IODP Proposal Cover Sheet

976 - Full

North Iceland Rift Propagation

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Title	Rift propagation north of Iceland: A case of asymmetric plume dynamics?
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Area	Jan Mayen Ridge and Iceland Plateau

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Abstract

The crust below the Iceland Plateau north of Iceland is the least understood within the North Atlantic, yet potentially holds clues to constrain fundamental aspects of plume dynamics and associated crustal formation. The Iceland Plume and North Atlantic spreading ridges have interacted since continental breakup (~55 Ma). Spreading along the Reykjanes Ridge south of Iceland has been continuous, and geochemically enriched mantle from breakup to the present has been feeding into the northern part of the Reykjanes Ridge. By contrast, the model for the formation of the Iceland Plateau that this proposal will test is one of northward rift propagation into the East Greenland continental margin since ~50 Ma that overlapped with a northward retreat of spreading along the Aegir Ridge east of the plateau, until eventually rift propagation was replaced by formation of the Kolbeinsey Ridge within the western-most plateau (~23 Ma), and spreading along the Aegir Ridge ceased. Assuming an axis-symmetric plume structure, this ostensible link between the plume and rift-propagation suggests that a comparable plume enrichment within the crust of the Iceland Plateau is present. However, indications are that neither at present, nor in the past, is such symmetry to be found. Instead, a distinct shift from enriched compositions in the south to depleted compositions north of Iceland exists today. A transect of seven holes will test our tectonic model of rift propagation, and will at the same time map the temporal evolution of the mantle from which the Iceland Plateau formed in order to test if, and for how long this asymmetry extends back in time. This evolution, combined with existing geophysical constraints on crustal thickness, modeling of the lithological composition of plume mantle and its potential temperature (Tp) will support geodynamic modelling of plume nature and its deep origin. One important objective is to examine the hypothesis that mantle plumes may be rooted in Large Low Shear Velocity Provinces (LLSVPs) at the core-mantle boundary, and that distinct geochemical reservoirs in these provinces and adjacent mantle can be preserved through vertical, laminar flow during plume ascent, and result in a strong compositional zonation within the lithosphere. Or alternatively, if melting processes acting on well-mixed mantle can disentangle different mantle components and generate a similar zonation. Secondary objectives are the transition into the ice-house world during the Oligocene and variability in sea-surface temperature and ice-cover during the Plio-Pleistocene, studies that the Icelandic Plateau is well positioned for.

Scientific Objectives

Primary objectives:

- Test the model that explains the formation of the Iceland Plateau by northward propagation of rifting from the Iceland Plume into the East Greenland continental margin and operating in parallel with a northward retreating Aegir Ridge as a coupled pair of propagating and retreating rifts until the eventual formation of the Kolbeinsey Ridge and associated complete cessation of spreading along the Aegir Ridge.

- Based on these new constraints on the development of the Icelandic Plateau, investigate the nature and compositional changes of the mantle source, mantle potential temperature, and possible continental lithosphere contaminants during the time of rift propagation and into the early history of the Kolbeinsey Ridge.

- Use our new and refined understanding of the tectono-magmatic history of the Iceland Plateau to develop geodynamic models of thermochemical plumes originating near the core-mantle boundary, and likewise address the consequences of melting processes and mantle flow at shallower depths for the observed crustal formation and isotopic zonation within the North Atlantic spreading ridges interacting with the Iceland Plume.

Secondary objectives:

- Sampling of the sub-Arctic Oligocene record of the transition into the ice-house world within an important conduit for Atlantic-Arctic oceanic exchange.

- Plio-Pleistocene evolution in sea-surface temperature and ice-cover in a region prone to record these, and a locus of deep-water formation representing the Northern edge of the Atlantic Meridional Overturning Circulation (AMOC).

Our objectives address themes ‘Earth Connections’, Challenges 8, 9, and ‘Climate and Ocean Change,’ Challenge 2.

Non-standard measurements technology needed to achieve the proposed scientific objectives

Proposal History

Submission Type: Resubmission from previously submitted proposal

Review Response

We thank the SEP reviewers for flagging a number of points that could be improved in a revised proposal. We here respond one by one to each of the points raised, some of which we received additional comments on from SEP reviewers during the revision.

Multiple hypothesis and key questions: We have defined three main objectives, and the drilling and modeling strategy for each of these are laid out. These specific objectives and the broader scope of work are now within the ‘Project ackground and motivation’ chapter. In addition to objectives, to be understood as what we more concretely can achieve by drilling, questions, models and hypotheses are mentioned as appropriate in the main text to illustrate the ‘grand themes’ of global importance that our proposed drilling will contribute to address (see also below, ‘Better links to other expeditions’).

Clarity, including sketches illustrating scientific questions, tectonic evolution and models to be tested: In consultation with SEP reviewers, two new figures (2, 9) have been added, and one figure and one table removed. Centered around new fig. 9, a new section explains how the observations from drill cores directly will help test different hypotheses. Tectonic history is presented in figure 2 and frequent references in the text are made to this figure for improved clarity. Consistent coloring of drill sites has been implemented. In some figures we only show primary sites in order to simplify maps.

Better links to other expeditions: There now is a new section explaining linkages in more detail than before. Comments on an earlier draft of the proposal were received from PI’s of south- and north Atlantic Expeditions 391, 395 and 396. There is agreement that drilling plans for any of these three experiments should not change. Collaboration post-cruise for all four projects would be desirable (e.g., liaison activity between post cruise meetings, joint conferences). Collectively, the four projects will represent a major, concerted effort by IODP to address competing hypotheses regarding fundamental questions regarding nature and origin of mantle plumes, and the interplay between mantle plumes and seafloor spreading.

Paleoceanographic objectives: The section has been expanded with more details as requested.

Drilling strategy: We followed suggestions to include sampling of IP-I stage (Site IPI-01A) setting the stage for all later crustal evolution. We also moved site SRCT-01A from alternate to primary status (now SRCT-01B, slightly relocated from 01A) to sample a tectonic unconformity critical for testing our tectonic model. Operations time provided by the JRSO allowed us to move previously alternate site (IPI-01A) into a primary site. Time for including Site SRCT-01B as primary site was at the cost of sampling stage IP-III in only one location (previously two sites at different offset from Iceland plume). In short, we now focus on the temporal evolution of rifting/mantle composition which is key to our model testing. Some primary sites been relocated to be at, or very close, to crossing seismic lines as suggested by SEP.

Proposed Sites (Total proposed sites: 12; pri: 7; alt: 5; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
IPI-01A (Primary)	67.055214 -8.307984	1295	426	100	526	Target the southeastern IPR-I igneous margin of extensive and progressively younger lava plateaus covering the SDRs and plateau basalt equivalent. Sample igneous section for geochronological, geochemical, and volcanological studies. Reoccupation of Site 350 of DSDP Leg 38, that drilled 3 cores into basement by loosing 1 core and 43% recovery for the remaining 2 cores.
IPII-01B (Primary)	67.61727028 -8.75158581	1583	837	100	937	The IPR-II axial rift target is the objective that intersected IPR-I to SDRs and plateau basalt equivalent sections. Primary sampling for the igneous section for geochronological, geochemical, and volcanological studies. Secondary sampling for sediments for paleo-environment and subsidance history.
IPIII-03A (Primary)	67.57133108 -10.68247975	1777	485	100	585	This site targets the rift valley flood basalts of IRP-III phase at the northern extent of the Jan Mayen Trough volcanic zone. Primary objectives are the sampling for geochemical and geochronological studies and volcanological interpretations. The sediment cover would tie into the the paleo-environment and subsidance history for the northernmot end of the Jan Mayen Trough.
IPIV-01A (Primary)	67.586210 -12.253577	1766	339	100	439	Target flood basalts of rifting stage IPR-IV that overlays the TPU unconformity and IPR-III flood basalts of the Jan Mayen Trough to the east of the proposed site. Sampling is aimed for geochemical and geochronological studies and volcanological interpretations to compare these to the Kolbeinsey Ridge samples and potential influence of the proximal Iceland plume.
PKR-02A (Primary)	69.27684435 -10.6849484	1708	829	100	929	Targeting the imidiate transition from IPR-IV rifting stage into spreading along the Proto-Kolbeinsey Ridge along the outer western magmatic margin of the Jan Mayne Basin. Sampling the igneous section for difference in plume influence vs. mid-oceanic ridge basalts by detailed geochemical, age and petrographic analysis.
KR-01B (Primary)	69.212519 -12.762229	1834	245	100	345	Kolbeinsey Ridge controle site. Sampling the igneous section for mid-oceanic ridge basalts by detailed geochemical, age and petrographic analysis.
SRCT-01B (Primary)	68.15934198 -8.52727024	1289	605	0	605	Target the unconformity between deformed and non-deformed sediments within SRC syncline. Testing termination of transpressive faulting within the SRC of the JMMC and the complete rift propagation to the Kolbeinsey Ridge by detailed sediment biostratigraphic dating and paleo-environment analysis.
SRCT-01C (Alternate)	68.17090255 -8.59329336	1170	792	0	792	Target the unconformity between deformed and non-deformed sediments within SRC syncline. Testing termination of transpressive faulting within the SRC of the JMMC and the complete rift propagation to the Kolbeinsey Ridge by detailed sediment biostratigraphic dating and paleo-environment analysis.
IPIII-02A (Alternate)	68.649419 -8.189013	2037	487	100	587	This site targets the rift valley flood basalts of IRP-III phase at the northern extent of the Jan Mayen Trough volcanic zone. Primary objectives are the sampling for geochemical and geochronological studies and volcanological interpretations. The sediment cover would tie into the the paleo-environment and subsidance history for the northernmot end of the Jan Mayen Trough.
IPIII-01A (Alternate)	67.798970 -9.848865	1766	719	100	819	This site targets the rift valley flood basalts of IRP-III phase within a clear separation area between the last two visible SRC blocks of the JMMC within the Jan Mayen Trough volcanic zone. The igneous section is the primary target for geochronological, geochemical, and volcanological studies. The fairly undisturbed sediment cover would shed light on the paleo-environment and subsidance history.
IPIV-02A (Alternate)	69.464838 -9.858744	2170	394	100	494	Target flood basalts of rifting stage IPR-IV that overlays the TPU unconformity and IPR-III flood basalts of the Jan Mayen Trough to the east of the proposed site. Sampling is aimed for geochemical and geochronological studies and volcanological interpretations to compare these to the Kolbeinsey Ridge samples and potential influence of the distal Iceland plume. The paleo-environmental and subsidance history study would require sediment sampling and bistratigraphic analysis.

Proposed Sites (Continued; total proposed sites: 12; pri: 7; alt: 5; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
PKR-01B (Alternate)	69.684462 -10.410205	1899	532	100	632	Target the immediate transition from IPR-IV rifting stage into spreading along the Kolbeinsey Ridge along the outer western magmatic margin of the Jan Mayne Basin. Sampling the igneous section for difference in plume influence vs. mip-oceanic ridge basalts by detailed geochemical, age and petrographic analysis.