Precambrian Research 278 (2016) 87–107

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Microfossils from the lower Mesoproterozoic Kaltasy Formation, East European Platform

Vladimir N. Sergeev [a,*], Andrew H. Knoll [b], Natalya G. Vorob'eva [a], Nina D. Sergeeva [c]

[a] Geological Institute, Russian Academy of Sciences, Pyzhevskii per., 7, Moscow 119017, Russia
[b] Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA, USA
[c] Institute of Geology, Ufimian Scientific Center, Russian Academy of Sciences, Ufa, Russia

ARTICLE INFO

Article history:
Received 4 November 2015
Revised 10 March 2016
Accepted 19 March 2016
Available online 25 March 2016

Keywords:
Mesoproterozoic
Microfossils
Biostratigraphy
Eukaryotes
East European Platform

ABSTRACT

Basinal shales of the lower Mesoproterozoic Kaltasy Formation, sampled from three boreholes drilled into the southeastern East European Platform, Russia, contain abundant and moderately well preserved microfossils. 34 distinct entities have been identified, most assigned to simple sphaeromorphic or small filamentous taxa found widely and characterized by long stratigraphic ranges. Ornamented microfossils found in coastal successions of other lower Mesoproterozoic basins are absent, but large filamentous microfossils interpreted as possible benthic photosynthetic eukaryotes are recorded, drawing comparisons to relatively deep water shales in Siberia. In overall aspect, the Kaltasy microfossils are consistent with other broadly coeval assemblages, but they highlight the importance of environment, as well as age, in determining the distributions of remains that record the early diversification of marine eukaryotes. *Rectia magna* is described as a new species.

1. Introduction

Recent paleontological and biogeochemical research has sharpened our understanding of late Paleoproterozoic and early Mesoproterozoic marine ecosystems. Silicified coastal carbonate facies offer a view of benthic microbes, including abundant and diverse cyanobacteria (e.g., Zhang, 1981; Sergeev et al., 1995, 2007; Kumar and Srivastava, 1995), while carbonaceous compressions in fine-grained siliciclastic lithologies record both benthic and planktonic microorganisms across a range of lagoonal to basinal environments (e.g., Prasad et al., 2005; Nagovitsin, 2009; Agić et al., 2015; Vorob'eva et al., 2015). In many basins of this age, microfossils thought to be eukaryotic are largely restricted to coastal waters (Javaux et al., 2001), and an explanation for this may lie in the physical nature of mid-Proterozoic oceans. Geochemical data on iron-speciation, nitrogen isotopes, and trace metal abundances and isotopes concur in suggesting the surface mixed layer of mid-Proterozoic oceans lay above widespread and persistent anoxic water masses; episodic upward mixing of these subsurface waters may have inhibited eukaryotic diversification in open shelf environments (Anbar and Knoll, 2002; Johnston et al., 2009; Stueeken, 2013; Guilbaud et al., 2015).

Although widespread, subsurface anoxia was not universal in mid-Proterozoic oceans. Basinal shales in the lower Mesoproterozoic Kaltasy Formation, southeastern East European Platform, preserve geochemical evidence that, at least to the depth recorded by maximum flooding, water masses were oxic (Sperling et al., 2014). Here we report on microfossils preserved in Kaltasy shales. The Kaltasy microfossil assemblage preserves both cyanobacteria and eukaryotic microorganisms over a wider range of environments than is typical for microfossils of this age. At the same time, conspicuously ornamented taxa well known from other, broadly coeval basins are absent, prompting questions about the spatial as well as the time distribution of early eukaryotic microfossils.

2. Geological setting

2.1. Tectonic and stratigraphic framework

For many years, Russian geologists have discussed Meso- and early Neoproterozoic stratigraphy in terms of a Riphean stratotype located in the Bashkirian meganticlinorium, a large structure on the western slope of the southern Ural Mountains (Chumakov and Semikhatov, 1981; Keller and Chumakov, 1983; Fig. 1). The term Riphean, currently a formal unit of Russian Stratigraphic Scale, was originally established to encompass a large scale tectonic cycle, comparable to the Phanerozoic Caledonian or Hercynian orogenies

* Corresponding author. Tel.: +7 495 959 2923; fax: +7 495 953 0760.
E-mail addresses: sergeev-micro@rambler.ru, Vsergeevfossil@gmail.com (V.N. Sergeev).

http://dx.doi.org/10.1016/j.precamres.2016.03.015
0301-9268/

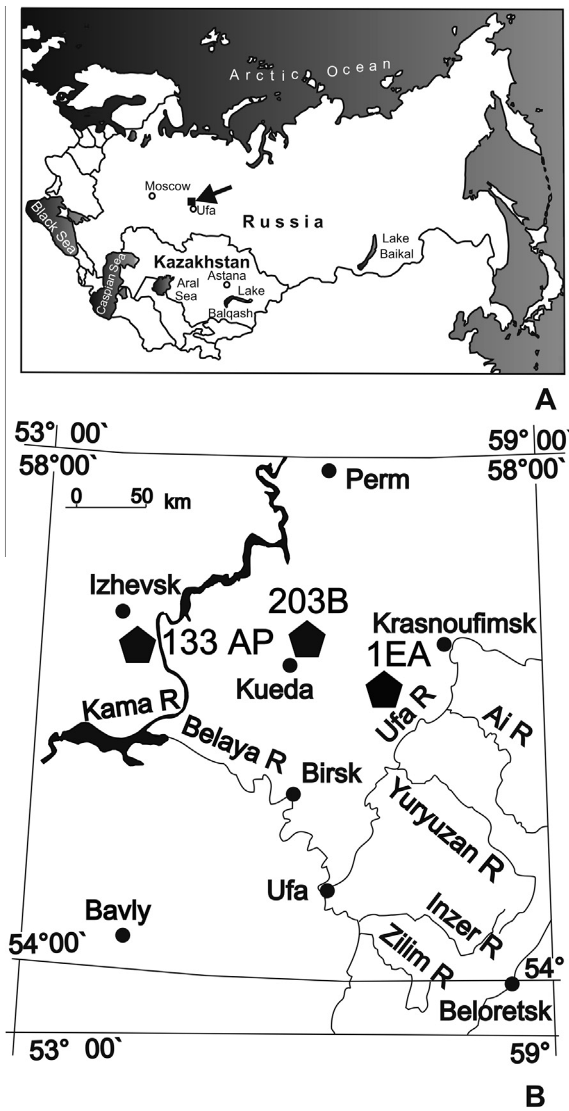

Fig. 1. (A) Index map of North Eurasia, indicating the location of the studied area (filled square at arrow). (B) Map of the southern Ural Mountains and Volgo-Ural region showing the locations of the microfossiliferous boreholes of the Kaltasy Formation (filled pentagons; see Section 3.1 for details), abbreviations: 203B – 203 Bedryazh, 133AP – 133 Azino-Pal'nikovo, and 1EA – 1 East Askino boreholes.

(Shatsky, 1964). Later, largely on the basis of stromatolitic assemblages, strata of comparable age were recognized across much of Siberia and the term acquired its present stratigraphic meaning. The Meso-Neoproterozoic succession in the Bashkirian meganticlinorium records the eastern flank of an extensive sedimentary basin that probably graded eastward into a continental margin; it can be correlated with confidence to strata in platform aulacogen (graben, or rift) sections of the adjacent East European Platform. The Uralian part of the basin, representing the margin *per se*, belongs to external part of the Timanian orogeny, deformed in Ediacaran (Vendian) and Late Paleozoic time (Puchkov, 2013).

Regionally, the Mesoproterozoic to lower Neoproterozoic (Tonian and Cryogenian) succession contains up to 15 km of weakly altered sedimentary and subordinate volcanogenic rocks, divided into the Burzyan, Yurmata, Karatau and Arsha groups, separated by unconformities (the Arsha Group, which occurs only on the eastern limb of the Bashkirian meganticlinorium, was recently added to the Riphean as a result of new isotopic data; Puchkov, 2005, 2013). The entire succession is overlain unconformably by the Ediacaran (Vendian) Asha Group (Fig. 2).

On the western limb of the Bashkirian meganticlinorium, the lower Mesoproterozoic (Lower Riphean) is represented by the Burzyan Group, traditionally divided into the Ai (siliciclastic and volcanogenic rocks, 1500–2000 m thick), Satka (predominantly carbonates 900–1800 m to 2000–2400 m thick, but thinning significantly to the west), and Bakal (shale–carbonate unit, 900–1800 m thick) formations, in ascending stratigraphic order. Their counterparts on the Bashkirian Meganticlinorian eastern limb are the Bolshoi Inzer, Suran and Yusha formations, respectively.

In the Volgo-Ural region to the west, sub-surface Riphean stratigraphy is known from core and geophysical data. The Kyrpy, Serafimovka and Abdulino groups correlate with the Burzyan, Yurmata and Karatau groups, respectively (Fig. 2). The Kaltasy Formation occurs within the Or'ebash Subgroup of the Kyrpy Group (Kozlov et al., 2009, 2011; Kozlov and Sergeeva, 2011). Kaltasy strata include mixed carbonates and shales, correlated with the Satka Formation in the Ural Mountains (Keller and Chumakov, 1983; Kah et al., 2007; Kozlov et al., 2009); the 1230–3600 m succession has been subdivided into three conformable members: Sauzovo, Arlan and Ashit. The Sauzovo Member (105–815 m thick) consists largely of dolostones that locally contain stromatolites, along with interlayers of dark gray to black shales and less frequent feldspar–quartz siltstones near its base. The overlying Arlan Member (535–1215 m thick) is comprised of carbonaceous shales (some of them fossiliferous) and subordinate siltstones, carbonates and dolomitic marls. The Ashit Member (230–1550 m thick) consists of dolostones with stromatolite horizons and thin interbedded shales. Fossiliferous samples come from shales of the Arlan and Ashit members in three cores: 133 Azino-Pal'nikovo, 203 Bedryazh and 1 East Askino (Figs. 1 and 2; Kozlov et al., 2011).

As described by Sperling et al. (2014), the Arlan Member in the 203 Bedryazh core (and in 1 East Askino) consists almost entirely of dark, parallel laminated shales with minor, commonly diagenetic micrite/dolomicrite. Clay-rich laminae predominate, with thin intercalations that contain appreciable quartz silt. Fine sand grains of angular quartz occur in some laminae; commonly these float in a finer matrix and may have been transported into the basin by wind. No wave- or current-generated sedimentary structures are present in more than a kilometer of stratigraphic thickness, suggesting persistent deposition below storm wave-base. Consistent with this view, Kah et al. (2007) argued that the 203 Bedryazh drill core penetrates some of deepest Arlan facies found in the entire basin. Kah et al. (2007) also suggested that the cyclic granular dolostones and fine-grained sandstones recovered by the 133 Azino-Pal'nikovo borehole record shallow water, high-energy platform environments near the western limit of the Kama–Belaya aulacogen. Although basinal environments in many lower Mesoproterozoic basins were anoxic, and sometimes euxinic (Sperling et al., 2015, and references therein), Fe-speciation geochemistry of the Kaltasy succession indicates oxic water throughout the range of depths recorded by the succession (Sperling et al., 2014).

2.2. Age of the Kaltasy Formation

The age of Kaltasy correlatives in the southern Ural Mountains is constrained by the ~1380 Ma Mashak volcanics in the overlying Middle Riphean (Mesoproterozoic) Yurmata Group (Puchkov et al., 2013; Krasnobaev et al., 2013a) and by ~1750 Ma basalts 200 meters above the base of the Ai Formation (Puchkov et al., 2012; Krasnobaev et al., 2013b). More directly, a series of K–Ar dates obtained for glauconite from the Arlan Member provides ages of 1510, 1520 and 1425 Ma in Borehole 3, Buranovo area; 1488 and 1469 Ma in Borehole 36, Arlan area; and 1358 and 1334 Ma in Borehole 191, Urustamak area (Keller and Chumakov, 1983; all age estimates have an uncertainty of approximately 3%; Gorozhanin, personal communication, 2015). Illite from mudstone of the