The Submicroscopic Structures of Mesozoic—Cenozoic Fe–Mn Stromatolites

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Abstract—The results of the study of submicroscopic structures of oceanic oxide ores are described. The objects of study were Co-bearing Fe–Mn crusts from the Magellan Seamounts and Fe–Mn nodules from the Clarion–Clipperton province. The evolution of structural elements is traced in the crust section from the Lower Campanian–Maastrichtian to Pliocene–Quaternary layers. It was found that growing nodules actively entrap hosting sediments into the layered cover. The entrapment mechanism of sediments by nodules was revealed.

Keywords: Fe–Mn nodules, Co-bearing crusts, stromatolites, oncolites, submicroscopic structures

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INTRODUCTION

The onset of the Mesozoic–Cenozoic manganese epoch is related to the beginning of the breakup of the Pangea supercontinent at the end of the Middle Jurassic and the formation of the modern structure of the World Ocean. This specific stage of the Earth’s evolution produced a new type of oceanic crust and a new sedimentation regime; intense basaltic magmatism led to the large scale accumulation of Fe–Mn ores, which is lasted until the present (Geodinamika ..., 1999).

The Mesozoic–Cenozoic Fe–Mn ore genesis resulted in the formation of two types of oceanic oxide ores: Fe–Mn nodules of abyssal depressions and Co-bearing crusts of seamounts, the total resources of which exceed 100 Gt of the dry ore mass (Avdonin and Sergeev, 2003; Geodinamika ..., 1999). The Co-bearing crusts and deep-water nodules are referred to a special type of Fe–Mn stromatolites (Avdonin et al., 2012).

Their most striking peculiarity is a typical layered structure, which allows us to use a historical—geological approach of the study.

The layered crust section is an original record of the Mesozoic–Cenozoic Fe–Mn ore genesis from the Campanian–Maastrichtian until the present. Based on (Mel’nikov, 2005), four macrolayers are distinguished in the crust section from the Magellan Seamounts: the Upper Paleocene to Lower Eocene (I-1), the Middle to Upper Eocene (I-2), the Miocene (II), and the Pliocene–Quaternary (III). Locally, the main section is underlain by relict (R) Campanian–Maastrichtian and Upper Paleocene (?) layers.

The comparison of the crust layers with the same age crusts of sedimentary cover allowed us to reveal that layers I-1 and I-2 precipitated under shelf and upper batial (a depth less than 600 m) conditions. The relict layers could be formed at shallower depths up to the photic zone. Upper layers II and III were formed at a depth close to the modern one, i.e., from 1200 to 3000 m (Mel’nikov and Pletnev, 2013).

The study and typification of submicroscopic structures led to the conclusions that the nodules and crusts are composed of almost the same structural elements, whose typomorphic peculiarities indicate their stromatolite nature.

MATERIALS AND METHODS

A detailed study with a Tescan-Vega/xmu SEM showed that all crust macrolayers represent an assemblage of the same structural elements (columns, nodules, globules, etc.), which repeat from layer to layer. Nonetheless, we managed to obtain several regularities, which allow the establishment of the most typical structural associations for each layer. The evolution of these associations is as follows.

The relict layers are characterized by wavy—layered morphology and coarse radial—layered edifices. Their leading structural motive reflects the penetration of oxide Fe–Mn microforms through the phosphate sediment.

The fine-scaly homogeneous layer I-1 is characterized by wavy—layered forms with columnar structures...
(Fig. 1b). One can observe columns and branches (Fig. 1d).

Layer I-2 starts and ends with a series of closely adjoined short columns (Fig. 1a). The main layer consists of dendrite coarse-columnar aggregates with large cavities between them (Fig. 1b).

Layer II has a ternary structure: dense rows of columns are developed from the top and bottom (Fig. 2d) and bushy intergrowths of branching columns are dominant in the center (Fig. 2c).

Layer III is mostly composed of dense rows of direct fine columns (Figs. 2a, 2b).

Thus, generally, a rather definite picture of the common regularly developed structure is evident.

Most typical structures formed by assemblages of individual elements may be noted. First, these are bushy or dendrite structures that are typical of layer II, which occur in all layers in various modifications. These are also biomorphic structures that clearly demonstrate the growth evolution from the beginning to the end. Some final elements serve as the beginning of next similar assemblage and all of them have more or less similar sizes: the most developed structures are up to 4 mm high and 2 mm across. All branches of “bushes” grow synchronously with the same rate and simultaneously stop growing, which is resulted in perfect morphological forms (Fig. 2c).