HIMALAYAN OROGENY: NEPAL'S EARTHQUAKES

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PRESENTATION GOALS AND OBJECTIVES

Goal of this presentation is for the observer to gain a generalized overview of earthquake activity in Nepal.

Three *objectives* outlined below will be used to achieve this goal.

- 1. Illustrate why and how the Himalayan Mountains formed.
- 2. Various causes will be identified as to why earthquakes occur in Nepal, as well as identifying the primary triggering mechanism for the earthquakes.
- 3. Illustrate graphically the number of and frequency of recorded earthquakes of magnitude, $M \ge 4$, occurring in Nepal in the previous 50 to 60 years since 2011.

The Himalaya Mountains Records one of the most dramatic, visual evidence of the Forces of Plate Tectonics.

Himalaya mountain range formed by the collision of the Indian Plate with Eurasian (Tibetan) Plate around 55 millions years ago (see figure). About that time, scientists believe that the northward moving Indian plate first collided into the southern edge of Tibetan (Eurasian) plate. This continental – continental collision (Convergent Plate Boundary) kicked-off the Himalayan Orogenic Process (mountain building).

This continental – continental collision continues today!



Diagram Modified from: http://cosscience1.pbworks.com/f/1248192707/Module10-015.gif

What Happens During this Continental-Continental Collision?

The leading edge of the plate (oceanic crust) carrying India is subducted beneath the Eurasian plate. The landmasses (continental crust) collide and pushing-up the land mass. This collision continues today.

Simply put:

Two tectonics plates collide into each other; the India Plate's oceanic crust being slightly denser sinks under (subducted, pulled beneath) the less dense Eurasian Plate.

As the continental crust of both plates merge into one, the intervening oceanic sediments and rock get sandwiched in between both crusts. This pushing and piling of rock ontop-of rock builds-up the Himalayas Mountains.



Diagrams Modified from Source: http://cosscience1.pbworks.com/

Based on recent Global Positioning System (GPS) data, the Indian plate moves nearly 5 cm per year (about 2-inches) plowing into Asia. However, GPS data also suggests that Tibet pushes only about 3.2 cm (1.3 inches) into Asia each year.

Major Consequence of this Continental-Continental Collision and Plate Subduction are Earthquakes



Stresses build-up as a result of the continents colliding – release of this stress (or energy) is in the form of earthquake.

Analogous to understanding this release of energy

- think of two cars colliding head-on, the two cars represent the two Plates, as the cars collide the impact releases energy shattering the vehicles.

Diagram Modified from:

http://www.geol.ucsb.edu/faculty/hacker/geo102C/lectures/HinduKush.jpg

An earthquake can take the form of either:

- A sudden and sometimes violent movement of the earths' surface caused by the release of built-up energy in the earth's crust, *or*
- It can be a slow release of energy occurring over a longer time interval on the order of days, weeks, months, or years.

Earthquakes can be caused by different processes, such as:

- ➤ Tectonic activity,
- Volcanic eruptions,
- ➢ Mass wasting (landslides, avalanches),
- Isostatic rebound,
- Atmospheric phenomena (tornadoes, monsoons),
- Extraterrestrial (meteoritic/asteroid impacts), and
- ➤ Man-made.

However, the most common type of earthquakes are *Tectonic Earthquakes*.

Tectonic Earthquakes occur when rocks in the earth's crust fracture due to geological forces created by movement of tectonic plates.

There are three primary type of plate tectonic boundaries:

- 1. Divergent (extensional),
- 2. Transform (sliding past each other), and
- 3. Convergent (compressional).

Each of the Plate boundaries are subject to different inter-plate stresses, producing three generalized types of earthquakes.

- A. Extensional,
- B. Compressional, and
- C. Transform



Extensional



Transform



Compressional

Nepal's Earthquake Activity

Nepal Seismically Active

The Himalayan Kingdom of Nepal is located at the boundary between Indian and Eurasian (Tibetan) tectonic plates placing the country in a highly seismically active region of the Himalayas.

Earthquake Magnitudes Experienced in Nepal

Although Nepal experiences many earthquakes, a majority of the documented earthquakes are below a magnitude of 7.

Predicting Earthquakes in Nepal

Earthquakes are the result of several natural geologic processes. However, regardless of recent advances in seismic monitoring, causational effect analysis and event forecasting, predicting when a major earthquake event may occur is tenuous at most.

Nepal - Seismicity Map

Map source United States Geological Survey, downloaded 24 Jul 2011 from

http://earthquake.usgs.gov/earthquakes/world/nepal/seismicity.php



Note: Each circle represents a recorded earthquake. Most of Nepal's earthquakes are relatively shallow (\leq 33 Km depth) and located near the estimated boundary between the India - Eurasian Plates.

The 2 most common causes of earthquakes occurring in Nepal are;

- Compressional (continental-continental convergence), and
- Extensional.

Note: Compressional type earthquakes are believed to be by far the most dominant type; only recently is there mounting evidence that extensional type maybe occuring.



Magnitude-Frequency Data (1911-1991)

The graph (left) presented by the National Society of Earthquake Technology– NEPAL shows the seismic record between 1911 to 1991.

Note: That a total of 71 earthquakes are reported over the 80-years between 1911 to 1991; a rate of nearly 1 per year.

The next two slides illustrates the frequency of recorded earthquake occurrences in Nepal between June 1994 to July 2011.

Graphical presentation of data used in preparing the following Figures 1 and 2 were compiled from data made available by,

National Seismological Centre Department of Mines and Geology Lainchaur, Kathmandu, Nepal Telephone: 977-1-4410141, 977-1-4421828 Fax: 977-1-4412056 Email: nscdmg@mos.com.np Website: http://www.seismonepal.gov.np/Introduction.htm

Please contact the National Seismological Centre by going to their website and downloading the raw data; you may also contact me at the email address provided on the title page of this presentation for the data. **Please give all appropriate credit when using this data**.

MONTHLY REPORTED EARTHQUAKES IN NEPAL, M \geq 4 June 1994 to July 2011





Annual Number of Nepal Earthquakes , ${\rm M} \geq 4$ 1994 to 2011 a



Figure 2: Data used to prepare the above graph was compiled and tabulated from data made available by the National Seismological Centre, Department of Mines and Geology, Lainchaur, Kathmandu, Nepal.

QUESTION?

The last slide (Figure 2, Slide Page 14) provided information that indicates that Nepal experiences approximately 16-17 Earthquakes of $M \ge 4/year$.

However, the graph and data presented by the National Society of Earthquake Technology–NEPAL (on Slide Page 10) suggests that between 1911 to 1991that only about **1 Earthquake** of $M \ge 4/year$

Is earthquake activity really increasing?

Although this is not a geology class, it is important to understand a little how the Nepal Himalayan region is geomorphogically described.

Therefore, the next 3-slides provide some basic information on the geomorphic/physiographic area of the Nepal Himalaya.

Generalized Geomorphic - Physiographic Profile the Nepal Himalaya



Hagen (1969) divided Nepal into eight physiographic provinces from south to north (as seen in the diagram to the left). Each province is geographically oriented east to west.

While this classification fits what is regionally observed throughout the Himalaya it characteristically represents the geomorphic / physiographic zones of Nepal.

Source: Map presented at <u>http://www.ranjan.net.np/geology_of_nepal/geology_of_nepal.htm</u> and referenced its sources as, *Hagen, T., 1969, Report on the geological survey of Nepal preliminary reconnaissance: Zürich, Mémoires de la soc. Helvétique des sci. naturelles, 185 p.*

Generalized Geological Cross- section Nepal Himalaya



Some geologists (and geographers) prefer using a 5zone classification scheme that includes Terai, Churai, Middle Mountain, High Mountain and High Himalaya. However, on the next slide I present a descriptively similar but modified version of that prepared by Upreti (1999). I also include 8 geomorphic zones (physiographic provinces) in the next slide's table.

Source: Diagram presented at <u>http://www.ranjan.net.np/geology_of_nepal/geology_of_nepal.htm</u> and referenced its' sources as, *Dahal, R., K., 2006, <u>Geology for Technical Students</u>, Bhrikuti Academic Publications, Kathmandu, Nepal, 746p.. 17*

Geomorphogical Division of the Nepal Himalaya

(modified after Upreti, 1999)

Zone	Geomorphic Unit	Width, km (mi)	Altitude, m (ft)	Primary Rock Types	Landform Developed By
1	Terai (Northern edge of the Gangetic Plain)	20-50 (12-50)	100-200 (328 - 656)	Alluvium: coarse gravels north near foot of mountains becoming finer southward	River deposition, erosion, tectonic uplift
2	Churia Range (Siwaliks)	10-50 (6-50)	200-1300 (328 - 4265)	Sandstone, mudstone, shale & conglomerate.	Tectonic uplift, erosion, slope failure
3	Dun Valleys	5-30 (5-19)	200-300 (328 - 984)	Valleys within Churia Hills filled with coarse-fine alluvial sediments	River deposition, erosion & tectonic uplift
4	Mahabharat Range	10-35 (6-22)	1000-3000 (3281 - 9843)	Schist, phyllite, gneiss, quartzite, granite, limestone belonging to the Lesser Himalayan Zone	Tectonic uplift, weathering, erosion, slope failure
5	Midlands	40-60 (25-37)	300-2000 (984 - 6562)	Schist, phyllite, gneiss, quartzite, granite, limestone geologically belonging to the Lesser Himalayan Zone	Tectonic uplift, weathering, erosion, slope failure
6	Fore Himalaya	20-70 12-43.5)	2000-5000 (6562 - 16404)	Gneisses, schists, phyllites, marbles mostly belonging to the northern edge of the Lesser Himalayan Zone	Tectonic uplift, weathering, erosion, slope failure
7	Higher Himalaya	10-60 (6-37)	>5000 (>16404)	Gneisses, schists, migmatites, marbles belonging to the Higher Himalayan Zone	Tectonic uplift, weathering, erosion (rivers, glaciers), slope failure
8	Inner and Trans Himalaya	5-50 (3-31)	2500-4500 (8202-14764)	Gneisses, schists, marbles of Higher Himalayan Zone and Tethyan limestones, shale, sandstone etc. belonging to the Tibetan-Tethys Zone	Tectonic uplift, wind & glacial erosion, slope degradation by rock disintegrations

In Summary:

- The Kingdom of Nepal occupies the central sector, nearly one third, of the 2400 km long Himalayan Mountain range.
- ➤ The region was formed approximately 55 million years ago when the India Plate collided with the Eurasian Plate. This collision is still very active today.
- Although, the primary mechanism of earthquake generation is thrust faulting due to collision of both continental land masses, other causes exist for earthquakes occurring in Nepal.
- > Nepal is located within a very active tectonic region that frequently experiences earthquakes of magnitude ≥ 4 .

