DRAINAGE NETWORK AND SEISMOLOGICAL ANALYSIS OF ACTIVE TECTONICS IN NANGA PARBAT HARAMOSH MASSIF, PAKISTAN

Faisal Shahzad, Syed Amer Mahmood and Richard Gloaguen

Remote Sensing Group, Institute of Geology, Freiberg University of Mining and Technology, Freiberg, Germany
geoquaidian@gmail.com

1. INTRODUCTION

Nanga Parbat Haramosh Massif (NPHM) lies on the western margin of Himalayas, which is one of the most active regions in the world [1]. The devastating earthquakes of 5.3 and 6.2 Mb on 1st and 20th November, 2002 and their aftershock distribution suggest that the area is tectonically active [2]. The stream profile analysis was applied on the extracted drainage network to calculate geomorphic indices [3]. The seismic activity of the area was investigated using focal mechanism solutions (FMS), source characterization and event sequence [4-6]. The anomalous drainage patterns, drainage discontinuities and spatially variable distribution of geomorphic indices were correlated with the seismic activity in the area.

2. STUDY AREA

NPHM is the part of north-western Himalayan Fold and Thrust Belt (NWHFTB)[1] which was produced due to the thrusting of the Indian plate beneath the Eurasian plate during Himalayan orogeny. This massif consists of gneisses and schists with complex fault system. The recent seismic activity lies on an active seismic zone between Sassi and Raikot from north to south and is called as Raikot - Sassi fault zone. This zone consists of complex faults with Raikot and Shahbatot faults as major areas of interest. Indus River flow along this massif in east-west direction and cuts these faults. The drainage pattern of the area is disconnected and linearized at various locations. This massif is characterized by uplift rates of greater than 7mm/yr with high seismicity [1, 2, 7].

3. METHODLOGY

3.1. Drainage Network Analysis

The drainage network of the area was extracted from Shuttle Radar Digital Elevation Models (SRTM 90m DEMs). We used D8 algorithm [8] on each pixel location and then used a least cost algorithm to calculate flow paths. The network consists of extracted streams with elevation and area as function of spatial location. The extracted network is under steady state condition and was analyzed using stream profile analysis. The spatial distribution of geomorphic indices i.e. concavity and steepness indices was prepared using the results from each stream profile. We used steepness index map to prepare a relative uplift rate map of the area [3, 9, 10].

3.2. Seismological Analysis

Seismological analysis is an important tool in tectonic investigations. We compiled an earthquake catalog of the study area using data from USGS, HMT, ISC and local resources. The Focal mechanism Solutions (FMS) were calculated using Beach Ball Calculator (BBC) [6]. The seismicity is observed along all parts of NPHM and especially in Raikot – Sassi fault zone. We identified group of earthquakes with similar orientation using the method proposed by Frohlich [4]. The earthquake sequence pattern with similar orientation was further analyzed using fractal dimension approach [5]. We used box counting method to calculate the fractal dimension [11].

4. RESULTS AND DISCUSSION

Drainage pattern of NPHM is disconnected at different location especially along the active Raikot-Sassi fault zone. The stream profile analysis of Indus River in the massif revealed four different locations of active faults. The spatial distribution of geomorphic indices suggests that the western portion of the massif is more deformed as compare to any other location. We observed variable relative uplift rates of 7 – 13 mm/yr in different locations with higher rates in the area along Raikot fault. The FMS and source characterization suggests that the active faults are mostly strike slip with major thrust component. The lower fractal dimension values suggest that the events have failed to fill up the plane in source zone. The heterogeneous drainage pattern, stream profile analysis and seismological characteristics suggest the active nature of the area. We found that the western portion of the massif is highly deformed and relates to strike slip dominated thrusting.

5. REFERENCES

[1] A. H. Kazmi and M. Q. Jan., *Geology and Tectonics of Pakistan*: Graphic Publishers. Karachi, 1997.

[2] A. A. Khawaja, Monalisa, S. A. S., Q. Z. Chaudhry, M. Rafiq, and A. T. Khan, "Recent Seismic Activity Along the Western Margin of the Nanga Parbat Haramosh Massif, Pakistan," *Islamabad Journal of Sciences*, vol. 13, pp. 18-27, 2003.

[3] F. Shahzad, S. A. Mahmood, and R. Gloaguen, "Stream profile and neotectonics analysis of Hazara Kashmir Syntaxis using shuttle radar digital elevation data," *In 3rd IEEE International conference on emerging technologies, Pakistan*, 2007.

[4] C. Frohlich, "Display and quantitative assessment of distributions of earthquake focal mechanisms," *Geophysical Journal International*, vol. 144, pp. 300-308, 2004.

[5] R. Jain, B. K. Rastogi, and V. P. Dimiri, "Fractal Dimension of the 1999 Chamoli Earthquake from Aftershock Studies in Garhwal Himalaya," *Pure and applied geophysics*, vol. 160, pp. 2329–2341, 2003.

[6] F. Shahzad, "Software development for Fault Plane Solution (FPS) and Isosiesmal Map," in *M.Sc. Thesis, Quaid-i-Azam University*. Islamabad, Pakistan., 2006.

[7] M. P. Searle, M. A. Khan, J. E. Fraser, S. J. Gough, and M. Q. Jan, "The tectonic evolution of the Kohistan-Karakoram collision belt along the Karakoram Highway transect, north Pakistan," *Tectonics*, vol. 18, pp. 929-949, 1999.

[8] J. F. O'Callaghan and D. M. Mark, "The extraction of drainage networks from digital elevation data.," *Computer Vision, Graphics, & Image Processing*, vol. 28, pp. 323-344, 1984.

[9] E. Kirby and K. Whipple, "Quantifying differential rock-uplift rates via stream profile analysis," *Geology*, vol. 29, pp. 415-418, 2001.

[10]C. Wobus, K. Whipple, E. Kirby, N. Snyder, J. Johnson, K. Spyropolou, B. T. Crosby, and D. Sheehan, "Tectonics from topography: Procedures, promise and pitfalls," in Tectonics, Climate and Landscape Evolution, GSA Special Paper 398, 2006.

[11]R. Gloaguen, "Remote sensing analysis of crustal deformation using river networks," presented at IEEE-IGARSS, Boston, 2008.