

# Variations in morphological and geochemical characteristics in shallow-water Mn-Fe nodules with varying water depths

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In this study, we explore the morphological and geochemical characteristics for 440 manganese nodules collected from two different water depths [ARA12B-St52 (150 m) and ARA12B-St58i (73 m)] on the continental shelf of the East Siberian Sea from the ARA12B expedition in 2021. We also discussed the variations in the characteristics of manganese nodules with varying water depths in the Arctic Sea. The sizes of the nodules are generally greater than 3 cm at both sites. However, there is an obvious difference in the morphology with water depths. For the nodules collected at 150 m, brown-black colored tabular, tube, and ellipsoidal shapes with a rough surface texture are dominant. On the other hand, yellow-brown tabular shapes with a smooth surface texture are common for the nodules collected at 73 m. Furthermore, the slope of trend line between size and weight is significantly different at both sites: particularly, the slopes of nodules at 150 and 73 m are 1.60 and 0.84, respectively. This indicates the difference in the internal structure, porosity, and constituting elements between both nodules. Micro X-ray Fluorescence (m-XRF) results clearly demonstrate that the internal textures and chemical compositions are different with water depths. The nodules at 150 m are composed of a thick Mn-layer and a thin Fe-layer centered on the nucleus, while the nodules at 73 m are alternately grown with thin Mn- and Fe-layers around the nucleus. The average chemical compositions obtained by m-XRF are 40.6% Mn, 5.2% Fe, and 7.9 Mn/Fe ratio at 150 m, and 10.3% Mn, 19.0% Mn, 19.0% Mn, and 0.6 Mn/Fe ratio at 73 m. The chemical compositions of the nodules at 150 m are similar to those of nodules from the Peru Basin in the Pacific Ocean, while the compositions of the nodules at 73 m are similar to those of nodules from the Cook Islands or the Baltic Sea. The observed morphological and geochemical characteristics of the nodules show a clear difference at the two sites, which indicates that the aqueous conditions and formation processes of the nodules in the Arctic Sea vary with the water depths.