EARTHQUAKE DATA MAPPING OF HINDUKUSH RANGE THROUGH GIS

MINI PROJECT

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Section: B

Department: Civil Engineering

GIS/RS APPLICATION TO CIVIL ENGINEERING (Lab)

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INTRODUCTION

1.1 General Description

Pakistan is situated in a highly seismically active region which has experienced many disastrous earthquakes during historical times. The last 100 years alone include the 1945Makran coast earthquake with magnitude above 8.0, the Mach earthquake in August 1931, M 7.3, the Quetta earthquake in 1935, M 7.4, the Pattan earthquake in 1974, M 6.0, and the recent disastrous Muzaffarabad earthquake in October 2005, M 7.6, which has shaken the entire nation in many ways. Many active faults exist in Northern and Southern areas of Pakistan and more than half of the total population are living with earthquakes and will have to continue doing that.

1.2 Earthquakes

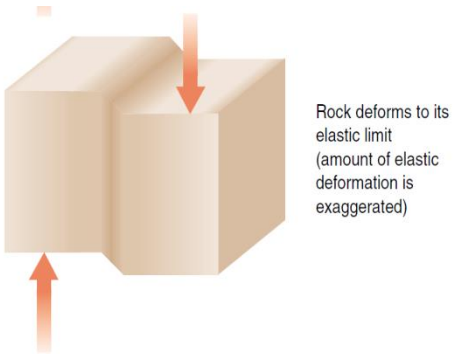
An **earthquake** is a sudden motion or trembling of the Earth caused by the abrupt release of energy that is stored in rocks. Before the plate tectonics theory was developed, geologists recognized that earthquakes occur frequently in some regions and infrequently in others, but they did not understand why. Modern geologists know that most earthquakes occur along plate boundaries, where huge tectonic plates separate, converge, or slip past one another. The effects of earthquakes, such as ground motion and displacement, damage to buildings, and quake caused fires, landslides and seismic sea waves (tsunami) .Earthquakes commonly affect other parts of Earth systems. Intense shaking associated with an earthquake not only can cause tremendous damage and loss of life but can also trigger landslides that may disperse pathogenic microbes into the atmosphere and cause additional human health concerns. Such was the case after the 1994 Northridge, California earthquake. Another effect on the biosphere may be the unusual behavior of animals just before an earthquake, as reported by Chinese scientists. Ground breakage associated with earthquakes may affect the hydrosphere by creating new lakes (sag ponds), increasing groundwater flow from springs, and displacing stream channels. Tsunami generated by submarine earthquakes may cause tremendous damage to the coastal environment. Earthquakes are largely confined to a few narrow belts on Earth. This distribution was once puzzling to geologists, but here we show how the concept of plate tectonics neatly explains it. As geologists learn more about earthquake behavior, the possibility exists that we will be able to forecast earthquakes. We conclude the chapter with a look at this developing branch of study.

Earthquakes in Pakistan

Pakistan is situated in a highly seismically active region which has experienced many disastrous earthquakes during historical times. . The last 100 years alone include the 1945 Makran coast earthquake with magnitude above 8.0, the Mach earthquake in August 1931, M 7.3, the Quetta earthquake in 1935, M 7.4, the Pattan earthquake in 1974, M 6.0, and the recent disastrous Muzaffarabad earthquake in October 2005, M 7.6, which has shaken the entire nation in many ways. Many active faults exist in Northern and Southern areas of Pakistan and more than half of the total population are living with earthquakes and will have to continue doing that. The October 2005 Muzaffarabad earthquake enhanced the consciousness about the increasing vulnerability that the growing population is confronted with.

1.3 CAUSES OF EARTHQUAKES

Tectonic forces acting deep in the Earth may put a *stress* on the rock, which may bend or change in shape (*strain*). If you bend a stick of wood, your hands put a stress (the force per unit area) on the stick; its bending (a change in shape) is the strain. Like a bending stick, rock can deform only so far before it breaks. When a rock breaks, waves of energy are released and sent out through the Earth. These are **seismic waves,** the waves of energy produced by an earthquake. It is the



seismic waves that cause the ground to tremble and shake during an earthquake. The sudden release of energy when rock breaks may cause one huge mass of rock to slide past another mass of rock into a different relative position. As you know from chapter 6, the break between the two rock masses is a *fault*. The classic explanation of why earthquakes take place is called the **elastic rebound theory** (figure 1.1). It involves the

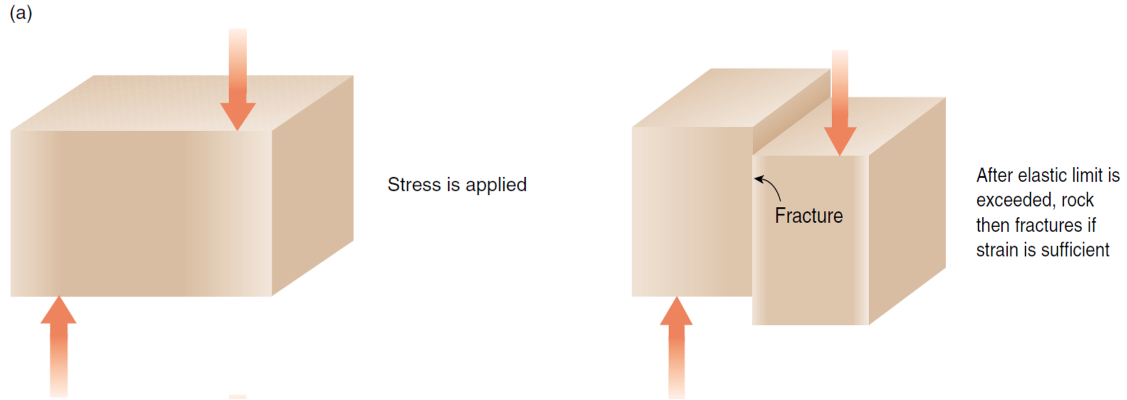


FIGURE 1.1 the elastic rebound theory of the cause of earthquakes. (*A*) Rock with stress acting on it. (*B*) Stress has caused strain in the rock. Strain builds up over a long period of time. (*C*) Rock breaks suddenly, releasing energy, with rock movement along a fault. Horizontal motion is shown; rocks can also move vertically or diagonally.

Sudden release of progressively stored strain in rocks, causing movement along a fault. Deep-seated internal forces (*tectonic forces*) act on a mass of rock over many decades. Initially, the rock bends but does not break. More and more energy is stored in the rock as the bending becomes more severe. Eventually, the energy stored in the rock exceeds the breaking strength of the rock breaks suddenly, causing an earthquake. Two masses of rock move past one another along a fault. The movement may be vertical, horizontal, or both (figure 7.2). The strain on the rock is released; the energy is expended by moving the rock into new positions and by creating seismic waves.

FIGURE 7.2

Horizontal offset of trees in an orchard, 1979, El Centro, California. *Photo by University of Washington Libraries, Special Collections, John Shelton Collection*

Seismic waves

Seismic waves are generated by the release of energy during an earthquake. They travel through the earth like waves travel through water.

The location within the Earth where the rock actually breaks is called the **focus** of the earthquake. Most foci are located within 65 km of the Earth's surface; however, some have been recorded at depths of 700 km. The location on the Earth's surface directly above the focus is called the **epicenter**.

The study of seismic waves and earthquakes is called seismology, which is a branch of Geophysics.

More than one type of seismograph is needed to record both vertical and horizontal ground motion

Types of seismic waves

- Surface waves
- Body waves

1.4 Methodology

The methodology adopted for the current work is comprised of laboratory work only because we get data from Pakistan Metrological Department. These are discussed as follow:

1.4.1 Field Data

Earthquake Data information

The main data bases for earthquake information in this study are:

• PMD, Pakistan Meteorological Department, historical database.

• PDE, United State Geological Survey, database.

• ISC, International Seismological Centre England, database.

1.4.2 Laboratory work

1.4.2.1 ARC GIS 10.2.1

In Computer Lab Arc GIS is used for mapping the data

1.4.2.2 Google earth

Goole earth is use as remote sensing tool for the study of targeted area.

1.4.2.3 Base Maps

In the Computer lab of Department of Geography, different maps were studied and use as base maps for the mapping of targeted area.

Seismic zones of Pakistan and Hindu Kush

Seismic zonation

For the project of hazard assessment of Pakistan the study region was divided into 19 seismic zones and this division was based on the seismicity, geology, source mechanism and the stress direction of the region. The region 5, 6 and 7 were further subdivided with respect to depths as these zones have the seismicity for different depths. These zones were analyzed at depths 75 km and 210 km as these contributes to the seismic hazard values. There is clustering of earthquakes in the northwest (Hindukush), northeast (zone 1) and at southwest (Quetta region) of Pakistan, these are the main contributor of seismic hazard.

Seismic source zones

There are altogether 19 area zones defined for this project, as delineated in the following.

(Seismic Hazard Analysis and Zonation for Pakistan, Azad Jammu and Kashmir by Pakistan metrological and norsar Norway July, 2007)

Zone 1; Kohistan-Kashmir

Zone 2; Northern Baluchistan

Zone 3; Quetta-Sibi

Zone 4; Southern Baluchistan

Zone 5; Northern Afghanistan-Tajikistan

Zone 6; Hindu Kush

.**Zone 7; North Western Afghanistan-Tajikistan Border Region**

Zone 8; Eastern Afghanistan

Zone 9; Makran Coast

Zone 10; Runn of Kuchch

Zone 11; Sindh-Punjab

Zone-12; Pamir-Kunlun

Zone 13; Indian Kashmir

Zone 14; Upper Punjab-NWFP

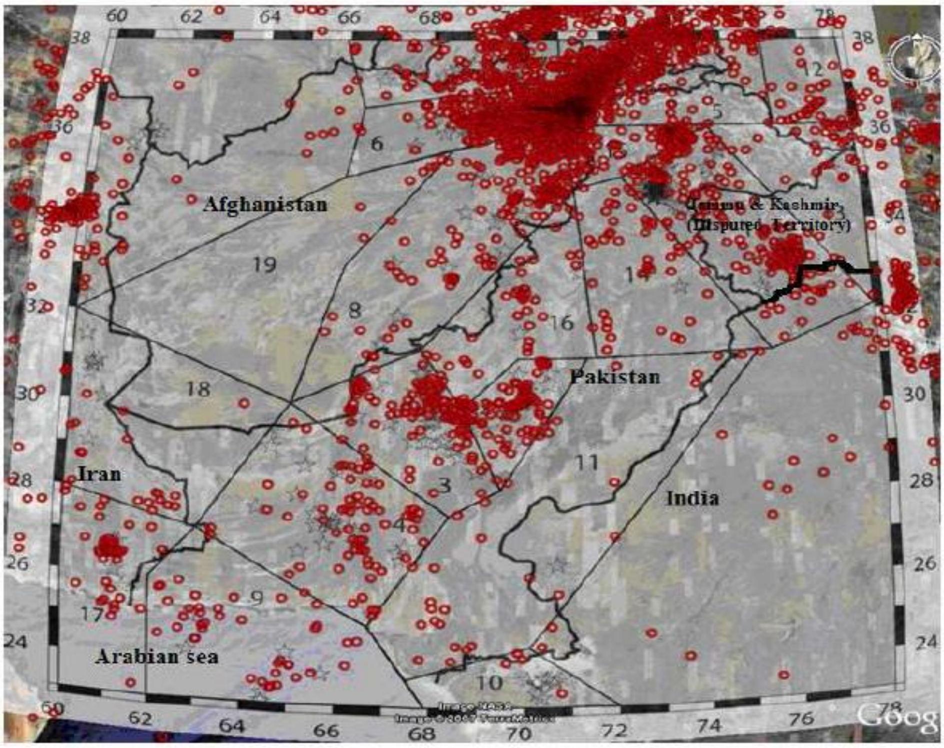
Zone 15; Chitral

Zone 16; Koh e Suleiman

Zone 17; South West Iran

Zone 18; Western Baluchistan

Zone 19; Central & Southern Afghanistan



Fig; Seismicity of the region (map with the 19 zones overlaid in Google Earth).

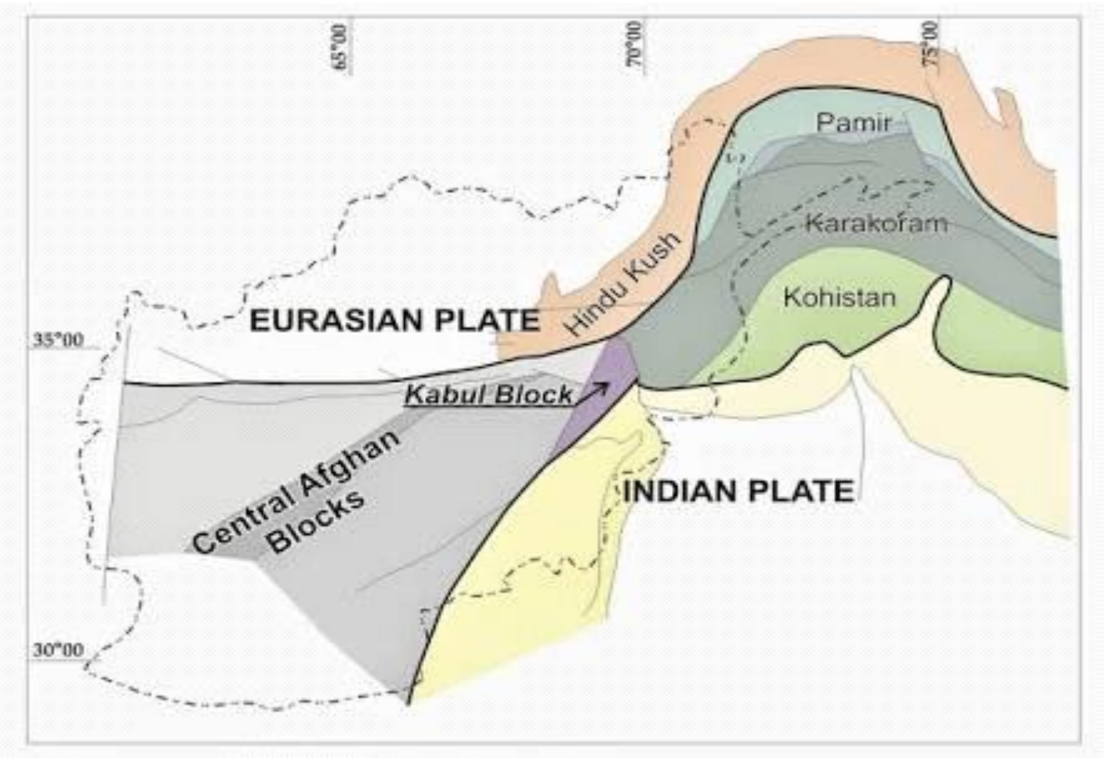
Seismic zones of Hindukush

Experts say collisions between Indian, Eurasian plates may cause Hindukush earthquakes. The United States Geological Survey (USGS) has termed the Hindu Kush “one of the most seismically hazardous regions on earth”. However, nearly all of the recent tremors felt in the region originated deep in the earth’s crust, nearly 200km below the surface.

The USGS has stated that most such earthquakes are caused by tectonic plates rubbing together. According to a report by the National Geographic Society, the two plates are colliding at a rate of about 1.5 inches a year, pushing up the Himalayan mountain range in the process. Due to friction along the plate boundaries, the collisions are not smooth or even.

Dr Rasul said “Since the Indian Plate is sliding under the Eurasian plate, there could be friction caused by the presence of a massive rock formation, either under the Indian plate or the Eurasian plate “There are on average four earthquakes a year measuring five or more on the Richter scale, with the epicenters occurring within 60 kilometers (37 miles) of the Hindu Kush. The Indian continent is moving north, and it is colliding with the Eurasian continent, and that results in the subsequent uplift of the Himalayan Mountains and the Tibetan plateau, Dr Brian Baptie of the British Geological Survey Said. "It's this collision that is the cause of all the seismic activity that is going on in this area."And also due to this collision as a result, the Himalayas are still rising. Satellite measurements put their ascent at about five millimeters per year.

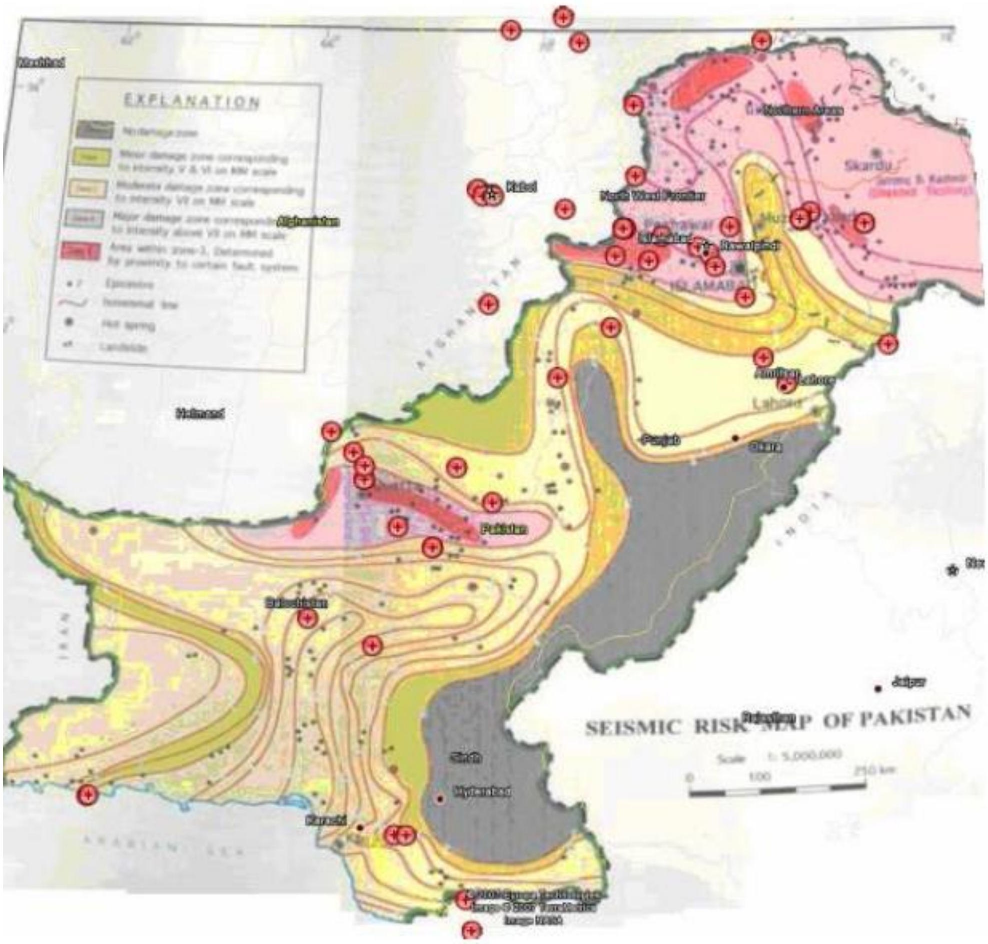
Hindu Kush lies in the area of collision of the Eurasian and Indian tectonic plates. The geological activity born out of this collision, also responsible for the birth of the Himalayan mountain range, is the cause of unstable seismicity in the region...



Map; British Geological Survey

Seismology of the Study Region

The seismicity of the region is directly related to the geo-tectonic processes; however, the quantitative monitoring of the seismicity only goes some 100 years back. With the long term processes in action the short seismicity monitoring time is a serious limitation, but a limitation which we have to accept.



Map; Seismic risk map (prepared by Geological Survey of Pakistan) overlaid with historical seismicity.

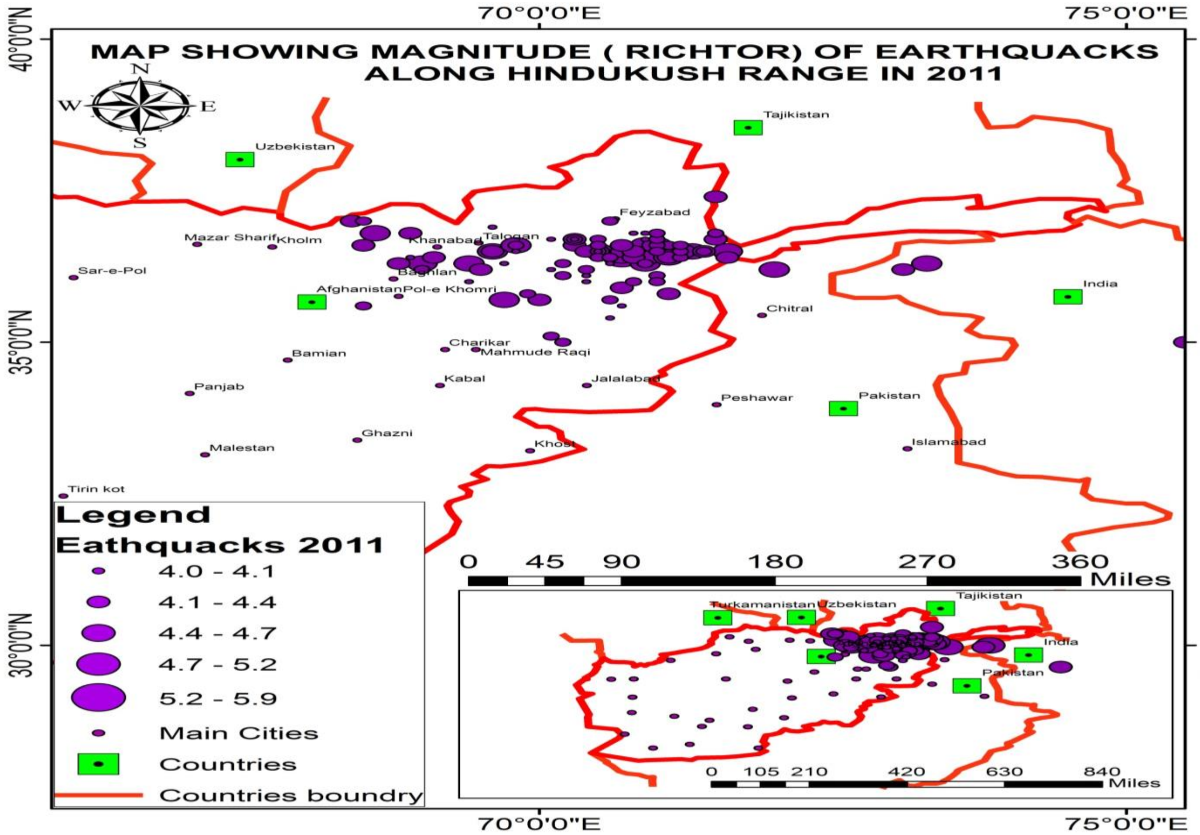
ANALYSIS AND EVALUATION

Hindu Kush earth quacks evaluations

The Hindu Kush region generates regularly very large earthquakes, occurring down to 300 km depth, which are also felt in Pakistan. The compressive stress direction of this region is NNW-SSE, albeit with a somewhat bimodal nature the direction of crustal stress in Kashmir is NE-SW, perpendicular to the line of plate collision and MBT. In the Hindu Kush region the earthquake mechanism is generally thrust faulting occasionally normal faulting whereas in Kashmir, the earthquakes mainly show thrust fault mechanism with a clear NE-SW compression. Both the Karakoram and Hindu Kush ranges are caused by the collision of the Indian plate into the Eurasian plate the Indian plate collides and under plates the Eurasian plate. The Hindu Kush and the Pamir constitutes one of the most seismically active earthquake zones in the world.

In the Kashmir region we find the important Hazara-Kashmir Syntax (HKS), which was formed due to the change in the Himalayan thrust interface direction from NE in Kashmir to NW along the Indus. The Punjal thrust and the Main Boundary Thrust (MBT) are folded around this syntax and are subject to a 90o “rotation” from one side to the other. The Panjal thrust, MBT and Muzaffarabad thrust are truncated by the active Jhelum fault (Baig and Lawrence, 1987).

Beside other faults in this region, the Jhelum fault acts as an active left lateral oblique reverse fault. The general seismicity pattern of the Jhelum Ambore zone is low activity of regular earthquakes with magnitudes ≤ 4.0. The historical and instrumental seismic data from this region show no earthquake with a size exceeding magnitude 6.8.


MAP SHOWING MAGNITUDE (RICHTOR) OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2011
70°0'0"E
75°0'0"E
40°0'0"N
35°0'0"N
30°0'0"N
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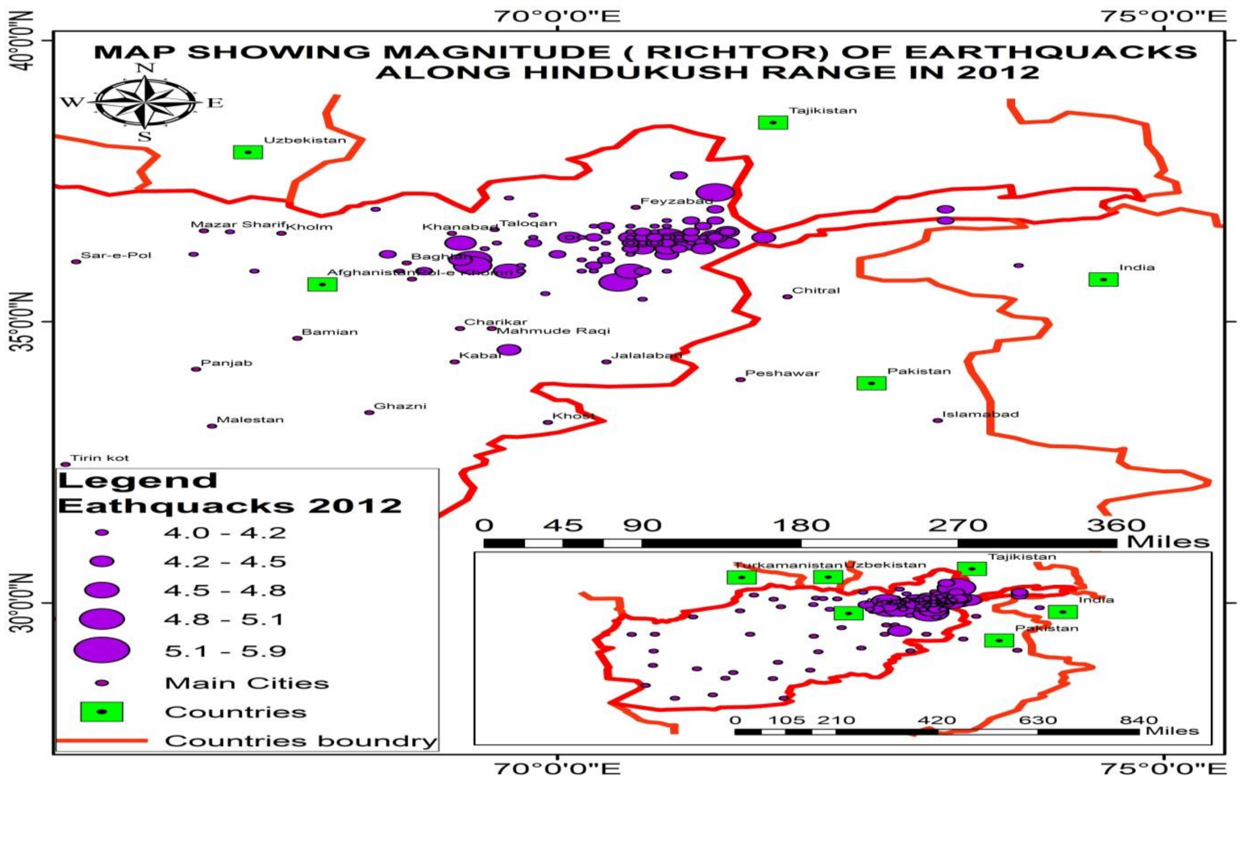
Uzbekistan
Tajikistan
Feyzabad
Mazar Sharif
Kholm
Khanabad
Taloqan
Sar-e-Pol
Baghlan
Afghanistan
Pol-e Khomri
Chitral
India
Charikar
Mahmude Raqi
Bamian
Kabal
Jalalabad
Panjab
Peshawar
Pakistan
Ghazni
Islamabad
Malestan
Khost
Tirin kot
Legend
Eathquacks 2011
4.0 - 4.1
4.1 - 4.4
4.4 - 4.7
4.7 - 5.2
5.2 - 5.9
Main Cities
Countries
Countries boundry
0 45 90 180 270 360
Miles
Turkamanistan
Uzbekistan
Tajikistan
India
Pakistan
0 105 210 420 630 840
Miles


MAP SHOWING MAGNITUDE (RICHTOR) OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2012
70°0'0"E
75°0'0"E
40°0'0"N
35°0'0"N
30°0'0"N
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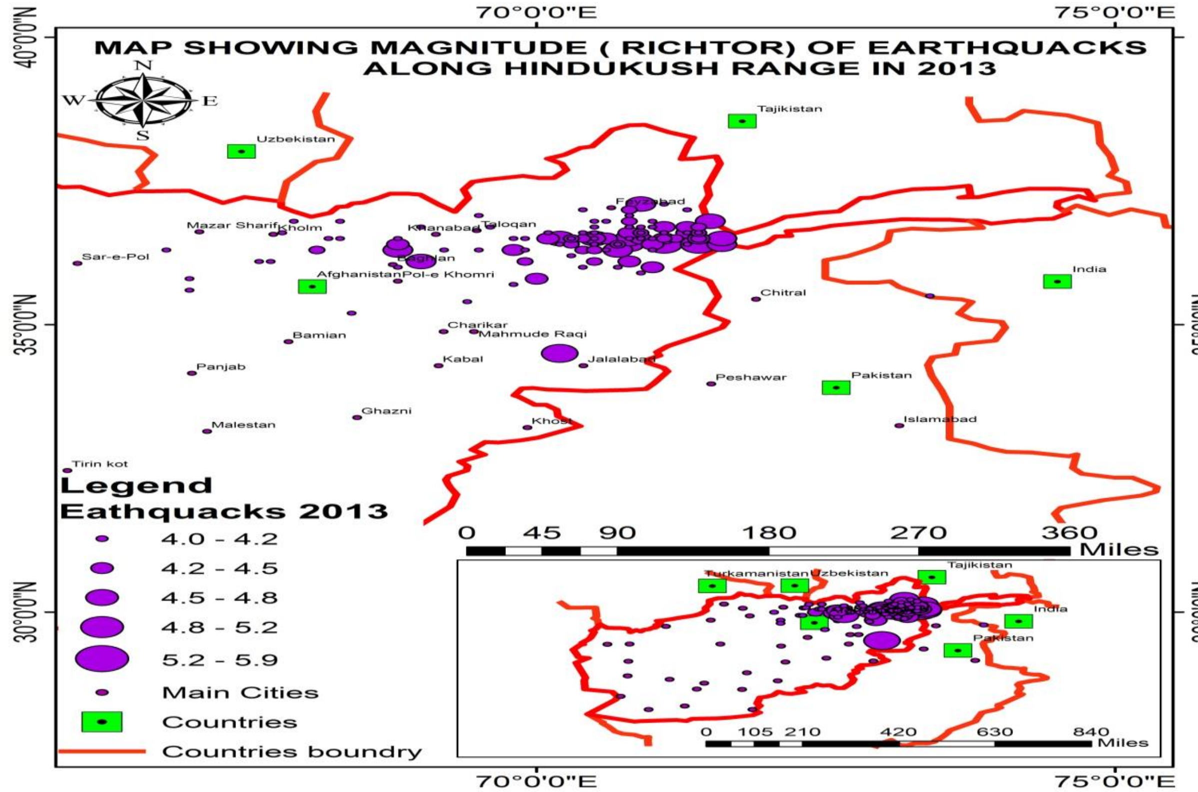
Uzbekistan
Tajikistan
Feyzabad
Mazar Sharif
Kholm
Khanabad
Taloqan
Sar-e-Pol
Baghlan
Afghanistan
Chitral
India
Charikar
Mahmude Raqi
Bamian
Kabal
Jalalabad
Panjab
Peshawar
Pakistan
Ghazni
Islamabad
Malestan
Khost
Tirin kot
Legend
Eathquacks 2012
4.0 - 4.2
4.2 - 4.5
4.5 - 4.8
4.8 - 5.1
5.1 - 5.9
Main Cities
Countries
Countries boundry
0 45 90 180 270 360
Miles
Turkamanistan
Uzbekistan
Tajikistan
India
Pakistan
0 105 210 420 630 840
Miles


MAP SHOWING MAGNITUDE (RICHTOR) OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2013
70°0'0"E
75°0'0"E
40°0'0"N
35°0'0"N
30°0'0"N
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Uzbekistan
Tajikistan
Feyzabad
Mazar Sharif
Kholm
Khanabad
Taloqan
Sar-e-Pol
Baghlan
Afghanistan
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Panjab
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Eathquacks 2013
4.0 - 4.2
4.2 - 4.5
4.5 - 4.8
4.8 - 5.2
5.2 - 5.9
Main Cities
Countries
Countries boundry
0 45 90 180 270 360
Miles
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Uzbekistan
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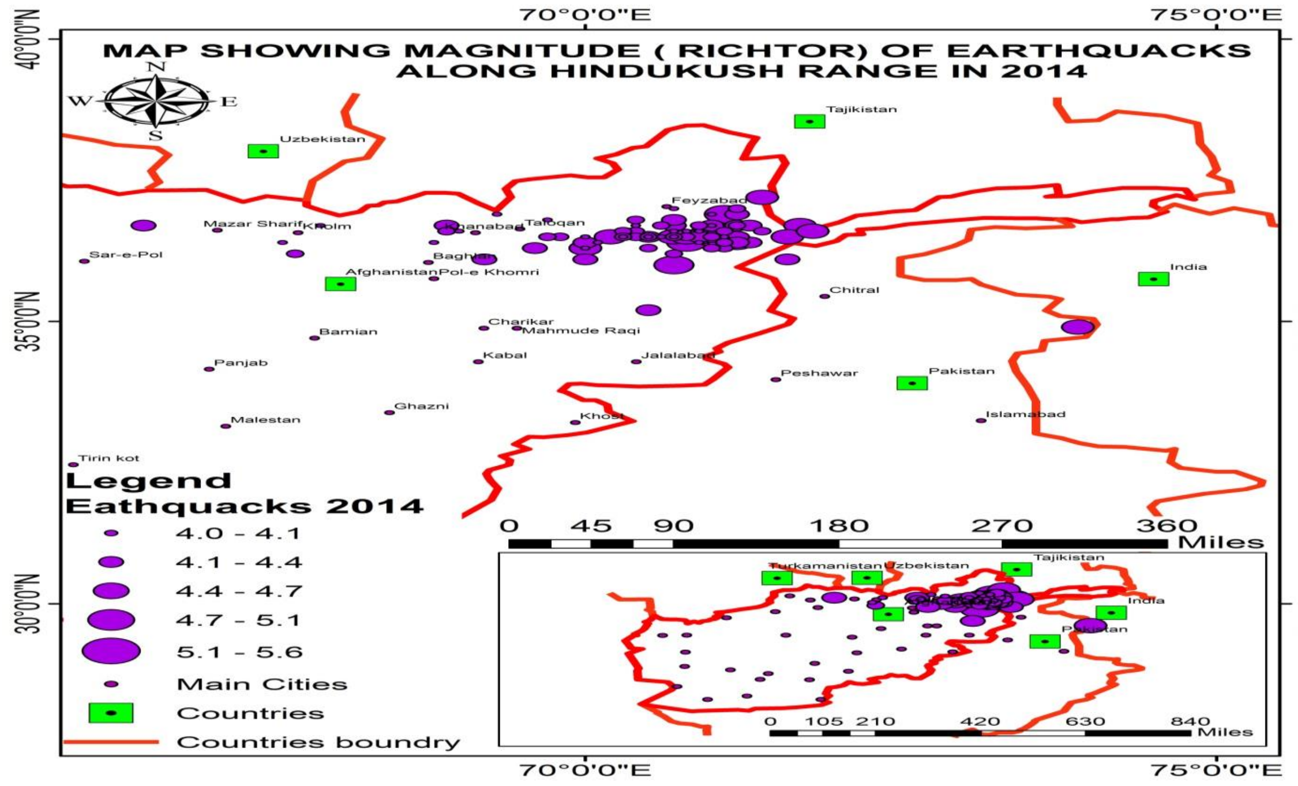
India
Pakistan
0 105 210 420 630 840
Miles


MAP SHOWING MAGNITUDE (RICHTOR) OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2014
70°0'0"E
75°0'0"E
40°0'0"N
35°0'0"N
30°0'0"N
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Tajikistan
Feyzabad
Mazar Sharif
Kholm
Khanabad
Taloqan
Sar-e-Pol
Baghlan
Afghanistan
Pol-e Khomri
Chitral
India
Charikar
Mahmude Raqi
Bamian
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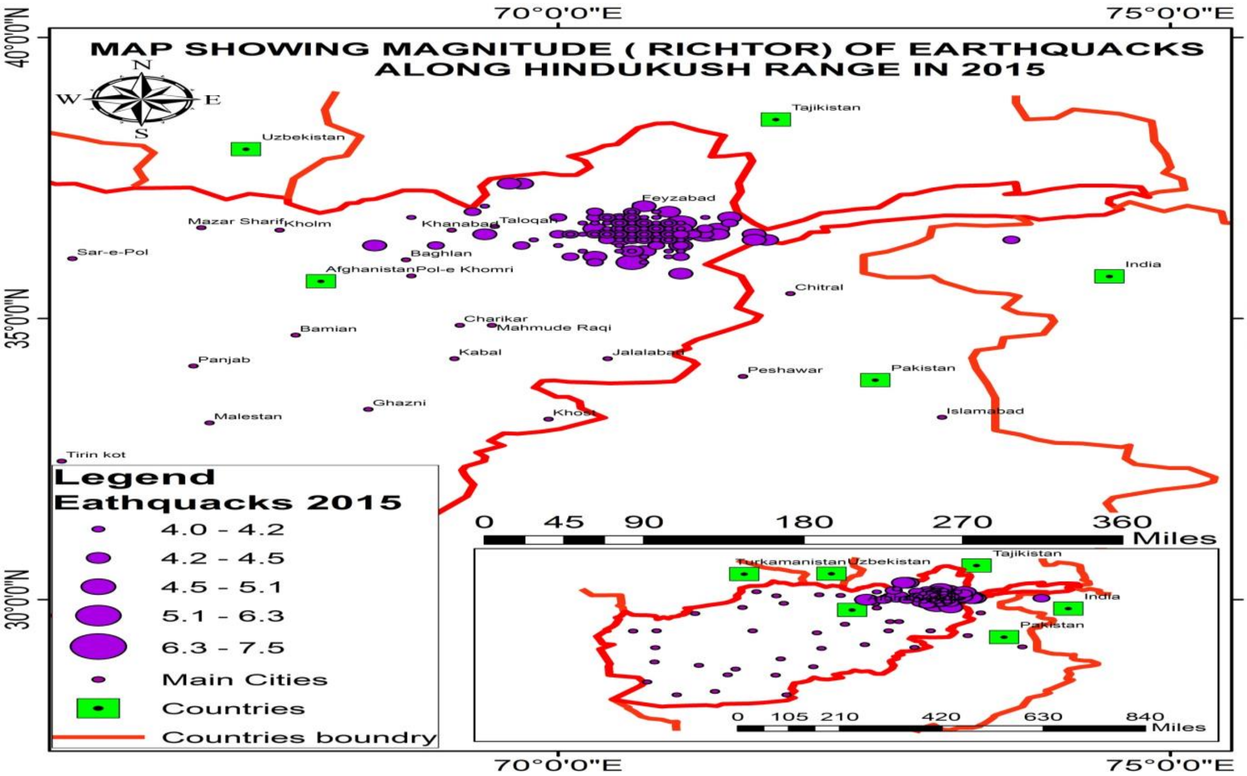
Jalalabad
Panjab
Peshawar
Pakistan
Ghazni
Malestan
Khost
Islamabad
Tirin kot
Legend
Eathquacks 2014
4.0 - 4.1
4.1 - 4.4
4.4 - 4.7
4.7 - 5.1
5.1 - 5.6
Main Cities
Countries
Countries boundry
0 45 90 180 270 360
Miles
Turkamanistan
Uzbekistan
Tajikistan
India
Pakistan
0 105 210 420 630 840
Miles



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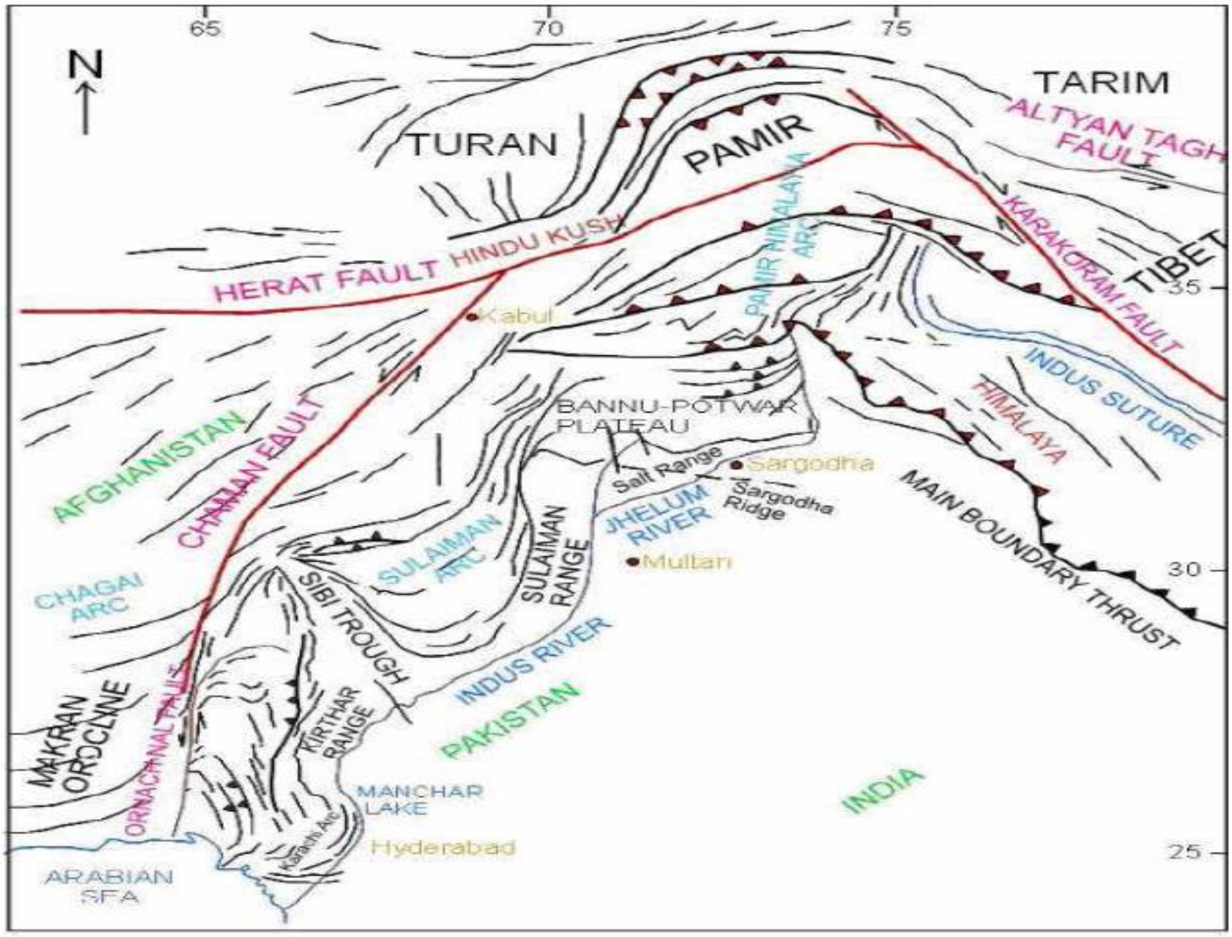
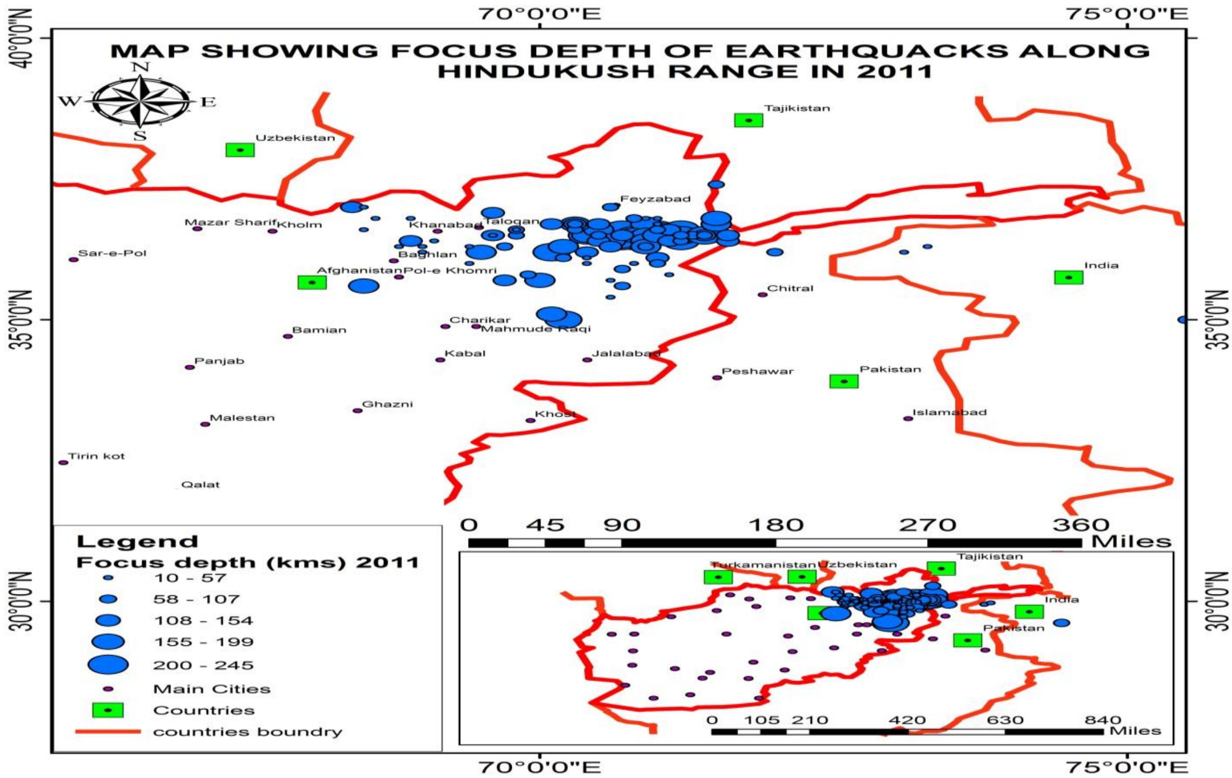


Map; Major tectonics related to Hindu Kush range (courtesy: Geological Survey of Pakistan).


MAP SHOWING FOCUS DEPTH OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2011
70°0'0"E
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Uzbekistan
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India
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Focus depth (kms) 2011
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58 - 107
108 - 154
155 - 199
200 - 245
Main Cities
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Turkamanistan
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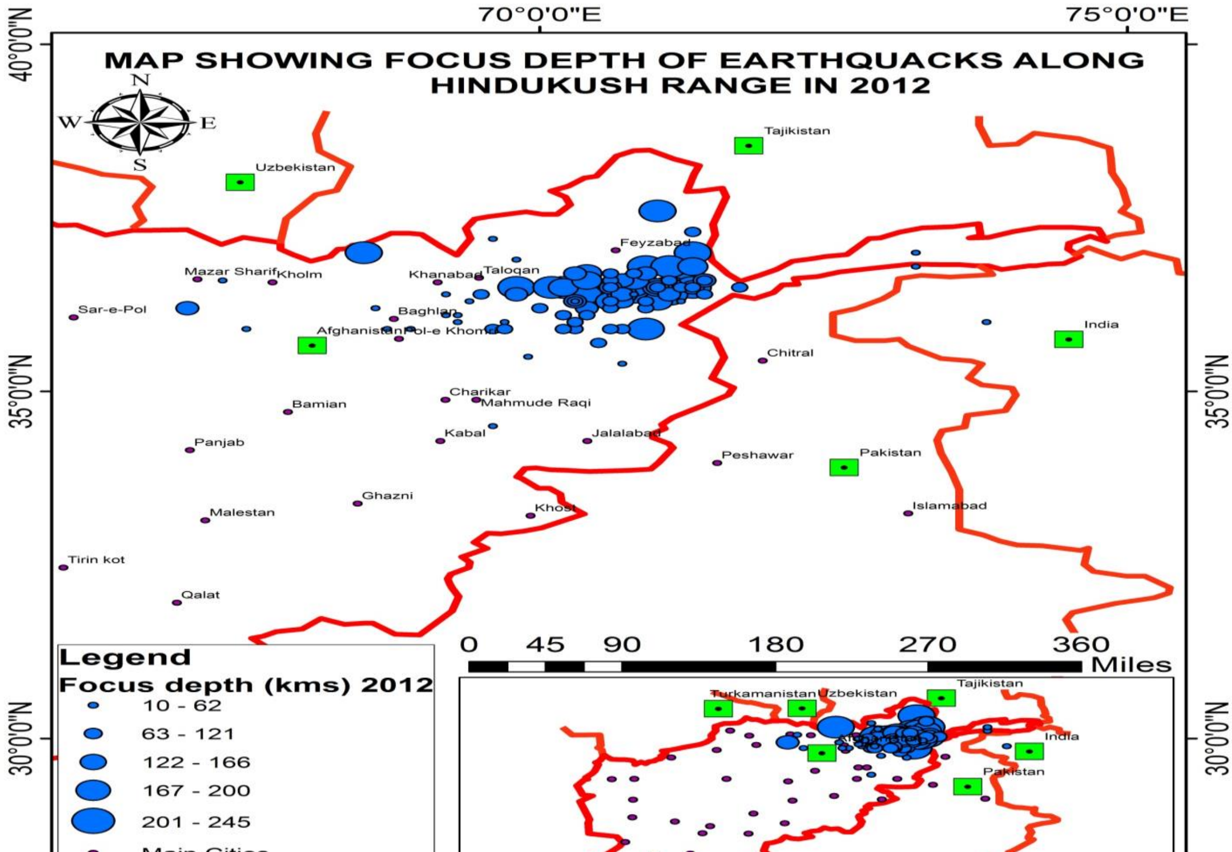
MAP SHOWING FOCUS DEPTH OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2012
70°0'0"E
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40°0'0"N
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30°0'0"N
Uzbekistan
Tajikistan
Afghanistan
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Legend
Focus depth (kms) 2012
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63 - 121
122 - 166
167 - 200
201 - 245
Main Cities
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countries boundry
Turkamanistan
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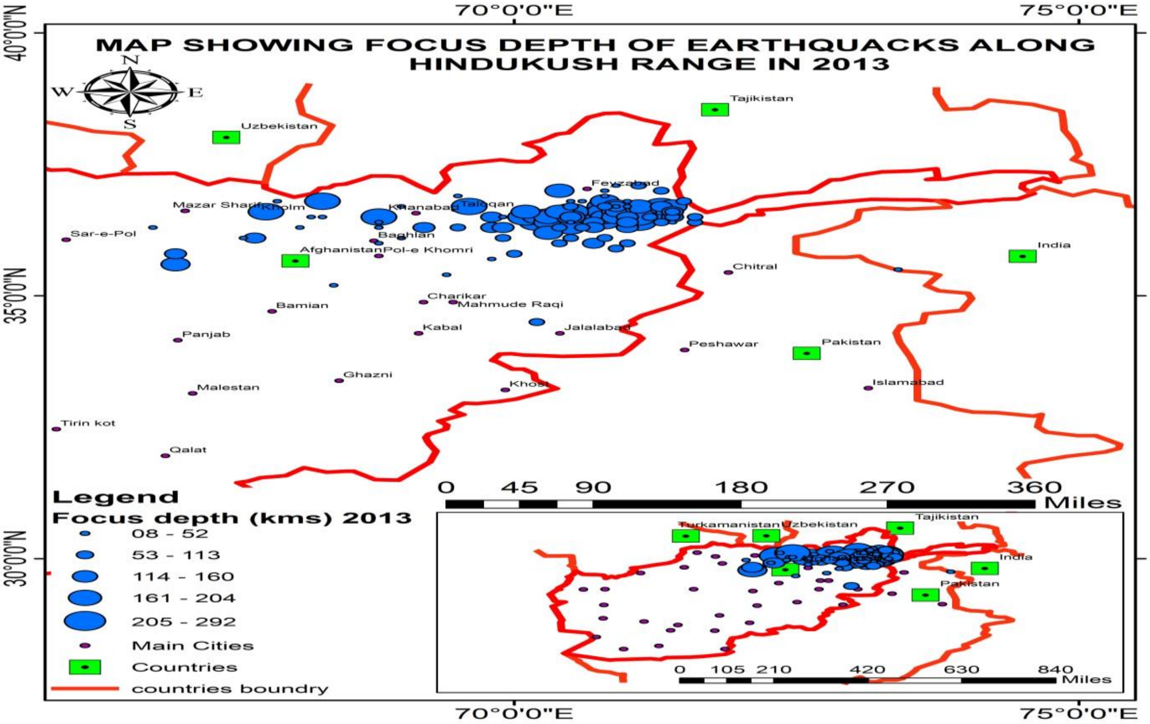

MAP SHOWING FOCUS DEPTH OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2013
70°0'0"E
75°0'0"E
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Focus depth (kms) 2013
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114 - 160
161 - 204
205 - 292
Main Cities
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countries boundry
Turkamanistan
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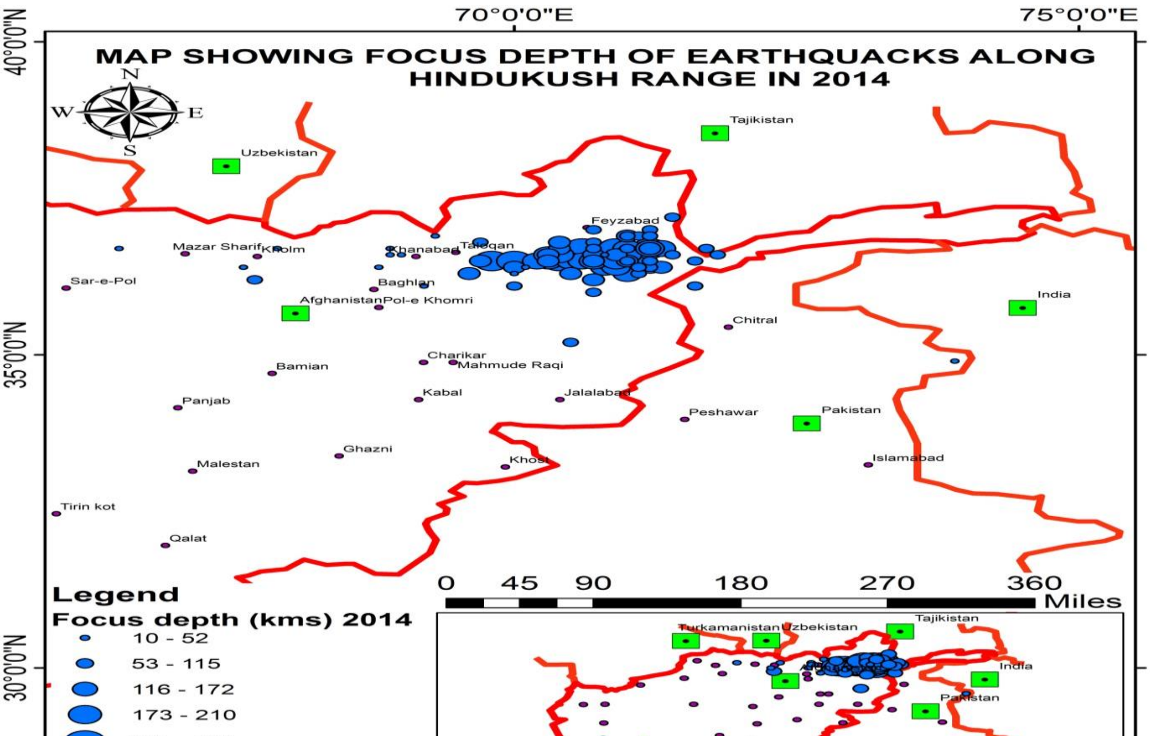

MAP SHOWING FOCUS DEPTH OF EARTHQUACKS ALONG HINDUKUSH RANGE IN 2014
70°0'0"E
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Focus depth (kms) 2014
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173 - 210
211 - 240
Main Cities
Countries
countries boundry
Turkamanistan
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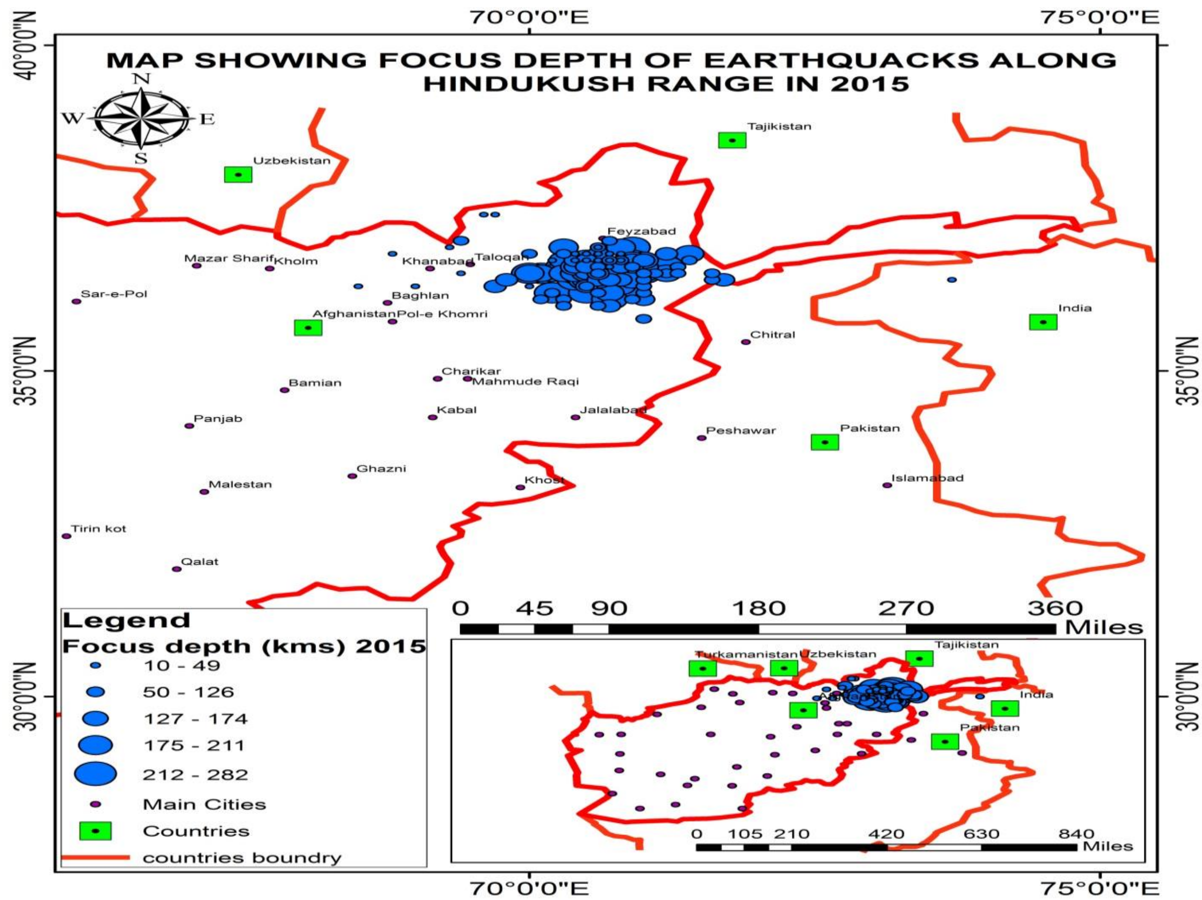

CONCLUSION

The detail data of Hindukush earthquakes and seismic zone from 2011 to 2015 are taken from Pakistan metrological department and then analyze and evaluate through ARC GIS 10.2.1 and presented on different maps year wise.

The following generalized conclusions are drawn from the

- The overall pattern of representation shows distribution of mild, moderate and violent earthquakes along Hindu Kush range in Pakistan and Afghanistan.
- Seismological information is used to define models for the potential earthquake sources that could influence the hazard at the site.
- Mapping of area sources based on the geologic history of the region in general and on earthquake occurrence statistics (historical and contemporary seismicity catalogues) in particular
- The seismic activity is associated with earthquakes of magnitude 5 and larger, and largely coincides with the surface trace of the Himalayan Main Central Thrust (MCT) rather than with the Himalayan Main Boundary Thrust (MBT) which represents the structural boundary.