Wholly numerical definitions of major stratigraphic boundaries?

Alan G. Smith
Department of Earth Sciences, University of Cambridge, Downing St, Cambridge, CB2 3EQ, UK, email: ags1@esc.cam.ac.uk

The comments in this presentation spring from involvement with the preparation of the new Geologic Time-Scale produced in 2004 as a result of a major collaborative international effort involving over 40 contributors, supported by the International Commission on Stratigraphy. In particular, the volume highlights the major differences between methods currently used to define stratigraphic boundaries in the Phanerozoic and in the Precambrian.

Global boundary Stratotype Sections and Points ("golden spikes")
The major divisions of the Phanerozoic time-scale are defined by Global boundary Stratotype Sections and Points, i.e. GSSPs or "golden spikes", located in specific stratigraphic sections. The purpose of the golden spike method for defining stratigraphic boundaries is primarily to set a global standard for the definition in rock of the boundary between two stratigraphic units. Once such a boundary has been defined, its position in all other sections must be found by correlation. Thus golden spike sections are ideally defined in a section that has several features that can be used for precise correlation to other sections, such as rapidly evolving fossils, a geomagnetic polarity transition; dateable ash beds; geochemical changes, and so on.

Consequences
Each GSSP uniquely defines a stratigraphic boundary in rock. It is the only place in the world where such a boundary is defined: elsewhere the position of the boundary has to be determined by correlation, which always involves uncertainty. The uncertainty is only negligible in special cases, such as a GSSP defined in a Milankovitch sequence and correlated to another Milankovitch sequence elsewhere, or perhaps by a GSSP defined at a polarity transition. In the case of a boundary defined exclusively by fossils, the uncertainty in correlation is generally of the order of 0.5 m.y., and in some cases may be as much as a few million years.

The numerical boundary definitions for the Precambrian
The current integers assigned to the numerical boundaries of Precambrian subdivisions are not uniformly distributed in time, but are chosen at what are considered to be the boundaries between major cycles of sedimentation and tectonics. Thus the boundaries are chronometric, rather than stratigraphic. It has been cogently argued that the boundaries between subdivisions should be moved to reflect "natural" subdivisions in the evolution of the planet, particularly for the early Earth. Such subdivisions would probably be applicable to the stratigraphic evolution of other terrestrial planets, including the Moon. By contrast, it has also been proposed that these numerical boundaries should be replaced by Precambrian GSSPs defined in rock sequences.

Consequences
Numerical boundaries are abstract concepts that are nowhere located in rocks. For example, the current 2500 Ma Archean/Proterozoic boundary can never be located precisely in a stratigraphic sequence. A high precision date of 2500 Ma will always have an experimental error associated with its determination. Moreover the date – and the stratigraphic position - will change when decay constants are redetermined, or the apparent homogeneity of standards used for calibration is shown to be incorrect by the application of new techniques. The alternative – to define boundaries by GSSPs – is likely to be difficult to implement because of the great difficulties in correlating Precambrian sequences in the absence of rapidly evolving fossils.

A suggestion

It may be worth considering the consequences of the somewhat radical suggestion that all stratigraphic boundaries eventually be defined mostly by integers related to their stratigraphic evolution, rather than by arbitrarily chosen values. How one could reach this goal while at the same time preserving the amazing detail in the Phanerozoic biostratigraphic stratigraphic record will be discussed. A major advantage of such an approach is that it might make stratigraphy more comprehensible to other scientists.