
Intensive efforts by paleontologists, evolutionary and developmental biologists, and geologists are leading to a much better understanding of the first appearance and subsequent explosive diversification of animals. The recognition of thin zircon-bearing air-fall ash beds interlayered with fossil-bearing rocks has allowed the establishment of a high-precision temporal framework for animal evolution. Refined laboratory techniques permit analytical uncertainties that translate to age uncertainties of less than 1 Ma and the potential for global correlations at even higher resolution (100-300 ka) when combined with integrated paleontological, chemostratigraphic, and geological data. This framework will allow evaluation of models that invoke both intrinsic and extrinsic triggers for Metazoan evolution and the Cambrian radiation. In particular, many have pointed out that the first appearance of metazoan fossils follows a period characterized by dramatic climate fluctuations and large fluctuations in the sequestration of carbon.

The oldest dated Metazoan fossils (Ediacarans) are younger than ca. 575 Ma and appear to just post-date the youngest Neoproterozoic glacial deposits ca. 580 Ma. The Doushantuo phosphatic rocks of south China preserve spectacular animal fossils but have not been precisely dated. Geochronological data from Neoproterozoic to Cambrian rocks in North America, Namibia, Great Britain, Siberia, and Oman indicate that Ediacaran fossils range from at least 575 Ma (Newfoundland) to <543 Ma (Namibia). Shelly fossils (Cloudina and Namacalathus) are > 548 to ca. 542 Ma. Complex trace-fossils occur at least as far back as 555 Ma (White Sea, Russia). The number and complexity of trace fossils increases dramatically through the Cambrian explosion which occurs over approximately a 10 Ma interval (530-520 Ma).

Outstanding questions remaining to be addressed are: 1) what are the durations and numbers of late Neoproterozoic glacial events and their relationship to diversity in the fossil record? 2) is the negative d^{13}C excursion at the Cambrian-Precambrian boundary globally synchronous and does it signal the extinction of Ediacaran and the creation of ecological niches for the ensuing Cambrian explosion? 3) can the molecular clock approach for determining divergence times be tested using the temporally well calibrated upper Cambrian and Ordovician fossil record? Answering these questions will involve pushing U-Pb zircon geochronology to its limits. Tests of accuracy and precision involving analysis of multiple samples in stratigraphic sequence, blind replicates, and inter-laboratory comparisons will be required.

Future progress will depend on additional geochronology for fossil-bearing rocks in which volcanic rocks have not been recognized. Our experience has shown that a “brute-force” approach of attempting to date any rock that might have a volcanic component is required. This often means analyzing a large number of grains (10-30) for each sample so as to distinguish between lead-loss, inheritance, and detrital contamination. In addition, as ash-beds are often thin (< 1 cm) and weather recessively, they are very difficult to recognize in outcrop. New techniques that involve establishing geochemical signals of volcanic rocks in well-logs has allowed new discoveries of thin ash-beds in the subsurface.