2018 ASPIRE WHITE PAPER;

TARGET NAME, GEOGRAPHIC AREA: ***The SPAR offset at 69°N, Kolbeinsey Ridge, North Central Atlantic.*** SUBJECT AREA: ***Bathymetry, geology, geochemistry, rift-relocation, transform evolution, hydrothermal venting and biology.***

Contact information: Primary contact: Bryndís Brandsdóttir, bryndis@hi.is, Institute of Earth Sciences, Science Institute, University of Iceland, tel: +354-5254774
Other contacts: Neil Mitchell, Neil.Mitchell@manchester.ac.uk, Univ. Manchester, UK;
Carmen Gaina, carmen.gaina@geo.uio.no, University of Oslo, Norway;
Christoph Beier, christoph.beier@fau.de, GeoZentrum Nordbayern Erlangen, Germany;
Emilie Hooft emilie@uoregon.edu, University of Oregon, USA;
Jeffrey A. Karson jakarson@syr.edu, Syracuse University, USA;
Isobel Yeo, i.yeo@noc.ac.uk, National Oceanographic Centre, Southampton, UK;
Katrin Linse, kl@bas.ac.uk, British Antarctic Survey, Cambridge, UK;
Sæmundur A. Halldórsson, saemiah@hi.is, Inst. Earth Sciences, SI, Univ. Iceland.
WILLING TO ATTEND WORKSHOP, YES

Brief Overview of Area

The central Kolbeinsey Ridge (KR), north of Iceland, is the least explored region of the Northern Mid-Atlantic Ridge (MAR). The KR is of multidisciplinary importance, with fundamental seafloor spreading structures that deflect strong currents supplying nutrients to the biosphere. The central KR represents hot spot-influenced spreading that contrasts with the Reykjanes Ridge (RR) south of Iceland. The region also includes the SPAR offset or overlapping spreading center (OSC) at 69°N (Figure 1). The KR is of high importance to the blue economy, it is the feeding ground of newly hatched capelin (*Mallotus villosus*), currently the most important migrating fish stock in the N-Atlantic, and a key food of cod and other species. The region is closely monitored by the Meteorological Offices and Coast Guards of Iceland, Denmark and Norway (http://www.seaice.dk/) and is free of sea ice, except in late winter and early spring.

Brief Summary of Current State of Knowledge

Spreading along the KR was initiated at ~26 Ma following a westward ridge jump from the extinct Ægir Ridge [Brandsdóttir et al., *G3,* 2015 and references therein; Gaina et al., *Geol. Soc. London, Spec. Publ.,* 2017; Figures 1 and 2]. The slow-spreading (1.5-1.8 cm/yr) KR has since evolved through repeated axial reorganizations, the last at anomaly 3A time (~5.5 m.y.) when a sinuous ridge axis split into four segments with non-transform offsets (NTOs) and spreading segments more orthogonal to the spreading direction [Appelgate et al., *Geology,* 1997].

The influence of the Iceland hot spot on the adjacent ridges, has been recognized geophysically and geochemically since the 1970s. Bathymetry, magnetics and gravity data, suggests plume pulses with a 5 Myr periodicity extending hundreds of kilometers N and S from Iceland. Deeper pulses of the Iceland plume may explain the asymmetric crustal production between KR and RR [Abelson and Agnon, *EPSL*, 2001]. Relative to other Mid-Oceanic Ridges, basalts (MORBs) from the KR are highly depleted in trace elements, with low Na_8, suggesting relatively high degrees of melting, and high Fe_8, suggesting deep initiation of melting [Klein and Langmuir, *JGR,* 1987; Elkins et al., *Chem. Geol.*, 2016 and references therein]. Furthermore, major and trace element studies along the RR and KR support decreasing extent of mixing between plume and normal MORB sources and decreased melting with distance from the plume.

Seismic crustal thickness along Iceland's neovolcanic zones and the adjacent mid-ocean ridges also support a decreasing extent of melt production with distance from the center of the plume [Hooft et al., *G3*, 2006 and references therein; Figure 1]. At similar distances from the Iceland hot spot, crustal thickness along the KR is 2–2.5 km less than on the RR, consistent with the asymmetry in plume-ridge interaction inferred from their axial depth and geochemistry. The crustal structure and thickness along the southernmost 225 km of the KR decreases northwards, from 12-13 km next to Iceland to 9-10 km north of the Iceland shelf. A 140 km cross-axis profile at 68°N revealed significant undulations in Moho depth east of the ridge with a minimum of 6 km, beneath 7.5 Myr crust, 75 km from the ridge axis, increasing to 12 km in 10-12 Myr old crust [Furmall et al., *Eos Trans. AGU*, 2008]. Lower crustal high-velocity domes and corresponding gravity highs mark the location of active and extinct rift segments within Iceland and the southern KR. Volcanic seamounts (Figure 2a,c,d) represent locally enhanced magmatic productivity. Four prominent seamounts are located within the SPAR region, at variable distance from the active ridge axis (Figure 1 center). SPAR focal mechanisms reflect left-lateral movement along an E-W striking faults. Overlapping earthquake distributions suggest an overlapping spreading center, with the KR propagating southwards.

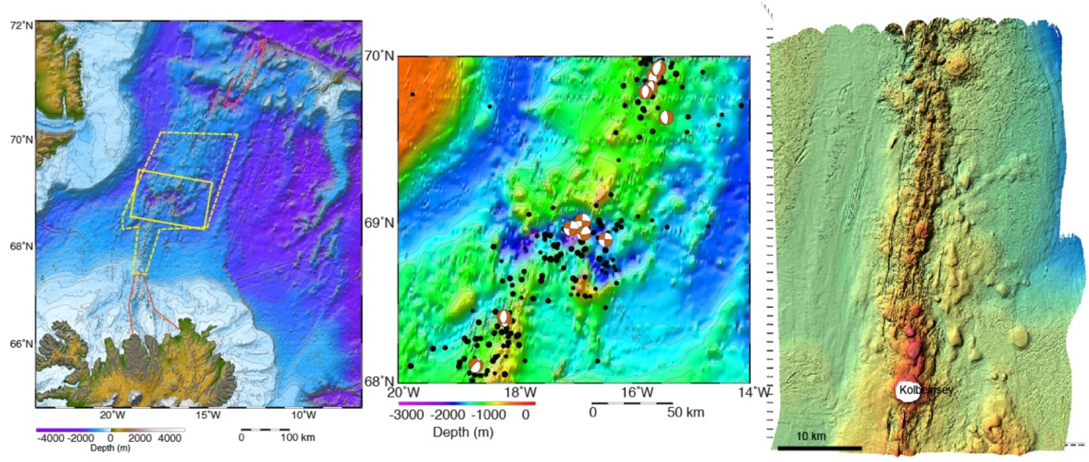

Figure 1, left: KR bathymetry based on ~100 m (30 arcsecond) grid from Smith and Sandwell, [2014]. Yellow dashed line delineates region to be explored, with emphasis on the SPAR offset at 69°N (yellow box). Red outlined regions have been mapped. Center: SPAR NEIC-earthquakes from 1970 (black dots) and CMT focal mechanisms 2005-2018. Right: EM300, 10 m gridded map of southernmost KR with segmented, left-stepping rift zones, along the plate boundary. Seamounts vary in size and distribution along the ridge axes. Sediment drape reflects relative age.

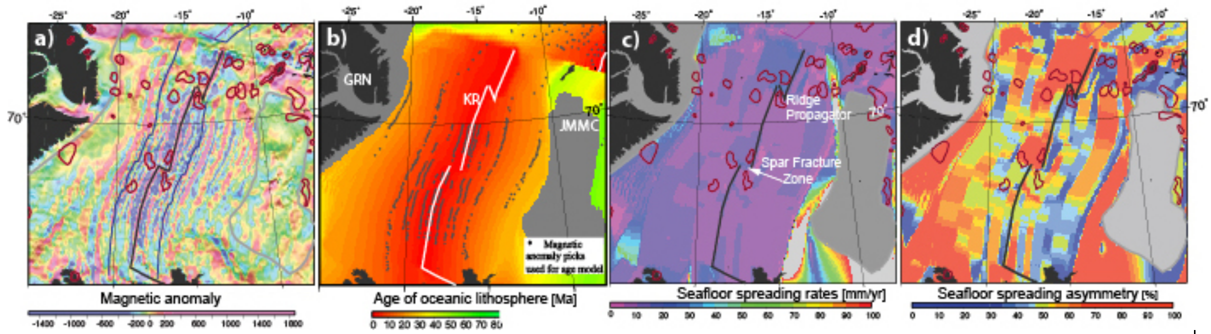

Figure 2. Magnetic anomalies (a), crustal age (b), spreading rates (c,d), and volcanic edifices (red) west of Jan Mayen Microcontinent, JMMC (Gaina et al., *Geol. Soc. London, spec. publ.,* 2017).

Rationale for Future Exploration:

Geology and geophysics: Mapping and sampling the KR and SPAR system will provide a contrasting view of hot spot-influenced spreading. The structure and timing of spreading processes can be contrasted for the KR and RR in the context of plume pulses. Further, as there are no comparable offsets on the RR, the evolution and migration of the SPAR offset can be assessed in the context of propagating rift zones and plume pulsations. Focusing on the young (<7 Myr) KR-SPAR offset at 69°N it will be possible to evaluate it as a migrating NTO, an OSC (rare on slow-spreading ridges) or some previously unknown type of structure. The glacial and post-glacial sedimentation drape along the KR is indicative of relative flow ages (Figure 1, right), using the distribution and backscatter intensity as a proxy for sediment thickness and hence age [Yeo et al., *EPSL*, 2016], will guide the identification and sampling of lava flows along the ridge axis. ***Geochemistry:*** Sampling the relatively steep fault scarps and volcanic edifices along the offset and adjacent KR can potentially provide the opportunity of sampling individual lava flows, in order to model the geological evolution of KR both in space and time. ***Hydrothermal and biological activity:*** Hydrothermal plumes have not been detected north of Kolbeinsey Island. Combined CTD and ROV surveys can search for hydrothermal venting and related biological activity in this poorly known spreading environment.

Relevant partnerships: *The Marine Research Institute of Iceland; The Icelandic Coast Guard.*