Precambrian Research 244 (2014) 42–52

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Crustal shortening during the Paleoproterozoic: Can it be accommodated by paleomagnetic data?

Henry Halls [a,b,*]

[a] Department of Geology, University of Toronto, 22 Russell Street, Toronto, Ontario M5S 3B1, Canada
[b] Department of Chemical and Physical Sciences, University of Toronto Mississauga, Mississauga, Ontario L5L 1C6, Canada

ARTICLE INFO

Article history:
Received 19 February 2013
Received in revised form 2 September 2013
Accepted 3 September 2013
Available online 4 October 2013

Keywords:
Paleomagnetism
Slave craton
Superior craton
Paleoproterozoic
Crustal shortening

ABSTRACT

In the last 130 million years, perhaps as much as 2000 km of intra-continental shortening has taken place within Asia during 10,000 km of convergence between Siberia and India (with ~8000 km being accommodated by oceanic subduction). Given that Earth was hotter during the Paleoproterozoic, crustal shortening at this time may have been equally, if not more, significant compared to today, warranting a search of the paleomagnetic data base for any supporting evidence. Paleomagnetic data from units on either side of the Paleoproterozoic Trans Hudson orogen in Canada have been chosen because this orogen bears close similarity both in size and history to the India-Siberia one. The data do not prove, but can accommodate, continental crustal shortening between the Archean Slave and Superior Provinces of about 3000 ± 1000 km. The results allow crustal shortening to have been a significant component of continental collision in the Paleoproterozoic, an important issue in any re-assembly of Precambrian continents. If true, the present dimensions of Precambrian shields, may be significantly different compared to those existing in earlier times.

1. Introduction

Geologists and paleomagnetists are actively involved in testing the idea that supercontinents like Pangea at 200 Ma, have existed before in the Precambrian and that the assembly and break up of these supercontinents may have occurred in a cyclical way (e.g. Li and Zhong, 2009). The assembly of Precambrian continents, while recognizing that Precambrian crust may not always be preserved in its original entirety due to later geological events, assumes that the fragments that are defined have retained their original shape and size. Consideration has not been given to the possibility that some of these fragments may represent a shortened and compressed expression of the original terrane, simply because no evidence exists that would raise this concern. However in the Phanerozoic the magnitude of intra-continental crustal shortening across the Tibetan plateau can be demonstrated to be at least 1200–1500 km over the last ~130 Ma (see the following section). In addition the Himalaya represents stacked upper crust decoupled from Indian plate continental lithosphere, with a restored minimum intra-continental shortening of ~500–900 km (Long et al., 2011; Webb, 2013). Therefore between the Indian and Siberian plates a total crustal shortening in the last 130 Ma is between 1700 and 2200 km. If crustal shortening across major collisional orogens in the geological past has been of similar magnitude, then if unrecognized, it could pose a serious problem for continental reconstructions prior to Pangea. Most geologists accept that Earth was hotter during the Paleoproterozoic (e.g. Abbott et al., 1994) and that plate tectonics was in operation at that time (e.g. Condie and Kroner, 2008). Plate tectonic processes were likely more vigorous, and lithospheric plates thinner and less viscous than at present, so that crustal shortening via fault slice stacking and the ability of lithosphere to squeeze out laterally under pressure (extrusion tectonics of Molnar and Taponnier, 1975) may have been enhanced compared to today, thus exacerbating the problem of continental reconstructions for these early times. Apart from palinspastic restoration the only other means of estimating crustal shortening is through paleomagnetism. The paleomagnetic method is able, for collision zones with a paleo-latitudinal orientation, to estimate from inclination differences the amount of crustal convergence involved, which includes that accommodated by wholesale subduction, together with a lesser fraction that is recorded as continental crustal shortening after initial collision. For certain geological units formed during the final stages of ocean closure, it may be possible to measure directly the amount of subsequent intra-continental crustal shortening. The Himalayan orogen has been compared in terms of its size and history to the Paleoproterozoic Trans-Hudson orogen in Canada (St.-Onge et al., 2006). However, the Trans-Hudson orogen is more deeply eroded with removal of most supracrustal

* Correspondence to: Department of Chemical and Physical Sciences, University of Toronto Mississauga, Mississauga, Ontario L5L 1C6, Canada. Tel.: +1 905 828 5363; fax: +1 905 828 3717.
E-mail address: henry.halls@utoronto.ca

0301-9268/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.precamres.2013.09.005

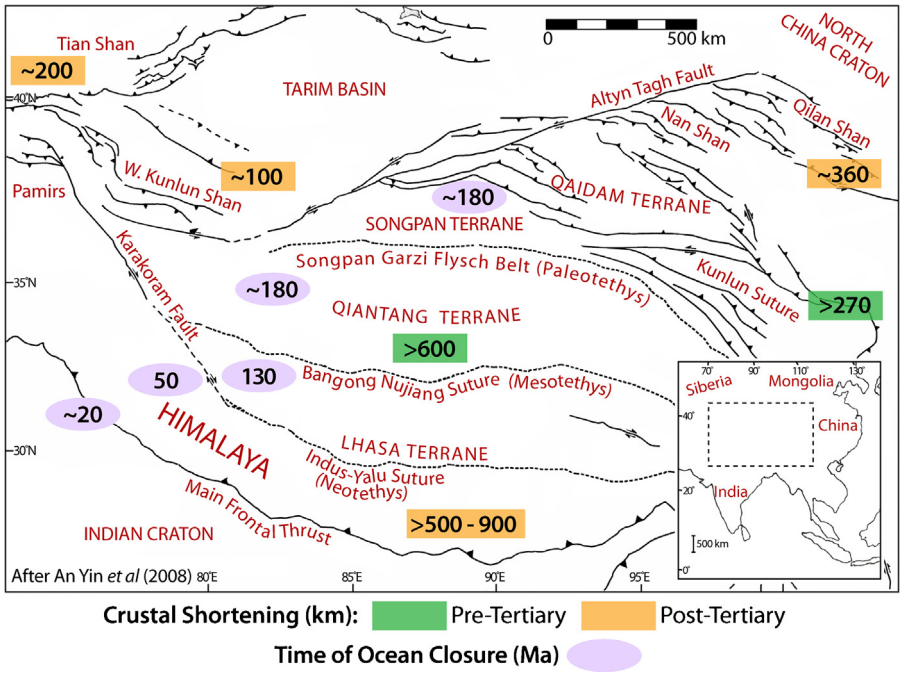

Fig. 1. Geological map of the Tibetan Plateau and adjoining terranes after Figure 1 of Yin et al. (2008). Intra-continental crustal shortening estimates (km) are given in rectangular boxes (dark grey/green for Pre-tertiary and light grey/orange for Post Tertiary). Times of ocean closure in Myr, are given in the oval labels. Major sutures are shown as dotted lines, major thrust faults in solid lines with teeth marks on the hanging wall side. See text for details.

sedimentary sequences, so that palinspastic restoration is not possible, placing total reliance on paleomagnetic data for an answer. A modest amount of paleomagnetic data exists from the Archean Provinces (Superior, Churchill and Slave) that lie on opposites sides of the Trans Hudson orogen. This paper will explore whether these paleomagnetic data can accommodate significant intra-continental crustal shortening between the Slave and Superior Provinces.

2. Crustal shortening across the India-Asia collision zone

Although repeated re-activation of faults occurs throughout the Himalayan-Tibetan orogen up to recent times, a progressive increase in age of the various collisional sutures occurs towards the north. The Kunlun and older terranes of NE Tibet are separated from the Qiangtang microcontinent to the south by the Songpan Garzi flysch belt that represents the suture zone of the Paleotethys ocean that closed somewhere between 220 and 180 Ma (Fig. 1).

The Shiquanhe-Gaize-Amdo thrust (Bangong-Nujiang suture) separates the Qiangtang Terrane from the Lhasa microcontinent to the south and represents closure of the Mesotethys ocean at about 130 Ma (Yin and Harrison, 2000). However activity along this suture also occurred up to about 30 Ma (Kapp et al., 2005). The Himalayan terrane (Fig. 1) and associated bounding faults represent closure of the Neotethys ocean at about 50 Ma with activity lasting to the present, including an apparent spike after 25–20 Ma corresponding to the collision of India and the final closure of the Tethys ocean (Van Hinsbergen et al., 2012). The 1000 km-wide Himalayan-Tibetan orogen therefore represents a collage of at least four accretionary events stretching over a time of approximately 200 Ma (Yin and Harrison, 2000).

In terms of the amount of intra-continental crustal shortening represented by these events, we can approximately subdivide them into pre- and post ~50 Myr ago:

2.1. Shortening after 50 Ma

A detailed examination of shortening based on geological field studies gives an estimate of 600–750 km of N-S shortening since 50 Ma across and north of the Tibetan Plateau (Van Hinsbergen et al., 2011). Across the Himalaya, the total measured shortening since 50 Ma reaches about 500–900 km with a maximum roughly equidistant from the margins of the Indian indentor (Long et al., 2011). Here most of the shortening is after ~25 Ma, but a further amount may have occurred during the earlier (~50 Ma) collision, the details of which have been obscured by intense Miocene metamorphism and deformation. From the foregoing, the total amount of crustal shortening after 50 Ma is between 1000 and 1500 km but the convergence that was accommodated in the same time was considerably more whereby the record of a significant portion of the shortening has been destroyed by later collision in the Himalaya and erosion, alongside wholesale subduction of lithosphere without accretion.

2.2. Crustal shortening before 50 Ma

Across the Lhasa and Qiangtang terranes, Kapp et al. (2005) estimate a shortening of more than 470 km over a distance of 473 km (a 50% shortening) which is mostly prior to the Indo-Asian collision. Volkmer et al. (2007) estimate a 54% shortening in a region within the Lhasa terrane, not explicitly covered by Kapp et al., during the late Cretaceous-Paleocene, where shortening started at 131 Ma (U–Pb) and lasted until about 56 Ma (Ar–Ar). Therefore, two independent studies endorse a minimum 50% shortening across the Qiangtang and Lhasa terranes before the Indo-Asian collision. Given the combined width of the two terranes at about 750 km, the total shortening may be about 750 km. Fifty percent shortening during accretion has been documented elsewhere; for example, over the last 6 Ma as a result of the Yakutuk terrane collision in Alaska (Meigs et al., 2008).

Therefore the total intra-continental crustal shortening across the Indo-Asian orogen since the last ~130 Myr is at least 1700 km and could be more than 2200 km. The shortening estimate does not include any across (1) the Himalaya prior to the Miocene, (2) the ~180 Ma Songpan Garzi terrane (the Paleotethys suture zone, Fig. 1) and (3) the Jurassic Mongol-Okhotsk orogen north of the region