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Configuration of the Late Paleoproterozoic supercontinent Columbia: Insights from radiating mafic dyke swarms

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Abstract

Remnants of 2.1–1.8 Ga orogens can be recognized in nearly every craton assembled within reconstructions of the Rodinia supercontinent, although no particular pattern of laterally extensive orogenic belts emerges. These cratons may be the fragments of an older supercontinent formed in response to the collision and accretion of even older cratons during the early Earth history. Paleomagnetic constraints have played a limited role in many previous reconstructions of the early Precambrian supercontinent mainly because of the poor age control and a large scatter of the paleomagnetic poles. The geometry of giant radiating dyke swarms and orogenic belts provide important constraints for the reconstruction of the Pre-Rodinian supercontinent.

Some early unmetamorphosed and undeformed mafic dyke swarms in North China, Southern Peninsular India and North America share coeval age of ~1.85 Ga. If these continents are assembled, the overall pattern exhibited by the mafic dyke swarms appears to constitute a giant radiating swarm, with a piercing point between the Cuddapah rift in South India and the Xiong'er aulacogen in North China. This suggests that the North China Craton, Indian Craton and Canadian Shield may be fragmented from the same landmass. The reconstruction of ~1.85 Ga giant radiating dyke swarm attempted in this paper suggests that the North China Craton, India Craton and Canadian Shield were united together to form a landmass within the Columbia supercontinent before its extension and break-up.

The 1.90–1.85 Ga Andean-style North Orogenic Belt suggests that a subduction zone existed on the northern margin of the North China Craton. Wopmay Orogenic Belt developed in a 1.88–1.84 Ga continental volcano-plutonic arc, which is interpreted as the product of eastward subduction of oceanic lithosphere. The Transantarctica Orogenic Belt in East Antarctica may be another candidate to be linked with the subduction zone. The North Orogenic, Wopmay Orogenic and Transantarctica Orogenic Belts could be connected to form a continuous subduction zone. The orogenic comparison strengthens the configuration of the Columbia supercontinent proposed by the reconstruction of the giant radiating dyke swarm. The Laurentia, West Australia and East Antarctica were relatively stable from 1.85 Ga to 1.20 Ga as inferred from the data on dyke swarms, magmatism and the paleomagnetism. These continents constituted the core of the Columbia supercontinent in the Late Paleoproterozoic time. The North China Craton and Indian Craton were however separated from the Columbia supercontinent during the Mesoproterozoic time.

Keywords: Supercontinent Columbia; Extension; Giant radiating dyke swarm; Orogenic belts; North China Craton

1. Introduction

The continental fragments on the globe have been assembled into supercontinents during various periods in Earth history. At least four supercontinental assemblies have been recognized which include: Pangaea, from 350–165 Ma; Gondwanaland, from 550–400 Ma; Rodinia, from ~1050–750 Ma; and Columbia, from ~1.85–1.25 Ga (Hoffman, 1991; Dalziel, 1995; Park et al., 1995; Rogers, 1996; Li, et al., 1999; Zhao et al., 2002; Rogers and Santosh, 2002, 2003; Condie, 2003; Pesonen et al., 2003; Li, et al., 2004; Zhao et al., 2004a,b; Rogers and Santosh, 2004; Li, et al., 2005).

During the past decade many workers have reconsidered Hoffman's (1989) early speculation that a Paleo-Mesoproterozoic supercontinent may have existed before Rodinia. In reconstructions

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of the Rodinian supercontinent, 2.1–1.8 Ga orogens can be recognized in nearly every craton, although no specific pattern of laterally extensive orogenic belts emerges. Nevertheless it is evident that these cratons might represent the fragments of an older supercontinent formed in response to the collision and accretion of even older cratons during this period (Nast, 1997; Zhao et al., 2002; Rogers and Santosh, 2002, 2003; Bleeker, 2003). The Paleoproterozoic supercontinent has been termed the "pre-Rodinian supercontinent" or "Columbia" (also called Nuna) (e.g. Rogers, 1996; Condie, 2000, 2002; Zhao et al., 2002; Rogers and Santosh, 2002, 2003; Zhao et al., 2004a,b; Kusky et al., 2007a).

Paleomagnetic constraints have played only a limited role in many previous reconstructions of the early Precambrian supercontinent mainly because there was poor age control and a large scatter of the paleomagnetic poles, or because the dated paleomagnetic poles were not coeval (Buchan et al., 2001; Meert, 2002; Rogers and Santosh, 2002). In this context, the geometry of giant radiating dyke swarms and orogenic belts provide important constraints in the reconstruction of Pre-Rodinian supercontinent. Rogers and Santosh (2002) proposed that eastern India was once connected to the western side of North America, based on the existence of rifts with similar ages in the two continents. Zhao et al. (2002, 2004a,b, 2006) also proposed that a Paleoproterozoic supercontinent existed in the period 2.1–1.8 Ga based on coeval orogeny and anorogenic magmatism, however, their model implied that the configuration of the supercontinent Columbia resembled the later supercontinent Rodinia (Fig. 1a and b). This poses a difficulty in that the Paleoproterozoic orogens are markedly different from the Rodinian orogens, both in space and in time.

Mafic dyke swarms and rifts formed during the early extension of the supercontinent, and their existence allows some constraints to be drawn on the relative configuration of the various cratons involved. In particular, in the cases where the giant radiating mafic dyke swarms and volcanics constitute Large Igneous Provinces (LIPs), the center of these may indicate the location of a superplume (Ernst et al., 2000; Ernst and Buchan, 2001; Ernst et al., 2005). Identification of such center and the geometry of the radiating coeval mafic dyke swarms and rifts provide the major source of data that we use in this paper to propose an alternate configuration of the Paleoproterozoic supercontinent Columbia. When the Paleoproterozoic orogens are also superimposed on this geometry, the resulting scenario strengthens our new hypothesis on the configuration supercontinent Columbia.

2. Early extension events in the supercontinent Columbia in the Late Paleoproterozoic time

2.1. Tectonic framework of the North China Craton

The position of the North China Craton has been seldom considered or has remained controversial in previous models of Columbia (Zhao et al., 2002, 2004a,b). Even though the North China Craton is a relatively small crustal fragment, the craton may play an important role in providing constraints for the extension geometry of Columbia.

The North China Craton, China's oldest continental fragment, is composed of three main Archean elements including the Eastern Block, Western Block, and the intervening Central Orogenic Belt (Zhao et al., 2001; Kusky et al., 2001) (Fig. 2).

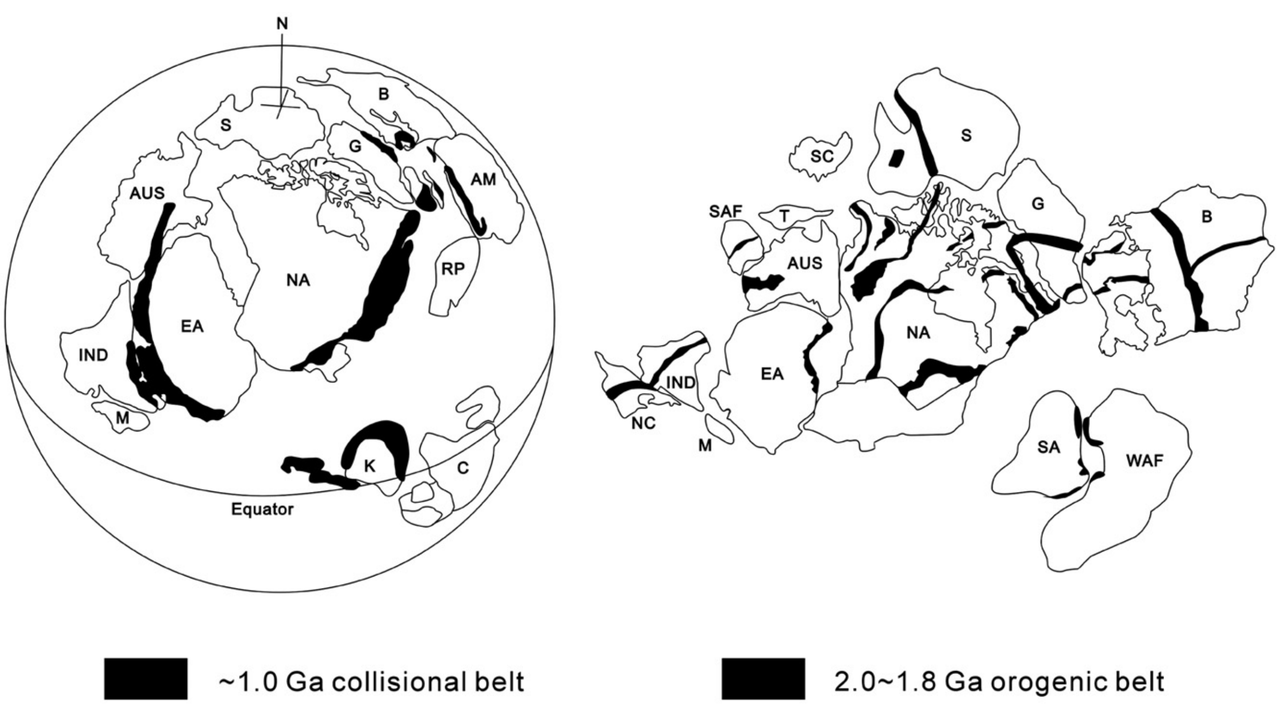

Fig. 1. Two supercontinents in Earth's history: (a) Rodinian (Dalziel, 1995), and (b) possible pre-Rodinian (Zhao et al., 2004). Abbreviations: AM—Amazonia; AUS—Australia; B—Baltica; C—Congo Craton; EA—East Antarctica; G—Greenland; IND—India; K—Kalahari Block; M—Madagascar; NA—North America; NC—North China; RP—Rio de la Plata; S—Siberia; SC—South China; T—Tarim; SAF—South Africa; SA—South America; WAF—West Africa.