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GEOW INSTITUT FÜR GEOWISSENSCHAFTEN

HCE HEIDELBERG CENTER FOR THE ENVIRONMENT

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386 buoyancy and ascent velocity are significantly underestimated. The density of CO_2 rich submarine basaltic melt is 9 % higher than the equivalent values of the quenched rock with a typical porosity of 20 %. The densities of subaerial phonolite and subglacial rhyolite with a porosity of 30 % are 23 % and 30 % smaller than the densities of the corresponding magmas, respectively.

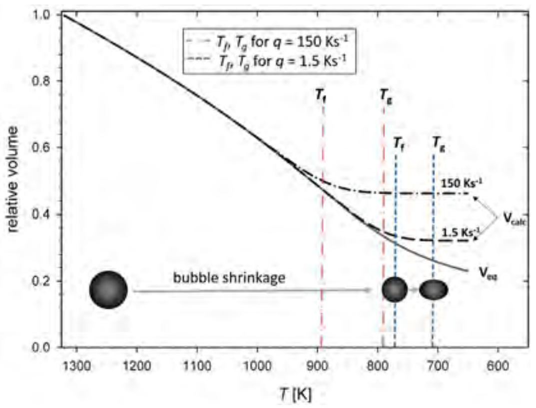

Fig. 1. Relative volume of a H_2O bubble in hydrous phonolitic melt (3 wt% H_2O) during isobaric cooling (P_q = 100 MPa; q = 150 and 1.5 K· s^{-1}) from a T_{melt} of 1323 K to T_q.

References:
Dingwell DB, Webb S (1990) Eur J Mineral 2: 427-449
Duan and Zhang (2006) GCA 70: 2311-2324
Giordano D, Russel JK, Dingwell DB (2008) EPSL 271: 123-134
Marxer H, Bellucci P, Nowak M (2015) J Volc Geotherm Res 297: 109-124
Nye JF (1953) Proc. R. Soc. London, A, Math. Phys. Sci. 219, 477-489

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Origin and evolution of magmas in the course of subduction initiation, Izu-Bonin Mariana arc – new research project from the Leibniz University of Hannover

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The process of subduction is considered as one of the major manifestations of a dynamic Earth. However, little is known about how subduction starts and proceeds. The so-called supra-subduction zones ophiolites are interpreted to be associated with subduction initiation and are potential rocks suited to understand geological processes occurring at the initiation of a subduction. Another unique example and key locality to study ongoing subduction initiation and arc evolution is the Izu-Bonin-Mariana (IBM) forearc system which demonstrates a similar lava chemostratigraphy as found in many ophiolites. According to one of the first conceptual model of Stern and Bloomer (1992), in the course of subduction initiation, the old and relatively dense oceanic lithosphere begins to sink into the asthenosphere. Lithosphere in the upper plate adjacent to the sinking lithosphere rapidly extends into the gap left as the dense lithosphere sinks. In this setting, mantle flows into the nascent mantle wedge and interacts with a small and variable contribution of fluids from the sinking plate. Melting induced by the fluid augments that resulting from decompression, leading to a higher degree of melting than at mid-ocean ridges. These MORB-like lavas with arc-signatures originating in this setting have been recently termed as *forearc basalts* (*FABs*, Reagan et al. 2010). Combination of rapid decompression melting with fluid enhanced lowering of the solidus leads to more extensive melting of the shallow asthenospheric wedge, creating refractory Mg-rich and Si-rich lavas such as *boninites* and high-Mg andesites and leaving an extremly refractory harzburgitic residue (Shervais, 2001). Thus, in the Stern-Bloomer model, the presence of boninites at the top of a FAB lava sequence is a major indicator of a subduction-initiation setting (Pearce, 2014). *The knowledge on the main changes in magma origin and magma evolution conditions at the transition from FAB to boninite is crucial to understand the general process of subduction initiation, the role of mantle reorganization and specifics of mantle melting regimes.*

In August-September 2014, IODP Expedition 352 (Expedition 352 Scientists, 2015) successfully cored 1.22 km of igneous basement and 0.46 km of overlying sediment, providing stratigraphically controlled suites of FABs and boninites. FABs were recovered at the two deeper water sites U1440 and U1441 and boninites at the two sites U1439 and U1442 drilled upslope to the west. The expected sequence of FABs presented at the base of the Bonin fore-arc volcanic succession followed by boninite-series lavas was not encountered at any of the drill sites. The presence of dikes at the base of the sections at Sites U1439 and U1440 provides new evidence that these lavas are underlained by their own conduit systems and that FAB and boninite group lavas are likely offset more horizontally than vertically. Preliminary on-board geochemical data (Expedition 352 Scientists, 2015) demonstrate that cored basalts from sites U1440 and U1441 are compositionally similar to FABs from Bonin and Mariana forearcs documented during diving expeditions (Reagan et al., 2010). FABs are typically aphyric to sparsely phyric, Plag-pyroxene-phyric basalts and dolerites. The differentiation trends (from basalt to andesite) indicate that all analyzed samples could derive from a similar parent magma composition. The small variations in CaO (and CaO/Al_2O_3) indicate differences in degrees of differentiation and/or pressures of partial crystallization. Overall, the compositions of FAB lavas erupted at Sites U1440 and U1441 are relatively evolved, with most MgO concentrations within the range 5–8 wt%. These lavas could have been fed from magma chambers that persisted throughout the eruptive history of FABs. Boninitic lavas from holes U1439C and U1442A are Ol- and Opx-phyric rocks with a groundmass of pale glass and acicular pyroxene. In contrast to FABs, lavas in both of the boninite sites have compositions that become more primitive (MgO-rich, Si-rich and Ti-poor) upward the holes. The extreme depletion of the mantle sources and/or high degrees of melting for boninitic lavas is reflected in the low TiO_2 concentrations (<0.3 wt%). The changes in composition support a model in which probably a system of persistent magma chambers was present early during genesis of boninite group lavas.

Our new research project (started in 2016) is aimed at understanding the evolution of petrological and geochemical characteristics of magmatic rocks at the initiation of a subduction process and during early arc development. The working plan of the project includes:

- Systematic petrological and geochemical investigations including microprobe analysis of matrix glasses, glass inclusions and mineral compositions for all representative FAB and boninite magma types. The mineral and glass compositions will be used to apply geothermobarometers to constrain magma storage conditions.
- Determination of crystallization conditions using available thermodynamic models for FABs and high pressure experimental studies of boninites. The experimental work of boninites is necessary considering the lack of high-pressure volatile-bearing experiments in high Si and high Mg systems. Experiments will be conducted up to 700 MPa and may also be useful to interpret the formation of boninitic melts from a harzburgitic source.
- Geochemical analyses of chalcophile and redox-sensitive elements/ratios in glasses. The results will be used to understand the effects of fO_2, partial melting and mantle preconditioning (Pearce and Peate, 1995) on the composition and evolution of magmas during the initiation of subduction processes.

References:
Expedition 352 Scientists. (2015) Izu-Bonin-Mariana Fore Arc: Testing subduction initiation and ophiolite models by drilling the outer Izu-Bonin-Mariana fore arc. IODP Prel. Rept. 352.
Pearce, J.A. (2014) Immobile Element Fingerprinting of Ophiolites. ELEMENTS 10, 101-108.
Reagan, M.K., et al. (2010) Fore-arc basalts and subduction initiation in the Izu-Bonin-Mariana system. Geochemistry, Geophysics, Geosystems 11, Q03X12.
Shervais, J.W. (2001) Birth, death, and resurrection: The life cycle of suprasubduction zone ophiolites. Geochem. Geophys. Geosyst. 2.

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Comparison of Heinrich Stadial 1 & 2 by the Analysis of sedimentary $^{231}Pa/^{230}Th$ from the North Atlantic

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The Atlantic meridional overturning circulation (AMOC) plays a key role in the distribution of heat, moisture and carbon and affects the gobal climate system [Rahmstorf 2002]. Freshwater-Events of the past, in particular Heinrich-Event I and II [Heinrich 1988; Hemming 2004], are believed to cause a significant reduction of AMOC strength, or in an extrem case, even a total cessation of thermohaline circulation and thus crucial changes in heat and carbon transport to northern Hemisphere. Heinrich-Events are characterised by iceberg discharge of continental ice sheets and their abrupt melting in the open North Atlantic, followed by the supression of deep water formation in the North due to salinity decrease of northern surface water.

This study adresses the reconstruction of the AMOC around Heinrich Stadial I and II (ca. 17 resp. 24 ka BP) in comparison with the Holocene (Hol) and Last Glacial Maximum (LGM) applying the $^{231}Pa/^{230}Th$ ratio as a kinematic proxy measured from deep sea sediments. ^{231}Pa and ^{230}Th are produced in the ocean through radioactive decay of their temporally and spatially uniform distributed parent isotopes ^{235}U and ^{234}U at a constant rate (activity ratio = 0.093). Due to the shorter residence time of ^{230}Th compared to ^{231}Pa, the $^{231}Pa/^{230}Th$ ratio indicates the strength of AMOC in the past [Yu et al. 1996] [Gherardi et al. 2009; McManus et al. 2004; Lippold et al. 2012; Böhm et al. 2014; Bradtmiller et al. 2014]. Here we present new $^{231}Pa/^{230}Th$ measurements combined with published data for the above mentioned time ranges (Hol, LGM, HS1, HS2).

A basin wide feature is the general decrease of $^{231}Pa/^{230}Th$ with water depth as a result of preferential advective export of ^{231}Pa over ^{230}Th [Lippold 2011] witnessing an actice AMOC mode during the Holocene. However, this trend is inverted during Heinrich Stadial 1 and can be interpreted as a substantially weakened overturning of North Atlantic Deep Water (NADW) during HS1 along with a Antarctic Bottom Water seizing much more volume of the Atlantic Ocean than during the Holocene. Comparing the $^{231}Pa/^{230}$ Th from the same sediment core locations between HS1 and HS2 yields mostly higher values for HS1 than for HS2. This finding suggests that there was a measurable reduction of the AMOC strength during HS2 compared to the Holocene, but not as dramatic as during HS1.

References:
Böhm, E., J. Lippold, M. Gutjahr, M. Frank, P. Blaser, B. Antz, J. Fohlmeister, N. Frank, M. B. Andersen & M. Deininger, 2014. Strong and deep Atlantic meridional overturning circulation during the last glacial cycle. Nature 517, 73–76.
Bradtmiller, L. I., McManus, J. F., & Robinson, L. F., 2014. 231Pa/230Th evidence for a weakened but persistent Atlantic meridional overturning circulation during Heinrich Stadial 1. Nature communications, 5.
Gherardi, J.-M., L. Labeyrie, S. Nave, R. Francois, J. F. McManus, *and* E. Cortijo, 2009. Glacial-interglacial circulation changes inferred from 231Pa/230Th sedimentary record in the North Atlantic region, Paleoceanography, 24, PA2204.
Heinrich, H., 1988. Origin and Consequences of Cyclic Ice Rafting in the Northeast Atlantic Ocean during the Past 130,000 Years. Quaternary Research, 29, 142-152.
Hemming, S. R., 2004. Heinrich events: Massive late Pleistocene detritus layers of the North Atlantic and their global climate imprint, Rev. Geophys., 42, RG1005.
Lippold, J., Gherardi, J. M., & Luo, Y., 2011. Testing the 231Pa/230Th paleocirculation proxy: A data versus 2D model comparison. Geophysical Research Letters, 38(20).
Lippold, J., Y. Luo, R. Francois, S. Allen, J. Gherardi, S. Pichat, B. Hickey and H. Schulz, 2012. Strength and Geometry of the glacial Atlantic Meridional Overturning Circulation. Nature Geoscience, 10.1038/NGEO1608.
McManus, J. F., Francois, R., Gherardi, J. M., Keigwin, L. D., & Brown-Leger, S., 2004. Collapse and rapid resumption of Atlantic meridional circulation linked to deglacial climate changes. Nature, 428(6985), 834-837.
Rahmstorf, S., 2002. Ocean circulation and climate during the past 120,000 years. Nature 419, 207-214.