

# The latest Cryogenian, Ediacaran and earliest Cambrian of the southwestern Siberian Platform: Stratotypes and limitotypes

## *El Criogénico terminal, el Ediacárico y el Cámbrico temprano en la Plataforma Siberiana sudoccidental: estratotipos y limitotipos*

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### ABSTRACT

A stratigraphic revision of the latest Cryogenian, Ediacaran and earliest Cambrian of the southwestern Siberian Platform is proposed here. All late Neoproterozoic stratigraphic units fill the Sayan foredeep. The sedimentary record is ascribed to the upper Cryogenian and Ediacaran Oselok Group and the lower Cambrian Ust'-Tagul Formation. They can be subdivided into members with a characteristic fossiliferous content ecology of Dickinsonia.

**Keywords:** Lithostratigraphy; Cryogenian; Ediacaran; Cambrian; Siberian Platform.

### RESUMEN

Se propone a continuación una revisión estratigráfica del Criogénico terminal, el Ediacárico y el Cámbrico temprano en la Plataforma Siberiana. Todas las unidades estratigráficas neoproterozoicas tardías llenan la cuenca remanente de Sayan. El registro sedimentario se adscribe al grupo Criogénico terminal y Ediacárico de Oselok y a la formación inferior cámbrica Ust'-Tagul. Se pueden subdividir en miembros a partir de su característico contenido en Dickinsonia.

**Palabras clave:** Litoestratigrafía; Criogénico; Ediacárico; Cámbrico; Plataforma Siberiana.

### Introduction

The late Cryogenian, Ediacaran, and lowermost Cambrian sediments described below are located in

the foothills of the East Sayan Range in the Iya, Uda, Biryusa, Tagul and Tumanshet river basins, southwestern Siberian Platform. All late Neoproterozoic stratigraphic units fill the Sayan foredeep.

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## Results

The sediments belong to the upper Cryogenian and Ediacaran Oselok Group and the lower Cambrian Ust'-Tagul Formation. The Oselok Group, with a total thickness of ~2100 m, is divided into distinct cyclic sequences and consists of the Marnya, Uda, and Aisa Formations which, in their turn, comprise several members (Sovetov, 2011). The correlation of the Oselok Group with the stratigraphic units of the Siberian craton is problematic (Sovetov, 2018).

The deeply eroded lower Cryogenian Karagassy Group is discordantly overlain by uppermost Cryogenian glacial, glaciofluvial, and glacial-lacustrine sediments of the Karapchetui member at the base of the Marnya Formation. The basal member named after the stratotype Karapchetui locality in the Uda valley fills  $\leq 100$  m deep glacial erosion valleys. It is composed of glacial boulder breccias and conglomerates and poorly sorted gravel sandstones, as well as dolomite and quartzite-like silt and sandstone debris of the Tagul and Ipsit formations of the Karagassy Group and glacial-lacustrine stromatolitic dolomite (Sovetov, 2011). The Karapchetui Member has stratigraphic equivalents found at Uraly Mount and at the localities of Plity, Ulakha, and Nersa. It was deposited during the first phase of the Marinoan glaciation when the respective glacier was the coldest at the base, caused brittle deformation of the underlying rocks, and moved northwestward. Deposition during the second Marinoan phase produced the Ulakha Member of black diamictite, which has its stratotype section in the Ulakha creek valley, a tributary of the Uda, and the base limitotype section at the Ozerki locality, where its erosive contact with the Tagul Formation stromatolitic dolomite is exposed in an outcrop. The second Marinoan phase was warmer and the glacier base apparently had higher temperatures than during the early phase, judging by abundant deposits carried by subglacial, intraglacial, and supraglacial meltwater streams in the southwestern and western directions. In the end of that phase, the glacier retreated having left relatively deep stagnant glacial lakes with H<sub>2</sub>S-rich bottom waters which became the source of the Tygnei Member black shale. The base of the Tygnei Member is buried under younger sediments and its top is bounded by fan delta and glaciofluvial deposits of the final phase

of the Marinoan glaciation. These deposits are found within a limited area in the Uda River catchment and consist of pebble sandstone with lenses of unsorted outwash plain conglomerates that belong to the Plity Member. The Plity stratotype section crops out at the Ozerki locality, and has a stratigraphic equivalent in the Biryusa River valley (Kedrovyy Member).

The lowermost Ediacaran sediments are represented by the Ozerki Member of laminate and wave-bedded marcasite-bearing dolomites (cap dolomites). The member is well exposed, with the base limitotype at the Ozerki locality. It lies either over the Ulakha Member tillite or over the Plity Member glaciofluvial sandstone, with a sharp boundary corresponding to a deposition gap in the beginning of the postglacial stage. The Ozerki Member grades into granular and stromatolitic sandy dolostones (sand waves) in the southwest, toward the open sea, and pinches out inward the Siberian craton. The deposits of three glacial phases, two interglacials, and one postglacial stage jointly make up the 275 m thick Ulakha sequence called after its key unit of diamictite (tillite).

The top of the Ozerki Member coincides with the eroded base of the second Ognit sequence which owes its name to the Ognit Member of orthoquartzite gravelly sandstone incised into dolostones to a depth of 3–4 m. The end of the Ozerki deposition was marked by a change from low stand to transgression, with the ensuing formation of sand fill in gullies and a black shale layer. The limitotype of the Ognit Member base is located near the Kirei River mouth, and its stratotype section exposed at the Kirei locality is composed of dark gray massive and platy orthoquartzite of sand bars. Sandstones alternating with black shales in depressions between sand bars store numerous trace fossils and casts of arboreomorphs (Sovetov & Solovetskaya, 2018). The *Arborea* fronds are cast in three dimensions and consist of a central primary stalk with emerging branches, of 3–10 cm length and 3 cm width in total. The cylindrical stalk is filled with sand and bears unclear segmenting traces. No attachment organs have been found so far, but circular discs, 2–3 cm in diameter, over sand surfaces resemble rooting holdfasts of *Rangea* and *Arborea* (Laflamme & Narbonne, 2004, 2008; Vickers-Rich *et al.*, 2013). All *Arborea* lie on the sand layers like small “fallen

trees”, but they apparently were buried *in situ* and thus preserved their primary slightly oblate shapes. The position of *Arborea* within bottom current lithofacies means that they lived in the upper shoreface, unlike other rangeomorph organisms (*Rangea* and *Charnia*). The *Arborea* genus appeared on the Siberian craton during the first postglacial high stand which had no relation to melting of glaciers. During the second transgression peak, the sea basin became much deeper and accommodated the Bolshaya Aisa Member sand tempestites with HCS structures (Sovetov *et al.*, 2012; Sovetov & Solovetskaya, 2017). The Ognit sequence including the Ognit and Bolshaya Aisa members (reaching a total thickness of 165 m) contains *Rangea*-type fossils and numerous traces of cup-shaped animals (with or without a central stem). They may be coelenterates of various genera named after the localities, such as *Sayanites*, *Aisites*, etc. (Sovetov *et al.*, 2012).

The continental deposits of the Nizhneudinsk Member of the Uda Formation lie over the Bolshaya Aisa members (Marnya Formation), which was deeply eroded during a regression event, possibly, of a global scale (Sovetov, 2011). Rivers flew from central Siberia and transported arkose gravel and sand into the marginal sea. The Nizhneudinsk Member stratotype and base limitotype sections are situated in the Uda valley at the Bolshaya Aisa locality. The member is well exposed and is one of reference stratigraphic units distinguished by geological surveys. The regression was followed by transgression, delta retrogradation (Unyl Member), and a transgression peak during which the Peshchernyi Member was deposited. The stratotypes and base limitotypes of the Unyl and Peshchernyi Mbs. are exposed in the Uda valley at the Ozerki and Plity localities. The Uda sequence encompasses the Nizhneudinsk, Unyl, and Peshchernyi members, and is of 125 m total thickness. Three sequences of the Marnya and Uda formations make up a regional-scale continental - marine complex of sediments that correlated over a large territory from the Yenisei Ridge in the north to the southwestern Baikal area in the south (Sovetov, 2018). After the deposition of the Peshchernyi Member limestone shelf facies in the second half of the Ediacaran, the sea retreated from the southwestern margin of the Siberian craton and produced a vast alluvial

plain associated with a giant transcratonic big river system.

The continental sediments belong to the Aisa Formation consisting of five members revealed in coastal cliffs of the Biryusa valley between Serebrovo and Solanaya communities. The Kagat Member in the lowermost section of the Aisa Formation in which deposits of small channels alternating with delta facies record the onset of big river expansion. The Kagat Member stratotype was described at the Kedrovyi locality in the Biryusa valley, and its base and top limitotypes were found in the Uda valley. The Muksut Member, with its stratotype sections at the Plity and Munguzuk localities in the left and right sides of the Uda valley, respectively, results from deposition within a big river valley. The overlying members of Lugovskaya, Serebrovo, and Tymbyr are present within a single section along the right side of the Biryusa valley. The Katalchikov Member at the top of the Aisa Formation was distinguished in the right side of the Tagul River opposite Katalchikov Island. Each alluvial member can be considered as a separate sequence varying in thickness from 150 to 500 m (1200 km in total). The Aisa Member alluvium lacks any fossils but *Rangea* and *Charnia* casts were found in the stratigraphic equivalent of the Katalchikov Member in the Kachergat Formation of Baikal region where alluvium is replaced by shelf facies with tempestites. These fossils are like for examples from another regions (Jenkins, 1985; Laflamme, Narbonne, 2008; Narbonne, 2004; Vickers-Rich *et al.*, 2013) The Aisa deposition completed the Ediacaran and Neoproterozoic sedimentary history of the southwestern Siberian Platform.

The Ust'-Tagul Formation, with numerous Cambrian ichnofossils in the upper part, lies over the eroded surface of the Aisa Formation. The lower Ust'-Tagul subformation is composed of a sand and conglomerate river deposits, which differs this sedimentary system from the Aisa alluvial systems. The Ust'-Tagul Formation has a sharp base, and its limitotype is well pronounced in the right side of the Tagul River, at the Katalchikov Island locality. Trace fossils *Trichophycus pedum* appear in a dolomite bed at the base of the Ust'-Tagul upper subformation, a few meters above the boundary between the alluvial and sea shoreface systems (Sovetov, 2018). The limitotype of this base is located in the right side

of the Biryusa, near Solanaya community (Sovetov & Jensen, 2010). The stratigraphic equivalents of the Ust'-Tagul Formation are of regional spread (Sovetov *et al.*, 2007), and the very existence of this stratigraphic unit demonstrates the effect of global geodynamic events on changes in faunal assemblages at the Ediacaran/Cambrian boundary. The upper Ust'-Tagul subformation consists of dolomites free from clastic components, as well as sandy and clayey dolomites with NaCl glyptomorphs, which are lithologically similar to the overlying Talaya Formation, where early Cambrian trilobites and archaeocyaths were found previously (Zhuravleva *et al.*, 1969). The upper Ust'-Tagul subformation is considered as an equivalent of the Nemakit-Daldyn stage of the regional stratigraphy, while the base of the Talaya Formation is correlated with the Usol'e Formation of inner regions in the Siberian Platform. The Usol'e Formation quoted to the base of the Cambrian Tommotian Stage of the Russian Stratigraphic Code (Sukhov *et al.*, 2016)

## Conclusions

The upper Cryogenian, Ediacaran and lowermost Cambrian sediments cropping out on the foothills of the East Sayan Range in the Iya, Uda, Biryusa, Tagul and Tumanshet river basins, southwestern Siberian Platform, are lithostratigraphically documented. All late Neoproterozoic stratigraphic units fill the Sayan foredeep. The sediments belong to the upper Cryogenian and Ediacaran Oselok Group and the lower Cambrian Ust'-Tagul Formation. They are subdivided into members with a characteristic fossiliferous content ecology of *Dickinsonia*.

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