



Editorial

Precambrian continental growth and tectonism: Introduction

It was the expansion of studies into Precambrian rocks in the 1960s and 1970s that first clarified the distinct differences between geological, geochemical and isotopic signatures of the Archean, Proterozoic and Phanerozoic eons. With the merging of the sea floor spreading and continental drift hypotheses into the unified paradigm of plate tectonics, the duration of this style of lithosphere deformation became a key field of research. Had plate tectonic processes analogous to the present day characterized the whole of Earth history, or did radically different tectonic styles operate during these three long eons? If so, how are they related to these geological signatures? The evidence bearing on these important questions is multifaceted and includes petrology, structural geology, stratigraphy, isotopic investigation, deep crustal imaging by reflection seismology and paleomagnetism. It is certain that there have been long term temporal changes related to secular cooling of the earth and to a slowing in the rate of rotation due to tidal friction but the predicted consequences of these phenomena might be expected to be gradual rather than episodic. Thus in the Precambrian earth we are dealing with a complex system with many interrelated parameters and the scope for ongoing research is enormous, this is especially so because many Precambrian terranes are still poorly understood due to political or accessibility reasons.

Whilst the subject areas embraced by geology and geochemistry in the Precambrian are diverse, the contributions of geophysics are mainly in the fields of deep crustal seismology and paleomagnetism. However even here there are important questions surrounding fundamental geophysical properties of the Precambrian earth. Thus the recognition from studies in several independent laboratories that glaciation occurred at the equator in both Paleoproterozoic and Neoproterozoic times has produced the “Snowball Earth” hypothesis, but even more tantalizing is the indication that these glaciations were concentrated *only* in low latitudes. Have changes in the obliquity of the Earth’s rotation played a part here? However, Proterozoic geomagnetic field inclinations are also found to be biased towards low latitudes, so is it time to question the key assumption that the earth’s magnetic field was then predominantly a geocentric axial dipole as at present?

The importance of Precambrian time to our understanding of the earth cannot be underestimated particularly because so much of the present continental crust was formed during these times. Distributions of zircon T_{DM} ages from a range of cratons

indicate that the majority of the crust was in place by ~ 1800 Ma following major crust-forming events in Late Archean times, and especially between ~ 2100 and 1800 Ma. The Precambrian crust is also the principal reservoir of many mineral deposits and again we find important secular changes in the style of mineralisation in the crust with Archean ores being largely volcanic exhalative and contrasting with Proterozoic ores emplaced predominantly by ensialic mechanisms, and these being followed in turn by a great diversification of emplacement settings during the Phanerozoic.

This thematic section of *Gondwana Research* is the partial outcome of a conference on “Precambrian Continental Growth and Tectonism” held at the Department of Geology, Bundelkhand University, Jhansi (India) during 22–27 Feb. 2005, and attended by 150 participants from 14 countries including Canada, France, Georgia, India, Iran, Japan, Kyrgyzstan, Mexico, Nepal, Norway, Poland, Russia, South Korea and the UK. Eighty five research papers were orally presented at this conference and 40 displayed in poster sessions, which was followed by a post conference field excursion in Bundelkhand craton. This thematic section brings together a varied suite of papers covering structural, petrologic, isotopic and paleomagnetic investigations of the Precambrian. It includes papers on areas which have hitherto been sparsely reported in leading Earth Science journals, and also presents some challenging reassessments of existing paradigms. We hope that it will be a valuable source for all those who are interested in the Precambrian era.

The first paper of this issue is a GR Focus paper by J.D.A. Piper on the paleogeography of the Proterozoic shields. It draws some large scale geotectonic conclusions about the geometry of supercontinents and links the demise of a Precambrian supercontinent to what is probably the largest single continental break-up event in geological history near the Proterozoic–Phanerozoic boundary. The other eight papers cover a wide range of investigations embracing different aspects of magmatism and crustal evolution and incorporate studies of structural geology, tectonics, metamorphism, metasomatism and fluids, sedimentation and sedimentary basins, geochronology and metallogeny. The regions of study include East Gondwana, the Eurasian plate, the Lapland granulite belt, the East European Craton, Northern Asia, Egypt, the Urals and the Central Iranian Basement.

With the rapid growth of specialization in studies of the Precambrian, it is all too simple for popular ideas to become

embedded in the thinking of the wider community and the Rodinia concept is an example. The correlation of Neoproterozoic sedimentary successions of Australia, Western North America and South China were originally used to produce the core of this reconstruction. Unfortunately it is apparent from the paleomagnetic evidence that these regions were nowhere near each other when these successions were deposited. Thus the paper by Piper argues for a quasi-integral Paleopangea model in place of the influential Rodinia model. He shows that the most recent paleomagnetic database for poles between 1300 and 500 Ma accords with this premise and the break-up of the supercontinent at around 600 Ma correlates with the multiple signatures of continental rifting and breakup shortly before the dawn of the Cambrian. The quasi-rigid premise proves to be a highly testable one because it requires conformity of the paleomagnetic poles to a single apparent polar wander path over a long period of ~700 Myr. The geometric shape of the Neoproterozoic supercontinent is also shown to be of intrinsic geodynamic significance because it is comparable to the Phanerozoic supercontinent Pangea and matches the form of the low order geoid. The implication is that whole mantle convection has operated to constrain continental crust towards regions of low gravitational potential through much of earth history.

The paper by Yoshida applies zircon data to address geochronological problems and the nature of orogenic events in East Antarctica, and discusses the relationship of Antarctic terranes to the Pan-African and Grenville orogenic belts. He finds ages older than 990 Ma for the Rayner Complex, i.e., central part of the Grenvillian Circum-East Antarctic Orogen (CEAO) and the Grenvillian orogen with a similar age range of ca. 1000 Ma to 1200 Ma is traceable from the Pinjarra Orogen in the western margin of Western Australia. He concludes that the tectonics of East Antarctica orogen (~1000 Ma) is not compatible with proposed Rodinia assemblies which therefore require reassessment.

Zemtsov discusses an important concept which has not hitherto had wide exposure in the scientific literature, namely the influence of the earth's rotation on continental motions. He proposes a new model for rotation of a continent for both hemispheres and determines forces that cause it to rotate. Earth rotation and the moment of frictional torque forces result in rotational continental motions in a direction opposite to the real rotation of the earth i.e. clockwise for Eurasian continents in the northern hemisphere; he suggests that this appears to be demonstrated by paleomagnetic and geological data for the early stages in the earth's history.

Mints et al. present new geochronologic and petrologic data on the ~21–23 km thick Lapland granulite belt (LGB) and examine their implications for the thermal structure of the lower crust. From analysis of the metamorphic assemblages they quantify the temperatures and pressures of high-grade metamorphism within the LGB and monitor its retrogression. During the M1 event these ranged from 960 to 860 °C at pressures of 14.0 to 10.3 kbar; during the M2 event there is a decrease from the lower to the upper part of the LGB assemblage from 860 °C at 12.4 kbar to 800 °C at 5.8 kbar; during the M3 event from 770 °C at 10.7 kbar to 640 °C at 4.8 kbar, and during M4 event

from 650 °C at 8.4 kbar to 550–500 °C at 4.5 kbar. These data allow them to establish a combined plume–plate tectonic model for the geodynamic and metamorphic evolution of the LGB at different stages between ~2.44 Ga and 1.87 Ga.

Wiszniewska et al. present a detailed synthesis of field geology combined with geochemical and geochronological data from the Proterozoic magmatic rocks in northeastern Poland. They interpret this region as an extension of the Svecofennian island arcs of the Fennoscandian Shield into Poland. The geochemical features of the study area show depletion in Th–U, Nb, P and Ti relative to the primitive mantle and their distribution on trace element discrimination diagrams (Y vs. Nb, Y+Nb vs. Rb, Hf–Rb–Ta and La–Y–Nb) are consistent with a volcanic arc environment. The new geochronological data and the simplicity of zircon populations suggest that the arc-related magmatic activity occurred at 1.82–1.80 Ga. Their results highlight the presence of Late Svecofennian crust at the southwestern margin of the East European Craton and near to the Trans-European Suture Zone. The authors also identify the existence of a Late Paleoproterozoic arc system (1.82–1.80 Ga) in part of northeast Poland.

Smelov and Timofeev review isotopic data from the basement of the North Asian Craton, a crustal block which comprises the largest Precambrian continental fragment. It is an interesting contribution from a part of the world that has hitherto been sparingly reported in the international literature. These authors find that the North Asian Craton appears to be underlain by Archean crust (55%), undifferentiated Archean and Proterozoic crust (13%), Paleoproterozoic crust (20%) and Mesoproterozoic crust (12%). A consistent younging of terranes towards the east and the south is observed from the Neoproterozoic Tunguska and West Aldan terranes, suggesting that crust-forming processes added to an ancient continental nucleus and were most extensive in the Neoproterozoic. The major periods of metamorphism occurred between ~2.6 and ~2.5 Ga and at ~1.9 Ga and these times probably reflect times of terrane amalgamation. Thus the North Asian Craton is predicted to have taken part in significant Mesoproterozoic and more recent plate tectonic processes, a conclusion supported by the presence of Mesoproterozoic crust in the Verkhoyansk fold-and-thrust belt.

Zoheir and Klemm have carried out a structural and metamorphic investigation to determine the evolution of the Allaqi–Heiani suture in Egypt and provide a very useful contribution to our understanding of one of the great sutures of the Arabian–Nubian Shield. They suggest that the 750–720 Ma Allaqi–Heiani suture in the Um El Tuyur area is the western extension of the Onib–Sol Hamed suture in south east Egypt and is composed of allochthonous ophiolitic thrust slices and island arc metavolcanic assemblages. The Um El Tuyur area underwent three stages of ductile deformation and metamorphism. The petrologic data suggest that peak metamorphic conditions were reached at temperatures of 534°–561 °C and pressures of 5.26–6.20 kbar coeval with the D2 deformation.

Kuznetsov et al. provide an important contribution to the understanding of the tectonic evolution in the Uralian and pre-Uralian geology of the East European Craton. They present new data from the Timan–Pechora region and demonstrate that the

northeastern Timanides and the northern pre-Uralides contain plutonic–volcanic associations (VPA) of I- and A-types, ranging in age from 700 to 515 Ma. I-type granitoids are parts of a differentiated calc-alkaline series with a positive correlation between total alkalinity and the SiO₂ content. The geochemical signatures are typical of an island arc, an active continental margin and a collisional zone. The latter data are interpreted in terms of convergence between Baltica and Arctica during the Late Neoproterozoic culminating in collision during the Cambrian.

In the final contribution of this thematic issue, Nadimi presents a review and new interpretation of the tectonic evolution of the Central Iranian basement. The author interprets Precambrian basement complexes in the Saghand region along the Chapedony and Poshte Badam faults as the oldest rocks of the Iranian microplate and considers that they were emplaced during Palaeo- to Mesoproterozoic time with consolidation concentrated between 2400 Ma and 2100 Ma. The greenstone belts, paleo-suture zones and ophiolitic rocks around the high-grade metamorphic rocks of central Iran confirm that an island-arc type cratonization occurred here. The presence of Neoproterozoic volcanics here is also an indication of stretching of the Arabian–Iranian continental crust during an extensional phase of Pan–African orogeny.

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