Some potential Proterozoic GSSPs

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Formal adoption of a Precambrian chronostratigraphic timescale will require placements of Global Stratotype Sections and Points (GSSPs) at well chosen locations in the geological record (Bleeker, 2004a, b; Robb et al., 2004). Formalization of GSSPs in a chronostratigraphic framework does not require complete abandonment of chronometric scales; for example, the geon scale (Hofmann, 1990, 1999) may be used in parallel with any stratigraphically based scheme according to the convenience of scientific communication. Given wide usage of prior chronometric subdivisions in Precambrian time, GSSP selection should be guided by these subdivisions, at least at the levels of eons and eras (see Robb et al., 2004). Thus an Archean-Proterozoic boundary should be placed in a rock succession at approximately 2500 Ma age, and eras within the Proterozoic Eon should conform broadly to a three-part subdivision of Paleo-, Meso-, and Neo-, that correspond approximately with their current chronometric boundaries at 1600 and 1000 Ma (Plumb, 1991). The names of these eons and eras need not change, for we have ample precedent of consistent terminology usage both before and after GSSP formalization. The symbolic meanings of three Proterozoic eras can remain unchanged as long as our present chronostratigraphic definitions adhere to the features of Earth history that governed selection of the currently formalized chronometric tripartite subdivision (most thoroughly described by Plumb and James, 1986). If the present endeavor results in Proterozoic eras defined by different geological features and events, then new names may need to be sought for those conceptually new intervals of time.

The Archean-Proterozoic transition encompassed several important irreversible changes to the Earth system, most notably the progressive cratonization of extant continental fragments (extensive dyke swarms, broad epicratonic cover successions, long and linear orogenic belts) and the onset of atmospheric oxygenation (earliest Superior-type banded iron-formations, disappearance of mass-independent fractionation of sulfur isotopes). Other transitions, such as growth of the geomagnetic field and increases in biodiversity, may have occurred during this interval but are presently too poorly known to constrain GSSP selection. As one of the most fundamental boundaries of geological time, with two of the most commonly used terms of the Precambrian interval, chronostratigraphic placement of the Archean-Proterozoic transition deserves the most respect for prior usage and definitions. A "transitional" eon inserted between Archean and Proterozoic (Bleeker, 2004b) is not favored here, for it abandons this widespread terminology and would occupy an interval of time (about 300 Myr) that is grossly discordant to other intervals of eon status (all > 500 Myr).

The best preserved and described stratified successions spanning this age are the Hamersley and Transvaal systems, respectively in Australia and South Africa, and the Huronian and Karelian successions, respectively in Canada and Russia. Each pair represents a different interval of time: the southern hemisphere deposits (in their more continuously exposed lower parts) span ca.2650-2450 Ma, whereas the northern hemisphere basins span ca.2450-2200 Ma (and younger in Karelia). If a GSSP is intended to approximate the existing Archean-Proterozoic chronometric boundary, then Australia or South Africa would be the most appropriate locales. One candidate GSSP would be the transition between underlying Gamohaan Formation carbonate into overlying Kuruman banded iron-formation (BIF) in the Kuruman Hills of South Africa; this section is well dated by U-Pb on interbedded volcanic ashes, constrained by carbon-isotope stratigraphy, and is part of an expansive regional exposure that allows litho-, sequence-, and chemo-stratigraphic correlation and can be well placed within a paleoenvironmental framework of deposition (e.g., Beukes, 1980, 1987; Klein and Beukes, 1989; Beukes et al., 1990; Hälbich et al., 1992; Sumner and Bowring, 1996; Altermann and Nelson, 1998; Sumner and Grotzinger, 2004). Placing the GSSP at the base of the Kuruman iron-formation would also confine most of the world's

Superior-type BIFs to the Proterozoic Eon, and, depending on the Paleo-Mesoproterozoic GSSP placement, probably also to the Paleoproterozoic Era. These Superior-type BIFs, which are most extensive in the geological record between 2470 and 1850 Ma (Klein and Beukes, 1992), require stable continental platforms for their extensive depositional areas, and at least indirectly manifest changes in atmospheric oxidation and/or biospheric development. Their widespread appearance in the rock record thus represents an appropriate choice for defining the Archean-Proterozoic transition. Atmospheric oxygenation was a protracted process that is indicated by different proxies at different ages (see Bekker et al., 2004), but all currently known examples would be confined to the Paleoproterozoic given the definition as recommended above.

Defining boundaries between eras of the Proterozoic is made more difficult by the luxury of a greater pool for selection among well preserved stratified successions. In addition, the current chronometric definition of the Paleo-Mesoproterozoic boundary, at 1600 Ma, is meant to emphasize the rather subtle distinction between stabilization of cratons following supercontinent assembly (Statherian) and tectonic subsidence with epicratonic sedimentation (Calymmian). In the intervening years following formal definition, the gross distinction between Paleoproterozoic and Mesoproterozoic has come to be characterized as one separating a world of dramatic and exciting global events in the former era, from one of relative tectonic and climatic quiescence and subtle evolutionary changes, especially toward the beginning of the latter interval (see Brasier and Lindsay, 1998).

If a Paleo-Mesoproterozoic GSSP is to conform to the concepts used in its sanctioned chronometric boundary, then it should be placed within a post-orogenic succession that represents the global aftermath of supercontinent assembly (with proposed names including Hudsonland, Nuna, Columbia, Capricornia, and perhaps others) at ca.1800 Ma. To my current knowledge, the best preserved rifted to passive-marginal successions deposited during and shortly after that age, in temporal order and with ages of initiation, are the Olifantshoek of South Africa (1930 Ma), Jixian of North China (1770 Ma), Espinhaço of Brazil (1750 Ma), Coppermine of northern Canada (1740 Ma), McArthur-Lawn Hill of northern Australia (1730 Ma), circum-Siberian margins (ca.1650 Ma), Bangemall of Western Australia (1640 Ma), Vindhyan of India (1630 Ma), and Riphean of Baltica (ca.1600 Ma). The most intensively studied among these is the McArthur-Lawn Hill superbasin, with diverse sedimentary facies that are amenable to study by numerous analytical methods. Within this expansive superbasin, a general evolution between synrift and postrift sedimentation is found within the Gun Supersequence of Southgate et al. (2000). In the McArthur River area, this transition is recorded within the Masterton-Mallapunyah lithostratigraphic interval, well exposed in the gorge of the Kilgour River. To the southeast, in the Lawn Hill / Mt Isa region, a compromise between low metamorphic grade and stratigraphic completeness exists around the Fiery Creek dome, where the Gunpowder and Paradise Creek Formations are separated by the Mt Oxide Chert marker horizon (a potential GSSP level, ca.1660 Ma, Page et al., 2000). This level is advantageous because it can be traced almost continuously across a marine paleobathymetric slope toward the Mt Isa region (Southgate et al., 2000), allowing fuller characterization of oceanic geochemistry and paleobiology through the Paleo-Mesoproterozoic boundary interval (e.g., Shen et al., 2003).

The Meso-Neoproterozoic chronometric boundary at 1000 Ma is most closely linked in Earth-system events to the culmination of Rodinia supercontinent assembly. Generally, the Neoproterozoic Era is characterized by more dramatic climatic and biological events than the preceding Mesoproterozoic interval, and GSSP selection should also reflect this aspect of surficial planetary evolution. Many of the world's best preserved volcano-sedimentary successions have ages either predominantly or completely on either side of 1000 Ma, with a uniquely notable exception of the Turukhansk in western Siberia. That composite section, comprising primarily carbonate rocks, has a well defined chemostratigraphy (Bartley et al., 2001) that permits correlations with other successions globally. As the currently defined Neoproterozoic Era contains an apparently monotonic rise (at present resolution) in marine 87Sr/86Sr carbonate values, as well as a general increase in the amplitude of 13C/12C carbonate oscillations

(Shields and Veizer, 2002), a suitable level for the basal Neoproterozoic GSSP would be at the nadir of 87Sr/86Sr values in the Derevnya-Burovaya succession of the Turukhansk, with current age estimates of ca.1020 Ma (Bartley et al., 2001).

Further subdivision of the Proterozoic Eon into chronostratigraphically defined Periods (i.e., with GSSPs) need not adhere to the chronometric subdivisions previously approved by ICS (Plumb, 1991), for some important updates to the ages of key rock successions and tectonic events may suggest alternative classifications of the various time intervals. For example, the formally defined Stenian Period at the end of the Mesoproterozoic Era has etymological basis in the "narrowing" of oceans that closed in concert with Rodinia assembly. This aspect alone is appropriate for the 1200-1000 Ma interval, but increasing recognition of widespread large igneous provinces during the same period (e.g., Keweenawan, Umkondo, Warakurna) would suggest a more generally dynamic term stemming from the Greek "kinesis" as originally proposed by Plumb and James (1986). The following chronometrically defined period, Tonian (1000-850 Ma; Plumb, 1991), is named for "stretching" of the newly assembled supercontinent; however, the earliest widespread manifestations of Rodinia's fragmentation are now dated at ca.830 Ma (Li et al., 2003), thus most post-Rodinia rifting is ironically excluded from the Tonian as presently defined. Other chronometrically defined periods, such as Siderian, Orosirian, and Cryogenian, remain pertinent to current dating of representative rock successions and could be formalized chronostratigraphically by GSSP selection (in the case of Siderian this coincides neatly with my above-recommended basal-Proterozoic GSSP).

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