Available online at www.sciencedirect.com
ScienceDirect
Tectonophysics 451 (2008) 225–241
TECTONOPHYSICS
www.elsevier.com/locate/tecto

Tethyan and Indian subduction viewed from the Himalayan high- to ultrahigh-pressure metamorphic rocks

S. Guillot [a,*], G. Mahéo [b], J. de Sigoyer [c], K.H. Hattori [d], A. Pêcher [a]

[a] *University of Grenoble, LGCA, OSUG, BP53, 38041 Grenoble cedex 9, France*
[b] *Laboratoire de Sciences de la Terre, UCB & ENSLyon, 69622 Villeurbanne, France*
[c] *Laboratoire de Géologie, ENS,75231 Paris cedex 05, France*
[d] *Department of Earth Sciences, University of Ottawa, Ottawa, Ontario, K1N 6N5 Canada*

Received 15 October 2007; accepted 6 November 2007
Available online 15 December 2007

Abstract

The Himalayan range is one of the best documented continent-collisional belts and provides a natural laboratory for studying subduction processes. High-pressure and ultrahigh-pressure rocks with origins in a variety of protoliths occur in various settings: accretionary wedge, oceanic subduction zone, subducted continental margin and continental collisional zone. Ages and locations of these high-pressure and ultrahigh-pressure rocks along the Himalayan belt allow us to evaluate the evolution of this major convergent zone.

(1) Cretaceous (80–100 Ma) blueschists and possibly amphibolites in the Indus Tsangpo Suture zone represent an accretionary wedge developed during the northward subduction of the Tethys Ocean beneath the Asian margin. Their exhumation occurred during the subduction of the Tethys prior to the collision between the Indian and Asian continents.

(2) Eclogitic rocks with unknown age are reported at one location in the Indus Tsangpo Suture zone, east of the Nanga Parbat syntaxis. They may represent subducted Tethyan oceanic lithosphere.

(3) Ultrahigh-pressure rocks on both sides of the western syntaxis (Kaghan and Tso Morari massifs) formed during the early stage of subduction/exhumation of the Indian northern margin at the time of the Paleocene–Eocene boundary.

(4) Granulitized eclogites in the Lesser Himalaya Sequence in southern Tibet formed during the Paleogene underthrusting of the Indian margin beneath southern Tibet, and were exhumed in the Miocene.

These metamorphic rocks provide important constraints on the geometry and evolution of the India–Asia convergent zone during the closure of the Tethys Ocean. The timing of the ultrahigh-pressure metamorphism in the Tso Morari massif indicates that the initial contact between the Indian and Asian continents likely occurred in the western syntaxis at 57±1 Ma. West of the western syntaxis, the Higher Himalayan Crystallines were thinned. Rocks equivalent to the Lesser Himalayan Sequence are present north of the Main Central Thrust. Moreover, the pressure metamorphism in the Kaghan massif in the western part of the syntaxis took place later, 7 m.y. after the metamorphism in the eastern part, suggesting that the geometry of the initial contact between the Indian and Asian continents was not linear. The northern edge of the Indian continent in the western part was 300 to 350 km farther south than the area east of the Nanga Parbat syntaxis. Such “en baionnette” geometry is probably produced by north-trending transform faults that initially formed during the Late Paleozoic to Cretaceous Gondwana rifting. Farther east in the southern Tibet, the collision occurred before 50.6±0.2 Ma. Finally, high-pressure to ultrahigh-pressure rocks in the western Himalaya formed and exhumed in steep subduction compared to what is now shown in tomographic images and seismologic data.

Keywords: Himalaya; HP-UHP metamorphic rocks; Subduction; India–Asia collision

1. Introduction

Since the first petrological description of eclogites by Haüy (1822), eclogites have been reported from many locations with

* Corresponding author. Laboratoire de Géodynamique des Chaînes Alpines, OSUG-UJF, 1381 rue de la Piscine, BP 53, 38041 Grenoble cedex 9, France. Fax: +33 476 51 40 58.
E-mail address: sguillot@ujf-grenoble.fr (S. Guillot).

0040-1951/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2007.11.059

ages ranging from Proterozoic to Phanerozic (e.g. Godard, 2001 for review). Such high-pressure (HP) low-temperature (LT) metamorphic rocks (blueschist and eclogite facies rocks) in orogenic belts provide valuable information related to subduction processes of oceanic lithosphere (Coleman, 1971; Ernst, 1973). The occurrences of pelitic rocks and continental rocks metamorphosed under eclogite facies conditions suggest that they are subducted and later exhumed (Compagnoni, 1977; Carswell, 1990). The discovery of coesite in pyrope-bearing quartzites in the Alps (Chopin, 1984) introduced the term ultrahigh-pressure (UHP) metamorphism and demonstrated that continental rocks can be subducted at a depth greater than 100–120 km. Consequently, characterization of HP to UHP rocks is important for better understanding of paleogeodynamic evolution of convergent zones. This paper focuses on Himalayan eclogites and blueschists derived from the Tethyan oceanic crust and the margin of the Indian continent metamorphosed under eclogite facies conditions, described as group B and C, respectively, by Coleman et al. (1965). Their studies, in terms of origin, metamorphic evolution, and timing of exhumation, give us important constraints on the dynamics of the India–Asia convergence.

Argand (1924) and later Gansser (1964) described the Himalayan range as a continent–continent-collision belt. By the 1970's, researchers demonstrated that the Himalayan collision resulted from the closure of the Tethyan Ocean through the subduction of the oceanic lithosphere (Desio, 1977; Sengör, 1979). Although, HP rocks have been reported in the Alpine belt as early as 1822 by Hauÿ, subduction related metamorphic rocks in the Himalaya only started to be recognized in the early 20th Century. Hayden (1904) and Berthelsen (1953) described garnet-bearing mafic rocks in the Tso Morari gneiss in eastern Ladakh, India. Because the plate tectonic theory had not been widely accepted, the significance of their work was not recognized until the 1980's. The first modern descriptions of blueschists in the Himalaya were carried out by Shams (1972) and Desio (1977) in Pakistan along the Main Mantle Thrust (MMT) and by Franck et al. (1977) and Virdi et al. (1977) in Ladakh India along the Indus Tsangpo Suture zone (ITSZ). Eclogites were first reported by Chaudhry and Ghazanfar (1987) in the Kaghan valley, and UHP coesite-bearing eclogites were first described in 1998 in the same area (O'Brien et al., 1999). All these rocks have been observed in or near the India–Asia suture zone, Main Mantle Thrust (MMT) in Pakistan or Indus Tsangpo Suture zone (ITSZ) in India and China. In addition, Lombardo and Rolfo (2000) reported the occurrence of retrogressed eclogites in southern Tibet, about 200 km south of the ITSZ. The discovery raised the question of the distribution and preservation of HP and UHP rocks. Relatively rare findings of HP to UHP rocks in the Himalaya compared to the Alpine belt are not only related to the difficulty in access but also the intense activity of collision and erosion that probably obliterated such rocks.

This paper reviews the occurrences of HP to UHP along the Himalaya belt, and discusses, in the light of their metamorphic evolution, the initial history and geometry of the India–Asia convergent zone prior to and during the collision.

2. High-pressure and ultrahigh-pressure rocks in the Himalaya

The tectonostratigraphy of the internal part of the Himalaya is briefly reviewed here in order to understand the significance of eclogitic rocks formed from the Indian plate. From the Nanga Parbat spur in the west and Namche Barwa spur in the east, the 2400 km long Himalayan belt is classically divided into juxtaposed zones (Fig. 1). The westward extension of the Main Central Thrust (MCT) and the Higher (or Greater) Himalayan Crystallines (HHC) in Pakistan remain controversial (e.g., Di Pietro and Pogue, 2004), thus a major boundary east of the Nanga Parbat syntaxis separates the central-east Himalaya from the western Himalaya (Fig. 1).

South of the ITSZ, the central Himalaya is divided into five main zones: the Sub-Himalaya, the Lesser Himalayan Sequence (LHS) between the Main Boundary Thrust (MBT) and the MCT, the HHC between the MCT and the South Tibetan Detachment (STD), the Tethys Himalaya and the North Himalayan massifs (Yin et al., 1999; Hodges, 2000; DeCelles et al., 2000).

The LHS is mostly a thick (>10 km) succession of Early to middle Proterozoic low grade metasedimentary rocks locally crosscut by mafic and felsic intrusion. Augen gneisses in the metasedimentary rocks show U/Pb zircon ages of ca. 1850 Ma (e.g. Le Fort, 1989). Detrital zircon ages in the LHS range between 2.6 and 1.8 Ga, suggesting that they derived from Late Archean to Early Proterozoic rocks in the Indian continent (DeCelles et al., 2000; Richards et al., 2005; Robinson et al., 2006). Permian and Paleocene sedimentary rocks of the Gondwana sequence and foreland basin sequence overlie the LHS (Fig. 3a) (Sakai, 1989). The HHC thrust southward above the underlying LHS along the MCT. The HHC consists of metasedimentary rocks dominantly younger than 800 Ma. Detrital zircons from these metasedimentary rocks yield ages of 800 to 1700 Ma and the augen gneisses generally located at the top of the HHC give ages ranging between 500 and 480 Ma (Le Fort et al., 1986; Parrish and Hodges, 1996; Robinson et al., 2001; 2006; Richards et al., 2005). The HHC experienced Barrovian metamorphism and igneous intrusion during the Neoproterozoic to Cambrian Pan-African event, along the tectonically active northern margin of Gondwana; the MCT could correspond to an Early Paleozoic suture zone (Manickavasagam et al., 1999; DeCelles et al., 2000; Marquer et al., 2000).

North of the HHC, the Tethys Himalaya is separated from the HHC by the STD but the two were originally in stratigraphical continuity (e.g. Colchen et al., 1986; Garzanti et al., 1986). The marine sedimentary rocks of the Tethys Himalaya deposited on the Indian continental margin from the Ordovician to the Paleocene (Garzanti et al., 1986). The Tethys Himalaya sedimentary rocks are also characterized by abundant mafic lenses intercalated in the sedimentary sequence, corresponding to transposed dykes and sills. These mafic rocks are related to Carboniferous and Permian rifting (Garzanti, 1999) and are lateral equivalents of the Panjal Trap, which is abundant in Pakistan and Kashmir (e.g. Papritz and Rey, 1989).