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Transverse faults and block movements in Nepal Himalaya: results from satellite interpretation

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ABSTRACT

The study of aerial photographs and satellite images has revealed the youngest tectonic history of Nepal Himalaya. The nappes and thrust sheets piled up during the Alpinie orogeny are now breaking into smaller blocks and slide aside the northward pushing and subducting Indian Plate. Since the Pleistocene, faults are opening perpendicularly or obliquely to the regional trend, and blocks are moving laterally. Local pressure structures were developed by these movements. There is selective erosion in the regional synclines and anticlines of the Lesser Himalaya. The upper sections of the Higher Himalayan Crystalline and Tibetan Series are generally preserved in depressions on top of the Lesser Himalaya. The Lesser Himalayan rocks themselves are mainly outcrop in the anticlinal areas.

STRUCTURAL OVERVIEW OF NEPAL HIMALAYA

The synoptic view over large areas on satellite images provides general or detailed tectonic structures within different areas of the Himalaya. Some of the images reflect the recent history of the Himalayan mountain building (Hoppe, 1993, 1996).

The Himalaya in Nepal are subdivided into the following tectonic units from south to north: the alluvial Gangetic Plain, the Sub-Himalaya (Siwaliks), the Lesser Himalaya, the Higher Himalaya and the Tethys Himalaya. Also, these tectonic units form in general, the geographical units within Nepal Himalaya (Fig. 1). The boundary between the Gangetic Plain and the Siwaliks is the intra-Siwalik thrust known as the Main Frontal Thrust (MFT). The boundary between the Siwaliks and the Lesser Himalya is formed by the deep rooted Main Boundary Thrust (MBT) and the accompanying small and normal Main Boundary Active Fault (MBAF). The Main Central Thrust (MCT) marks the boundary between the Lesser and the Higher Himalaya. But within the geographical unit of the Lesser Himalaya, large areas of Higher Himalayan Crystalline are thrust over the Lesser Himalayan rock series by the southern continuation of the Main Central Thrust, mainly unnamed or locally called the Mahabharat Thrust (Gansser, 1964; Nakata, 1989).

MBT and MCT are the result of the subduction of the Indian Plate underneath the Eurasian Plate. Other results are block faulting and lateral movements along vertical faults cutting through the Himalayan rock units at a later stage of the nappe movements and still active today.

MAIN TECTONIC FEATURES IDENTIFIED IN SATELLITE IMAGES

Block Faulting Visible on Large Area Meteorological Satellite Data

The National Oceanographic and Atmospheric Administration Television Infrared Observing Satellite (NOAA TIROS-9) with its multispectral Advanced Very High Resolution Radiometer (AVHRR) system provides an overview of Nepal and the surrounding countries in a single image. Despite the low spatial resolution of the image

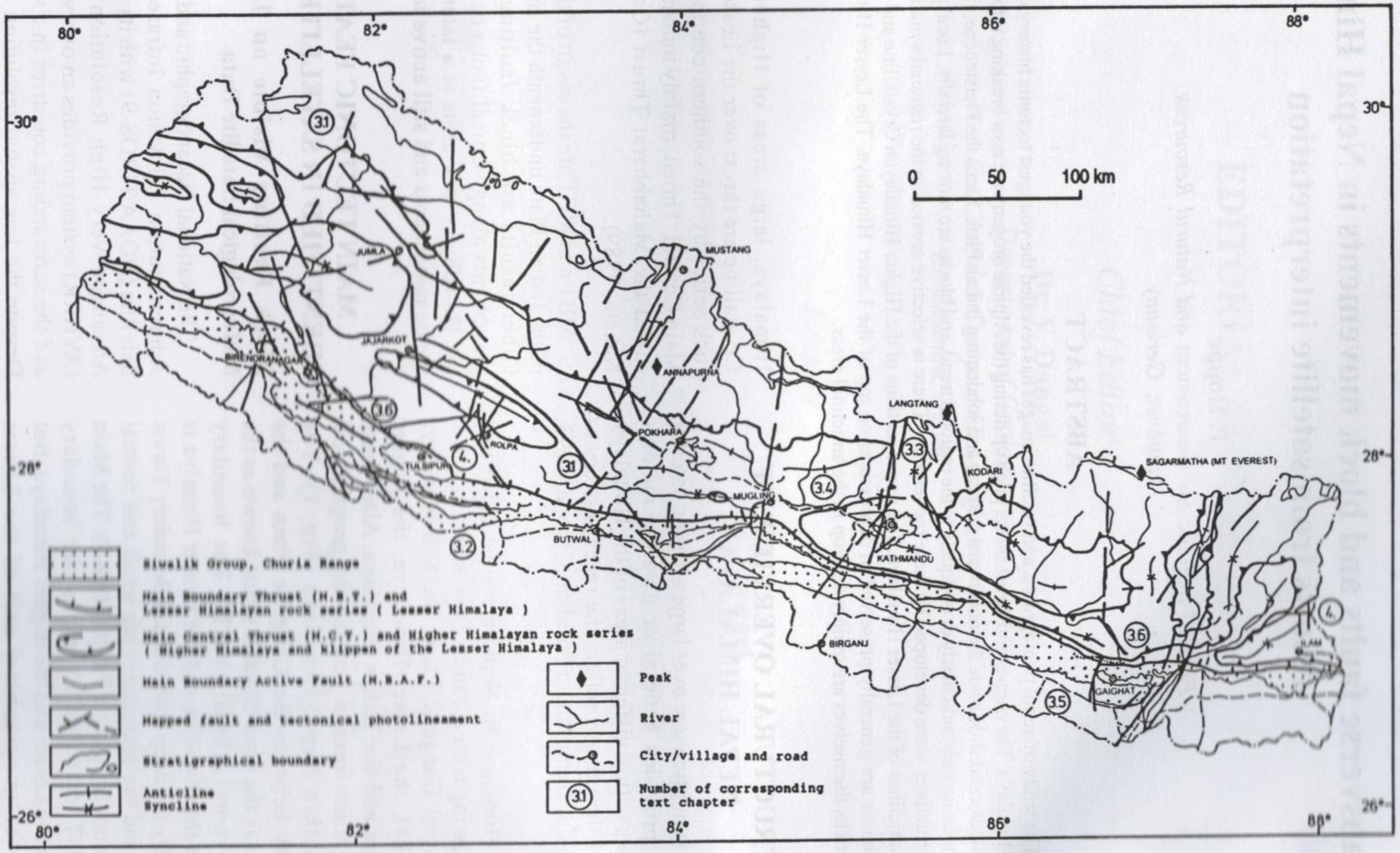

Fig. 1: Schematic tectonic map of Nepal based on the 1:1,000,000 scale Geological map of Nepal (Amatya et al., 1996) and satellite image interpretation.

of approximately 1 km per raster point, the main features of the block faulting are recognisable. To neutralize the pressure of the northward moving Indian subcontinent, the Himalayan rocks are breaking along perpendicular crossing and obliquely passing vertical fault systems. Transverse movements along these faults direct the bigger or smaller blocks straight to the north or laterally to the west and east to compensate the stress. One of these transverse faults is passing in western Nepal from Butwal up to Jajarkot, where the strong earthquakes in 1993 demonstrated its tectonic activity. This prominent fault system continues towards the northwest close to Rara Lake up to the Kali headwaters in Tibet. Towards southeast, the fault system continues along the Narayani-Gandak River down the junction with the Ganges River at Patna, India (Number 3.1 on Fig. 1). The big northern tributaries to the Ganges follow the prominent fault systems crossing the Himalaya as the Sapta Koshi- Kamla River in continuation of the Arun valley fault system in SSW-NNE direction.

Lateral Pressure Features on LANDSAT Images of the Churia Range

During lateral movements of one block along another, indications of local pressure are evident. Remarkable features are shown by the Sub-Himalayan hill chains or Churia Range. These chains have edges due to changes of the strike directions spreading up to the so called Dun valleys in between. At some places, gentle folds with amplitudes of some tens or hundreds of meters and a north-south verging fold axis are crossing perpendicularly the main strike direction of this range close to a vertical block fault. SE of Tulsipur in midwestern Nepal, the cut-off chains of Siwalik rocks are laterally pushed into each other en-echelon over several kilometres (Corvinus, 1993; Number 3.2 on Fig. 1). Most of these features could be traced on several types of satellite images and aerial photographs except the smaller folds indicating pressure at some block boundaries which were detected only during the fieldwork.

The North-South Depression Crossing the Higher and the Lesser Himalaya at Kathmandu

The spurs of more or less north-south directed lineaments visible on LANDSAT images north of Kathmandu in the vicinity of the Main Central Thrust gives an idea of a graben structure crossing the Himalaya similar to the Mustang Valley in western Nepal. In the field, a flexure-like dipping of the Higher Himalayan Crystalline nappe base towards east into the Kathmandu - Langtang depression was observed, accompanied by smaller step - faulting (Number 3.3 on Fig. 1). A field survey from the Kathmandu Valley up to Helambu area tracing three groups of Higher Himalayan gneisses cleared the question of the MCT. The end of the high grade metamorphic Higher Himalayan Crystalline at an east-west trending MCT at the north of Kathmandu does not exist. In the depression, the slightly north and northeast dipping Higher Himalayan Crystalline continues from the north towards the south keeping more or less the same level by antithetic faults. At the northern rim of the Kathmandu Valley, in the Shivapuri Mountains, these gneisses are bending down steeply dipping towards south under the Palaeozoic rock series of the Kathmandu Complex which is comparable with the Tibetan Sedimentary Series of the Higher Himalaya. Therefore, the southern border of the whole complex, the so called Mahabharat Thrust, is the southern end of the overthrusting nappe series and thus part of the MCT.

Vertical Block Movements in South Central Nepal

This downward bending zone at the northern rim of the Kathmandu Valley continues about 100 km further to the west passing through Malekhu and Mugling and crossing obliquely the regional trend. This structure is visible on the LANDSAT images as a broader zone of steeply dipping rock formations. In the field, a flexure zone between the low grade metamorphic Lesser Himalayan series and the partly high grade metamorphic formations of the overthrusting Higher Himalayan series can be observed. The steeply south or overturned north dipping flexure is the border of a bigger block of Higher Himalayan rocks (mostly the upper part of Kathmandu Complex), which was preserved due to its deeper position than the northern flexure (Number 3.4 on Fig. 1). Here, the Lesser Himalayan rocks are outcropped.

Large klippen of the Higher Himalyan Crystalline and Tibetan Series (locally known as the Kathmandu Complex), preserved in wide synclines resting on top of the Lesser Hiamalayan rocks are typical for the whole country. On the contrary, where large anticlines are lifting up, the underlying Lesser Himalayan rock formations are now exposed in large areas. Because of the morphological similarities of the two rock formations of the Lesser and the Higher Himalayas, it is hardly recognizable on the present satellite imagery.

Selective Lateral Movements along Faults

During the preliminary satellite image interpretation for fieldwork in eastern Nepal, it was found that the straight ridges of Siwalik rocks in the Churia Range west of Gaighat are displaced along a dextral, north-south running fault by approximately 10 km. The field work confirmed this interpretation and that also the MBT and the neighbouring Precambrian-Palaeozoic rocks are displaced. The displacement of the MBT of approximately 2 km only at the same fault indicates once more the rigid competence of the deep reaching metamorphic rock pile of the Lesser Himalaya in contrast to the shallow rooted, incompetent sediments of the Churia Range (Number 3.5 on Fig. 1).

The Main Boundary Active Fault

The area west of Gaighat also hosts a special fault in the main strike direction. The spur of this fault forms a small depression lineament along slopes or river terraces. This led to its detection on the aerial photographs and LANDSAT imagery by a dark shadow line running along its southern border. As this north dipping active fault with 30 to 50 m displacement is located sometimes north sometimes south but always close to the MBT, it is called Main Boundary Active Fault (MBAF). The same feature is erroneously described in midwestern Nepal as Main Boundary Fault. This can lead to misunderstanding, since this name is frequently used for the MBT, too. West of Gaighat, the MBAF could be followed on LANDSAT TM images over a distance of approximately 25 km, and in mid-western Nepal east of Birendranagar (Surkhet) over 75 km (Mugnier et al., 1994; Number 3.6 on Fig. 1).

Crosspoints of lineaments with Ore Concentrations

Another important tectonic features detected from LANDSAT TM images were lineaments crossing each other in the star shape areas of a few square kilometers. One area is located in midwestern Nepal around Libang - Rolpa. Another location is in north of Ilam, eastern Nepal, which is additionally connected with distinctly marked circular features. Both areas are known for their placer gold deposits, and exploration for primary gold is carried out there (Tshering, 1972; Number 4 on Fig.1). The intersections of large lineaments are worldwide known as mineralized zones.

CONCLUSIONS

All the tectonic movements depicted from aerial photographs and satellite images show the tectonic evolution of Nepal towards the end of the phase of far reaching overthrusting mainly along the Main Boundary Thrust (MBT) and the Main Central Thrust (MCT). The continuous pressure of the northwards drifting and subducting Indian subcontinent is causing a block faulting within the rigid Himalayan block. Numerous earthquakes at these block boundaries indicate that these zones are tectonically active. The blocks cut off by the vertical faults are also moving laterally along these faults pushed by the Indian subcontinent. In central Nepal, they are pushed towards north along the perpendicularly crosssing faults, whereas in western Nepal towards northwest to the sides along the large transverse faults. Pressure features as folds and smaller thrusts are also connected with these movements.

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