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The Upper Ordovician of northeastern Gorny Altai: stratigraphy and deposition environments

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Abstract

Comprehensive lithofacies and biofacies analysis provided constraints on the origin of Upper Ordovician clastic and carbonate deposits in northeastern Gorny Altai, which form large low-elevated flat carbonate banks located relatively close to the shore. The sediments were deposited during the Sandbian and early–middle Katian stages, according to new conodont data. Upper Ordovician sections in northeastern Gorny Altai store record of two global regressions: the early Sandbian (Vollen Lowstand) and early Katian (Frognerkilen Lowstand) events.

Keywords: Ordovician; facies; deposition environment; conodonts; Gorny Altai

Introduction

Identification of marine deposition environments is a challenging problem that arouses much discussion. The suggested solutions are often ambiguous, even within the same basin. In a previous publication, we (Sennikov et al., 2011) reported paleodepth estimates for Cambrian and Ordovician oceanic basins and adjacent deep shelf zones in the territory of the present Altai Mountains. This study focuses on shallow-water shelf facies. The Late Ordovician basin of Gorny Altai was inhabited by taxonomically diverse benthic communities and scarcer pelagic assemblages. Lithological data can place preliminary constraints on water depths, offshore distances, and dynamic activity (energy) of the Altai Ordovician sea basins, while data on biota has implications for water salinity and temperatures. Various combinations of different fauna groups also provide reference for updating sea depth estimates based on lithofacies, for various deposition environments.

The temperature, salinity, depths, and energy of the Altai marine basins were inferred proceeding from the greatest possible amount of lithological and biological (paleoecological) parameters, including structure and texture of sediments, grain sizes, facies change, sediment thickness, taxonomy and structure of fauna assemblages, etc., as it is commonly done in reconstructions of this kind (Shurygin, 2005; Wilson, 1975; Zakharov, 2016, etc.).

Late Ordovician ecosystems

Late Ordovician ecosystems formed at the final stage of the Ordovician biodiversification event (Webby, 2004). Reef ecosystems originated during the longest Late Ordovician highstand event (Nielsen, 2004, 2011) due to the activity of reef-building organisms: Coelenterata—Tabulata (appeared in the earliest Ordovician), Rugosa (appeared in the Middle Ordovician and expanded in Late Ordovician), Stromatoporoidea (appeared in the Cambrian and expanded in the Late Ordovician), and first Heliolites. Concurrent expansion of coelenterata and algae in many geological provinces worldwide produced large-scale reef systems like the present Great Barrier Reef in Australia. Reef systems of this kind are known from the Altai where they are major components of the Late Ordovician Khankhara and Tekhten Formations, either as individual reefs or reef clusters and belts in the Charysh–Inya and Anuy–Chuya facies zones in the western and central parts of the area (Sennikov et al., 2008).

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Most of Late Ordovician deposits of the Uimen–Lebed' facies zone in northeastern Gorny Altai belong to the Gur'yanovka Formation. The formation is remarkable by several features: (i) absence of dome-shaped organic carbonate buildups (bioherms, bioherm massifs, or reefs) despite the presence of algae and various groups of corals; (ii) extremely diverse large fauna groups: algae, brachiopods, trilobites, ostracods, nautiloids, tabulate corals, heliolitids, rugose corals, stromatoporoids, bryozoans, crinoids, and conodonts; (iii) high total numbers of genera and species in fauna groups. These features are common to deposits of large barrier reef systems and related back-reef basins of clastic-carbonate deposition, such as the Khankhara straton, which is the only match for the Ordovician Gur'yanovka straton in the western Altai–Sayan Folded Area in diversity of oryctocenoses.

The Gur'yanovka Formation limestones were deposited in saline and warm seawater, as indicated by faunas. Stenohaline corals, brachiopods, and trilobites in the absence of stromatolites and dolomites record normal salinity while stenothermal corals, numerous thick-walled and often large brachiopod shells and high taxonomic diversity of fauna groups suggest warm temperatures. Therefore, we expect sea depths and patterns of clastic input to be potential limiting factors of deposition rather than water temperature and salinity. That is why the consideration below focuses mainly on the depths of the Late Ordovician sea in northeastern Gorny Altai and on offshore distances in its different parts, or the distances from the clastic provenance of sediments. Applying the actualistic approach, we make reference to respective average parameters in the present marine basins of clastic-carbonate deposition, though being aware that the depths of wave base and light penetration in Paleozoic seas had multiple controls and could vary strongly. In this study the fair weather wave base (FWB) and storm wave base (SWB) depths are tentatively assumed to be 10 m and 20–30 m, respectively. The light penetration (photic) zone is assumed to be 150 m thick: euphotic zone from 0 to 30–80 m and disphotic zone from 30–80 to 150 m below the water surface.

New lithostratigraphic and biostratigraphic data

In 2009 through 2016, we performed special stratigraphic research in reference sections of the Gur'yanovka Formation in the northeastern Gorny Altai area, southern Siberia (Fig. 1). The work included careful documenting composite sections layer-by-layer; assigning previously found faunas to newly distinguished stratigraphic units and subunits; collecting fossils, including conodonts extracted from chemically proceeded carbonate samples.

The Gur'yanovka Formation parastratotype is exposed in the right side of the Lebed' River, upstream of former Stretinka Village, with visible contacts with the underlying Karasa Formation and the overlying Chebor Formation. A large part of the Gur'yanovka Formation in the middle of the Bura strtaotype section in the Lebed' River right side near former Gur'yanovka Village is hidden under vegetation and encloses dike layers. The Lebed' and Bura sections, with fossils therein, were extensively studied in previous years (Dzyubo, 1960; Krivchikov et al., 1976; Kul'kov and Severgina, 1989; Melnikova, 2010; Petrunina et al., 1984; Sennikov et al., 2008; Sennikov, 1962; Severgina, 1978, 1984).

In the ***Lebed'*** section, the Gur'yanovka Formation basal member composed of greenish and dark gray medium to coarse (up to gravel) polymictic sandstones lies over greenish-gray siltstone of the Karasa Formation top containing graptolites of the Darriwilian teretiusculus terminal zone, in the right side of the Lebed' River, 300 m upstream of the third river shallow from former Stretinka Village (Fig. 2). The basal member is overlain by organic limestones intercalated with limy siltstones and mudstones.

The Gur'yanovka Formation is overlain by purple clayey mudstones of the Chebor Formation with gradual 1 m thick transition. The boundary between the two formations in this section may follow the base of the purple and lilac mudstone or rather the top of uppermost limestone or limy mudstone. The latter interpretation is consistent with red coloration appearing in the Gur'yanovka Formation limestone at the top of the Gur'yanovka Glade and Biya sections (see below). Therefore, the Gur'yanovka Formation–Chebor Formation boundary may correspond to the member 17 base instead of the member 18 top (Fig. 2).

The thickness of the Gur'yanovka Formation in the Lebed' section is within 200 m, though it was previously overestimated to >500 m (Krivchikov et al., 1976), possibly, because some riverside outcrops became hardly accessible and the strike of some members aligns with the river stream direction.

According to previous data (Dzyubo, 1960; Krivchikov et al., 1976; Kul'kov and Severgina, 1989; Sennikov, 1962; Melnikova, 2010), the Stretinka section contains the fauna assemblages of *Severginella altaica* (Sev.), *Salopia uxunaica* (Sev.), *Glyptomena subgirvanensis* Sev., *Schizophorella altaica* (Sev.), *Schiz. shorica* Sev., *Multicostella (Chaulistomella) lebanonensis* Cooper, *Austinella lebediensis* Sev., *Boreadorthis togaensis* Sev. brachiopods; *Ceraurinus* cf. *icarus* (Bill.) trilobites; *Grammolomatella* sp., *Eurychilina*? sp. ostracods; *Nyctopora elandiensis* Dz. tabulates; and *Cyrtophyllum* ex gr. *jaconurensis* Dz., *Sibiriolites lebediensis* Dz. heliolitids. We have additionally identified *Chaetetes tchakerensis* Dz. heliolitids (member 6); *Nyctopora denticulate* Sok. et Tes., *Nyct. nicholsoni* (Rad.), *Calapoecia baragashiensis* Dz. tabulates (members 7, 9, and 13); and *Scandodus* sp., *Phragmodus undatus* Br. et M., *Panderodus* cf. *P. gracilis* (Br. et M.), *Aphelognathus* sp., *Belodina compressa* (Br. et M.), and *Drepanoistodus suberectus* (Br. et M.) conodonts (member 13) (Fig. 3).

Limestones occupy a half of the total Lebed' section volume (Table 1). They are commonly dark gray, with low clay contents, and enclose 0.5–1.0 cm pure algal nodules, as well as larger and purer nodules of 1–3 cm. Clay material often produces nodular textures on eroded surfaces or forms separate 5–7 cm layers. The sediments contain locally numerous round or oval algal nodules, 0.5 to 1.0–1.5 cm in diameter, and abundant (70–80% of the rock volume) 2–3 cm algal