Distribution particularities of nodules occurrence in the eastern Clarion–Clipperton Zone (NE Pacific)

Особенности в разпространението на полиметалните конкреции в източната част на полето Кларион–Клипертон (Североизточен Тихи океан)

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Резюме. Изследвани са закономерности в разпределението и вариациите на полиметалните конкреции в източната част на конкреционното поле Кларион–Клипертон (СИ Тихи океан). Плътността на залягане на полиметалните конкреции (на базата на 209 станции) е от 0 до 22.6 kg/m^2, като най-продуктивна е дълбочината на дъното в интервала 4300–4500 m. За първи път са открити погребани конкреции в дънните утайки като на 15 станции тяхната плътност е по-висока от повърхностните. Сложните морфологичните особенности на морското дъно предопределят характера на конкрециеносните залежи в изследвания район.

Key words: polymetallic nodules, Clarion–Clipperton Zone, Interoceanmetal.

Introduction

The richest nodule deposits and, consequently, most exploration claims registered with the International Seabed Authority (ISA) are located in the Clarion–Clipperton Fracture Zone (CCZ) nodule field of the northeastern tropical Pacific. The current resource estimates showed that the CCZ manganese nodule deposits constitute a world-class nickel resource, with significant quantities of manganese, copper, and cobalt (Von Stackelberg, Beiersdorf, 1991; Morgan, 2000). As benefits an organization concerned with future development of the deep-sea resources, most of the Interoceanmetal Join Organization (an intergovernmental consortium certified by Bulgaria, Cuba, Czech Republic, Poland, Russian Federation, and Slovakia) research effort has been directed towards understanding of the seafloor topography, geological setting, and polymetallic nodule-related problems.

Study site, materials and methods

Data and information for this study were collected in May–June 2004 and June–July 2009 in the area covers more than 60 000 km^2 in the eastern part of the CCZ between 9°46'–13°17' N and 119°25'–121°08' W. Samples from a total of 209 stations at localities preliminary chosen in compliance with the exploration strategy were collected with a 0.25 m^2 spade box corer equipped with a photo-camera. Sediment and nodules cores were processed and analyzed at considered depth intervals following the adapted standard protocols.

Bathymetric map at a scale of 1:200 000 generated from multi-beam echo-sounder system was used as a base to define the seafloor topography and spatial distribution pattern of sediments and nodule deposits (Kotlinski, Zadornov, 2002).

Bottom sediments covering the seafloor consist of Marquesas and Clipperton formation deposits and the following four lithofacies are divided: calcareous and clayey-calcareous nanofossil; siliceous (radiolarian) clay, zeolithic (red deep-sea clay) and denser zeolithic crusts; and siliceous-clayed and calcareous-clayed silt.

Results and discussions

The studied area features all genetic nodule types (*H, HD and D),* known from the Clarion-Clipperton zone. As a rule, contents of Mn, Ni, Cu and Co for *D*-type are 30±1%, 1.4±0.1%, 1.2±0.1%, and 0.16±0.01% respectively. In others, contents of Mn reach 33% and Cu content is higher than that of nickel (subtype D_1). The majority of *D*-type (41% of stations) and its D_1-subtype (32%) nodules are dominant within the area.

The nodule abundance varies from 0 to 22.6 kg/m^2, averaging 9.6 kg/m^2; thus, at 108 stations (52%) recorded abundance >10 kg/m^2. The seafloor nodule coverage (%) was estimated from 0 to 99%, high nod-

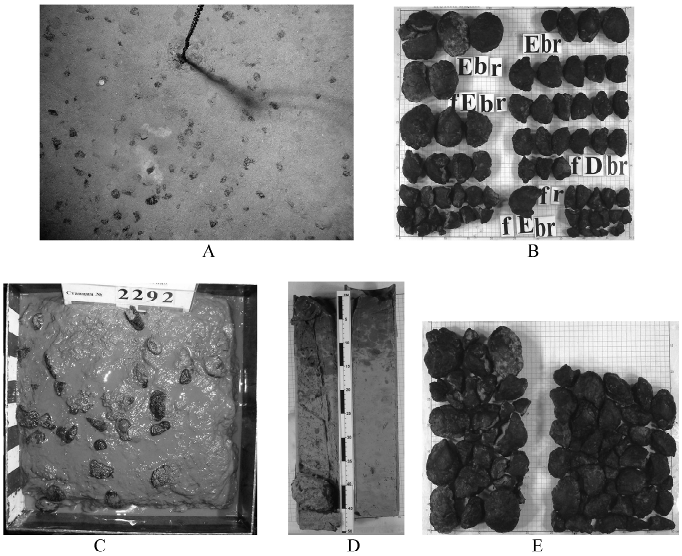

Fig. 1. Representative seafloor and nodule photographs from sample station 2292 (July 2009) in the eastern Clarion–Clipperton Zone, water depth 4530 m
A, bottom photograph with partly sediment-blanket nodules and relatively small nodule surface abundance (8.9 kg/m^2); *B,* template data with nodule morphotypes and surface texture E (ellipsoidal), D (discoidal), f (fragments), b (botryoidal) and r (rough); *C,* onboard photograph of the boxcore sample with surface nodules; *D,* core cross-section with buried nodules (11.3 kg/m^2) occurring at 5 and 40 cm depth; *E,* summary template data with buried nodules (left) and surface nodules (right)

ule coverage (more than 50%) was fixed at 155 stations, including 8 stations with coverage more than 80%. Comparing both seafloor photographs and templet data at the actual sampling station clearly shows that the templet data was to consistently yield per cent nodule coverage that inferred from the bottom photograph due to their overlap by sediments (Fig. 1). For the first time, besides sediment-blanketed nodules, the buried nodules (with abundance from 0.2 to 22.1 kg/m^2) were found in completely beneath the sediment, and they are vertically recorded down to 45 cm in sediment cores (Kotlinski, Stoyanova, 2007). At 15 stations the abundance of buried nodules was higher than that found on the seafloor surface stations, but they did not differ in morphology or size from those found on the surface (Fig. 1).

Depth dependence of nodule abundance within the studied area showed that the seafloor depth range of 4300–4500 m was the most productive interval for the nodule occurrence. Examination of the relationship between seafloor morphology and nodule abundance showed that most of the stations (about 68%) were located on a flat terrain of the seafloor (undulating plains, trough axles); 22% of all stations were placed on sloping part of the bottom (slopes of horsts, troughs, volcanic hills); and 10% of stations were situated at horsts top. In general, stations that yielded high nodule abundances were found to be situated virtually on all types of the seafloor morphology.

The summary of data on the relationship between 108 stations with nodule abundance higher than 10 kg/m^2 and seafloor morphology forms in the studied area showed that the highest number of nodule-rich sites accounted for 61 stations was found on undulating plains; other types of seafloor morphology were found to horst slopes (32 stations), and to trough slopes and horsts top (9 and 6 stations, respectively). It was suggested that the complexity of the seafloor morphology is reflected on nodule deposits delineated in the studied area. As shown by the analysis of bottom photographs and data supplied by seafloor sampling, nodule deposits are mainly band- or extensive coating-shaped. The first are typical of seafloor areas featuring highs and ridges, while the other type of coverage is found mostly on undulating plains. Because the apparent relationship between high nodule abundances and water depth intervals, the role of bottom topography perhaps jointly with bottom currents and sediment chemistry became a significant local control factor defining their distribution pattern. Other possible factor related to the benthic faunal activity but it is beyond the scope of this paper.

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