



# The distribution of microfossil assemblages in Proterozoic rocks

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## ABSTRACT

A biostratigraphic model of the temporal distribution of distinctive Proterozoic microfossil assemblages is suggested, based on studies of upper Precambrian chert-embedded and compression-preserved organic-walled microfossils from the reference sections of Eurasia, North America and Australia. Microfossils from 2.0 to 0.542 Ga can be divided into seven successive informal global units which can be compared to standard units of the International and Russian time scales. Each unit is characterized by a particular association of taxa, typified by the fossil assemblage that gives it its name. These form broad biostratigraphic units comparable to assemblage zones of Phanerozoic successions; in general (but with minor differences) they correspond to chronostratigraphic units accepted by the International Commission on Stratigraphy. The units are: (1) Labradorian, the upper part of the Paleoproterozoic (Orosirian and Statherian), 2.0–1.65 Ga; (2) Anabarian, lower Mesoproterozoic (Calymmian–Ectasian)/Lower Riphean–lower Middle Riphean, 1.65–1.2 Ga; (3) Turukhanian, upper Mesoproterozoic (Stenian)/upper Middle Riphean, 1.2–1.03 Ga; (4) Uchuromayan, lower Neoproterozoic (late Stenian–Tonian)/lower Upper Riphean, 1.03–0.85 Ga; (5) Yuzhnouralian, upper Neoproterozoic (Cryogenian)/upper Upper Riphean, 0.85–0.63 Ga; (6) Amadeusian, lower Ediacaran/lower Vendian, 0.63–0.55 Ga; (7) Belomorian, upper Ediacaran/upper Vendian, 0.55–0.542 Ga.

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## 1. Introduction

Biostratigraphic correlation is a major pursuit of paleontology, and no less so for the Proterozoic than for Phanerozoic rocks. Considerable advances have been achieved during the past 10–15 years. First, remains of unicellular eukaryotes characterized by high morphological complexity and high (for the Precambrian) rates of evolutionary turnover were discovered in assemblages of both organic-walled and silicified microfossils. Second, a biostratigraphic paradox of cyanobacterial assemblages was discovered: some taxa which have modern counterparts at the generic or even specific level and do not demonstrate any changes in morphology from early in the Proterozoic to the present (over at least the past 2 Ga), nonetheless occur in fossil assemblages having limited temporal distribution that differ in microbial composition from those of the present.

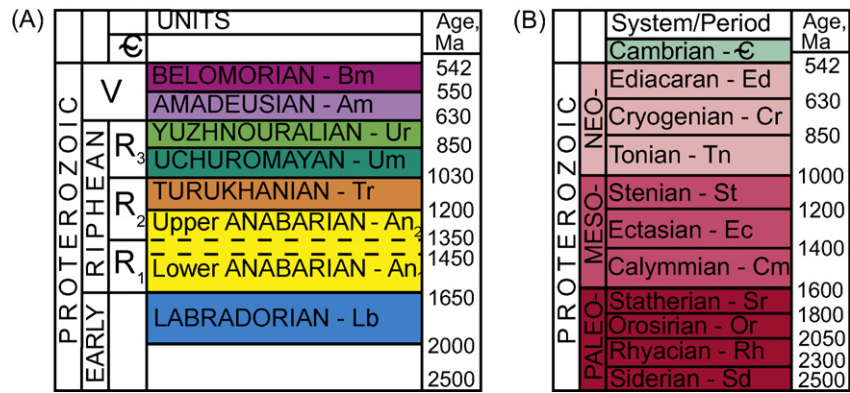
As a result of these and other such advances, a series of Proterozoic microfossil-defined biostratigraphic units has been proposed based on the successive occurrence of distinctive fossil assemblages (Sergeev, 2006b). Although these informal units do not correspond exactly to standard units of either the Russian (Semikhatov, 1995) or the International (ICS) stratigraphic time scales (Plumb, 1991), they represent a promising basis for continuing micropaleontological

research, perhaps helping to identify prospective formal units of the global stratigraphic time scale. The term “unit” is used for these subdivisions (in preference to the earlier proposed term “proterohorizon”; Sergeev, 2006b) as a close Proterozoic analogue of the local or assemblage zone (of a given fauna) commonly used in biostratigraphic practice. The informally proposed units have been correlated with the Russian Proterozoic Scale, which is *de facto* a chronostratigraphic scale (Semikhatov, 1995; Resolution... , 2001). In addition, comparisons have been drawn to the main units of the International Proterozoic scale (Plumb, 1991; see also Gradstein et al., 2004; Ogg et al., 2008) which is chronometric, except for the Ediacaran Period (Knoll et al., 2004, 2006a). Despite theoretical differences in the bases of the two scales, they divide Proterozoic time in similar ways. Almost all of the informal microfossil-defined units coincide, with minor differences, to the detailed units (systems) of the International scale, such as the Tonian and Cryogenian. Generally speaking, it now appears promising that microfossils can help to characterize, and perhaps ultimately even to define the periods of the ICS Proterozoic time scale.

In this paper, I revisit this issue, proposing a tentative model of microfossil distribution based mainly on studies of successive Meso–Neoproterozoic (Riphean and Vendian) microbiotas in cherts from the key sections of Northern Eurasia and comparing them to other Proterozoic assemblages of chert-embedded and compression-preserved organic-walled microfossils, distributed globally. Use of the term “unit” for such subdivisions is not formally recognized internationally, but because the main divisions

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**Fig. 1.** Micropaleontological units of the Precambrian. (A) The Russian Stratigraphic Scale and the established units. Key: R<sub>1</sub> – Lower Riphean, R<sub>2</sub> – Middle Riphean, R<sub>3</sub> – Upper Riphean and V – Vendian. The two dashed lines show alternative positions of the boundary between Lower and Upper Anabarion units. (B) The International Stratigraphic Scale.

here defined are intended to represent an informal “working hypothesis,” to be evaluated by further study, they are here referred to simply as “units.” Seven principal units are recognized for the Proterozoic Eon, embracing the interval from ca. 2000 to 542 Ma: Labradorian, Anabarion, Turukhanian, Uchurmayan, Yuzhnouralian, Amadeusian, and Belomorian (Fig. 1). The unique micropaleontological characteristics of each unit reflects both evolutionary changes (mostly of eukaryotes, but possibly also of some groups of cyanobacteria) and changes in physical and chemical parameters of the atmosphere, hydrosphere, and lithosphere which caused environmental variations reflected in the compositions of fossil microbial assemblages. The older temporal limit of the succession of strata comprising each microfossil-defined unit is determined by the time in geological history when the fossil record becomes sufficiently representative to enable the subdivision to be discerned. Since microfossils are rare in Archean and early Paleoproterozoic deposits, the informal units here defined begin at 2.0 Ga and, to be consistent with accepted biostratigraphic practice, end at the Precambrian/Cambrian boundary (even though main changes in the composition of known microbiotas occur slightly later, approximately at the beginning of the Atdabanian Stage of the Lower Cambrian). In accordance with the rules of the Phanerozoic stratigraphy, the lower boundaries of the microfossil-based subdivisions are defined by the position of the lower boundaries of the oldest assemblage-containing strata and its stratigraphic equivalents. Each such unit is characterized by the most typical microbiota of its particular time-segment, and the name of each unit is derived from the geographic or paleobasinal location of this characteristic assemblage.

It should be noted that the proposed subdivision of the late Paleoproterozoic, Mesoproterozoic and Neoproterozoic uses only silicified (chert-embedded) and compression-preserved organic-walled microfossils, even for Ediacaran (Vendian) deposits. Although remains of multicellular animals have been reported from pre-Ediacaran and even Mesoproterozoic successions (Horodyski, 1982; Grey and Williams, 1990; Fedonkin and Yochelson, 2002), these records remain problematic. Because such records are sparse and their age and biogenicity are often uncertain or disputed, such structures are currently unsuitable for use in biostratigraphy.

## 2. The Proterozoic micropaleontological units

### 2.1. Labradorian unit (Orosirian–Statherian)

The Labradorian unit (stage) occupies the upper part of the Lower Proterozoic (Paleoproterozoic: Orosirian–Statherian), 2.0–1.65 Ga. The typical microbiota comes from the Gunflint Formation of the North America (Orosirian), approximately 1.9 Ga. (The

Gunflint Formation stratigraphic counterpart occurs in the Labradorian trough.)

Silicified microbiotas known from this interval are of two main types: Belcher and Gunflint, differing both in the taxonomic composition of microorganism remains and in facial–ecological position (Fig. 2).

#### 2.1.1. Gunflint-type microbiotas

The typical microbiota of the Labradorian unit is described from the Gunflint Iron Formation of the Animikie Supergroup, 1.9 Ga (Barghoorn and Tyler, 1965; Awramik and Barghoorn, 1977; Hofmann and Schopf, 1983; and others). It includes two groups of microfossils. The first group comprises morphologically simple trichomes and sheaths of *Gunflintia* and *Animikiea*, as well as coccoid microfossils of *Huroniospora*, *Leptoteichos*, and *Corymbococcus*, representing remains of cyanobacteria and iron-oxidizing bacteria (Knoll, 1996). The second group embraces remains of morphologically bizarre umbrella-shaped, dumbbell-shaped, star-like (and of other shapes) microorganisms belonging to *Kakabekia*, *Xenothrix*, *Archaeorestis*, *Eoastrion*, *Eosphaera*, and other genera. Among these genera supposed remains of heterotrophic bacteria are present, including iron bacteria (*Eoastrion*) and, putatively, even unicellular eukaryotes (*Eosphaera*). The sedimentation of the Gunflint-type microfossil assemblages is estimated as relatively deep-water within the proximal or distal part of open shelf. The singularity of the microbiotas is predetermined by their close relation with iron-ore formations, canalizing their taxonomic composition of morphologically complex microfossils. Assemblages of the Gunflint type are described from several upper Paleoproterozoic localities: the Odjick and Sokoman formations of Canada, the Chuanlinggou Formation of China, and the Frere, Barney Creek, and Duck Creek formations of Australia (see review in: Hofmann and Schopf, 1983; Semikhatov et al., 1999; Southgate et al., 2000).

#### 2.1.2. Belcher-type microbiotas

*Belcher-type microbiotas* are dominated by morphologically simple entophysalidacean (*Eoentophysalis*) and chroococcacean (*Eosynechococcus*, *Myxococcoides*, and other genera) cyanobacteria and less numerous filamentous hormogonion cyanobacteria, mostly the hollow sheaths of *Siphonophycus*. These genera have modern counterparts at the generic and even specific levels among living cyanobacteria of shallow-water ecological settings. Belcher microbiotas, are described from shallow coastal (upper subtidal–intertidal) carbonates, 2.0–1.65 Ga: the Amelia, Balbirini, Bungle Bungle, and Paradise Creek formations of Australia (Hofmann, 1976; Hofmann and Schopf, 1983; Southgate et al., 2000). The Gunflint-type microbiotas are restricted to the Paleoproterozoic only and disappear along iron formations while the

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