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Seismotectonics and large earthquake generation in the Himalayan region

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ABSTRACT

Bounded by the western and eastern syntaxes, the Himalayan region has experienced at least five M~8 earthquakes during a seismically very active phase from 1897 through 1952. However, there has been a paucity of M~8 earthquakes since 1952. Examining of various catalogues and seismograms from the Gottingen Observatory, it is established that this quiescence of M~8 earthquakes is real. While it has not been possible to forecast earthquakes, there has been a success in making a medium term forecast of an M 7.3 earthquake in the adjoining Indo-Burmese arc. Similarly we find that in the central Himalayan region, earthquakes of M > 6.5 have been preceded by seismic swarms and quiescences. In the recent past, based on GPS data, estimates have been made of the accumulated strains and it is postulated that a number of M~8 earthquakes are imminent in the Himalayan region. We examine these estimates and find that while earthquakes of M~8 may occur in the region, however, the available GPS data and their interpretation do not necessarily suggest their size and time of occurrence and whether an earthquake in a particular segment will occur sooner in comparison to that in the neighboring segment. We also comment on the inference of occurrence of M~8 earthquakes based on M8 algorithm for the region. We conclude that while an M~8 earthquake could occur any time anywhere in the Himalayan region, there is no indication as of now as to where and when it would occur. We impress on the need for preparedness to mitigate the pending earthquake disaster in the region.

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1. Introduction

The continuing interaction of the India Eurasia continental plates has given rise to the mighty Himalaya and the Tibetan Plateau. It is a classical example of collision tectonics, and attracts scientists to understand the orogenic processes, global climate change and its relation with the erosion and tectonic processes. Geographically, the Himalayan mountain range lies between the eastern and western Himalayan syntaxes. The northern boundary of the Himalayan range is considered at the east-flowing Yarlung Tsangpo and west-flowing Indus River whereas the southern boundary is the Main Frontal Thrust (MFT) that marks the topographic break and also the northern limit of the Indo-Gangetic plains (Yin, 2006). Geologically, the Himalayan region is divided into (1) Outer or Sub-Himalaya (Tertiary strata); (2) Lesser or Lower Himalaya (non-fossiliferous low-grade metamorphic rocks); (3) Greater or Higher Himalaya (crystalline complex consisting of gneisses and aplitic granites); and (4) Tethyan Himalaya (marine, fossiliferous strata). There are four major structural units in the Himalaya, (1) the Main Frontal Thrust (MFT), that lies between the sediments of the Indo-Gangetic plains and Outer Himalaya; (2) the Main Boundary Thrust (MBT), that lies between the Outer and Lesser Himalaya; (3) the Main Central Thrust (MCT), that lies between the Lesser and Higher Himalaya and (4) the South Tibet Detachment (STD) that lies between the Higher and Tethys Himalaya (Fig. 1). The Indus Tsangpo Suture Zone (ITSZ) marks the northern boundary of the Tethys Himalaya (Chatterjee et al., 2013; Hebert et al., 2012). From west to east, the Himalayan region has been divided into the western (Kashmir, Zanskar, Spiti, Himachal, Garhwal Kumaun), central (Nepal, Sikkim and south-central Tibet), and eastern (Bhutan, Arunachal and southeastern Tibet) segments (Thakur, 1992; Yin, 2006).

The Indian plate moves towards northeast at a rate of about 5 cm/year and about 2 cm/year of the convergence between the India and Eurasia is accommodated in the Himalayan region. According to the most acceptable and widely applicable model of underthrusting and earthquake occurrence, the convergence in the Himalaya is accommodated on the detachment (Seeber and Armbruster, 1981). The detachment (also referred as the decollement or the Main Himalayan Thrust, MHT) is the surface between the underthrusting Indian shield rocks and the overlying Himalayan rocks (Fig. 1). The part of the detachment that lies under the Outer and Lesser Himalaya is seismogenic and slips episodically in a stick–slip manner. It accumulates strain during the interseismic period when it is locked, which is released during the infrequent earthquakes through a sudden slip on the detachment. The detachment that lies under the Higher and Tethys Himalaya slips aseismically and does not contribute to strain accumulation. The gently dipping seismic and aseismic parts of the detachment are connected through a mid crustal ramp. In this model, the major thrusts, namely, the MFT, MBT, MCT and STD are assumed to be listric to the detachment. The great thrust earthquakes in the Himalaya occur on the seismogenic detachment under the Outer and Lesser Himalaya, whereas, the small and moderate earthquakes of the Himalayan seismic belt occur on the downdip part of the seismogenic detachment or on the mid-crustal ramp (Seeber and Armbruster, 1981; Ni and Barazangi, 1984; Molnar, 1990; Pandey et al., 1995, 1999; Gahalaut and Kalpna, 2001). A majority of the earthquakes of the Himalayan seismic belt are of the thrust type, with slip vectors perpendicular to the Himalayan arc (Fig. 2). Further north of the Higher

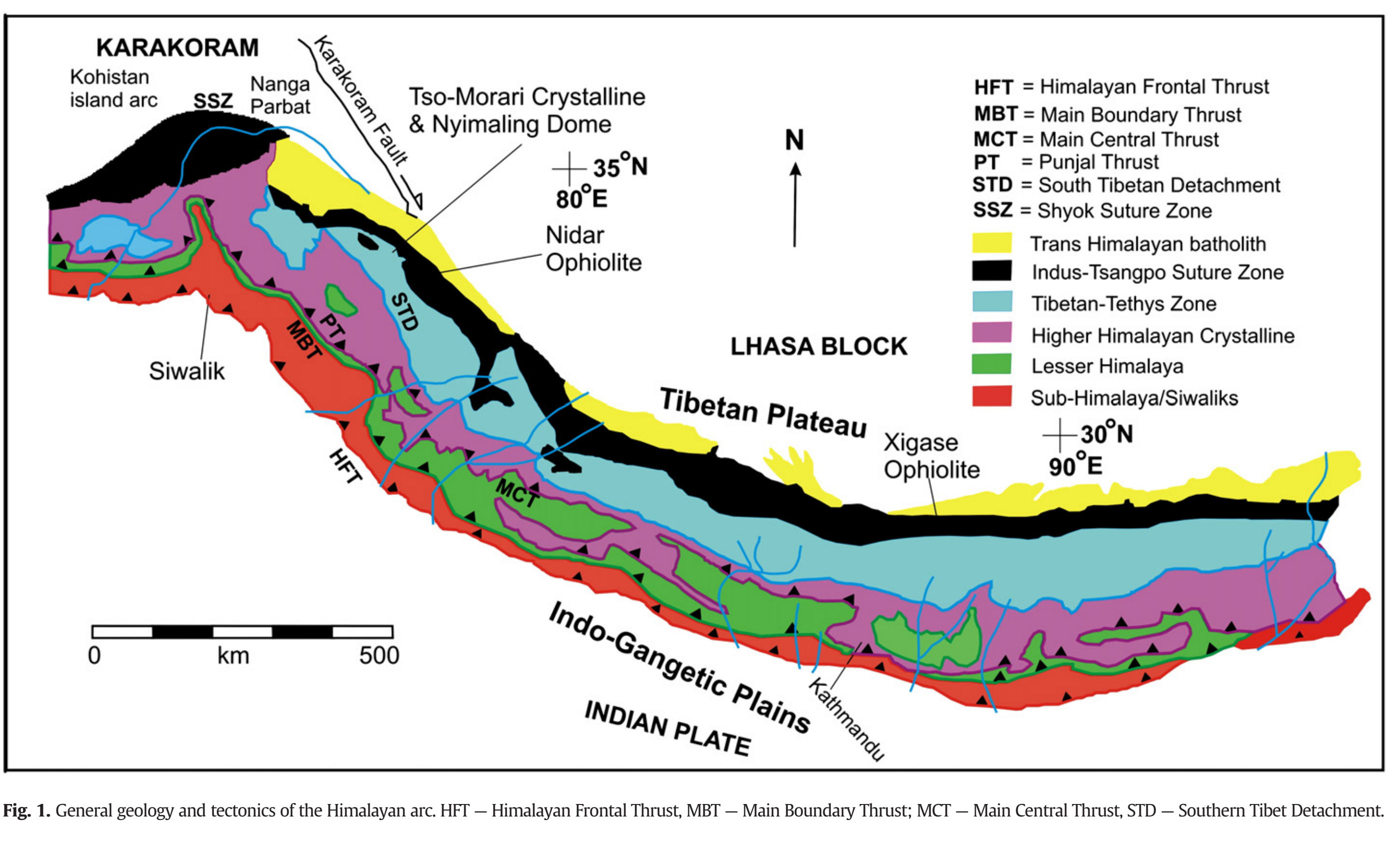

Fig. 1. General geology and tectonics of the Himalayan arc. HFT — Himalayan Frontal Thrust, MBT — Main Boundary Thrust; MCT — Main Central Thrust, STD — Southern Tibet Detachment.