Neoproterozoic stratigraphic comparison of the Lesser Himalaya (India) and Yangtze block (south China): Paleogeographic implications

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ABSTRACT
Recent studies of terminal Neoproterozoic rocks (ca. 590–543 Ma) in the Lesser Himalaya of northwestern India and the Yangtze block (south China) reveal remarkably similar facies assemblages and carbonate platform architecture, with distinctive karstic unconformities at comparable stratigraphic levels. These similarities suggest that south China may have been located close to northwestern India during late Neoproterozoic time, an interpretation permitted by the available, yet sparse paleomagnetic data. Additional parallels in older rocks of both blocks—similar rift-related siliciclastic-volcanic successions overlying metamorphic basement, and comparable glaciogenic intervals of possibly Sturtian and Marinoan or Varanger age—suggest that this spatial relationship may have developed earlier in the Neoproterozoic. With the exception of basal Cambrian phosphorite and comparable small shelly fossils, stratigraphic contrasts between northern India and south China and increasing biogeographic affinity between south China and northwestern Australia suggest that south China may have migrated toward northwestern Australia during the Cambrian.

Keywords: Neoproterozoic, Lesser Himalaya, India, south China, stratigraphic comparison, tectonic reconstruction.

INTRODUCTION
The hypothesized Proterozoic supercontinent of Rodinia has attracted considerable interest recently (e.g., Bartley and Kah, 2001; Powell and Meert, 2001). One point of debate concerns the position of south China within Rodinia. Paleomagnetic constraints for south China from 1100 to 500 Ma are few, and available data permit several possible reconstructions (Evans et al., 2000). In one reconstruction, Li et al. (1995) suggested that south China was between the eastern side of the Australian craton and the western side of Laurentia. This interpretation was based in part upon the presence of 1.9–1.4 Ga crust in both Cathaysia (southeastern China; Fig. 1C) and the Priest River Complex (southwestern Canada) that could account for detrital zircons of appropriate age in the lower Belt Supergroup of Montana and adjacent Canada. Additional support for this hypothesis includes (1) the similarity in age and chemistry of mafic dikes and sills in southern Australia and south China (Li et al., 1999, 2003), (2) the existence of an erosional surface above ca. 825 Ma rocks in both regions (Li et al., 1999), and (3) similar rifting history between south China and southeastern Australia from ca. 820–750 Ma (Ling et al., 2003; Wang and Li, 2003).

However, this reconstruction presents several difficulties: (1) other zircon provenance evidence places Australia directly against Laurentia, although details of the configuration and timing of breakup remain elusive (e.g., Wingate and Giddings, 2000; Karlstrom et al., 2001); (2) the syrinf to early passive-margin succession of south China (ca. 820–750 Ma) resembles coeval strata of the eastern Australian craton and western Laurentia only grossly (Drexel et al., 1993; Narbonne and Aitken, 1995; Wang and Li, 2003), and the orientation of sedimentary basins was not taken into account; (3) syrinf magmatism from ca. 860–730 Ma in Australia and south China is not unique (e.g., Singh et al., 2002); (4) early Neoproterozoic (ca. 950–850 Ma) collision-related volcanic rocks in south China (Ling et al., 2003) have no correlatives in southeastern Australia; and (5) the similarities in Cambrian faunal provinces between south China and northwestern Australia (e.g., Burrett et al., 1990) require south China to have migrated a great distance during late Neoproterozoic time. In light of these difficulties, we explore an alternative arrangement.

NEOPROTEROZOIC STRATIGRAPHY OF INDIA AND SOUTH CHINA
Neoproterozoic rifted margins developed along the northern edge of India (Fig. 1A; Kumar, 1985) and along the southeastern and western sides of the Yangtze block (Fig. 1C; Li et al., 1999). In both areas, the timing of the rift to postrift transition is tentatively interpreted to correspond with a level within the glaciogenic interval (Fig. 2). A passive-margin setting is inferred with confidence for postglacial carbonate rocks on the basis of platform scale, comparatively simple physical stratigraphic and facies architecture, and the thickness of successions, with no evidence for either synsedimentary tectonism or igneous activity. Figure 2 summarizes pertinent lithostratigraphy and lateral facies variations.

Preglacial Successions (Early Neoproterozoic)
In the Lesser Himalaya, the preglacial succession consists of locally tuffaceous siliciclastic rocks and associated minor mafic volcanic rocks, possibly rift-related, unconformably overlying Mesoproterozoic metamorphic rocks (Kumar, 1985; interval A1 in Fig. 2A). Facies become finer overall toward the northwest, from nonmarine sandstone and conglomerate (Nagthat Formation) at the Nainital syncline to nearshore siltstone and sandstone (Chandpur and Nagthat Formations; Jaunsar Group) in the region between the Garhwal and Nigalidhar synclines, to shale, siltstone, and sandstone (Simla Group) at Simla (Fig. 1B). An erosional unconformity is present at or near the Chandpur-Nagthat contact. The age of the rocks is constrained indirectly by U-Pb dates of 771 ± 2 and 751 ± 3 Ma for volcanic rocks (Malani igneous suite) west of the study area, in Rajasthan (Torsvik et al., 2001).

In south China, correlative strata (interval B1 in Fig. 2B) unconformably overlie 819 ± 7 Ma (U-Pb) granites (Ma et al., 1984) in the Yangtze Gorge area and Mesoproterozoic (≥1000 Ma) metamorphic rocks assigned to the Lengjiaxi and Sibao Groups. Nonmarine sandstone in the Liantuo Formation is equivalent to the upper part of the Banxi Group (Wujiangxi Formation), which is separated from shale and siltstone of the underlying Madiy Formation by an erosional unconformity. At Huaihua (location 10 in Fig. 1D), the Banxi Group is composed mainly of basinal shale and siltstone with abundant turbidites. Associated rift-related mafic volcanic rocks and tuff (Li et al., 1999, and references therein) have been dated to 748 ± 12 Ma (U-Pb; Ma et al., 1984).
Synglacial Successions (Sturtian and Marinoan Glacial Intervals)

The Jaunsar and Simla Groups in northwestern India are unconformably overlain by glaciogenic diamictite, siltstone, and sandstone of the Blaini Formation (interval A2 in Fig. 2A). The Blaini is divided into a lower interval composed of three to four units of massive diamictite separated by siltstone and mudstone; a middle interval of siltstone and sandstone with lenses of ferruginous shale; and an upper interval of diamictite with an erosional unconformity (Jiang et al., 1996).

In south China, glaciogenic rocks unconformably overlie the Liantuo Formation or Main Boundary thrust, and is not palinspastically reconstructed. B: Neoproterozoic and Cambrian outcrop in Lesser Himalaya, India, and sections used to construct Figure 2A. C: Neoproterozoic tectonic framework for south China, emphasizing inferred continental rift systems ca. 800 Ma (modified from Li et al., 1999). D: Geologic map of study area, and sections used to construct Figure 2B.

PALEOGEOGRAPHIC IMPLICATIONS

These stratigraphic similarities suggest a close paleogeographic relationship between the Yangtze block and the Lesser Himalaya during latest Neoproterozoic time (Fig. 3). Whether south China and India formed a contiguous passive margin is uncertain. The southwestern side of the Yangtze block was strongly deformed and metamorphosed during the Cenozoic, and the possible basement connection is difficult to evaluate. Various Tethyan Gondwana blocks (Fig. 3) were interpreted by Husseini and Husseini (1990) to have been sutured to the Salt Range-Kashmir region of greater India by ca. 620 Ma. In that case, a direct link between northwestern India and south China would be improbable when the stratigraphy of the two regions is most similar. The corresponding number and stratigraphic level of sequence boundaries in both regions suggest a eustatic influence on stratigraphic development as well as paleogeographic affinity.

An earlier spatial relationship between
Figure 2. Generalized Neoproterozoic stratigraphy and regional stratigraphic cross sections for Lesser Himalaya, India (A) and south China (B). Numbered sections are located in Figure 1. A1: Jaunsar and Simla Groups. NT—Nagthat Formation; CH—Chandpur Formation. U-Pb age of 823 ± 5 Ma is from Singh et al. (2002). A2: Glaciogenic Blaini Formation. A3: Infra Krol Formation and Krol Group. AC—phosphorite-chert nodules containing acanthomorph acritarchs and cyanobacteria Salome hubeiensis; E—interval of reported Ediacaran fossils; SS—small shelly fossils; N1, N2—negative δ¹³C excursions; Gr—Group. Circled numbers 1–8 locate regional discontinuities and karstic and/or erosional unconformities. B1: Liantuo Formation (LT) and Banxi Group. WQ—Wuqiangxi Formation; MD—Madiyi Formation. LJX-SB—Lengjiaxi and Silbao Groups. U-Pb ages of 819 ± 7 Ma and 748 ± 12 Ma are from Ma et al. (1984). B2: Glaciogenic and associated units. B3: Doushantuo and Dengying Formations. Symbols and numbers as in A3.
The stratigraphic development of northwestern India and south China diverged after the earliest Cambrian; in India, the siliciclastic Tal Group is unconformably overlain by Permian rocks, whereas a carbonate platform persisted in south China until the Silurian. South China may have begun to drift away from northwestern India and toward northwestern Australia in the Early Cambrian, a juxtaposition consistent with the close biogeo- graphy affinity between south China and northwestern Australia in the early to middle Paleozoic (e.g., Burrett et al., 1990).

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