Manchester Geological Association

Saturday 16th January 2010 – Scenes from the Precambrian

13.30 – 14.15	Precambrian Shields – What can they tell us about the Origin of Continents? Professor Hugh Rollinson, University of Derby
14.15 – 15.00	Early Life – The Archaean Story Professor Euan Nisbet, Royal Holloway, University of London
15.00 – 15.30	Coffee Break
15.30 – 16.15	Continental Evolution during Archaean and Proterozoic times: The Palaeomagnetic Evidence Dr. John Piper, University of Liverpool

The name ‘Precambrian’ dates from Adam Sedgwick’s original investigations into the geology of Wales, where he dubbed the system of rocks ‘Cambrian’. In Caernarvonshire he observed that some gnarled rocks underlay, and were therefore older than, the Cambrian rocks; these he termed pre-Cambrian.

Precambrian rocks form but a small percentage of the British succession; worldwide, however, they cover a much larger percentage of the earth’s surface, occupying large parts of Canada, Greenland, North and South America, Scandinavia, Siberia, Africa, Arabia, India and Australia.

These Precambrian areas are of great economic importance, containing, as they do, most of the world’s supply of industrially important metals, such as iron, nickel, cobalt, copper and zinc. They also host virtually all of the world’s chromium, platinum, gold and diamonds.

From a purely geological point of view, though, Precambrian rocks are of the greatest importance for providing the only evidence we have to support and test theories about the formation of the earth, the evolution of continental crust, or the origins of the earliest life forms.

Precambrian Shields – What can they tell us about the Origin of Continents?

Professor Hugh Rollinson, University of Derby

The Earth is unique amongst the rocky planets of the solar system in having a granitic continental crust, i.e. that crust which makes up the major land masses. Some of this crust is exceptionally old, well over 2.5 billion years old and is preserved in Precambrian Shield areas, or Cratons. These rocks are predominantly granitic and, we believe, reflect the process of continent formation in the early Earth. Their antiquity tells us that the process of continental crust-formation is very ancient, although our best evidence shows that the Earth continents have grown in size over geological time. This lecture will address the question of how do continents form, and why this process makes Earth unique as a planet.

The presentation will survey the processes of continent formation gleaned from the author's work in the Precambrian Shields of West Africa, Southern Africa, West Greenland, Scotland, and western Russia.

Early Life – The Archaean Story

Professor Euan G. Nisbet, Royal Holloway, University of London

Life probably began sometime around 4 billion years (Ga) ago, when the early meteorite bombardment had slowed and ocean-boiling events had ceased. The ~3.8 Ga Isua belt in Greenland may contain isotopic traces of very early life, possibly living around hydrothermal systems but also perhaps including methanogens and planktonic forms. Biogenic methane emission may have helped sustain greenhouse warming under the faint young sun.

By 3.5 Ga, anoxygenic photosynthesis may have evolved. Both the Barberton belt, South Africa, and the Pilbara belt, Australia, seem to recorded isotopic and other traces of living biological consortia. Perhaps around 2.9 Ga ago, large scale stromatolites are recorded in the Steep Rock Group, Canada, the Pongola Succession, South Africa, and the Mushandike rocks, Zimbabwe. C and S isotopes, as well as other lines of evidence, suggest oxygenic photosynthesis, with oxygen release. This may have challenged the methane greenhouse, perhaps initiating glaciation.

By 2.7 Ga ago, stromatolites were widespread, for example in the Belingwe belt, Zimbabwe and complex biological consortia existed. Most of the modern metabolic reactions probably operated. Though the deep oceans and probably the atmosphere were reducing, oxygen-rich waters may have existed in the photic zone of the water. Around 2.4 to 2.3 Ga ago, in the Great Oxidation, the wider environment became oxidising. Since then, the air has been largely biogenic. The O_2:CO_2:CH_4 ratios of the air may reflect the complex co-evolutionary fine-tuning between the greenhouse and the biological community.

Continental Evolution during Archaean and Proterozoic times: The Palaeomagnetic Evidence

Dr. John Piper, University of Liverpool

The geological record of consolidation and uplift of crustal protolith identifies three major groupings of Archaean cratonic nuclei (Rogers and Santosh 2004). These comprise 'Ur' (~3.0 Ga cratons of Southern Africa, Western Australia), 'Arctica' (~2.5 Ga cratons of Greenland, Fennoscandia, Laurentia and Siberia) and 'Atlantica' (~2.0 Ga cratons of Western Africa and South America). The ~2.9-2.0 Ga palaeomagnetic record from Ur and Arctica shows that these groups occupied opposite limbs of a symmetrical crescent shaped protocontinent ('Protopangaea'). The pole was essentially static with respect to the poles during the long interval ~2.7-2.2 Ga and since this coincides with the later granite-greenstone tectonics, it probably reflects the dominance of small-scale convection in the upper mantle. After 2.2 Ga apparent polar wander movements are often rapid and seem to reflect the transition to orogenic and mobile belt tectonics, which prevailed throughout the remainder of the Proterozoic. However, a surprising discovery from palaeomagnetism is the recognition that unique configurations apply to large continental shields for protracted periods of time. This evidence defines the development of a larger supercontinent, Palaeopangaea, with a prolonged quasi-integrity that provides a general explanation for the distinctive geological and geochemical signatures of continentality that characterise the Proterozoic Eon of Earth history

(2.5-0.542 Ga). The reconstruction of Protopangaea implies that at least 35-50% of the present continental crust had been derived from the mantle by late Archaean times, and metallogenic provinces and zones of intense strike slip deformation (‘straight belts’) show a prominent axial alignment with the supercontinent reconstruction.

During the latter part of Mesoproterozoic and in Neoproterozoic times the palaeomagnetic records from diverse shields define long tracks of 1-2 Ga duration, which form the limbs of elongated loops. These comprise the Gardar Track (~1.3-1.14 Ga), the Keweenawan Track (~1.14-1.04 Ga), the Grenville-Sveconorwegian Loop (~1.14-0.85 Ga) and the Franklin-Adelaide Track (~0.8-0.6 Ga). The latter terminated in a protracted quasi-static interval between ~0.74 and 0.6 Ma. This interval correlates with the interval of widespread global glaciation and suggests that little continental motion occurred during these times. The palaeomagnetic data explicitly scatter in the signature of continental break-up between ~0.6 and 0.55 Ga and during this latter interval it is not yet possible to define any polar wander paths with confidence. A wide range of evidence including environmental and geochemical indicators, alkaline magmatism, dyke emplacement and the subsidence history of passive marine margins all conform to the palaeomagnetic chronology by being focussed between ~630 and 550 Ma. This concentrated Eocambrian signature is evidently the most important episode of continental break-up in geological history. The supercontinental reconstructions derived from the palaeomagnetic evidence show that crust accretes into symmetrical crescent-shaped forms confined to single hemispheres on the globe. By analogy with Phanerozoic Pangaea and the present-day geoid, this is interpreted to reflect the operation of large-scale, presumably whole mantle, convection driving the continental crust towards regions of minimum gravitational potential.

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