Ecological consequences of strong earthquakes in the Himalayas

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Abstract

Seismic catastrophes in the Himalayas result from strong earthquakes which take place annually. Rather high seismic activity of the Himalayas is due to tectonic structures and active modern geodynamics of mountainous territory. Seismic hazard exists on the whole territory of the Himalaya, but the possibility of such a hazard is various. The biggest seismic hazard (70–80%) exists along the lines of main deep faults and on the north-west and south-east margins of the Himalayas. Due to the special features of tectonic structure earthquake foci are confined to longitudinal active tectonic zones—Main Boundary Faults and Main Central Thrusts and peripheral areas—“syntaxis” of mountain territory. In XIX century, earthquakes with a magnitude of 8 were registered, and also many others which didn’t cause considerable destructions. Later, in XX century, in 1991 destructive earthquakes were registered in Garhwal Himalaya, during which more than 1000 of people died, 30000 houses were demolished and destroyed within a radius of 60 km. Ecological consequences of catastrophic earthquakes are diverse and result in environment modification. Among direct most significant damages of mountain territory there are geological and geomorphologic, hydrologic and hydrogeological, geophysical, geochemical, atmospheric and biological. The most significant and easily detected transformations result in destruction of plant cover, animal habitats and sometimes even themselves, in disruption of traditional habitats and above-ground migration routes, change of water regime, reallocation of water reserves, deterioration of the quality of forage grasslands and etc.

Keywords: seismic disaster; environmental impact; seismicity; allochton; border fault; transvers divisibility

Seismic catastrophes in the Himalayas result from strong earthquakes which take place annually. Rather high seismic activity of the Himalayas is due to tectonic structures and active modern geodynamics of mountainous territory.

1. Prerequisites of strong earthquakes.

Distinctive features of Alpine structure of Nepal Himalaya are defined by the presence of two huge allochton laminations which are composed of metamorphic complexes of Hindustan craton and are overlaid with their passive continental margin precipitations (Ganser, 1967). The suture line of Indus-Tsangpo is situated in the rear part of this cover-overthrust construction. In the south in front of Hymalayan thrust front, there is the Siwalik complex system of deformations of Indo-Gangetic foredeep inner part: folds, fault wedges, listric overlaps including Main Frontal Fault.

The main features of Alpine geodynamics of the Himalayas are: the division of Hindustan craton edge into the system of tectonic wedges and plates and simultaneous movement of the last ones towards the south, so that zone edges of the Main Central and Main Boundary thrusts in the eastern part of Nepal are separated from each other no more than 4-5 kilometers; the Siwalik formation in form of unique inland accretionary wedge over underthrust of Hindustan subcontinent; folded deformations of allochton plates following the formation of overlapped structure (Geological map of Nepal, 1994).

The newest geodynamics of the Himalayas takes place in Quaternary Sub-Period, when young tectonic movements in the near-surface parts of the earth crust occur after deep erosive denudation sheet of the Alpine structure, especially in West Nepal, where the front part of upper allochton is divided into several big erosion remnants. The deepness of vertical erosion dissection in Nepal Himalaya is the greatest on Earth. Moreover, the Himalayas are situated on the biggest descent of pediment surface on continental land(osculating minimal ground elevations), the elevation changes of which sometimes exceed 4500 m by 200 km. Furthermore, the great part of elevation changes on this descent takes place under the High Himalayas. The existence of this descent should define gravitational instability of mountain structure. (Khain, 1984).

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Structure contour of Nepal Himalaya has transverse and longitudinal division. The transverse division mainly coincides with the one of geological structure and is defined by alternation of transverse extension of narrow structured zones of the Siwalik, the Lower and High Himalayas, Trans-Himalaya (Tibetan Himalayas), rear Indo-Tsangpo suture zone (Figure 1).

The Siwalik anticlines in relief are marked with steeply-sloping uplands and low-mountain ranges with height up to 800m and width to 50 km. Its assembly represents the series of low mountain ridges, which extend to the east to the flowage of the Sun Kosi out of the mountains, where they take turn into narrow gently-sloping pedestal. The cliff of the Lower Himalayas rises behind the Siwalik, which coincides with the exposure of the main Boundary Thrust (Efremov, 2016).

The Lower Himalayas have double formation, including chain of the Mahabharata elevations in the south and complex aggregate of intermontane steps, small troughs and fault-block valleys. They have formed a special middle degradation, the elements of which are the valleys of Kathmandu and Pokhara. Block uplifts and ridge faults of the Mahabharata are usually confined to huge erosion remnants of allochton of the Main Central Fault and to fields of fresh rocks occurrence on the metamorphic complex. In both cases their synclinal formation is observable. As well as the Siwalik, the fault-block mountain chain of the Mahabharata is reduced at the flowage of the Sun Kosi out of the mountains and is completely wedged at 88° east longitude (Ufimtsev, 2005).

The middle degradation in the Himalayas is observed the most in Kathmandu area and in the basin of the river Trishuli, where it represents a complex system of multiple-elevation tectonic levels and small troughs. In the north, the middle degradation borders with particular cambered planes of structure contour, which are referred to as the pedestal of the High Himalayas.
Combined, these planes represent a formation in form of huge monocline, split with transverse faults which are well-defined to the south of Khumbu Himal (Everest).

To the east of the river Arun this convex descent of structure contour, on which the High Himalayas rest, in fact, constitutes all Lower Himalayas, where the difference in elevation on it reaches 3000m and more. The southern boundary of the High Himalayas in the west of Nepal follows the exposure of the Main Central Thrust zone, and to the east of cross aisle of the Trisuli - Bagmati, apparently, it takes shape of its newly-formed branch.

The High Himalayas is a system of block outshots which are situated on a high tectonic level. It is possible that it is formed on proper fault planes (digitations) of the Main Central Thrust which, according to the observations in Khumbu Himal, are often confined to interformational contacts or stratification planes (Geologic – tectonical…, 1980).

The Tibetan Himalayas is a system of cuesta-like blocks and bending folds near the suture line, the central parts of which are made either of Miocene crouan or domes. (Geological map of Nepal. 1994).

The longitudinal division of structure contour of Nepal Himalaya is defined by the presence of submeridional splits, the main ones of which represent lowerings of structure contour, accompanied with elevations of specific triangular shape. These are the passages of the Mustang, Trisuli-Bagmati and Arun, which divide mountain structure into sections different from each other by details of newer structure. The transverse lineaments of the Himalayas extend to the north towards Tibet, where they are connected with rift-related assemblies of troughs.

The newest geodynamics of the Himalayas represents a complex phenomenon. The movement of the hugest crust-mantle block to the north with vertical dimension up to 1500km with excess of density is a background process in it. It is exactly what defines the closure of the Neo-Thetys, overthrust-folding of Hindustan craton outskirts and following newest orogeny of the Himalayas. It also defines the underthrust of Hindustan subcontinent under this mountain structure and the formation of accretionary wedge of the Siwalik.

The continuing tectonic concentration in the Himalayas mainly takes place due to allochthonous plates and wedges movement. In Mahabharata elevations of rock massifs are mostly defined by squeezing-out of synclinal nuclei of erosion remnants of upthrusts into vacant half-space. It is possible that this process takes place mostly due to gravitational gliding of subsurface parts of lithosphere over the sharp descent of mountain pediment surface (Jaros, 1978).

In the High Himalayas and Trans-Himalaya allochton movement of the Main Central Thrust to the south is accompanied by its lateral contraction due to tectonic concentration of monoclinic plates in the formation of passive continental margin. Apparently, in the northern part of the Trans-Himalaya the process of tectonic magmatic transformation of lithosphere has begun and roof uplifts of single crests take place because of buoying of granite massifs and metamorphic nuclei. This points to the fact that the lithosphere of the Himalayas is consolidated near the suture line, at least up to the Conrade discontinuity (Ufimtsev, 2005).

2. Seismic features of the Himalayas.

Because of features of tectonic structure and active newest geodynamics, the Himalayas have undergone multiple earthquakes, among which there have been catastrophic ones. Seismic hazard exists on the whole territory of the Himalayas, but the possibility of such a hazard is various. The biggest seismic hazard (70 -80%) exists along the lines of main deep faults and on the north-west and south-east margins of the Himalayas (Figure 2).
Due to the special features of tectonic structure earthquake foci are confined to longitudinal active tectonic zones—Main Boundary Faults and Main Central Thrusts and peripheral areas—“syntaxis” of mountain territory (Figure 3).

In Historical Records scientists were able to determine some seismic features of single areas of the Himalayas. In chronicles of Tarihi-Kashmir and Tbakati-Abkari, written by medieval Indian and Kashmirian confidants of sultan, it is said about an earthquake of 1505 which shook valley of Srinagar within 200 km. It was a catastrophic earthquake which destroyed towns, caused a death toll of hundreds of people and changed the flowage of the Jhelum.

In XIX century, earthquakes with a magnitude of 8 (measured 7.5 on the Richter scale) were registered, and also many others which didn’t cause considerable destructions. Later, in XX century, in 1991 destructive earthquakes were registered in Garhwal Himalaya, during which more...
than 1000 of people died, 30000 houses were demolished and destroyed within a radius of 60 km (Yury Efremov, 2016).

According to the seismic station readings and on the basis of evidence from areas situated at a respectful distance from epicenter, it is known about Himalayan earthquake of 1950 – the greatest seismic catastrophe happened in the high-mountain part of Tibet near Indo-Chinese border. It was counted that the energy of this earthquake roughly corresponded to explosion energy of 100 atom bombs. According to the stories told by eye-witnesses, terrible hum going from the earth interior turned into thundering crash. Dust rose up and the sky darkened because of it. Near the epicenter no one could remain standing. Even in Kolkata at a distance of more than 1000 km, the population was very scared because of earth shocks.

In Brahmaputra river-valley, which is situated at a distance of more than 100km from the Himalayas, vibrations in subsoil caused qualms of sea-sickness among people. Cars were cast away at an 800 m distance, railroad tracks section of 300 m length lowered almost by 5 m, and the road bed was completely destroyed.

Annually more than 1000 earthquakes with magnitude of 2 to 5 on the Richter Scale are registered in Nepal. It is established that in fact major earthquakes take place every 75 years in the Kathmandu valley.

Such a terrible earthquake happened in 1934, which killed 10000 people. It was the most horrible accident in XX century. If such an earthquake happened in the centre of Kathmandu city, the destructions would be more catastrophic. According to the prognoses of seismic regionalization in conditions of unstable soil and very old residential buildings, 60% of housing stock can be destroyed and hundreds of human lives can be ruined.

As seismologists had assumed, the most destroying earthquake happened after 80 years on the 25th of April 2015. The earthquake epicenter with a magnitude of 7.9 was within 80 km to the north-west from Kathmandu. The earthquake stocks caused a series of aftershocks and destructions on the territory of the country, including the historic centre of Kathmandu. The central and east regions were damaged the worst. In Kathmandu up to 90% of houses were demolished, the historic centre of the capital was almost destroyed. There are no more Durbar Square, Dharahama and Bhimsen Towers listed as UNESCO world heritage sites, ancient temples became piles of stone. According to crude data, 9.0 thousands of people died and 101.000 were injured. In total, in whole Nepal 500.000 of houses were destroyed and 269.000 were damaged. The general damage makes up more than 10 billion dollar.

On Sunday morning Indian military who maintained a rescue operation in the region of Everest reported a horrible scene they saw. The run-off after the earthquake avalanche in Nepal killed 65 mountain climbers. They all died in the area of the base camp.

On the 15th of May strong earthquake shocks repeated with a magnitude of 7.4. These were a little less than those happened at the end of April. Now, according to crude data 140 people died and almost thousand people were injured.

3. Ecological consequences of catastrophic earthquakes

Consequences of catastrophic earthquakes are diverse and result in environment modification and causing damage to infrastructure followed by numerous victims. Among direct most significant damages of mountain territory there are geological and geomorphologic, hydrologic and hydrogeological, geophysical, geochemical, atmospheric and biological. Such modifications result in environment transformations, which significantly change ecological situation on these and adjacent grounds. The most significant and easily detected transformations result in destruction of plant cover, animal habitats and sometimes even themselves, in disruption of traditional habitats and above-ground migration routes, change of water regime, reallocation of water reserves, deterioration of the quality of forage grasslands and etc.

Geological changes of the natural habitat are most pronounced at strong earthquakes. It is known that faults and chasms on the earth surface frequently appear during large earthquakes. The zone length of such faults reaches during intensive earthquakes dozens and even hundreds of
Kilometers. At the same time visible displacements of single structure blocks of earth crust originate which cause considerable changes of single micro-and mesoforms of relief.

For instance, the earthquake which took place in spring 2015 in Nepal led to tension slackening in the earth crust which, in some way, may have changed the relief of the Himalayas. It influenced on the height of the highest world top-Everest. According to the report of Noncommercial consortium of geophysical studies UNAVCO, after the cataclysm in 2015, the growth of the highest world mountain decreased by 2.54 cm. The findings of scientists were based on data recovered from the “Sentinel-1A” satellite, passing by on the 29th of April preceding year (www.livescience).

German Aerospace Center also concluded that a part of ground surface in Kathmandu region 55 miles long and 18 miles wide (around 88.5 within 29 km, more than 2.5 thousands of km2) was lifted up by 91 cm from its previous level.

Professor Roger Bilham, a fellow at the Cooperative Institute for Research In Environmental Sciences, estimates the growth of the Annapurna Range (8091 m) as the result of earthquake by 20cm. (Geologic - tectonical map, 1980).

Seismic processes are a “trigger” for activation of present-day catastrophic processes- earth slips, rock falls, debris flows, barrier lake rash. Examples of such natural disasters are numerous.

Relief changes near the epicenter were colossal. Many falls of ground, earth slips and debris flows happened in mountains largely saturated with moisture of monsoon rains. Roughly estimated, the overall weight of moved rock refuse made up around 2 billion tones. [Yury Efremov, 2016].

In Nepal, a program has been developed to reduce the risk and damage from catastrophic earthquakes. It provides for further study of seismic phenomena, strict control of earthquakes at seismic stations, measures for the construction of facilities for new anti-seismic technologies, and warning of the population about possible catastrophes. The program includes modern geophysical methods that reduce the risk and damage from catastrophic earthquakes. In Nepal, a huge work was done to eliminate the devastation after the catastrophic Earthquakes in April 2015.

Nepalese scientists work in close cooperation with foreign colleagues, organize regular conferences and seminars, dedicated to the acute problems of geology and seismology.

Conclusions

1. Ecological implications of big earthquakes are diverse and are always followed by major changes of the environment and infrastructure destructions, and deaths of many people. The biggest changes of the environment and catastrophic destructions of cities and human settlements with great losses of life happen in epicenters of earthquakes and within a radius of 100-200 km.

2. It isn’t always possible to estimate the ecological hazard and damage from seismic catastrophes fully, because methods of estimates of earthquake prognosis and their consequences causing ecological catastrophes haven’t been sufficiently developed till present moment.

3. Seismologists and engineers face a problem of development of earthquake prognosis which hasn’t been developed till present moment, and also measures for decreasing ecological hazard and damage from seismic catastrophes providing for solid and reliable protection of existing infrastructure and population.

References

