ science-plan-for-2013-2023). As IODP is an international scientific effort and major investment (multi-million £) and since IBM has been repeatedly selected as a major target to understand subduction processes, the proposed studentship will surely be on the spotlight for new and unique insights. Furthermore, this student project is highly relevant and excellent fit to the ongoing NERC-funded Deep (Mantle) Volatiles Consortia (http://www.deepvolatiles.org), where Savov is a Co-PI and actively involved in the science and training of postdocs +PhD students.

Training and Support:

The student will join two active research groups of the Institute of Geophysics & Tectonics (IGT): the High Temperature Geochemistry Research Group and the Volcano Studies Group (more info on group members and current projects can be found here: http://www.see.leeds.ac.uk/research/igt/high-temperature-geochemistry/ and also here: http://www.see.leeds.ac.uk/research/igt/high-temperature-geochemistry/). Training of in-situ mineral chemistry via EPMA/LA-ICP-MS techniques, as well as isotope ratio determination via TIMS and MC-ICP-MS instruments will be provided in- house or in the labs of our long term research partners at CNR-(Pisa, Italy) and the FIU/Univ. South Carolina (USA).

Selected Relevant Publications:

Arculus et al., 2015; A record of spontaneous subduction initiation in the Izu–Bonin–Mariana arc, *Nature Geoscience 8 (9), 728-733.*

Brandl et al., 2017. The arc arises: The links between volcanic output, arc evolution and melt composition, *Earth Planet Sci. Lett*. 461, 73-84.

Bryant et al., 1999. Laser ablation–inductively coupled plasma–mass spectrometry and tephras: a new approach to understanding arc-magma genesis. *Geology* 27(12):1119–1122.

Hickey-Vargas et al., 2007. Origin of diverse geochemical signatures in igneous rocks from the West Philippine Basin, *AGU Geophysical Monograph Series,* 166*,* 287-303.

Ishizuka et al., 2011. Making and breaking an island arc: a new perspective from the Oligocene Kyushu-Palau arc, Philippine Sea. *G-cubed,* 12(5):Q05005.

Savov et al., 2006. Petrology and geochemistry of West Philippine Basin basalts and early Palau-Kyushu arc volcanic clasts from ODP Leg 195, Site 1201D: Implications for the early history of the Izu- Bonin- Mariana arc, *J. Petrology*, 47(2): 277-299.

Straub et al., 2004. Volcanic glasses at the Izu arc volcanic front: new perspectives on fluid and sediment melt recycling in subduction zones. *G-cubed* 5(1):Q01007.