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GR Focus

The Xiong'er volcanic belt at the southern margin of the North China Craton: Petrographic and geochemical evidence for its outboard position in the Paleo-Mesoproterozoic Columbia Supercontinent

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ABSTRACT

The Xiong'er volcanic belt, covering an area of more than 60,000 km^2 along the southern margin of the North China Craton, has long been considered an intra-continental rift zone and recently interpreted as part of a large igneous province formed by a mantle plume that led to the breakup of the Paleo-Mesoproterozoic supercontinent Columbia. However, such interpretations cannot be accommodated by lithology, mineralogy, geochemistry and geochronology of the volcanic rocks in the belt. Lithologically, the Xiong'er volcanic belt is dominated by basaltic andesite and andesite, with minor dacite and rhyolite, different from rock associations related to continental rifts or mantle plumes, which are generally bimodal and dominated by mafic components. However, they are remarkably similar to those rock associations in modern continental margin arcs. In some of the basaltic andesites and andesites, amphibole is a common phenocryst phase, suggesting the involvement of H_2O-rich fluids in the petrogenesis of the Xiong'er volcanic rocks. Geochemically, the Xiong'er volcanic rocks fall in the calc-alkaline series, and in most tectono-magmatic discrimination diagrams, the majority of the Xiong'er volcanic rocks show affinities to magmatic arcs. In the primitive mantle normalized trace-element diagrams, the Xiong'er volcanic rocks show enrichments in the LILE and LREE, and negative Nb–Ta–Ti anomalies, similar to arc-related volcanic rocks produced by the hydrous melting of metasomatized mantle wedge. Nd-isotope compositions of the Xiong'er volcanic rocks suggest that 5–15% older crust has been transferred into the upper lithospheric mantle by subduction-related recycling during Archean to Paleoproterozoic time. Available SHRIMP and LA-ICP-MS U–Pb zircon age data indicate that the Xiong'er volcanic rocks erupted intermittently over a protracted interval from 1.78 Ga, through 1.76–1.75 Ga and 1.65 Ga, to 1.45 Ga, though the major phase of the volcanism occurred at 1.78–1.75 Ga. Such multiple and intermittent volcanism is inconsistent with a mantle plume-driven rifting event, but is not uncommon in ancient and existing continental margin arcs. Taken together, the Xiong'er volcanic belt was most likely a Paleo-Mesoproterozoic continental magmatic arc that formed at the southern margin of the North China Craton. Similar Paleo-Mesoproterozoic continental magmatic arcs were also present at the southern and southeastern margins of Laurentia, the southern margin of Baltica, the northwestern margin of Amonzonia, and the southern and eastern margins of the North Australia Craton, which are considered to represent subduction-related episodic outbuilding on the continental margins of the Paleo-Mesoproterozoic supercontinent Columbia. Therefore, in any configuration of the supercontinent Columbia, the southern margin of the North China Craton could not have been connected to any other continental block as proposed in a recent configuration, but must have faced an open ocean whose lithosphere was subducted beneath the southern margin of the North China Craton.

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1. Introduction

Well established pre-Rodinian connections between cratonic blocks on the Earth have led to the proposal of a Paleo-Mesoproterozoic supercontinent, named Columbia or Nuna (Hoffman, 1996, Rogers and Santosh, 2002; Zhao et al., 2002a,b, 2004a; Rogers and Santosh, in press; Santosh et al., in press-a). The creation of this supercontinent involved the fusion of nearly all continental blocks, each of which was itself a drifted fragment of some still older continental assembly (e.g. Kenorland, Hoffman, 1996; Ur, Rogers, 1996). The fusion of these continental fragments to assemble Columbia was completed by global-scale collisional events in the period 2.1–1.8 Ga, which formed the 2.1–2.0 Ga Transamazonian Orogen in South America, 2.1–2.0 Ga Eburnean Orogen in West Africa, ~2.0 Ga Limpopo Belt in Southern Africa, 1.9–1.8 Ga Trans-Hudsonian Orogen and its equivalents in North America, Nagssugtoqidain Orogen in Greenland, 1.9–1.8 Ga Kola-Karelia Orogen in Baltica, and 1.9–1.8 Ga Akitkan Orogen in Siberia (Fig. 1a). Following its final assembly at ~1.8 Ga, the Columbia supercontinent underwent long-lived (1.8–1.3 Ga), subduction-related outward accretion along some of its continental margins, as evidenced by 1.8–1.3 Ga magmatic arcs bordering the present southern and southeastern margins of Laurentia, southern margin of Baltica, northwestern margin of Amonzonia, and southern and eastern margins of the North Australia Craton, which consist of juvenile volcanogenic sequences and granitoid suites resembling those of present-day island arcs and active continental margins. The fragmentation of Columbia commenced about 1.6 Ga ago or slightly earlier, as indicated by widespread 1.6–1.2 Ga intra-continental rift zones and anorogenic magmatism including anorthosite–mangerite–charnockite–granite suite (AMCG), rapakivi granites, kimberlites, lamproites and carbonatites, and its final breakup was marked by the emplacement of 1.35–1.21 Ga mafic dike swarms in all cratonic blocks which may mark the youngest piercing points at which the cratonic blocks in the Columbia Supercontinent can be paleomagnetically and geologically linked.

The North China Craton is one of the oldest continental blocks in the world, containing rocks as old as 3.85 Ga (Liu et al., 1992; Song et al., 1996; Liu et al., 2008; Wu et al., 2008; Wilde et al., 2008). Although the North China Craton was not included in the initial Columbia configuration (Fig. 1b) of Rogers and Santosh (2002), this craton does preserve a record of both the assembly and breakup of Columbia. Recent geological data indicate that the formation of the basement of the North China Craton involved at least two Paleoproterozoic collisional events. The first collisional event occurred at 1.95–1.92 Ga, forming the Khondalite Belt along which the Yinshan Block in the north and the Ordos Block in the south amalgamated to form the Western Block (Fig. 2; Zhao et al., 2005a; Santosh et al., 2006; Wan et al., 2006; Xia et al., 2006a,b; Santosh et al.,

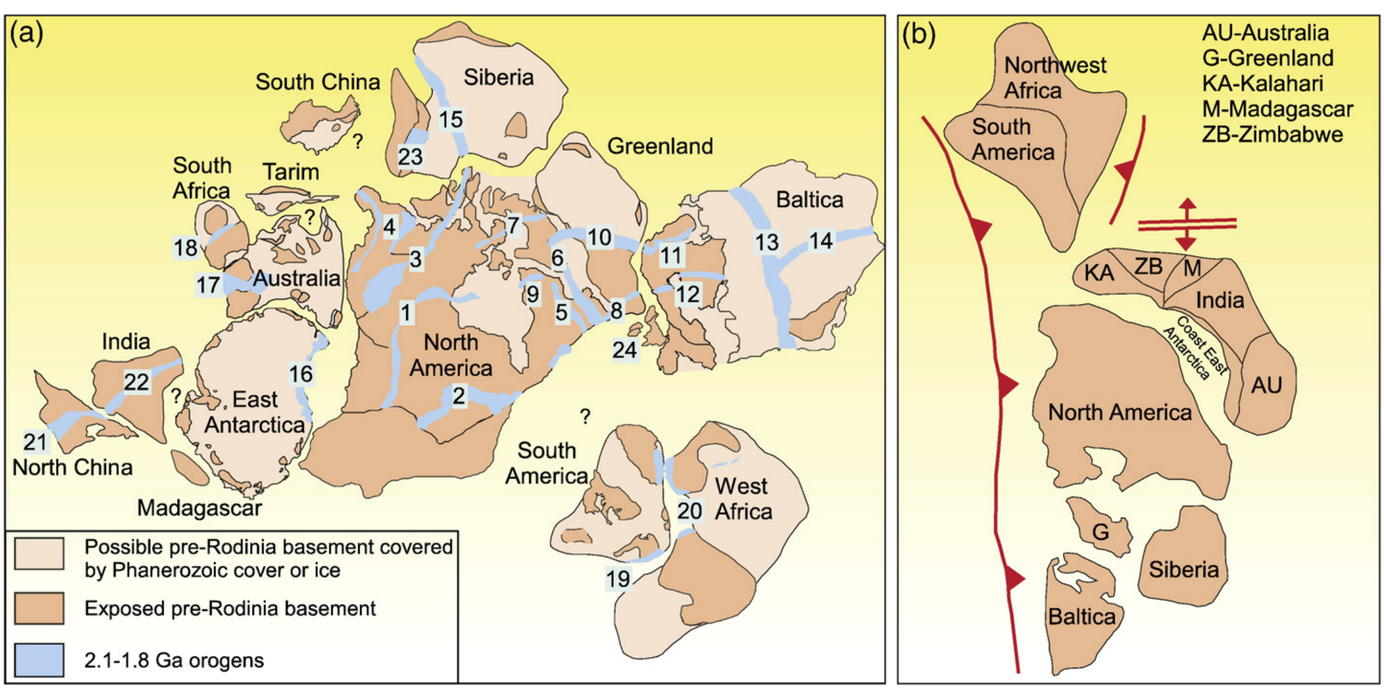

Fig. 1. The proposed Paleo-Mesoproterozoic supercontinent Columbia, configured by (a) Zhao et al. (2002a, 2004a) and (b) by Rogers and Santosh (2002). 1–Trans-Hudson Orogen; 2–Penokean Orogen 3–Taltson-Thelon Orogen; 4–Wopmay Orogen; 5–New Quebec Orogen; 6–Torngat Orogen; 7–Foxe Orogen; 8–Makkovik-Ketilidian Orogen; 9–Ungava Orogen; 10–Nugssugtoqidian Orogen; 11–Kola-Karelian Orogen; 12–Svecofennian Orogen; 13–Volhyn-Central Russian Orogen; 14–Pachelma Orogen; 15–Akitkan Orogen; 16–Transantarctic Orogen; 17–Capricorn Orogen; 18–Limpopo Belt; 19–Transamazonian Orogen; 20–Eburnean Orogen; 21–Trans-North China Orogen; 22–Central Indian Tectonic Zone; 23–Central Aldan Orogen; 24–Scotland.