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GR focus review

Gondwana from top to base in space and time

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ABSTRACT

Gondwana is reviewed from the unification of its several cratons in the Late Neoproterozoic, through its combination with Laurussia in the Carboniferous to form Pangea and up to its progressive fragmentation in the Mesozoic. For much of that time it was the largest continental unit on Earth, covering almost 100 million km^2, and its remnants constitute 64% of all land areas today. New palaeogeographical reconstructions are presented, ranging from the Early Cambrian (540 Ma) through to just before the final Pangea breakup at 200 Ma, which show the distributions of land, shallow and deep shelves, oceans, reefs and other features at nine selected Palaeozoic intervals. The South Pole was within Gondwana and the Gondwanan sector of Pangea for nearly all of the Palaeozoic, and thus the deposition of significant glaciogenic rocks in the brief Late Ordovician (Hirnantian) and the much longer Permo-Carboniferous ice ages help in determining where their ice caps lay, and plotting the evaporites in the superterrane area indicates the positions of the subtropics through time. Reefs are also plotted and selected faunal provinces shown, particularly at times such as the Early Devonian (Emsian), when high climatic gradients are reflected in the provincialisation of shallow-marine benthic faunas, such as brachiopods.

In Late Palaeozoic and Early Mesozoic times, Gondwana (with Africa at its core) lay over the African large low shear-wave velocity province (LLSVP), one of two major thermochemical piles covering ca. 10% of the core–mantle boundary. The edges of the LLSVPs (Africa and its Pacific antipode) are the plume generation zones (PGZs) and the source regions of kimberlite intrusions and large igneous provinces (LIPs). Our palaeomagnetic reconstructions constrain the configuration of Gondwana and adjacent continents relative to the spin axis, but in order to relate deep mantle processes to surface processes in a palaeomagnetic reference frame, we have also rotated the PGZs to account for true polar wander. In this way, we visualize how the surface distribution of LIPs and kimberlites relate to Gondwana's passage over the PGZs. There are only two LIPs in the Palaeozoic (510 and 289 Ma) that directly affected Gondwanan continental crust, and kimberlites are rare (83 in total). This is because Gondwana was mostly located between the two LLSVPs. The majority of Palaeozoic kimberlites are Cambrian in age and most were derived from the African PGZ. Sixty-six Early Mesozoic kimberlites are also linked to the African LLSVP. All known LIPs (Kalkarindji, Panjal Traps, Central Atlantic Magmatic Province and Karoo) from 510 to 183 Ma (the lifetime of Gondwana) were derived from plumes associated with the African LLSVP, and three of them probably assisted the breakup of Gondwana and Pangea.

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1. Introduction

From its unification in the Late Neoproterozoic to its amalgamation with Laurussia in the Carboniferous to form Pangea, Gondwana was the largest unit of continental crust on Earth for more than two hundred million years. The superterrane of core Gondwana included the modern continents of South America, Africa, and most of Antarctica and Australia, as well as Madagascar and the Indian Subcontinent, which is 64% of all land areas today and 19% of the total Earth surface. In addition, Florida and most of Central America, southern Europe, and much of south-central and south-eastern Asia all formed parts of Gondwana at different times, and, as discussed below, the continents of North China, South China, Tarim and Annamia (Indochina) might also have been integral parts of Gondwana during the latest Precambrian. Even the large continents of Baltica and Siberia were very close to the superterrane in Late Neoproterozoic and Early Palaeozoic times.

The name Gondwana (or Gondwanaland as it is also often called, but we prefer the shorter version) was originally coined by H.B. Medlicott and H.F. Blanford of the Indian Geological Survey in 1879 for a sedimentary sequence of non-marine rocks in India, but became much more widely known after its use by Suess (1885) for the regions, chiefly in India, which hosted the distinctive Late Palaeozoic *Glossopteris* Flora. Suess imagined that the various floral provinces had flourished on continents which had always been in their present positions, but that they had been linked by land bridges in the Late Palaeozoic which had been subsequently drowned beneath oceans through isostatic readjustments. However, the concept of Gondwana was much changed and enlarged by Wegener (1915), who postulated for the first time that the major components of what we here recognise as Gondwana had been united as a single superterrane during the Late Palaeozoic, as characterised both by the *Glossopteris* Flora and also by the presence of glacial deposits that could only have been formed in a polar region; and that the different sectors of Gondwana had subsequently travelled apart across the oceans. There was much opposition to Wegener's ideas on continental drift and the concept of a previously-united Gondwana, largely due to the lack of a plausible mechanism for the necessary continental movements; although some authors, for example in the substantial book by Du Toit (1937), continued to promote continental drift. That scepticism continued amongst most of the geological community until the advent of the plate tectonic theory in the 1960s, as reviewed by Torsvik and Cocks (2012).

In the past three-quarters of a century there has been an avalanche of publications on Gondwana; for example, the volumes edited by Vaughan et al. (2005) and van Hinsbergen et al. (2011), as well as the numerous papers in this journal and elsewhere, and only a small proportion of them are included in the present review. De Wit et al. (1988) constructed a magnificent map of the entire Gondwanan area on a large scale. Cocks and Fortey (1988) offered palaeogeographical maps of Gondwana at several intervals in the Lower Palaeozoic, and we have also previously published together global maps for the whole Palaeozoic (Cocks and Torsvik, 2002; Torsvik and Cocks, 2004) in which Gondwana is conspicuous due to its size; but all of those papers are now outdated, particularly in the accuracy of their progressive positioning of Gondwana through time. We have more recently considered two sectors of Gondwana, the north-eastern margin (Torsvik and Cocks, 2009) and the central sector (Torsvik and Cocks, 2011), but those papers only covered parts of the superterrane and for restricted time periods. Thus we feel that it is now timely to pen a relatively brief overview of the superterrane as a whole, from its original Late Neoproterozoic amalgamation, through its Carboniferous merger with Laurussia to form Pangea, and continuing on to the subsequent history