Earth and Planetary Science Letters 415 (2015) 25–37

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

The Brahmaputra tale of tectonics and erosion: Early Miocene river capture in the Eastern Himalaya

Laura Bracciali [a,b,*], Yani Najman [b], Randall R. Parrish [a,c], Syed H. Akhter [d], Ian Millar [a]

[a] NERC Isotope Geosciences Laboratory, British Geological Survey, Keyworth, Nottingham, United Kingdom
[b] Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom
[c] Department of Geology, University of Leicester, Leicester, United Kingdom
[d] Department of Geology, University of Dhaka, Dhaka, Bangladesh

ARTICLE INFO

Article history:
Received 25 September 2014
Received in revised form 18 January 2015
Accepted 20 January 2015
Available online 6 February 2015
Editor: A. Yin

Keywords:
Brahmaputra
Yarlung Tsangpo
Eastern Himalaya
river capture
U–Pb chronology
rutile

ABSTRACT

The Himalayan orogen provides a type example on which a number of models of the causes and consequences of crustal deformation are based and it has been suggested that it is the site of a variety of feedbacks between tectonics and erosion. Within the broader orogen, fluvial drainages partly reflect surface uplift, different climatic zones and a response to crustal deformation. In the eastern Himalaya, the unusual drainage configuration of the Yarlung Tsangpo–Brahmaputra River has been interpreted either as antecedent drainage distorted by the India–Asia collision (and as such applied as a passive strain marker of lateral extrusion), latest Neogene tectonically-induced river capture, or glacial damming-induced river diversion events.

Here we apply a multi-technique approach to the Neogene paleo-Brahmaputra deposits of the Surma Basin (Bengal Basin, Bangladesh) to test the long-debated occurrence and timing of river capture of the Yarlung Tsangpo by the Brahmaputra River. We provide U–Pb detrital zircon and rutile, isotopic (Sr–Nd and Hf) and petrographic evidence consistent with river capture of the Yarlung Tsangpo by the Brahmaputra River in the Early Miocene. We document influx of Cretaceous–Paleogene zircons in Early Miocene sediments of the paleo-Brahmaputra River that we interpret as first influx of material from the Asian plate (Transhimalayan arc) indicative of Yarlung Tsangpo contribution. Prior to capture, the predominantly Precambrian–Paleozoic zircons indicate that only the Indian plate was drained. Contemporaneous with Transhimalayan influx reflecting the river capture, we record arrival of detrital material affected by Cenozoic metamorphism, as indicated by rutiles and zircons with Cenozoic U–Pb ages and an increase in metamorphic grade of detritus as recorded by petrography. We interpret this as due to a progressively increasing contribution from the erosion of the metamorphosed core of the orogen. Whole rock Sr–Nd isotopic data from the same samples provide further support to this interpretation. River capture may have been caused by a change in relative base level due to uplift of the Tibetan plateau. Assuming such river capture occurred via the Siang River in the Early Miocene, we refute the "tectonic aneurysm" model of tectonic–erosion coupling between river capture and rapid exhumation of the eastern syntaxis, since a time interval of at least 10 Ma between these two events is now demonstrated. This work is also the first to highlight U–Pb dating on detrital rutile as a powerful approach in provenance studies in the Himalaya in combination with zircon U–Pb chronology.

1. Introduction

Studies of crustal-scale orogenic systems provide important insights into processes of intra-continental deformation and the dynamic links between continental tectonics, surface processes, climate feedbacks and the biosphere on a global scale. The extent, rate and timing of erosion influence the metamorphic and structural evolution of mountain belts (England and Richardson, 1977; Beaumont et al., 1992; Willett et al., 1993), as well as influencing their exhumation pattern and rate (e.g. Beaumont et al., 2001; Zeitler et al., 2001a; Robl et al., 2008). In this context, the investigation of fluvial drainage evolution provides a key to understanding tectonic–erosion interactions. Importantly, the reorganisation of drainage systems can also heavily affect the nature, magnitude and

* Corresponding author at: NERC Isotope Geosciences Laboratory, British Geological Survey, Keyworth, Nottingham, United Kingdom.
E-mail addresses: laurabrac74@gmail.com (L. Bracciali), y.najman@lancaster.ac.uk (Y. Najman), rrp@bgs.ac.uk (R.R. Parrish), shakhter@univdhaka.edu (S.H. Akhter), ilm@bgs.ac.uk (I. Millar).

http://dx.doi.org/10.1016/j.epsl.2015.01.022
0012-821X/

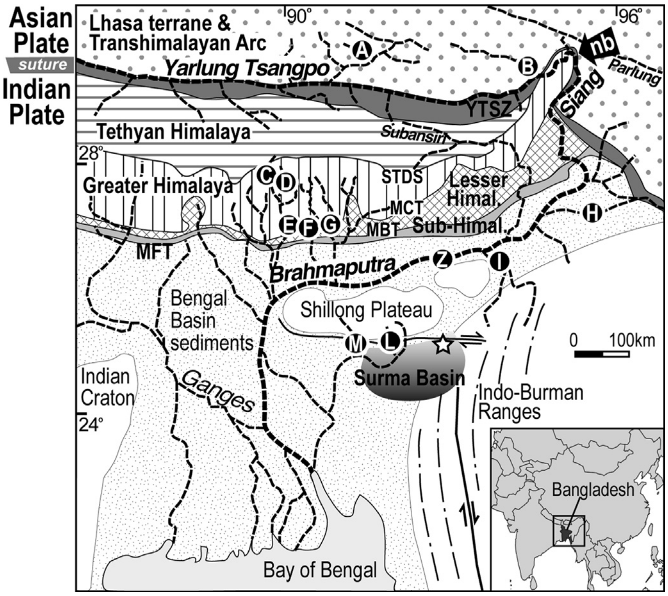

Fig. 1. Major fluvial drainages of the Eastern Himalayan region superimposed on a schematic geological map (Najman, 2006). Location of the represented region in Eastern Asia is shown in inset. Yarlung Tsangpo Suture Zone (YTSZ) separates Asian (Lhasa terrane and the Transhimalayan Arc) from Indian plate (Tethyan, Greater, Lesser and Sub-Himalaya). nb: Namche Barwa massif and site of the proposed capture; STDS: South Tibetan Detachment System; MCT, MBT, MFT: Main Central, Boundary and Frontal Thrusts. Sand sampling locations along modern rivers: A: Lhasa River tributary; B: Niyang; C: Mo Chu; D: Pho Chu; E: Puna Tsang Chu; F: Mangdi Chu; G: Mau Khola; H: Burhi Dihing; I: Dhansiri; Z: Brahmaputra; L: Dauki; M: Jadhu Kata. Star in Surma Basin indicates location of sampling area (see Supplemental Fig. S1 for further details).

spatial distribution of sediment supply to sedimentary basins by significantly changing the size of the hinterland catchment area.

In the eastern Himalaya, assessment of paleodrainage networks has been used to document crustal strain (Hallet and Molnar, 2001) and surface uplift (Clark et al., 2004; Stüwe et al., 2008). In this region the modern Yarlung Tsangpo River, one of the main rivers of Asia, flows east along the suture zone which separates the Indian plate in the south from the Asian plate to the north, then crosses the Namche Barwa massif of the eastern Himalayan syntaxis where it bends sharply south, traverses to the Himalaya as the Siang River and finally flows to the Bengal plains as the Brahmaputra River (Fig. 1).

Considerable debate has existed as to whether the Yarlung Tsangpo–Brahmaputra paleodrainage: (i) having maintained its current routing without river capture was antecedent to Himalayan orogenesis (Harrison et al., 1992 and references therein); (ii) was antecedent to the development of the Namche Barwa syntaxis (that occurred <4 Ma according to Seward and Burg, 2008; see also Lang and Huntington, 2014); or (iii) whether the Yarlung Tsangpo originally flowed southeast and eventually connected to the Brahmaputra via one or more capture events (e.g. Seeber and Gornitz, 1983; Brookfield, 1998; Clark et al., 2004; Cina et al., 2009; Chirouze et al., 2012a). Some authors have even suggested that the Yarlung Tsangpo may have reversed its flow (Burrard and Hayden, 1907; Cina et al., 2009).

In this paper we use the term *river capture* (also known as *river piracy*) to indicate the type of drainage rearrangement (i.e. transfer of a river's flow to another river) that occurs with the interception of a river by an adjacent river which is experiencing aggressive headward erosion (Bishop, 1995). The point at which river capture is considered to have occurred is taken to be indicated by a sharp change in channel direction, known as the elbow of capture, and implies capture of both the catchment area and the drainage lines (the drainage network) above the elbow. Considerably lower elevation of the capturing stream is essential to provide the steep headwater gradients necessary for stream piracy. The other two types of drainage reorganisation (Bishop, 1995) are *river diversion* (redirection of drainage into an adjacent catchment by a range of mechanisms of divide breaching, including channel migration, tectonic processes such as tilting or doming, or catastrophic avulsion by high magnitude water flows) and *river beheading* (the appropriation of a river's catchment area to an adjacent river without preservation of the appropriated catchment's area drainage lines that results, for example, in truncated valleys hanging in the escarpment as a result of escarpment retreat).

The river capture of the Yarlung Tsangpo by the Brahmaputra has been cited as the cause of the recent rapid exhumation and young metamorphism of the Namche Barwa syntaxis (the proposed site of capture, Fig. 1), and is thought to be an example of tectonic–erosion coupling (Zeitler et al., 2001b). However, independent tests of the occurrence and timing of river capture are sparse and a general consensus has not been reached. Seeber and Gornitz (1983), although arguing for a general antecedence of the Himalayan rivers with respect to the Himalayan topography, did not rule out a possible capture of an ancestral Yarlung Tsangpo–Lohit River by the Brahmaputra. Brookfield (1998) suggested that an ancestral Tsangpo–Irrawaddy was truncated by headward erosion from the Brahmaputra not earlier than the Late Miocene. According to Zeitler et al. (2001b) the rapid fluvial incision likely following capture of the Yarlung Tsangpo by the Brahmaputra caused the very rapid recent exhumation of the Indian plate metamorphic rocks of the Namche Barwa syntaxis during the Plio-Pleistocene. Clark et al. (2004) suggested that the Yarlung Tsangpo was sequentially captured by the paleo-Red, Irrawaddy and Lohit Rivers, before its final capture by the Brahmaputra occurred prior to 4 Ma, based on the proposed age of the localised uplift of the Namche Barwa syntaxis, whilst Seward and Burg (2008) argued for the existence of an antecedent Yarlung Tsangpo–Brahmaputra drainage probably since ∼20 Ma.

Cina et al. (2009) and Chirouze et al. (2012a) observe Transhimalayan arc provenance in the Siwalik foreland basin south-west of the syntaxis by 7 Ma while Lang and Huntington (2014) possibly by 13 Ma (based on the correlation to the dated Siwaliks section of Chirouze et al., 2012b). Each of the three studies speculates on alternative scenarios for the evolution of the Yarlung Tsangpo, requiring either a transverse river (such as the Kameng or Subansiri) or a paleo-Yarlung Tsangpo–Brahmaputra (antecedent according to Lang and Huntington, 2014 or not antecedent according to Cina et al., 2009 to the growth of the Namche Barwa syntaxis) to deliver Transhimalayan Arc-derived detritus to the Siwalik foreland basin. These models are further discussed at the end of Section 5.

We have applied a multi-disciplinary approach (including whole rock petrographic and isotopic data and detrital single grain U–Pb dating) to the paleo-Brahmaputra sedimentary record preserved in the northern Bengal Basin (Surma Basin, Fig. 1) in order to constrain the paleodrainage evolution of the Brahmaputra. In particular we address whether capture of the Yarlung Tsangpo occurred and if so when this happened. Finally, we interpret our results in the wider context of regional Himalayan tectonic events.

2. Geology of the modern-day Yarlung Tsangpo–Brahmaputra catchment

The Ganges and Yarlung Tsangpo–Brahmaputra rivers drain the Himalaya and converge in Bangladesh to form one of the world's largest sub-aerial fluvio-deltaic systems (the present-day Bengal Basin, Fig. 1) and the world's largest submarine fan system (the Bengal Fan). The Yarlung Tsangpo originates in Tibet and flows eastwards along the Indus–Tsangpo Suture Zone that separates the Indian plate from the Asian Plate (Fig. 1; see Hodges, 2000;