Ichnofossils from the Lower–Middle Ordovician boundary interval in the St. Petersburg region, Russia

Maria Savitskaya

Department of Historical Geology, Geological Faculty of St. Petersburg State University, Universitetskaya Embankment 7/9, 199034, St. Petersburg, Russia

The investigated region is located in the northwest of the Russian platform where Ordovician rocks occupy an elevated area called the "Ordovician Plateau". The plateau is bounded in the north by a prominent natural escarpment known as the Baltic–Ladoga Klint. The main natural outcrops follow the Klint line and are located in canyons and valleys of the rivers dissecting the plateau. The interval under consideration includes the Leetse Formation (Varangu, Hunneberg and partly Billingen regional stages) and the Volkhov Formation (uppermost Billingen and Volkhov regional stages). The Leetse Formation consists of quartz sandstone with high contents of glauconite grains, interbedded with glauconite-bearing clay limestone. The Volkhov Formation is traditionally subdivided into three units: (1) the "Dikary Limestone" ($B_{II}\alpha$); (2) the "Jeltiaki Limestone" ($B_{II}\beta$); and (3) the "Frizy Limestone" ($B_{II}\gamma$). The "Dikari Limestone" consists of up to 2.20 m thick hard, well-bedded, glauconitic limestone, varying from bioclastic packstone or grainstone to marlstone. The "Jeltiaki Limestone" consists of up to 1.6 m thick clayey limestone, yellow, red or variegated in colour, interbedded with clay. The 2.7 m thick "Frizy Limestone" consists predominantly of light grey nodular glauconitic limestone, intercalated with numerous lens-like beds of clay.

The Billingenian and Volkhovian beds in the vicinity of St. Petersburg provide an extremely rich fossil record of early deep bioturbation and early bioerosion. Twelve ichnogenera have been identified in the studied sections: *Gastrochaenolites*, *Trypanites*, *Circolites*, *Bergaueria*, *Chondrites*, *Palaeophycus*, *Thalassinoides*, *Dolophichnus*, *Phycodes*, *Planolites*, *Macaronichnus* and *Arenolites* (Dronov *et al.* 2002). The top of the Leetse Formation (Vassilkovo Member), interpreted as a transgressive systems tract of the Latorp depositional sequence (Dronov & Holmer 1999), is dominated by *Thalassinoides*, *Planolites*, *Palaeophycus* and *Chondrites.* The Billingenian part of the Volkhov Formation (highstand systems tract) is dominated by *Dolophichnus*. The previous phase in the substrate development showed basically the same genera as the top of the Leetse Formation (*Thalassinoides*, *Chondrites*, *Planolites*). The Volkhov Regional Stage represents a full cycle of deposition and is interpreted as a single depositional sequence. The hardground surfaces at the base and top of the Volkhov Stage are interpreted as the lower and upper sequence boundaries. The ten upper beds of the "Dikari limestone" represent a lowstand systems tract. The "Jeltiaki" and "Frizy" limestones represent the transgressive and highstand systems tracts, respectively. The hardground at the base of the sequence demonstrates a complex boring history with *Gastrochaenolites* aff. *oelandicus* as the prevailing component. The lowstand systems tract starts with beds having numerous, heavily bored hardgrounds, remnants of *Thalassinoides* ichnofabric and vertical *Dolophichnus*-like structures. The top of the "Dikari Limestone" (Bratvennik and Butok beds) shows a very specific trace fossil record including large *Bergaueria*, the system of *Phycodes* and network of *Thalassinoides*. The ichnologic record of the transgressive systems tract starts with a prominent hardground at the top of the "Dikari Limestone". It is marked with small *Trypanites* and probably also small rounded pits of *Circolites*. The following "Jeltiaki" section of muddy limestones intercalated with claystones has basically two common ichnotaxa, *Thalassinoides* and *Chondrites*, which often penetrates the fill of *Thalassinoides*. Specific beds are dominated by *Palaeophycus*, *Planolites*, *Macaronichnus* and *Arenolites*-like ichnofabrics. The ichnofabric of the highstand systems tract consists chiefly of *Thalassinoides*. The upper portion of the "Frizy Limestone" demonstrates, in addition, several beds with *G.* aff. *oelandicus*, *Bergaueria* and *Trypanites/Circolites* borings. The unconformity at the top of the sequence is marked by a hardground surface with *Trypanites*-like borings. Ichnofabric distribution patterns across the studied interval show a close relationship between the ichnofabric and the sea-level change.

References

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