Taking into account the planet’s beginning history and biota, as well as the finding of fossil micro-organisms in meteorites dated 4.6 billion years ago, it is highly improbable that life originated on Earth.

The organization level of Precambrian fossils (i.e., older than 542 million years) is the most reliable indicator we have of the state and parameters of Earth’s biosphere, for example, atmospheric composition and the average temperature of the planet’s surface (see Figure 1). At present, blue-green algae (cyanobacteria), unicellular and multicellular eukaryotes (i.e., non-bacteria), and coelomates (e.g., sea urchins) are believed to have appeared in terrestrial geological history much earlier than was previously supposed. Our knowledge of and ideas about early Earth are very important for considering the problem of the origin of life. A key boundary is probably about 4Ga (four billion years), which falls between the periods documented and undocumented by the geological record. Accordingly, here we consider the history and probable surface conditions of the planet before 4Ga.

The history of the atmosphere is commonly divided into two stages: reducing (oxygen-free) and oxygen atmosphere, which formed about 2.5–2.6Ga. What we know of Earth based on the geological record starts at 3.7–3.85Ga, which coincided with the end of the last-known intense meteorite bombardments. The oldest rocks known indicate a high proportion of metasedimentary formations (i.e., originating primarily in water basins and later altered by high pressure and temperature) in many dozens of so-called greenstone belts—see Figure 2—suggesting substantial amounts of water. Moreover, growth in the volume of sedimentary rocks about 3–3.5Ga suggests a very rapid increase in water volume (see Figure 3). Yet before 4Ga, Earth’s surface was free of the kinds of water masses that could have provided conditions suitable for wide colonization by micro-organisms. Indeed, researchers have concluded that the sedimentary and volcanic rocks contained in Archean (3.5Ga) greenstone “do not demonstrate any noticeable systematic distinctions from Phanerozoic [i.e., the current eon] analogue.”

Finally, research on the distribution of evaporites (rocks containing minerals such as salts and gypsum) over time indicates that stabilization of the oceanic salt regime, and the corresponding water volume of the world’s oceans, most likely began about 1.3Ga. This points to the existence of major recent groups of organisms beginning around this time.

Further evidence of the non-existence of water on Earth during 4.2–4.5Ga comes from the oldest zircons (a mineral widely found in metasedimentary rocks). Mineral grains are naturally rounded as a result of exposure to water (streams or waves). Yet oxygen isotopic study of zircon grains, as well as their acute-angular shape and size (up to 0.3mm), shows no evidence that they were rounded in water. It is more probable that they were carried into the sediment by volcanic ash or blown in from other deposits by the wind. Likewise, the uraninite (uranium-rich) grains believed to support an Archean reducing atmosphere are generally treated as rounded clasts (grains of sediment) and compared with rounded monazites (phosphate minerals): see Schopf’s Figure 4(a) and (b). Yet these images of grains

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Figure 2. The amount of sedimentary rock as a proportion of the total volume of rock in various regions through time. Note that there are no sedimentary rocks prior to 4.0Ga, showing that there was very little surface water on the planet before that time.

Figure 3. Estimated increase in Earth’s surface-water volume since 4.0Ga as a proportion of today’s surface-water volume.

Figure 4. The fossil prasinophyte Pechengia from Proterozoic phosphorites dated 2.0Ga (after Rozanov and Astafieva).^8

The appearance of eukaryotes (i.e., plants and animals) in the geological record is a very important problem. We see no reason to distrust the data of Timofeev showing that that spherical forms up to 0.1–0.15mm in diameter and tubes up to 0.03–0.04mm across are probably the remains of eukaryotic organisms. We restudied Timofeev’s original samples and collected new material from the same localities. Moreover, definitive eukaryotes were described by Belova and Akhmedov^10 from deposits aged 2–2.2Ga and phosphorites^9 aged 2.0Ga from the Pechenga river basin (see Figure 4). We confidently conclude that the fossils from these phosphorites are prasinophytes (unicellular green algae).

The paleontological record of multicellular eukaryotic organisms (metazoans), and particularly coelomates, indicates a high—almost recent—atmospheric oxygen content. These animals are identified not only by remains of their bodies but also by trace fossils, especially of their movements. In other words, only highly organized metazoans with developed muscular systems and hence consuming a considerable amount of oxygen can move actively on, or within, the sediment. Boring and burying traces dated 1.6Ga from North America, described by Kaufmann and Steidtmann,^11 as well as creeping traces discovered by Shishkin in deposits aged 1.4Ga from the northwestern Siberian platform, are most interesting. To our mind, the existence of Metazoa (*Udoakania problematica* Leites) aged 2.0Ga is a fact that is impossible to ignore. In addition to this data, the biochemical remains of multicellular organisms are already present in rocks aged 1.8Ga. Taking

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into account what we know of Earth’s early history and biota, as well as the finding of fossil micro-organisms in meteorites dated 4.6Ga, we conclude that it is highly improbable that life originated on Earth. As next steps, we plan to pursue this hypothesis through studies of the oldest sedimentary rocks on Earth and fossils, as well as new data on micro-organisms from extraterrestrial objects.

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