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Journal of Asian Earth Sciences 30 (2007) 113–130
Journal of Asian Earth Sciences
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# Temperature and age constraints on the metamorphism of the Tethyan Himalaya in Central Nepal: A multidisciplinary approach

C. Crouzet [a], I. Dunkl [b,c,*], L. Paudel [d], P. Árkai [c], T.M. Rainer [e], K. Balogh [f], E. Appel [a]

[a] Institut für Geowissenschaften, Universität Tübingen, Sigwartstrasse 10, D-72076 Tübingen, Germany
[b] Sedimentology and Environmental Geology/GZG, University of Göttingen Goldschmidtstrasse 3, D-37077 Göttingen, Germany
[c] Institute for Geochemical Research, Budaörsi út 45, H-1112 Budapest, Hungary
[d] Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal
[e] Montanuniversität Leoben, Institut für Geowissenschaften Peter Tunner Strasse 5, A-8700 Leoben, Austria
[f] Institute of Nuclear Research, Hungarian Academy of Science, Bem tér 18/c, H-4026 Debrecen, Hungary

Received 4 January 2006; received in revised form 10 July 2006; accepted 17 July 2006

**Abstract**

Metasediments of Devonian to Triassic age of the Tethyan Himalaya (TH) from several areas in central and western Nepal, between western Dolpo and Marsyandi Valley, were sampled for thermo-metamorphic studies (illite and chlorite "crystallinity", vitrinite reflectance, calcite–dolomite and chlorite-chloritoid geothermometers, K/Ar dating on illite-rich fractions and zircon fission track thermochronology). This paper reports, for the first time, the occurrence of chloritoid in the TH out of the range of granite contact aureoles. It also presents the first zircon fission track dating performed on TH metasediments. The peak temperatures of metamorphism have been around 250–300 °C, 320–350 °C, 330–370 °C and 400–450 °C in the western Dolpo, Hidden Valley, Manang and Marpha areas, respectively. In the Manang and Hidden Valley areas, illite K/Ar data are interpreted as ages of recrystallized K-white micas newly formed during metamorphism at around 25–30 Ma. In the Marpha area, illite K/Ar and zircon fission-track ages (12–15 Ma) are consistent representing cooling ages after metamorphic overprinting of higher grade than in the other areas. The joint investigation of the organic maturation and zircon FT chronology yields insight on the thermal calibration of zircon reset. The $R_{max}$ of 5.7% to ~8.0% indicates a temperature range of ca. 315–325 °C which is in the partial annealing zone of the zircon FT thermochronometer. Our results might be explained by the presence of a thick thrust sheet once existing above the study area.


*Keywords:* Tethyan Himalaya; Geochronology; Geothermometry; Illite "crystallinity"; Kübler index; Chlorite "crystallinity"; Vitrinite reflectance; K/Ar; Fission track

## 1. Introduction

The interest in the thermal history of sedimentary rocks has rapidly grown since the sixties especially in order to predict the timing of oil generation (for review see e.g. Mac Culloh and Naeser, 1989). The transition between diagenesis and low-grade metamorphism can be approached using several methods such as illite Kübler index ("crystallinity", KI), vitrinite reflectance (VR), conodont colour alteration, fluid inclusions, fission track (FT) thermochronology and clay mineral and zeolite assemblages.

In the Tethyan Himalaya (TH) of central Nepal, most of the previous thermo-metamorphic studies have focused on (1) the granitic bodies and their contact aureole in order to understand their genetics and emplacement mechanisms (see for example Guillot et al., 1995, 1999) and on (2) the relationships between the High Himalayan Crystalline (HHC) and the lower part of the TH (i.e., Godin et al., 1999a; Searle and Godin, 2003). Apart from the studies of Schneider and Masch (1993), Garzanti et al. (1994) and Bollinger et al. (2004), the pressure–temperature–time

* Corresponding author. Tel.: +49 551 39 79 21; fax: +49 551 39 79 96.
*E-mail address:* istvan.dunkl@geo.uni-goettingen.de (I. Dunkl).

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doi:10.1016/j.jseaes.2006.07.014

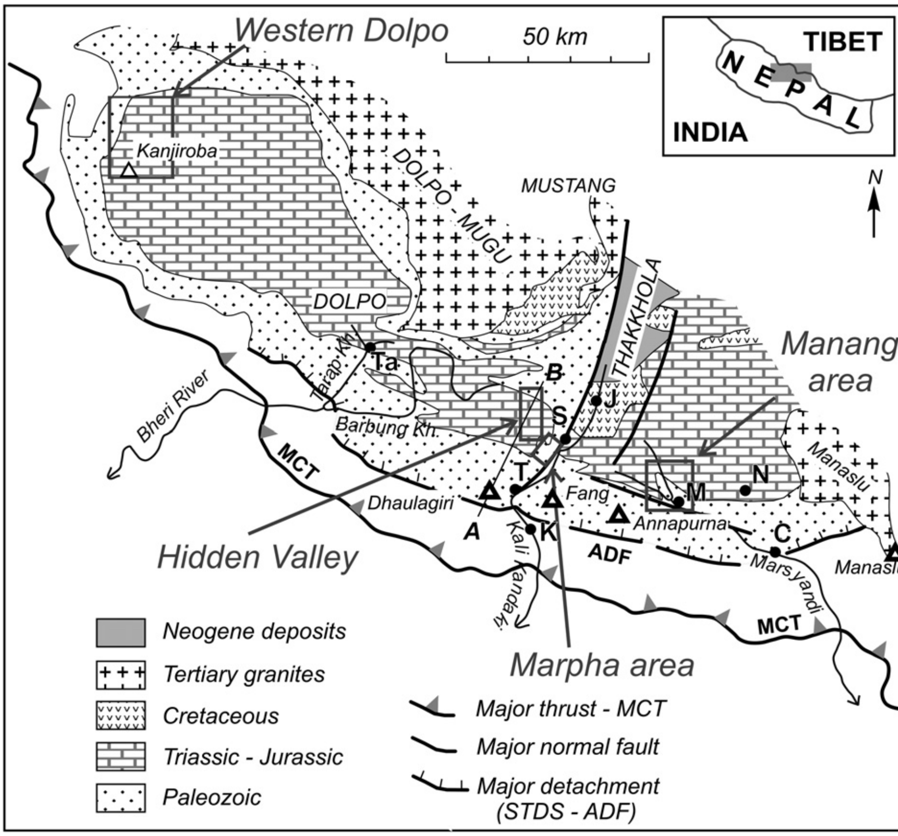


Fig. 1. Simplified geological map of the central Himalaya showing sampling areas (map after Garzanti et al., 1994). MCT: Main Central Trust, STDS: South Tibetan Detachment System (including Annapurna Detachment Fault: ADF). (A–B) location of the cross-section in Fig. 2. K, Kalopani; T, Tukuche; S, Syang; J, Jomosom; M, Manang; C, Chame; N, Nar; Ta, Tarap.

regime of the Himalayan orogeny (upper diagenesis to greenschist facies metamorphism) is still poorly constrained mainly due to the absence of indicative mineralogical assemblages.

The present paper includes analyses of KI, VR, carbonates and chlorite-chloritoid geothermometers, FT thermochronology and K/Ar dating on different grain size of illite–muscovite fractions. Samples from western Dolpo, Hidden Valley, Marpha (western margin of the Thakkhola Graben) and Manang area were studied (Fig. 1). Our multidisciplinary approach improves the knowledge on the metamorphic conditions in different parts of the TH of Nepal and contributes to a better understanding of the validity of the different methods used in low-grade metamorphism.

## 2. Geological setting

Across its 250–320 km width between the Indus-Tsangpo suture and the Gangetic plain, the 2500 km long Himalayan range is traditionally separated into five major tectono-metamorphic units. These are, from north to south, the Indus-Yarlung suture zone (IYSZ) representing the boundary between the Eurasian and Indian plates, the Tethyan Himalaya (TH), the High Himalayan Crystalline (HHC) thrusting over the Lesser Himalaya, and the Siwaliks (Gansser, 1964; Le Fort, 1975, 1996; Yin and Harrison, 2000; DiPietro and Pogue, 2004). The TH is considered as the stratigraphic cover of the HHC comprising a continuous sedimentary sequence ranging from Cambro-Ordovician to Early Cretaceous in central and western Nepal (Bodenhausen et al., 1964; Bordet et al., 1971; Fuchs, 1977; Bassoulet and Mouterde, 1977; Garzanti and Pagni Frette, 1991; Garzanti, 1999). It is generally interpreted as shelf sediments deposited on the passive northern margin of the Indian Plate (Bassoullet et al., 1980; Brookfield, 1993). An important feature in TH is the North Himalayan antiform, which is widely intruded by granitic bodies. Its southern wedge is underlined by the Kangmar thrust while it is bound to the north by the IYSZ (Burg et al., 1984; Zhang et al., 2004). To the south, the TH is often separated from the metamorphic basement of the HHC by north dipping normal faults which constitute the South Tibetan Detachment System (STDS), first suggested by Caby et al. (1983) and now largely accepted since the work of Burchfield et al. (1992). The high-grade metamorphism of the HHC decreases sharply and quite rapidly from south to north in the TH. In the Kali Gandaki area, the metamorphism reaches lower greenschist facies between Marpha and Syang villages (Garzanti and Pagni Frette, 1991). Southward, the Annapurna detachment juxtaposes psammites of greenschist facies (biotite-muscovite