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Active spreading processes at ultraslow mid-ocean ridges: The 1999-2001 seismo-volcanic episode at 85°E Gakkel ridge, Arctic Ocean

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The rate of magma and crustal production at mid-ocean ridges is thought to decrease with decreasing spreading rate. At ultraslow spreading rates below 10-20 mm/y full rate, heat loss by conduction greatly reduces melt production with less melt produced at increasingly greater depths.

Gakkel Ridge, the actively spreading mid-ocean ridge in the Arctic Ocean, opens at rates of 14 mm/y in the west decreasing to less than 6 mm/y at its eastern termination and demonstrates that magma production is not only a function of spreading rate. Whereas amagmatic spreading takes place at rates of about 12-10 mm/y, focussed melt production occurs at even lower spreading rates in long-lived discrete volcanic centres. One such centre is the 85°E volcanic complex at eastern Gakkel ridge where in 1999 a teleseismically recorded earthquake swarm consisting of more than 250 earthquakes over 9 months signalled the onset of an active spreading episode. The earthquake swarm is believed to be associated with volcanic activity although no concurrent lava effusion was found.

We analysed the teleseismic earthquake swarm together with visual observation and microseismic data recorded at this site in 2001 and 2007 and noted the following characteristics which may be indicative for volcanic spreading events at the still poorly explored ultraslow spreading ridges:

- unusual duration: The 1999 earthquake swarm lasted over 9 months rather than a few weeks as observed on faster spreading ridges. In addition, in 2001 seismoacoustic sounds which we interpret as gas discharge in Strombolian eruptions and a giant event plume maintained over more than one year indicate waxing and waning volcanic activity since 1999.
- unusual strength: The earthquake swarm was detected at teleseismic distances of more than 1000 km and included 11 events with a magnitude >5. No other confirmed mid-ocean ridge eruption released a comparable seismic moment. Rather than focussing in a narrow area or showing pronounced seismicity migration, the swarm activated the rift valley boundary faults in a large area. Along the entire Gakkel ridge, normal fault earthquakes occur predominantly at volcanic centres pointing to strong tectonomagmatic interplay.
- unusual change in swarm characteristics: Following 2-3 months of predominantly tectonic faulting, the swarm displays increasing non-double couple character events and an abrupt change in event rate preceded by three conspicuous events of high similarity located in the vicinity of potentially active volcanic structures. Brittle faulting may thus trigger later volcanic discharge or it could be in turn triggered by rising melts.
- unusual volcanic discharge: In 2007, Sohn et al. (2008) discovered abundant pyroclastic deposits containing limu o Pele at the 85°E volcanic complex and therefore postulated recent deep submarine explosive volcanism at this site. In order to drive these explosive eruptions at 4 km water depth, high volume fractions of magmatic volatiles must be accumulated locally, for example at the top of a magma chamber under a thick and stable lithospheric roof. Together with the Strombolian eruptions which we inferred from the seismoacoustic explosion signals recorded in 2001, this indicates that an explosive eruption style may be common for volcanic spreading events at ultraslow spreading ridges.

Sohn et al. (2008), Explosive volcanism on the ultraslow-spreading Gakkel Ridge, Arctic Ocean, Nature, 453,doi:10.1038/nature07075.