Geology of the Conrad Rise: Summary of six cruises by R/V *Hakuho-Maru*

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The Conrad Rise is one of the large morphological edifices in the southwestern Indian Ocean. Three large seamounts of Ob, Lena, and Marion Dufresne from west to east, and several small seamounts constitute the rise. Many studies have considered that the rise had originated from one of the Cretaceous hotspots in the Indian Ocean. Borisova et al. (1996) reported the petrology and geochemistry of igneous rocks. However, the origin, tectonic and geologic development, and the present environment of the Conrad Rise are still unclear. In the last decade and a half, we have performed six cruises at and around the Conrad Rise by R/V *Hakuho-Maru* (KH-07-4, KH-09-5, KH-10-7, KH-16-1, KH-19-1, and KH-20-1) and obtained rock and biological samples by dredging and geophysical data. The Conrad Rise is considered to be "oceanic plateau" which was formed by excess volcanism on the seafloor (e.g., Coffin and Eldholm, 2014). However, we hypothesize that the Conrad Rise is not simple "oceanic plateau" but continental crust or continental fragment underlies volcanic rock like the Kerguelen Plateau based on gravity anomaly, tectonic reconstruction, geochemistry of igneous rocks. It is also plausible that metamorphic and granitic rocks represent continental material layer like conglomerate from Elan Bank, Kerguelen Plateau (Ingle et al., 2002). Microfossils, shells, and deep-sea coral have important keys to understand the recent environment around the Conrad Rise. In this presentation, we summarize our new dataset and existing knowledge related to the geology of the Conrad Rise.

Cruise information: We conducted underway geophysics observations, including Multibeam bathymetry, total and vector magnetic fields, and gravity measurement during all cruises by R/V *Hakuho-Maru*. Dredge operations were done during three cruises, KH-10-7, KH-19-1, and KH-20-1. Locations of dredge sites and dredged materials are briefly listed in Table 1.

Table 1. Brief information on dredge site, location, and dredged materials at Conrad Rise by R/V *Hakuho-Maru.*

Cruise	Dredge site	location	Dredged materials
KH-10-7	KH-10-7St02	northeastern flank of Ob seamount	49 kg of igneous rocks, 30 kg of metamorphic and granitic rocks, and 30 kg of sedimentary rocks with shells and deep-sea corals
	KH-10-7St03	northeastern flank of Ob seamount	2 kg of igneous rocks and 18 kg of sedimentary rocks
	KH-10-7St05	northwestern flank of Lena seamount	60 kg of igneous rocks and 7 kg of sedimentary rocks.
KH-19-1	KH-19-1D4	small seamount north of Ob seamount	22 kg of igneous rocks and 12 kg of metamorphic and granitic rocks with deep-sea coral
	KH-19-1D5	northern flank of Ob seamount	18 kg of igneous rocks, 1 kg of metamorphic and granitic rocks, and 20 kg of sedimentary rocks with shells and deep-sea corals
KH-20-1	KH-20-1D1	small seamount west of Ob seamount	200 kg of igneous rocks and 18 kg of volcaniclastic sedimentary rocks and metamorphic/granitic rocks with deep-sea coral

Underway geophysics: Satellite-derived gravity anomalies show positive gravity anomaly without negative anomaly around Ob seamount. Negative gravity anomaly around seamount is a characteristic of a simple oceanic plate flexure due to crustal loading of excess materials like Hawaii islands. Based on underway gravity observations, the crustal thickness at Ob and Lena seamounts is estimated 23 km and 23~30 km, respectively. Our newly obtained total and vector magnetic field data reveal the

existence of a well-ordered magnetic anomaly with an east-west strike between Del Cano Rise and Conrad Rise. It suggests that the fossil spreading axis expected by MacLeod et al. (2017) was actually located between these rises, and the spreading ceased around Chron 33n. Based on our tectonic reconstruction by geomagnetic isochron determination, the Conrad Rise had made one large tectonic edifice with Del Cano Rise and southern Madagascar Plateau during Late Cretaceous.

Igneous rocks: We collected igneous rocks from Ob, Lena, and two small seamounts on the Conrad Rise by dredging during KH-10-7, KH-19-1, and KH-20-1 cruises. They occur as massive lava, porous lava, and volcanic breccia. Massive lava and porous lava contain xenolith or large xenocryst, which might be originated from the lower crust or upper mantle. Major element compositions indicate that most igneous rocks are alkali rocks, and lesser amounts of rocks are sub-alkali rocks. Trace element contents are similar to those from Marion and Crozet Islands and the Kerguelen Plateau. However, they have distinct Sr-Nd-Pb-Hf isotope compositions with samples from Marion and Crozet Islands as well as the Kerguelen Plateau, even in their present proximity (Sato et al., 2019).

Metamorphic and granitic rocks: Garnet-sillimanite gneiss from Ob seamount records high temperature and low pressure metamorphism characterized by spinel–cordierite symplectite (Ishizuka et al., 2011). We obtained monazite CHIME age from 980 to 1080 Ma (KH-10-7St02-203: inclusion in garnet), 677±57 Ma (KH-10-7St02-228: inclusion in garnet), 544±7Ma (KH-10-7St02-228: matrix), 1535±6Ma (KH-10-7St02-S12: matrix) and zircon U-Pb age from 1071 to 848 Ma (KH-10-7St02-203). The granitic rocks are mainly coarse- to medium-grained and pink to white in color. Modal analyses show most rocks to be classified into alkali granite to granite (Kobayashi et al., 2013). U-Pb of zircon in granite (KH-10-7St02-205) 1153±9 Ma as concordia age and 1149±9 Ma as U-Pb age.

Sedimentary rocks Several types of sedimentary rocks were dredged from the Conrad Rise. Hardly consolidated sedimentary rocks from Ob seamount comprise fine-grained arkose-arenite and -wacke and coarse-grained orthoquarzite-arenite. One sample is fine-grained graywacke (Kobayashi et al., 2013). Weakly consolidated mud from Ob seamount contains planktic foraminifera (mostly *Neogloboquadrina pachyderma*) and benthic foraminifera (*Globocassidulina subglobosa*). Volcaniclastic conglomerate from Ob seamount contains benthic foraminifera (*Cibicides refulgens* and *G. subglobosa*).

Molluscs and deep-sea corals Molluscs (*Trophon declinans, Dentalium salpinx, Limopsis marionensis, Acesta* sp*., Halicardia* sp.) recovered from the northern flank of Ob seamount (site KH-19-1D5) are considered to be Recent members because of their preservation. Probable fossil caenogastropods and scallops are also contained in coquina from site KH-19-1D5. Deep-sea corals including octocorals (Isididae gen. et sp. indet.) and scleractinian corals (*Deltocyathus* sp.) are collected from Ob seamount from sites KH-10-7St02 and KH-20-1D1 (Kozaka et al., 2020).

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