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First- and second-order global sequence stratigraphic correlations and accommodation charts for the Kaapvaal, Karelian, São Francisco (-Congo) and Slave cratons: An introduction

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ABSTRACT

This work provides a pilot study of global sequence stratigraphic correlation for the Precambrian for five chosen cratons. Detailed chronostratigraphic charts summarize the supracrustal geological evolution of each craton, and are in the form of adapted Wheeler diagrams to enable estimation of first- and second-order sequence stratigraphy for the cratons. Evidence within the Precambrian sedimentary record for events of apparent global significance is examined, across several preserved Precambrian cratons, utilising chronological data, inferred geodynamic and basin evolutionary histories, palaeosols, erosional hiatuses, and interpreted chemical, biochemical, palaeobiological, palaeoatmospheric and palaeoclimatic changes. The adapted Wheeler diagrams attempt to reflect time within hiatuses as well as within depositional sequences, in accord with the distinctly punctuated nature of the global stratigraphic record. The supercontinent cycle is examined for its antiquity and its application to Precambrian cratons, and a commentary is given on an emerging "conventional view" of the Precambrian wherein supercontinentality is seen as a global phenomenon by the Neoarchaean already (or alternatively only by ca. 2.0 Ga), on the nature of the "Great Oxidation Event" at ca. 2.4–2.3 Ga and possibly concomitant widespread glacial events at approximately the same time period. It is hoped that the present pilot study will stimulate an examination of accommodation changes over time for all ancient cratons, thus enabling a more comprehensive assessment of global correlations and high-order (first- and second-order) accommodation changes. This might lead to an improved appreciation of the inherent complexity of the individual facets making up the currently developing "conventional view" of Precambrian geological evolution.

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1. Introduction

This set of papers examines global correlations for the Precambrian time period for a group of Precambrian cratons from across the globe, based on detailed chronostratigraphic charts (summarizing the supracrustal geological evolution of each craton) shown as adapted Wheeler diagrams for individual sedimentary basin-fill successions, with the aim of establishing first- and second-order sequence stratigraphy for the chosen set of cratons. The ultimate aim of the project was to attempt a pilot study of global sequence stratigraphic correlation; this has not been done before at this scale. The separation of first-order sequences is related to specific tectonic settings in the evolution of a chosen craton, with the first-order sequence boundaries marking changes in the tectonic setting, while the subdivision of first-order sequences into Sloss-scale second-order sequences is at regional group and supergroup level. A set of four introductory papers examines major issues encompassed in such global correlation attempts, followed by the body of the collection of papers, which consists of four specific craton case-studies.

Earth evolution, in the Precambrian and later, essentially involves the interaction of a complex set of geological controls, viz. mantle-thermal processes, plate tectonics, sedimentation systems, palaeobiological evolution, palaeoatmospheric and palaeoclimatic changes, which together produced the extant rock record (e.g., Eriksson et al., 2004 and references therein). The aim of this set of manuscripts is to examine evidence within the Precambrian sedimentary record for events (of whatever genetic origin) that appear to be of *global significance*, rather than craton-specific or even more localised occurrences. To this end, correlations across several

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preserved Precambrian cratons are deemed significant, particularly as regards chronological data, interpreted geodynamic and basin evolutionary histories, palaeosols, erosional hiatuses, as well as chemical, biochemical, palaeobiological, palaeoatmospheric and inferred palaeoclimatic trends and changes.

The key element provided here is the chronostratigraphic charts, which are envisaged as adapted Wheeler diagrams, where the essential element is the time control; this implies attempting to establish how much time is in hiatuses versus depositional sequences - at least for the major stages of craton evolution, depending on the resolution that can be resolved for the chosen case-studies. From this basis, accommodation changes can be inferred. The reason that accommodation charts are utilised, rather than sea-level, relative sea-level, or subsidence curves, is because accommodation is the combination of *all* allogenic controls, and this avoids the very difficult inferences of how much of that space can be attributed to eustasy, or subsidence, etc. In addition, accommodation defines the space available for sediments to accumulate in both underfilled and overfilled sedimentary basins, and hence in any depositional setting, whether or not influenced by sea-level fluctuations (for a full exposition of these factors, see for example, Catuneanu, 2006). For each case study a discussion of the likely controls on accommodation is provided.

2. A “conventional viewpoint” framework for stratigraphic studies of the Precambrian time period?

There are many challenges for the Precambrian sedimentologist and stratigrapher, which are not experienced when working in the Phanerozoic and younger rock record. In the Phanerozoic, time control is of high quality, based not just on accurate radiometric dating but also on a reasonably complete, invertebrate and vertebrate fossil record. The succession of Wilson cycles and the interaction of mantle-thermal processes with the well defined plate tectonic regime in their genesis are well established; supercontinent reconstructions can be made with some confidence, and mobile belts, palaeoclimatic changes and palaeoatmospheric variability are reasonably well quantifiable.

Little of this predictable framework for sedimentological – sequence stratigraphic studies can be relied upon in a Precambrian context. The onset of Phanerozoic-Modern type plate tectonics, the nature of mantle-thermal processes and the importance and occurrence of mantle plumes and superplumes are as yet incompletely resolved (e.g., Eriksson et al., 2004 and references therein for an overview of many of the debated issues). While some argue for a “normal” plate tectonic regime deep into Archaean time (e.g., de Wit et al., 1992; de Wit and Hynes, 1995; de Wit and Ashwal, 1997; de Wit, 1998), others discount this and postulate that such a regime was only pertinent much later in the Precambrian (e.g., Hamilton, 1998); perhaps, a more reasonable approach is to discuss a *gradational* change from a mantle-dominated Earth to one where rigid plates and their migration slowly became predominant (Trendall, 2002), but debate on the timing of such a transition remains contentious (e.g., Eriksson and Catuneanu, 2004).

However, despite still-open debate on these issues (and many other unresolved Precambrian Earth evolution questions), there is also a widely held “conventional opinion” which constitutes a relatively fixed framework for the Precambrian, as discussed later in this section. A pertinent example of the apparent contradiction between highly divergent views and a possible “conventional view”, is provided by opinions on the Precambrian expression of the supercontinent cycle (e.g., Unrug, 1992; Rogers and Santosh, 2002), a concept implicit within studies of Phanerozoic sequence stratigraphy and one also related to postulated palaeoclimatic variation and biological evolution on the planet across the time scale (e.g., Aspler and Chiarenzelli, 1998). A rather confusing plethora of suggested supercontinental assemblies is to be found in the literature, including, for example: (1) ca. 3.0 Ga “Ur” (core of Indian cratons, with Kalahari, Western Dronning Maud, Napier, Pilbara); (2) ca. 2.5 Ga “Arctica” (Aldan, Anabar/Angara, Slave, Rae, Greenland, Hearne, Nain, Superior, Wyoming cratons); (3) ca. 2.0 Ga “Atlantica” (West Africa, Congo/Kasai, Guyana, Brazil, São Francisco, Rio de la Plata); (4) ca. >1.5 Ga “expanded Ur” (with addition of Zimbabwe, Madagascar, Bundelkhand, Aravalli, Yilgarn, Kimberley, Gawler cratons, Eastern Australian terranes); (5) ca. 1.5 Ga “Nena” (addition of Baltica and most of East Antarctica to “Arctica”) (see Rogers, 1996; Ruban, 2007). Many of the reconstructions of cratonic amalgamations rest on palaeomagnetic data, yet such data older than ca. 1.8 Ga are commonly considered unreliable; e.g., the palaeomagnetic data used to support the inferred ca. 1.9–1.5 Ga “Columbia” continent (Rogers and Santosh, 2002) is considered to be questionable (Meert, 2002). For >1.8 Ga reconstructions, thus, recourse must needs be had to geological data such as geochronology or matching of major structural features such as mobile belts (Meert, 2002).

Another proposed early Precambrian supercontinent, the Neoarchaean “Kenorland” (Williams et al., 1991), is well supported by a large geochronological database and has since been expanded to include the Baltic and Siberian shields in addition to the original assembly of the cratons of North America (Aspler and Chiarenzelli, 1998). In view of the evidence in favour of this amalgamation, which also extends to generally easily correlatable supracratonic sedimentary-volcanic successions (e.g., Ojakangas et al., 2001), Kenorland has tended to become relatively well established in literature and to have assumed something of a mantle of “convention”, supporting not just this specific example of a supercontinent, but also the broad concept of supercontinentality *per se* as a global state in the Neoarchaean (see discussion in Eriksson et al., 2009, 2011a,b). Within this framework of inference, a “southern equivalent” of Kenorland has also enjoyed wide support (e.g., de Kock et al., 2009, most recently), known variously as “Vaalbara” (Kaapvaal and Pilbara cratons; Cheney, 1996) or the expanded “Zimvaalbara” (Zimbabwe craton added; Stanistreet, 1993). For the latter postulated supercontinent, a common Neoarchaean-Palaeoproterozoic set of successor and distinctly coeval basins is suggested (e.g., Cheney, 1996; de Kock et al., 2009 and several others in between). For Kenorland, an analogous view has become well entrenched in literature, of correlated Palaeoproterozoic supergroups from the Superior (Huronian), Wyoming (Snowy Pass) and Fennoscandian (Karelian supergroups) cratons (e.g., Ojakangas et al., 2001). The suggested “convention” that is becoming an established point of view thus encompasses widespread supracrustal sedimentary-volcanic successions which occur across large swathes of apparently amalgamated cratonic plates in a set of essentially coeval basins, wherein individual sets of strata, reflecting specific interpreted tectonic and depositional origins (e.g., glacial; cf. Ojakangas et al., 2001; Young, 2004; and references therein), can be matched from basin to basin and are accepted as being chronological and palaeoenvironmental markers.

Ironically, despite the Phanerozoic being seen by many as a suitable genetic guide to Precambrian evolution (e.g., for tectonic regimes, basin-fills, and even arc complexes/greenstone belts - e.g., de Wit and Ashwal, 1997) this does not seem to apply to internal complexities within the Phanerozoic supercontinental sedimentary record, which is well studied, well dated and much better preserved than Precambrian basin sets; a pertinent example would be the very widespread Karoo basins of supercontinent Gondwana. Examining only those Karoo basins currently preserved on a single continent from Gondwana, namely Africa, in excess of 50 individual Karoo-type basins (Carboniferous – Jurassic) are known;

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