WORLD ENVIRONMENT DAY
JUNE 2022

on the theme of
ONLY ONE EARTH

Celebrated by
PAKISTAN ENGINEERING CONGRESS

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Engr. Najam Waheed has been a Council Member of Pakistan Engineering Congress for more than two decades. He has been an active member of the Congress serving as Secretary, Joint Secretary, Treasurer, and Convener of all important Committees of the Congress, and was elected as the President of the Pakistan Engineering Congress in December 2021. His vision has been manifested in a digital transformation of the Congress's services and has laid a strong foundation for future growth and developments of Engineers Communities.

His dedication to engineering development and the Pakistan Engineering Congress played a significant role in developing effective synergies with important professional bodies in the country, which would significantly contribute to engineers professional competence in a challenging environment of disruptive technologies and sustainable development.



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WORLD ENVIRONMENT DAY 2022

Message by Mahmood Akhtar Cheema Country Representative IUCN Pakistan

World Environment Day 2022 is the biggest international day for the environment. Led by the United Nations Environment Programme

(UNEP), and held annually since 1973, which is celebrated across the world.

This year World Environment Day 2022 is being hosted by Sweden. The theme of the year is '**Only One Earth**' which focuses on strengthening our relation with nature and our reliance on earth and its importance. It emphasizes the need to care for the only earth, only living place we have.

In Year 2021, Pakistan was the host for the World Environment Day and the celebrations were organized by Ministry of Climate Change and IUCN Pakistan. A range of events at different levels were organized during the year to enhance awareness among various stakeholders.

In the year 2021, as part of the World Environment Day, IUCN Pakistan with the support of UNEP and in partnership with the Ministry of Climate Change and IUCN Pakistan National Committee Members organized a series of events in all provinces of Pakistan and Azad Jammu and Kashmir.

The Government of Pakistan is fully committed to playing a leadership role in addressing the issue of climate change and the ongoing mega initiatives are instrumental in conserving the nature amongst them is the *Ten Billion Tree Tsunami* Programme (TBTTP), which aims to restore and enhance over 1 million hectares of forest across the country, supporting the conservation of biodiversity while generating livelihoods for the local community and above all enhancing the green cover to reduce increasing temperatures and combat climate change.

IUCN Pakistan, FAO and WWF Pakistan work in a consortium for the third party monitoring of the Ten Billion Tree Tsunami Programme. Monitoring of the Programme is on-going country wide in coordination with the TBTTP team and the provincial forest and wildlife departments.

Government of Pakistan's Protected Areas Initiative to develop 15 model protected areas across the country to conserve over 7,300 sq km of land area, is an important step towards the restoration of our unique ecosystems in the country. This also includes certification of seven select Protected Areas across the country with the IUCN Green List of Protected and Conserved Areas.

IUCN Pakistan has been instrumental in getting notified a number of protected areas across Pakistan including the Astola Island declared as Pakistan's first Marine Protected Area. IUCN Pakistan facilitated the process of bringing together all the stakeholders that included: the federal Ministry of Climate Change; Government of Balochistan; Pakistan

Navy; National Institute of Oceanography; WWF-Pakistan; Indus Earth Trust; and Sindh Forest and Wildlife Department. Further collaborative efforts are under way for bringing more areas under Protected Areas' regime for effective management of existing protected areas. Similarly IUCN Pakistan facilitated the notification of three new protected areas in Gilgit Baltistan, namely Handrap, Himalaya and Nanga Parbat National Parks. IUCN Pakistan is working with the Ministry of Climate Change and provinces to establish National Parks Service and certification of the protected areas under the IUCN Green List of Protected and Conserved Areas. Khunjerab National Park is the first one to be nominated by Government of GB for the IUCN Green List, similarly other provinces are also nominated their respective National Parks.

IUCN Pakistan assisted the Forest and Wildlife Department, Government of Balochistan, in designating the Juniper Forest Ecosystem as UNESCO's Man and the Biosphere Reserves. The process was led by IUCN Pakistan, with support by UNDP and in collaboration with Government of Balochistan, in consultation with key stakeholders including local communities and other relevant government departments.

IUCN Pakistan is implementing Biodiversity Safeguarding project with the support of Italian Government and in collaboration with Government of Gilgit Baltistan, in north of Pakistan to assess and mitigate the impacts of infrastructure development projects. Community led initiatives like nature-based tourism, youth initiatives like winter sports and biodiversity corridors in the national park, assessment of key flora and fauna species are some of the highlights.

IUCN's Business and Biodiversity Platform started off with its first chapter at the Port Qasim Area, in collaboration with top-notch private sector companies in Karachi. It has in its short duration launched a million mangroves plantation initiative, engaged businesses to provide their feedback on environmental degradation in the PQA area with a view to environmental betterment, and carried out exposure visits. This is a promising initiative meant to encourage businesses to invest in ecosystems and sustainable development. Besides, IUCN Pakistan is implementing various joint initiatives in collaboration with Government of Sindh, Government of Balochistan and various private sector institutions for restoration of mangroves along the coast of Pakistan. Under its recent projects IUCN has planted mangroves over 8000 hectares along the Sindh and Balochisan coasts. Mangrove plants have the highest carbon absorption capacity. According to the REDD Plus assessments an average tree absorbs around 12.5 Kgs of CO2 per annum.

Presently, IUCN Pakistan is implementing the Biodiversity Management Plan prepared for 720 MW Karot Hydropower project in partnership with the Governments of Punjab and AJK, local communities and schools through funding from Karot Hydropower Company (Pvt) Limited, initially for 2 years (2021-2022). Based on the remarkable performance of IUCN, the respective governments have endorsed extension of the project period for another 3 years. Multifunctional Management Plans for the two newly notified national parks of Azad Pattan and Murree Kahuta Kotli Satian are being prepared to address the key biodiversity concerns, while educating the local communities and youth.

In the present time, Climate Change is heavily impacting our one earth in multiple ways. Climatic conditions are highly unpredictable and has impacted ecosystems, biodiversity,

water availability, crop yield and much more. Increasing temperatures call for local actions for a larger impact. While it is important to increase green cover, conserve biodiversity, conserve water, it is essential to care for earth by reducing pollution, reducing emissions, reducing waste and improving our practices as responsible inhabitants of the this beautiful earth. Climate Change has so heavily impacted the ecosystems and the lives of living beings in multiple ways. Realizing the most important role of human beings in combating climate change, IUCN jointly with Ministry of Climate Change with the support of Green Climate Fund is working on the first National Climate Change Gender Action Plan (ccGAP) that focused on six select sectors including; agriculture and food security; forest and biodiversity; disaster risk reduction; integrated coastal management, water and sanitation; and mitigation, energy and transport.

The Covid-19 pandemic has made it clear that our dependence on healthy and vibrant ecosystems for our health, water, food, medicines, clothes, fuel, shelter and energy is only on this earth which reflects through this year's theme of ***"Only One Earth".***

Every year, on June 05, World Environment Day is celebrated worldwide to renew our resolve and commitment to make this world a better place for us and our coming generations. The theme gives us a very clear message that there is **ONLY ONE EARTH** and there is no other place to go therefore we need to protect this earth at every cost.

Thank you

Mahmood Akhtar Cheema

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Paper No. 131

SEISMICITY TREND ANALYSIS IN AND AROUND PAKISTAN REGION BETWEEN 1900 – 2022

Z. Rafi, N. Mahmood, Sajjad, S. Rafiq, M. Butt, A Najeeb

SEISMICITY TREND ANALYSIS IN AND AROUND PAKISTAN REGION BETWEEN 1900 – 2022.

By:

Z. Rafi, N. Mahmood, Sajjad, S. Rafiq, M. Butt, A Najeeb,

Seismic Division, Pakistan Meteorological Department, Islamabad

Key words: seismicity, seismic hazard, active faults, subduction zone

Abstract:

Pakistan exhibits heterogeneously seismicity distributed. The seismic and tectonic studies in the region confirm the existence of a complex active tectonic framework with high deformation rate in terms of earthquake activities. Pakistan region can be divided into several active seismic zones based on spatial and temporal distribution of earthquakes. A number of faults and fault systems exist in the region. This region has experienced many damaging earthquakes i.e. 1935 Quetta, 1945 Makran earthquake, 2005 Muzaffarabad earthquake, 2013 Awaran earthquakes in Pakistan; and the 2002 Hindu-Kush (Mw.7.4) and 2015 Hindu-Kush (Mw.7.5) earthquakes in Afghanistan. An analysis is carried out for the occurrence magnitude reported in the earthquake catalogue of PMD seismic Network from 1900 - 2022 with the aim to know the general features of the seismicity. The results obtained in trend analysis revealed that the earthquake frequency is higher in the Hindukush region as compared to rest of the seismic zones of Pakistan. Repeating seismic events are common in the Hindukush Region having an intermediate depth range 100-300km which causes strong shaking in adjacent areas. However, Hazara Kashmir Syntaxis and Northern Pakistan are seismically active regions which produce shallow earthquakes while Eastern and Western margins of Salt Range where Kalabagh and Jhelum faults are present are more active and produce mostly light to moderate size earthquakes. Suleman fold and thrust belt and Chaman fault zone (a strike-slip structure) are major source of seismicity in the south-western Pakistan. Makran Subduction zone is another major potential source. This can produce great earthquakes but return period is very long. An increasing annual seismicity trend is observed in the Hindukush zone (b>1.0) indicating higher tectonic stress release. Higher b-values are observed in the Northern Pakistan; however b-value is nearly same in other seismicity source zones of the Pakistan. Present study is based on an earthquake catalogue of PMD gives an overview of the seismic activities in and around Pakistan region. This study will help in scientific research to quantify the seismic hazard in the region against any major earthquake.

Introduction

Pakistan is situated on collision zone of Indian and Eurasian plates that has created the Himalayan mountain ranges which make them vulnerable to earthquakes. Pakistan geographically lies between 60°E to78°E & 24°N to 37°N. It has high density of active faults and is seismically one of the most active areas of the Asia. Tectonically it is located in the region of intersection of **three plates**, Indian, Eurasian and Arabian Sea plate. Therefore, the tectonics in the study region is very complex along with the

existence of many major fault systems in the Northern areas of Pakistan. Seismo-tectonic setting of the study region along with damaging earthquakes of Northern and North-western Pakistan are plotted in Figure-1. Pakistan is split along the boundary between the Eurasian and Indian plates where the India plate slides northward relative to the Eurasia plate in the east. These motions typically result in north-south to northeast-southwest strike-slip motion.

Pakistan is the fifth most earthquake-prone country in the world. The country straddles between the Indian and the Eurasian tectonic plates and is located on the Indus-Tsangpo Suture Zone, which is roughly 200 km north of the Himalaya Front. This makes it highly susceptible to earthquakes. **The Chaman Fault** is a major, active geological fault in Pakistan and Afghanistan that runs for over 850 km. The slippage rate along the Chaman fault system as the Indo-Australian Plate moves northward (relative to the Eurasian Plate) has been estimated at 10 mm/yr or more.

Other faults

- Main Karakoram Thrust.
- Riasi Thrust.
- Salt Range Thrust.
- Bannu Fault.
- Quetta-Chiltan Fault.
- Allah Bund Fault.
- Hoshab Fault.
- Makran Coastal Fault.

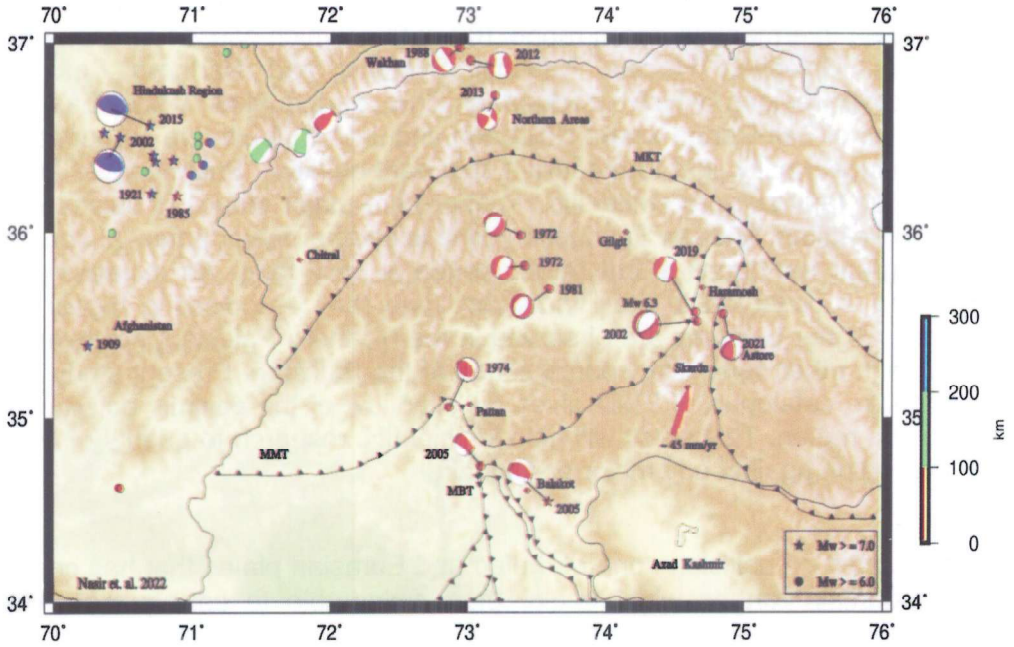


Figure-1: Seismo-tectonic setting of North and Northwestern Pakistan (Study Region) with major geological faults, significant earthquakes and their source mechanisms.

The study area can be divided into three regions on the basis of geological setting and seismic activities:

1. Hindukush Region Afghanistan
2. Hazara Syntaxis Region
3. Northern Areas of Pakistan

The Hindu Kush is an 800-kilometre-long (500 mi) mountain range in Central and South Asia to the west of the Himalayas. It stretches from central and western Afghanistan into northwestern Pakistan and far southeastern Tajikistan. The Hindu Kush seismic zone strikes due east-west at a latitude of about 36.4°N. Whereas seismic activity ceases at depths of 130-150 km in the east, the south-western part of the zone shows earthquakes reaching depths of up to 240 km. The earthquakes arising out of Hindu Kush region are said to be the result of slow collisions between the Indian subcontinent and the Eurasian tectonic plate. Deep earthquakes can also be caused by friction; if a small area deep inside a fault moves. The analysis indicates that the most probable largest annual earthquakes are close to 6.0, 4.9 and 5.0 for the three different zones.

The Hazara-Kashmir Syntaxis is an important tectonic element of internal arc system of the Pamir-Punjab Syntaxis. Hazara-Kashmir Transverse Trough, also termed as Hazara–Kashmir Syntaxis, is a seismically active region.

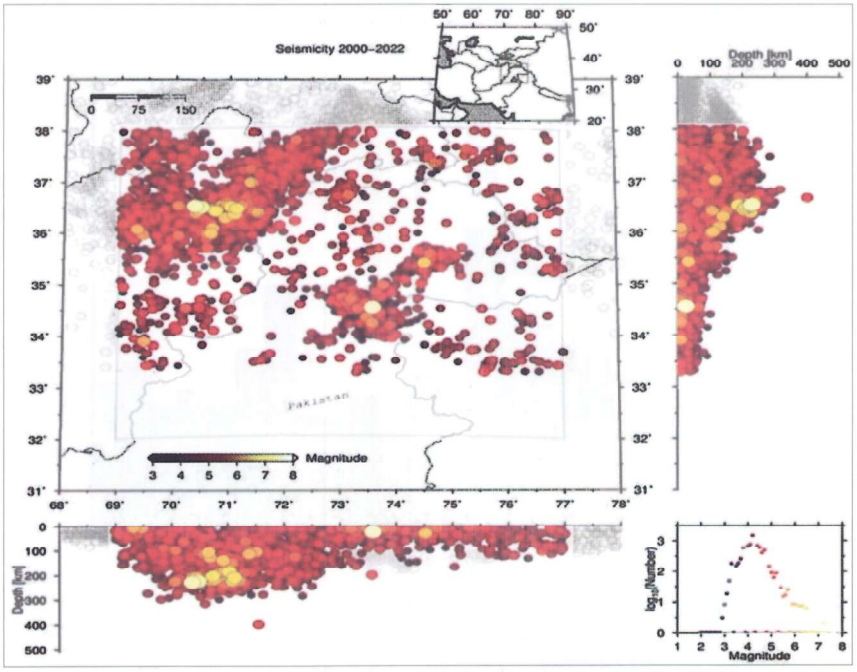


Figure-2: Spatial variation of seismicity in and around North Pakistan, depth-wise Seismicity distribution and Frequency Magnitude Plot (Jan 2000- Jan 2022).

Pakistan geologically overlaps both the Eurasian and Indian tectonic plates. Hence this region is prone to violent earthquakes, as the two tectonic plates collide. Earthquake catalogue is compiled from Jan 2000- Jan 2022 by using PMD, ISC and USGS sources. A review of the earthquake data compiled in the presented study indicates that

sufficiently large number of earthquakes (nearly 1000) occurred between (Jan 2000- Jan 2022). Spatial distribution of overall seismicity: depth-wise distribution and Frequency Magnitude Plot is shown in the Figure-2.

Some prominent earthquakes occurred in the above mentioned zones are listed in Table-1.

Table-1: Significant Earthquakes (Jan 2000 – Jan 2022) within Study Region

Date	Lat (°N)	Long (°E)	Depth (km)	Mw	Epicentre
2005-10-08	34.54	73.59	26	7.6	22 km NE of Muzaffarabad, AJK
2015-10-26	36.52	70.37	213	7.5	Hindu Kush Region, Afghanistan
2002-03-03	36.51	70.48	225	7.4	Hindu Kush Region, Afghanistan
2002-11-20	35.42	74.51	33	6.3	58 km SE of Gilgit, Pakistan

1. Evaluation of Earthquake Catalog for Hindukush Region Afghanistan:

Hindukush Seismic zone exhibits continuously higher level of seismic activities. More than 10000 events with magnitude Mw ≥ 4.2 are observed in the catalogue and average frequency of the earthquake occurrence is about 250 events/year (Figure-3a).

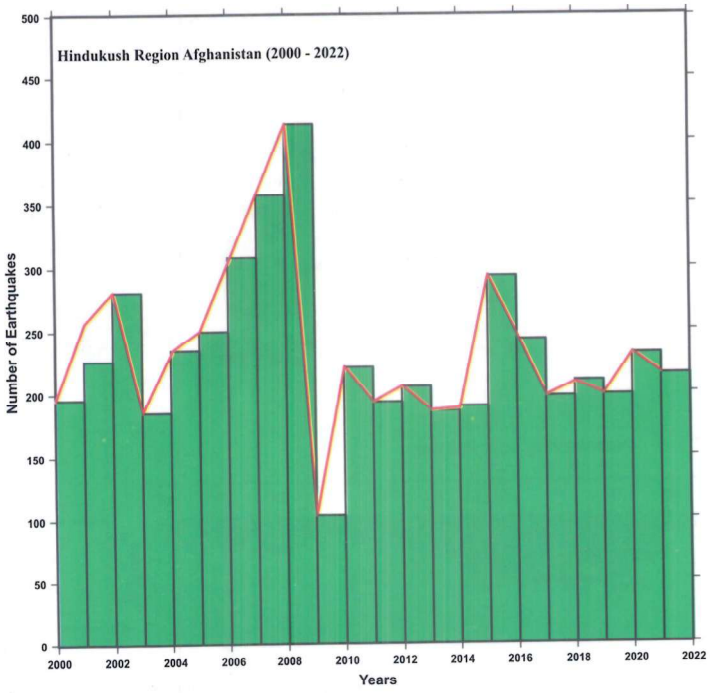


Figure-3a: Earthquake Frequencies in Hindukush Region Afghanistan (Mw≥4.2) and variation of trend (Jan 2000- Jan 2022).

The maximum earthquake magnitude potential observed in the Hindukush region is Mw > 7.0 in 10 - 15 years period and Mw > 6.5 in 5 - 7 years period from the recent earthquake patterns (Figure-3b).

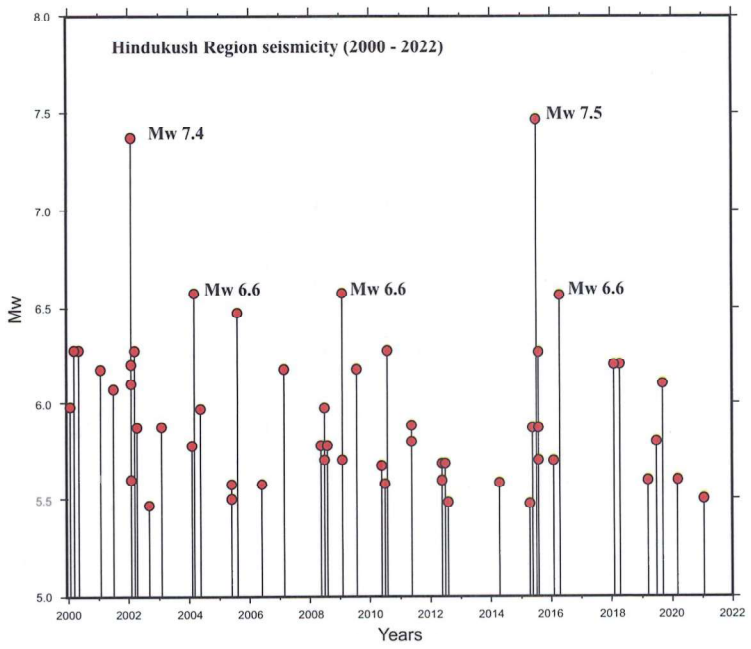


Figure-3b: Earthquake Magnitude (Mw≥5.5) distribution over time for Hindukush Region.

The repeating pattern is a prominent feature of this region resulting from periodic tectonic process. The cause of earthquake periodicities, however, remains a mystery. Two major earthquakes in the region occurred in 2002 and 2015 of Mw 7.4 and 7.5 respectively.

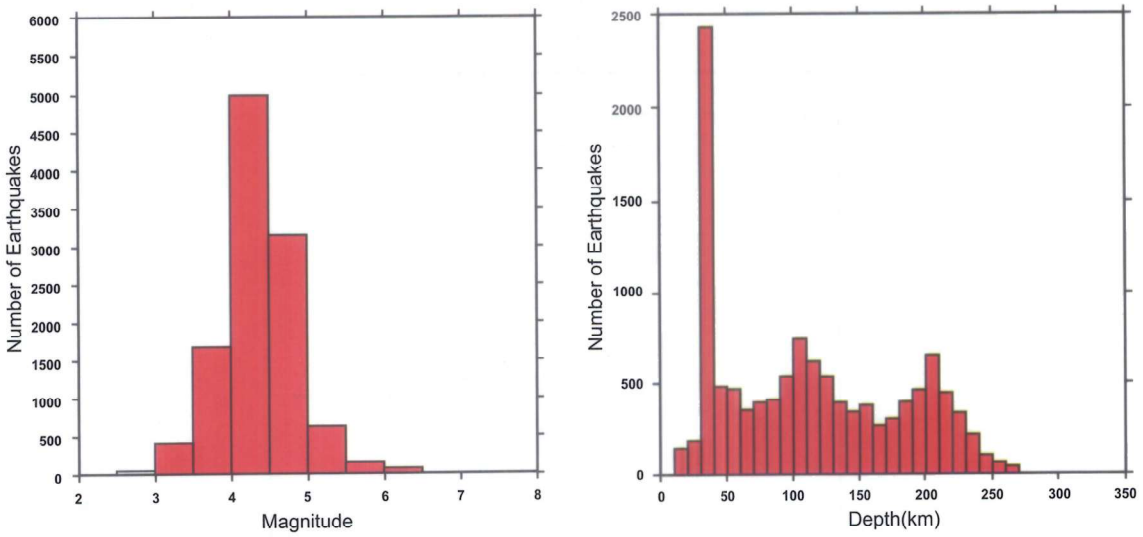


Figure-3c: Hindukush Region Earthquake Magnitude and Depths Histogram.

Magnitude histogram shows highest frequency for events lying between M 4 – 4.9. Most of these events lie at intermediate depths as shown in Figure-3c. There is an average of 20-30 earthquakes of Mw≥5.0 per year. These earthquakes are felt widely in different areas of Pakistan.

Maximum likelihood solution is used to estimate b-value and a-value of seismicity in Hindukush Region, Afghanistan plotted in Figure-3d.

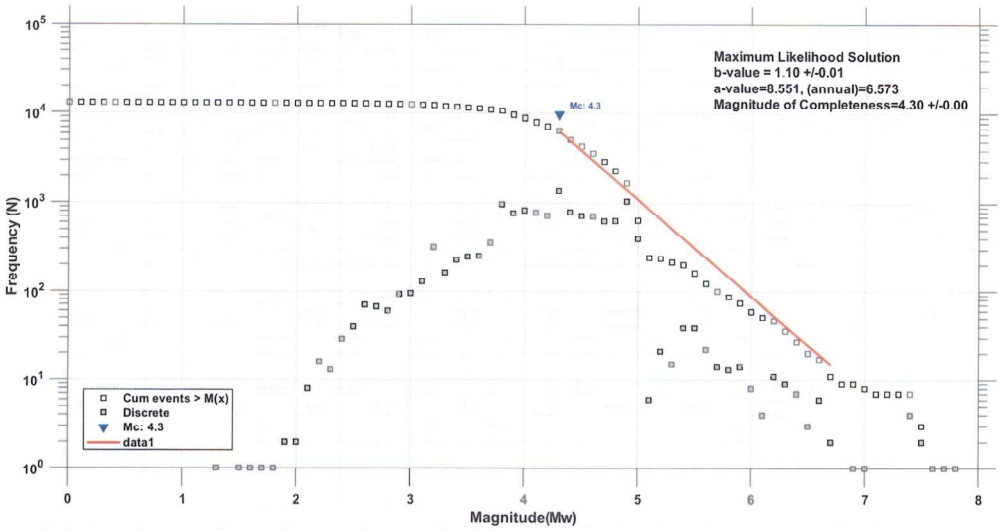


Figure-3d: b-value and a-value estimate for Hindukush Region (maximum likelihood solution)

The b-value based on maximum likelihood solution is estimated as 1.14 and a-value as 8.5, which is comparatively high, indicating continuous release of seismic energies.

2. Evaluation of Earthquake Catalog for Hazara Kashmir Syntaxis Region

Hazara Syntaxis is also a tectonically active region. Frequency of felt earthquakes is high. A large number of earthquakes occurred after the Kashmir earthquake (2005) of Mw 7.6, along with its aftershocks in this zone.

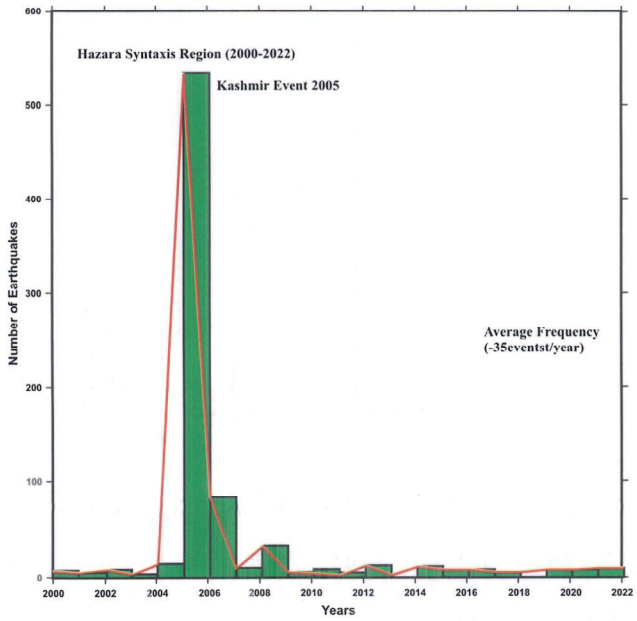


Figure-4a: Earthquake Frequencies in Hazara Syntaxis Region (Mw≥4.2) and variation of trend

This zone has a possibility of maximum earthquake magnitude of Mw > 7.0 in about 100 years return period time and Mw ≥ 5.0 in a period about 2 - 3 years.

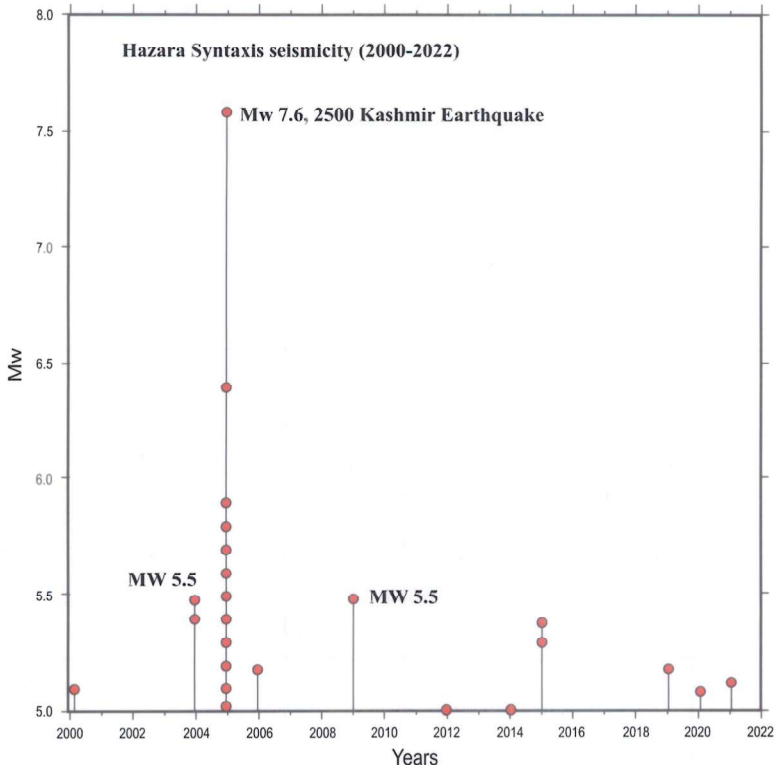


Figure-4b: Earthquake Magnitude (Mw > 5.0) distribution over time for Hazara-Kashmir Syntaxis

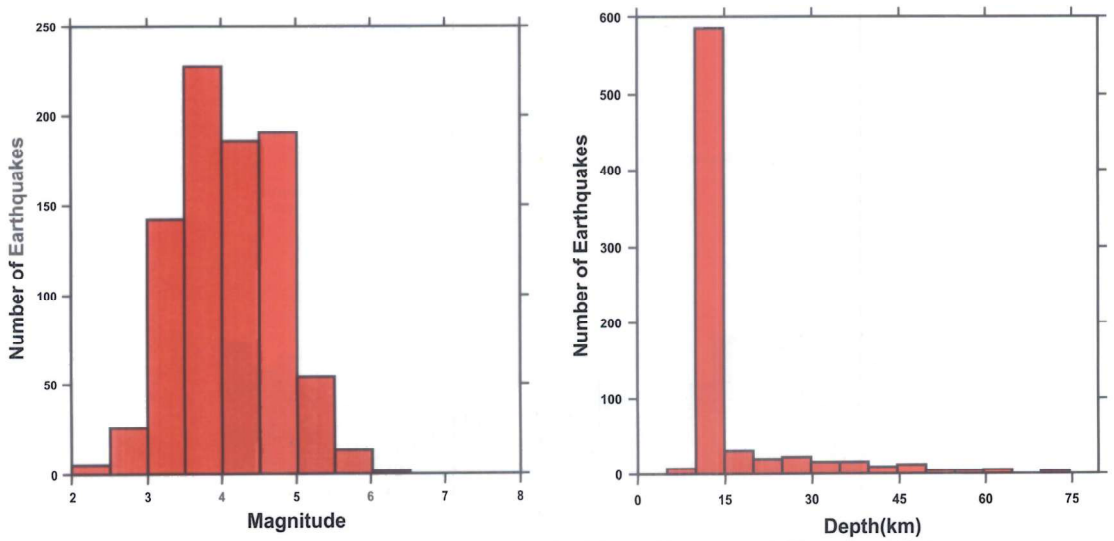


Figure-4c: Hazara-Kashmir Syntaxis Magnitude and Depths Histogram.

Magnitude histogram shows highest frequency for events lying between M 3.7 – 4.9. Most of these events lie at shallow depths as shown in Figure-4c.

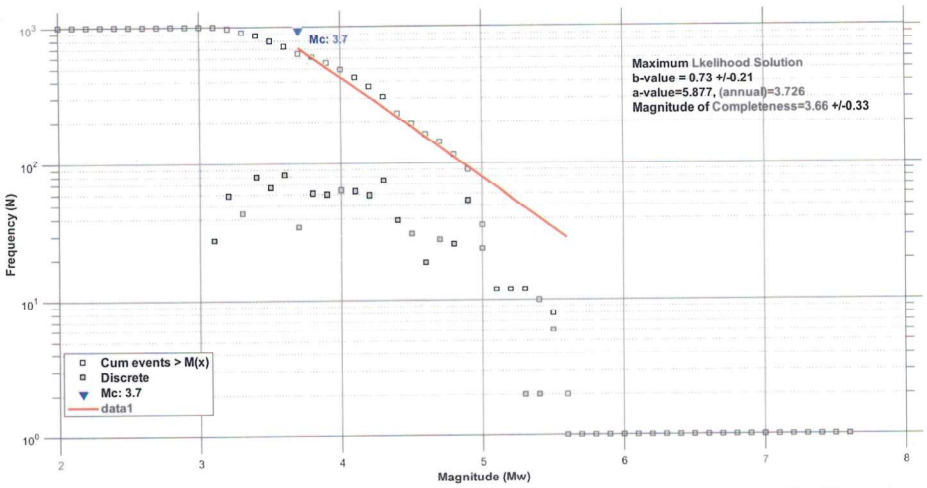


Figure-4d: b-value and a-value estimate for Hazara Syntaxis (maximum likelihood solution)

The b-value is estimated about 0.73±0.21 and a-value is 5.87, which is comparatively high, due to the presence of aftershock clusters.

3. Evaluation of Earthquake Catalog for Northern Areas of Pakistan

Northern Areas of Pakistan is also a tectonically active region. Frequent earthquakes occurred after an earthquake in 2002 of Mw 6.3, along Nanga Parbat-Haramosh Syntaxis.

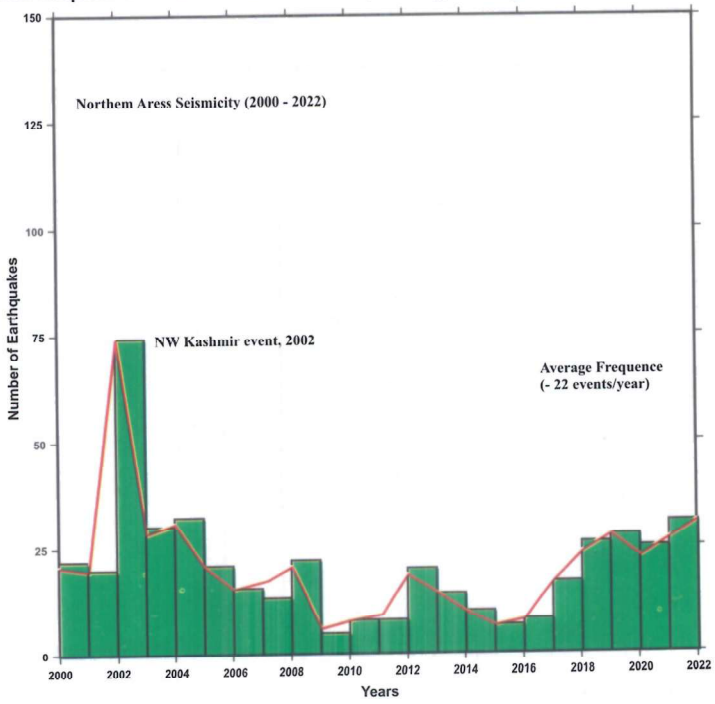


Figure-5a: Earthquake frequencies (Mw≥4.2) in northern areas of Pakistan (Jan 2000- Jan 2022).

This zone exhibits moderate size seismic activities continuously. Average frequency of felt earthquake occurrence is nearly 22 events/ year. Prominent earthquake in this zone occurred on Nov. 20, 2002 of Mw 6.3 with more than 80 aftershocks and Mw 5.6 in Dec 26, 2019.

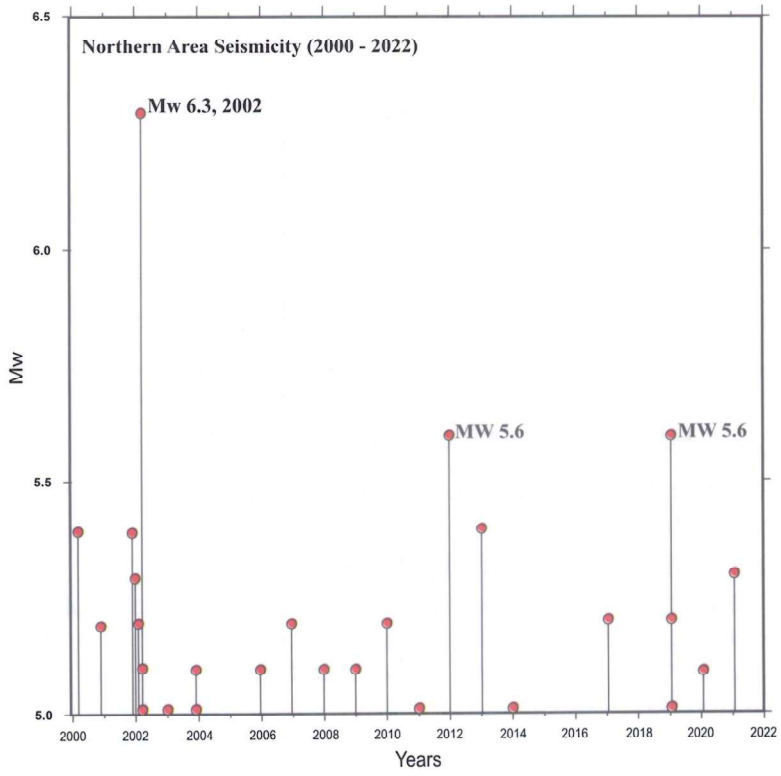


Figure-5b: Earthquake Magnitude (Mw > 5.0) distribution over time (Jan 2000- Jan 2022).

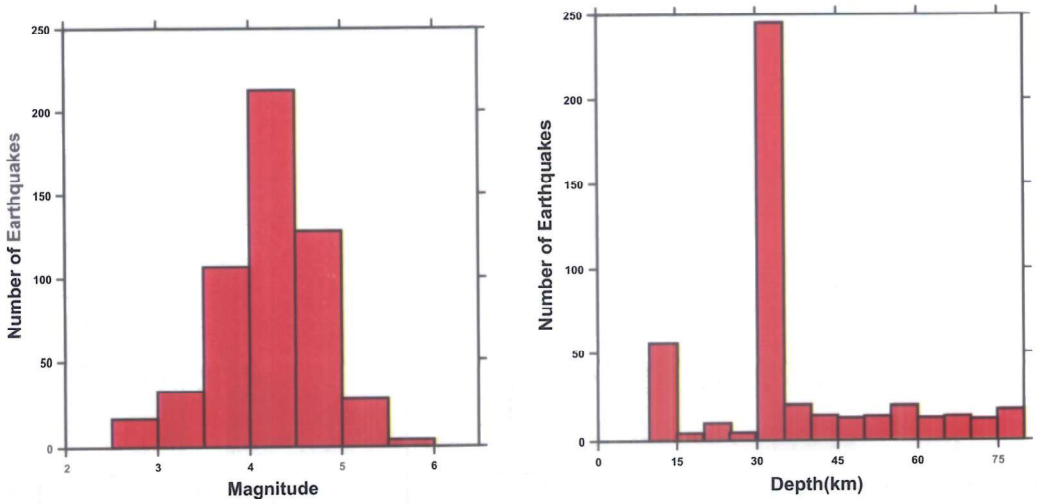


Figure-5c: Northern Region Magnitude and Depths Histogram plot.

Magnitude histogram shows highest frequency for events lying between M 3.5 – 6.3. Mostly these events lie at shallow depths as shown in Figure-5c.

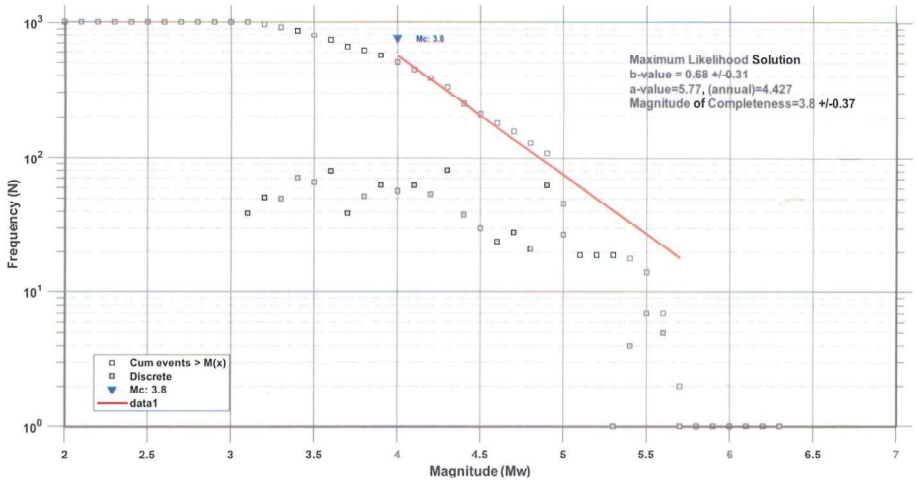


Figure-5d: b-value and a-value estimate for Northern Region.

The b-value is estimated about 0.68±0.21 and a-value is 5.77, which is also comparatively moderate to high.

Seismic Hazard Estimates for Study Area

Seismic hazard assessment (PGA) is computed for return periods of 50 years and 475 years by using earthquake catalogue compiled from PMD, ISC and USGS sources, historical and recent major earthquake records and data related to the tectonics of the region (Figure-6a and 6b).

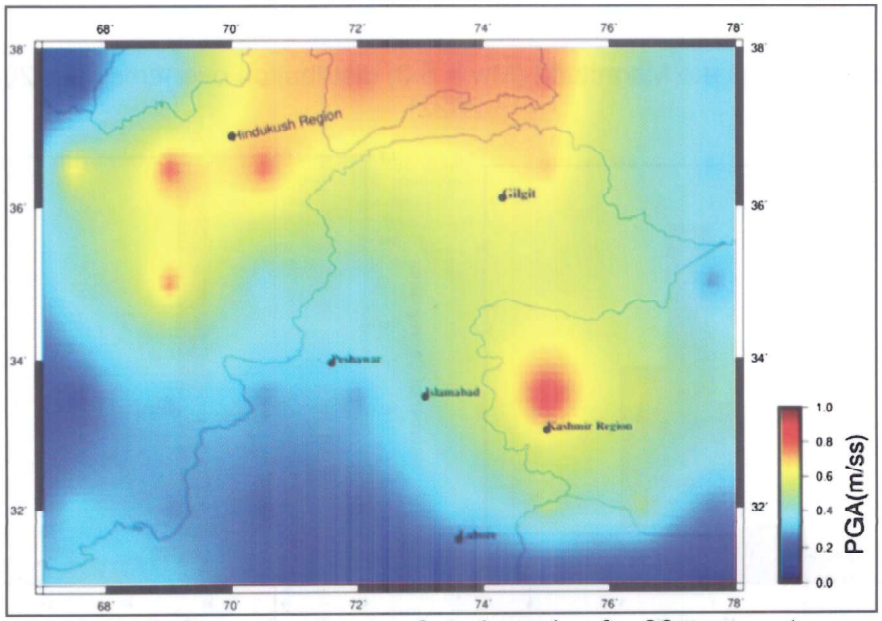


Figure-6a: Seismic hazard estimate of study region for 30 years return period in Northern Pakistan.

High seismic hazard exists in Hindukush and Northern Pakistan for 475 years return period time (Figure-6b).

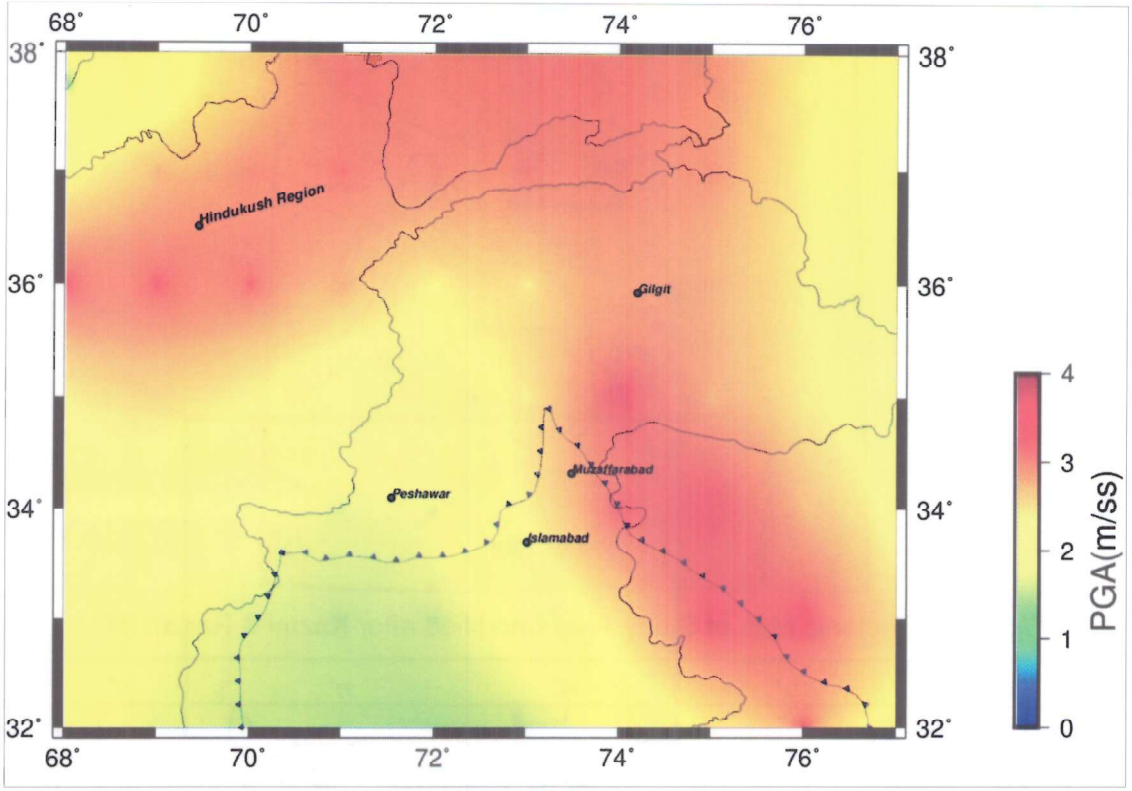


Figure-6b: Seismic hazard estimate of study region for 475 years return period.

Based on these maps and above analyzed seismicity pattern it is confirmed that damaging earthquakes are relatively high in Northern and Northwestern Pakistan, so it is important to quantify the hazard they pose to the built environment. The attenuation model selected for these estimates may underestimate the results.

Secrtion-2: Study on Potwar Basin, Salt Range Thrust etc

The study area includes Potwar Basin, Salt Range Thrust (SRT), Bannu Basin, Kohat Basin and Punjab Plain. The study area is mainly surrounded by Main Boundary Thrust (MBT) in the north, Kalabagh Fault in the west (Figure-1 & Figure-2). Historically few teleseismic events are located at the southern, central and eastern margin of the Salt Range. Along the eastern margin of Potwar Plateaue and Salt Range, Jhelum fault is apparently active and responsible for deep linear gorge of the Jhelum River between Muzaffarabad and Jhelum. In the south of Jhelum fault it appears as lineament and traced up to Ravi River. A number of teleseismic events are located along this lineament. The Jhelum fault, Kalabagh fault, Surghar fault and Sargodha Shahpur ridge are seismically active features (Kazmi& Jan, 1997).

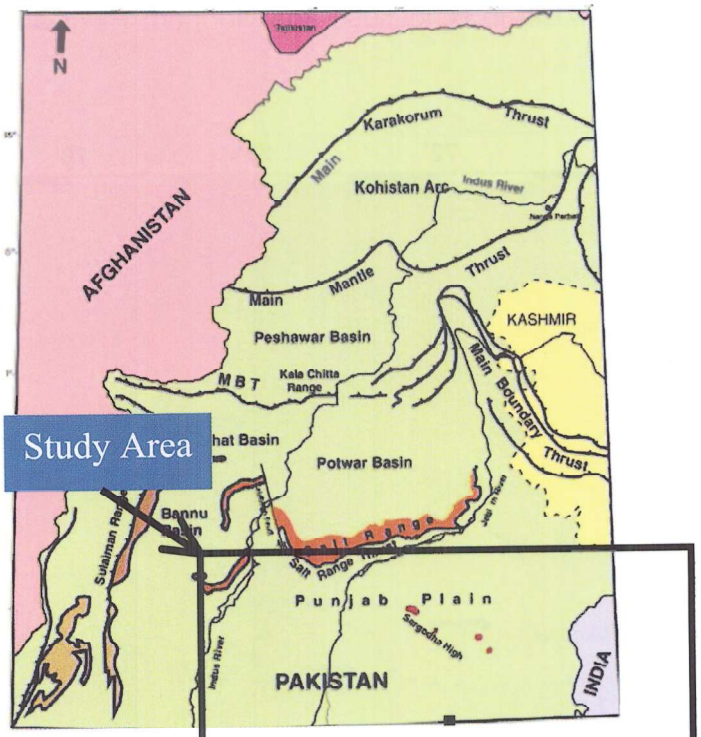


Figure-7: Tectonic Map of Study Area (modified after Kazmi & Rana 1982)

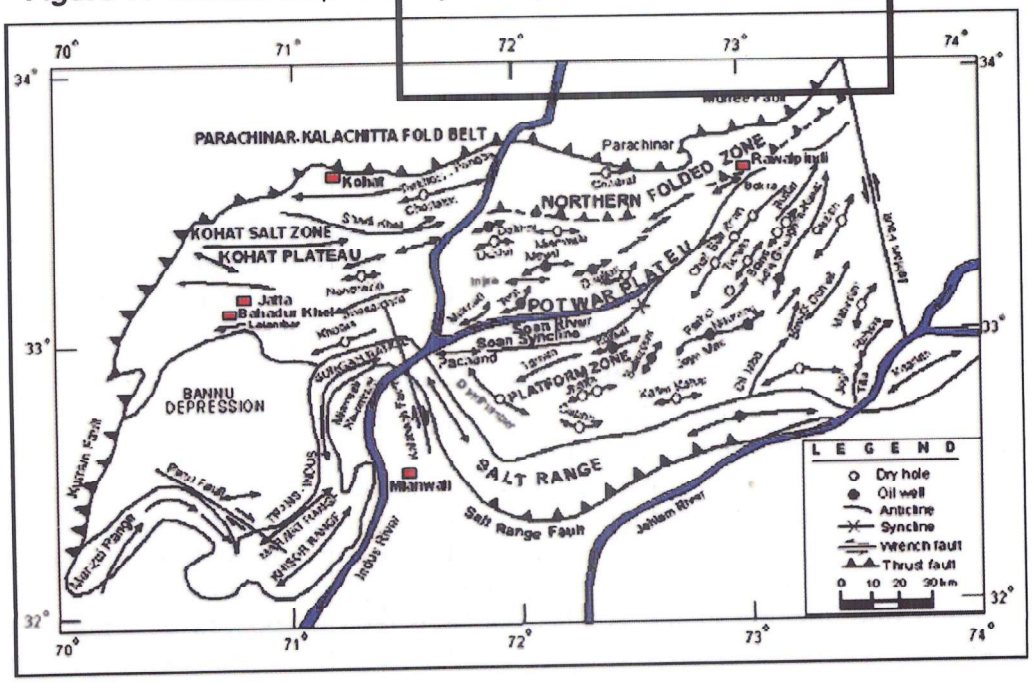


Figure-8: Detail Structural Map of the Study Area. The Potwar sub-basin is an active tectonic feature of the Himalayas and is a part of foreland fold-and-thrust belt in northern Pakistan. Potwar Plateau is situated in Rawalpindi, Attock, and Jhelum districts. It lies

between the Indus and Jhelum rivers and is bounded on the north by the Hazara Hills and on the south by the Salt Range. The range covers Jhelum, Chakwal, Kalabagh and Mianwali districts.

2.1 Seismicity Pattern:

Seismicity pattern of the study area shows micro to moderate level seismicity (Figure-3). Moderate level seismicity is located near Salt Range, only 3 earthquakes located in last 20 years. The western and eastern part of Salt Range Thrust is active for micro to light seismicity where Kalabagh fault and Jhelum fault are located respectively. Punjab Plains and 3 basins including Potwar, Bannu Kohat and have dispersed seismicity with micro to light level. Jhelum Fault is the north–south-oriented major structural lineament originating from the Hazara-Kashmir Syntaxis and extending southwards towards the Mangla Lake. None of the previous research addresses the subsurface model of this fault; consequently, its surface extent has been ambiguous and variably reported. The Rawat Fault is a geological fault in Pakistan. It runs through Punjab, from Rawat, Islamabad to Kashmir.

2.2 Seismic Trend Analysis:

The Figure-3 indicates the seismicity of the study area. Maximum earthquake occurs less than 4.0 magnitudes and then up to 4.9 magnitudes. This level of seismicity is considered to be less risky to the lives of people living in this area. According to the trend line in Figure-10, an average magnitude of earthquake is found close to 3.5. The level of seismicity is low and no significant clustering is found. From 2000 to 2011 a regular pattern of earthquakes is observed regarding magnitude. This area doesn't have potential of generating big earthquake.

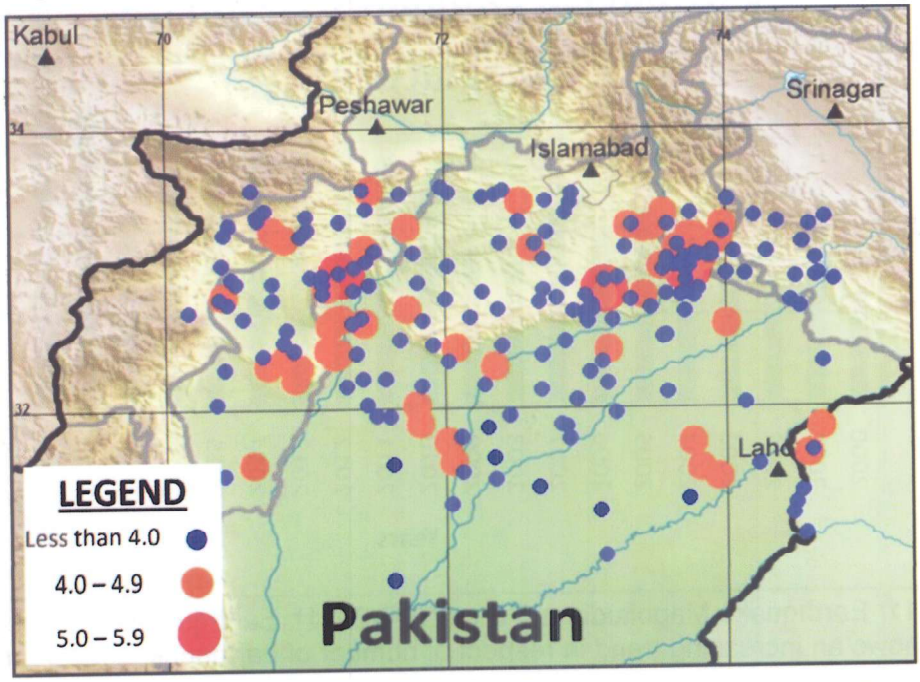


Figure-9: Seismicity Map of Study Area (2000-2021). Level of seismicity is low.

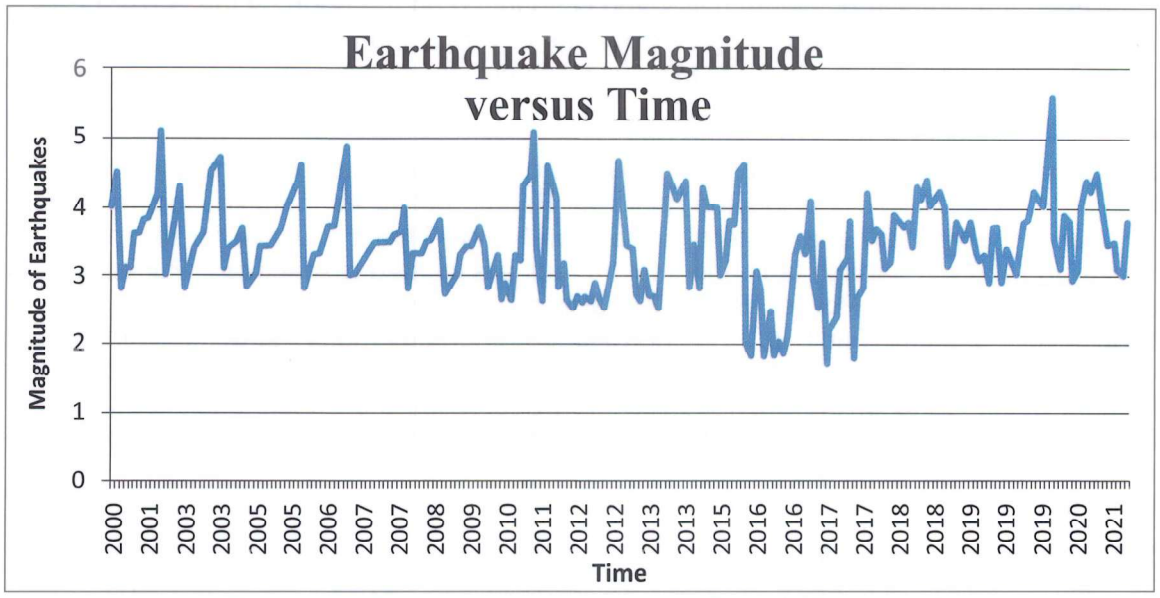


Figure-10: Earthquake Magnitude vs Time (2000-2021)

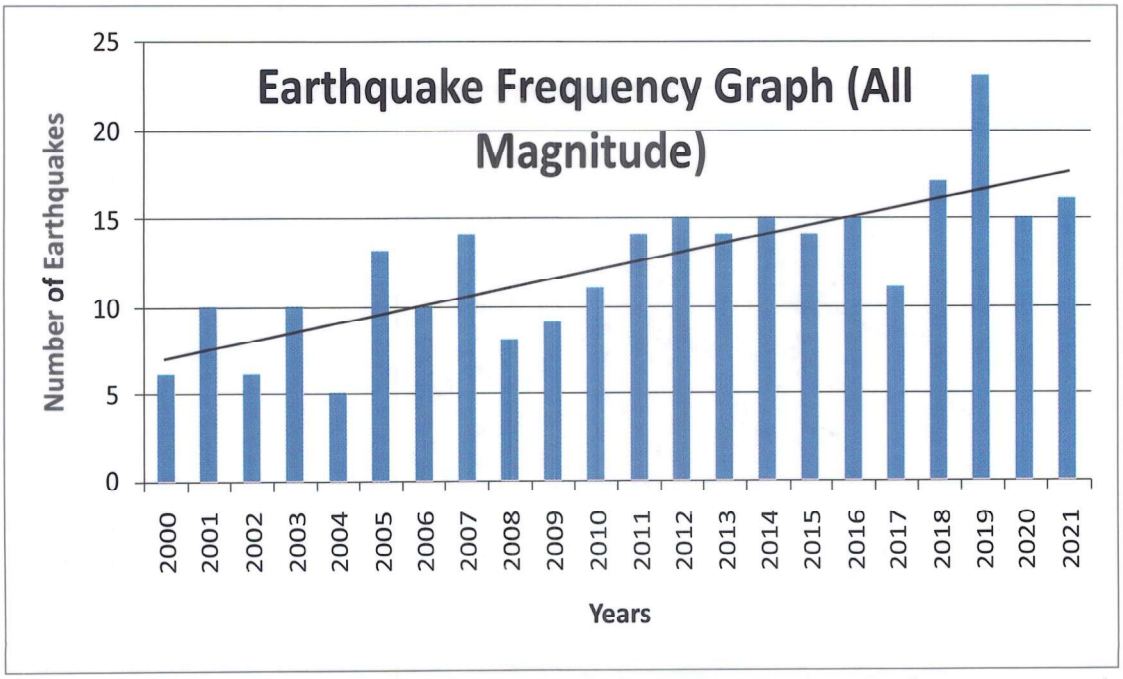


Figure-11: Earthquake Magnitude vs Time (2000-2021). Earthquake frequency graph shows an increasing trend in respect of number of earthquakes per year.

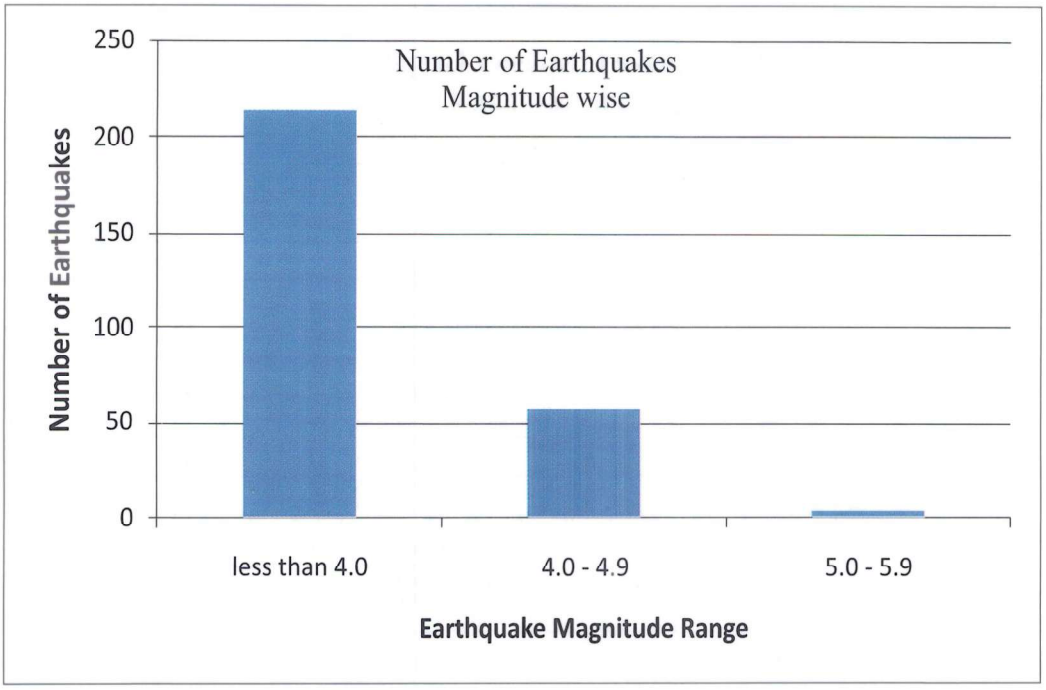


Figure-12: Frequency of earthquakes magnitude wise (2000-2021). Graph shows the number of earthquakes with categorized magnitudes. Obviously minor to light earthquakes are quite common in study area, Only-3 earthquakes are recorded above 5 magnitudes.

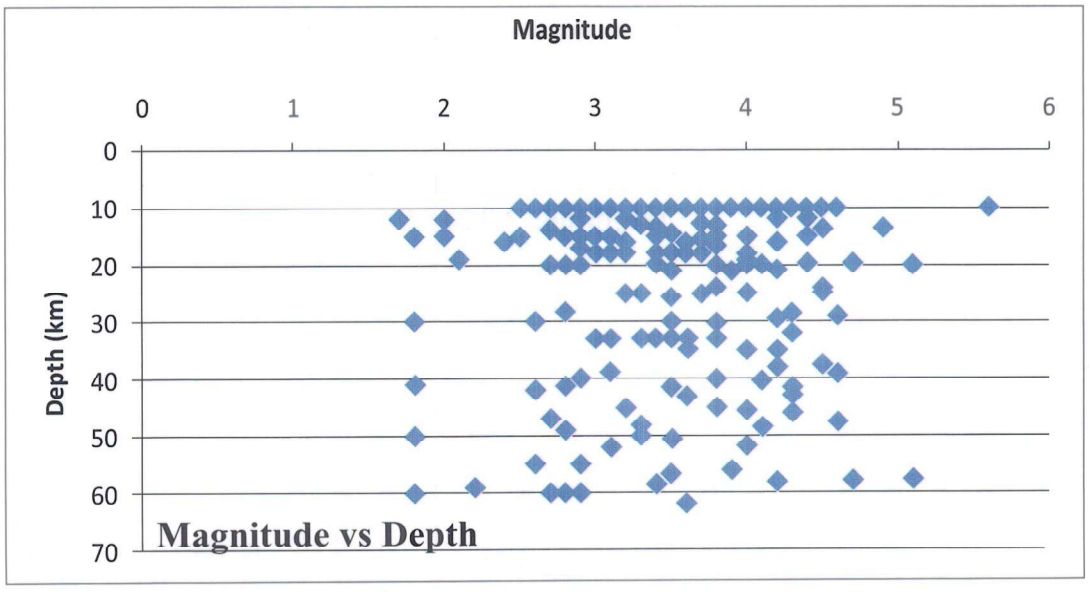


Figure-13: Earthquake Magnitude vs Depth (2000-2021). This figure represents a graph between magnitudes versus depth, showing a cluster between 10 to 20 km depth with magnitude range 3.5 to 4.5. The other depths of all magnitudes in the graph are dispersed.

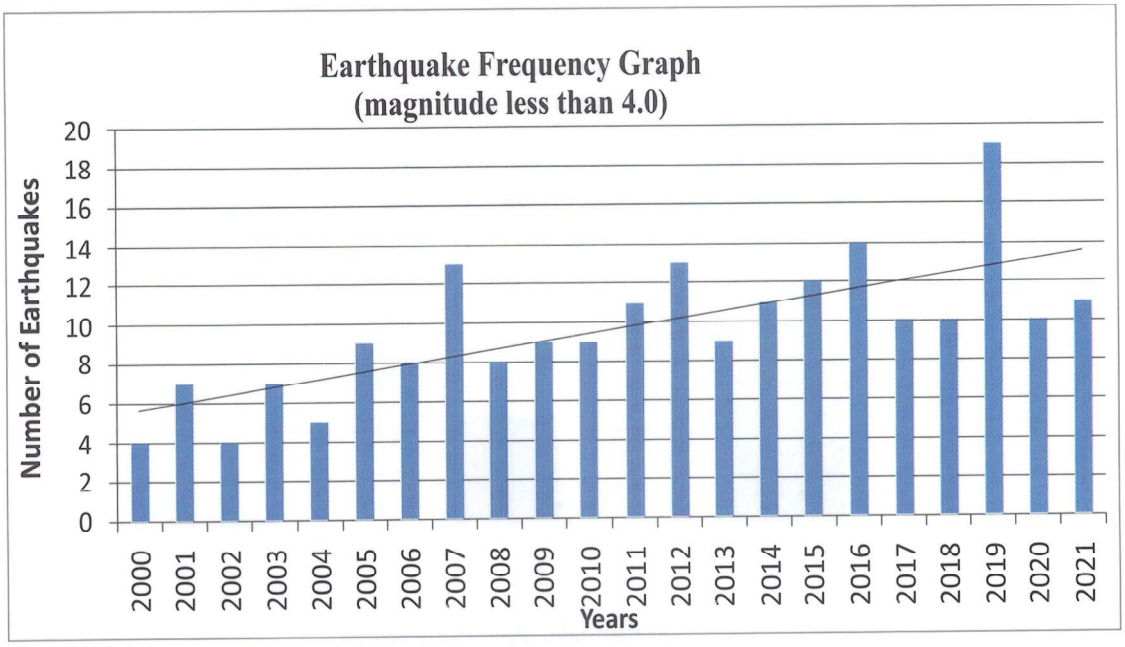


Figure-14: Earthquake Frequency graph with magnitudes less than 4.0. Data from year 2000-2021 indicates the increasing trend in earthquakes occurred per year. From 2018 to 2021 a regular and significant pattern in increase of number of earthquakes per year is observed. Earthquake frequency graph from year 2000-2021 indicates an increasing trend in less than 4.0 magnitudes. In 2019 highest number of earthquake was recorded which indicates the aftershocks of 5.6 magnitude of earthquake.

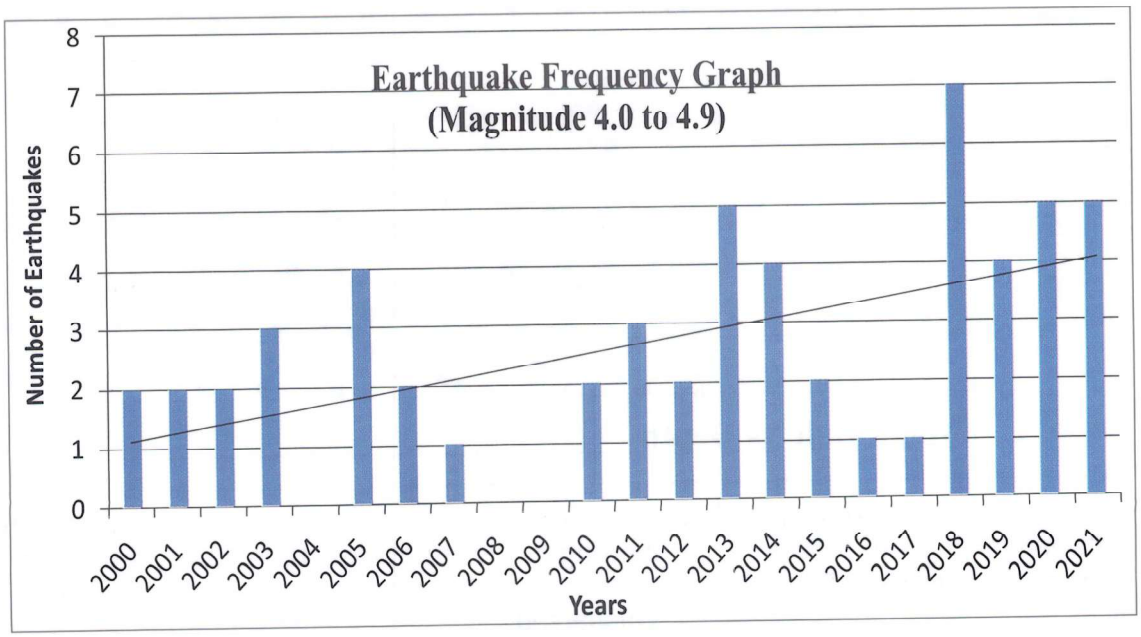


Figure-15: Earthquake Frequency graph with magnitudes 4.0 to 4.9

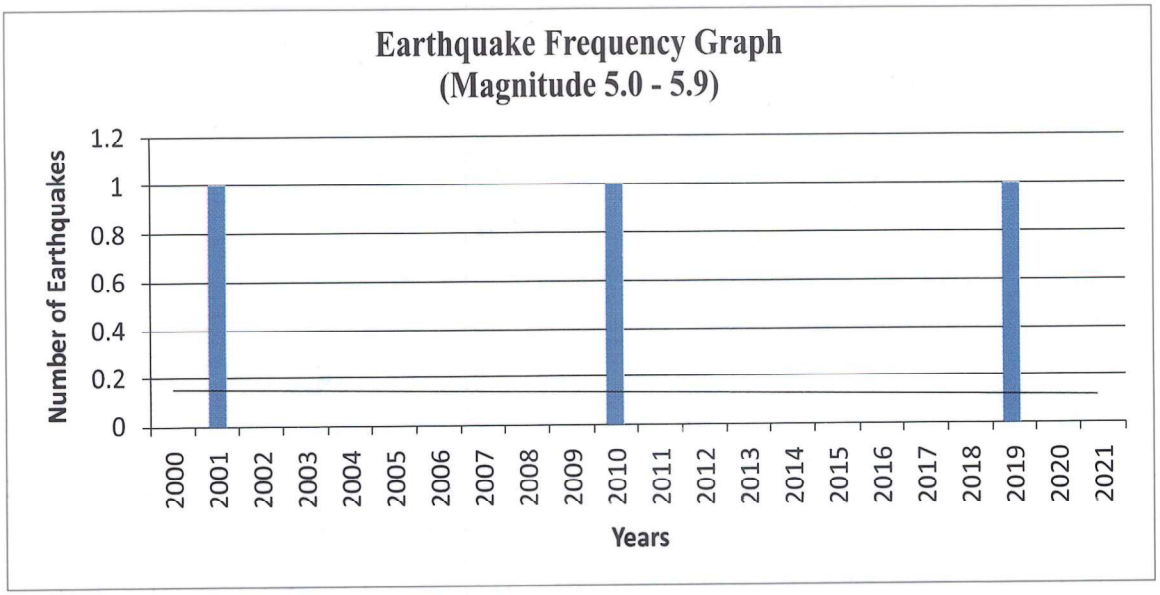


Figure-16: Earthquake Frequency graph with magnitudes 5.0 to 5.9. It shows the frequency of earthquakes regarding 5.0 to 5.9 earthquakes. Only 3 earthquakes are observed in 2010, 2009 and 2019.

The activity rate for any seismic source and the earthquake magnitude-frequency distribution, the most common model is based on the empirical Gutenberg-Richter law defined by:

$$\text{Log } (N) = a - b\ (M) \qquad \ldots\ldots (1)$$

Where N is the mean number of earthquakes whose magnitude is larger than M. Here a-value is used to represent the level of seismicity and Low b value suggests the stress.

Figure-11, a lower b-value or high stress will lead to large magnitude earthquake. Comparison of b value with maximum observed magnitude indicates a lower b-value from averaged data set. Although time window is very small it can be speculated that b-value trend suggests an increasing stress in the region.

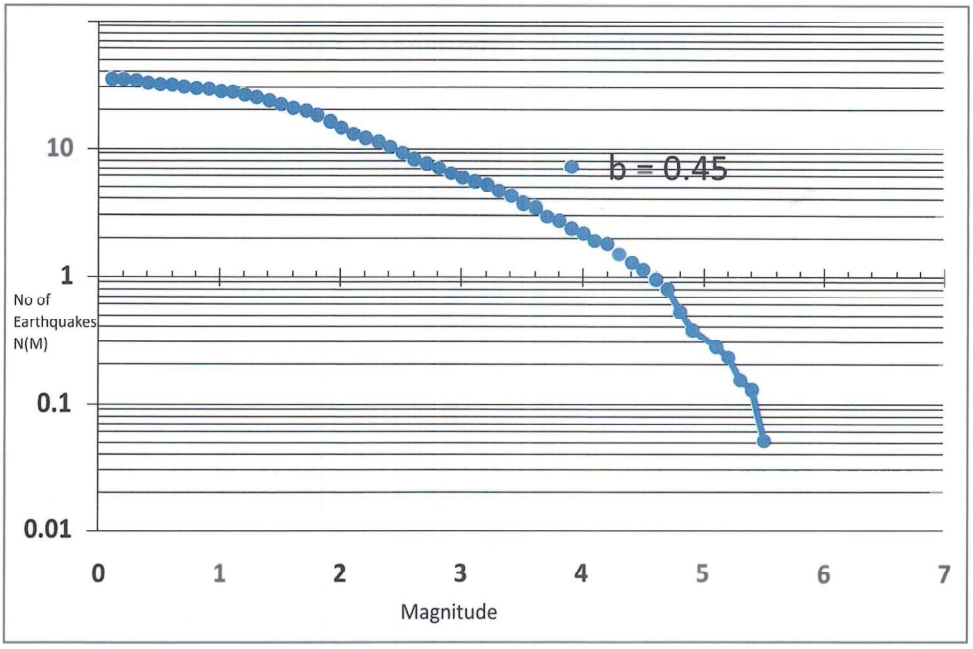


Figure-17: Recurrence model associated to the Exp(^b log 10) truncated to M_{max} = 5.6 Mw

Section-3: Seismic Trend Report For Lower Indus Basin And Kirthar Area (2010-2022)

Introduction:



Figure-18: Lower Indus Basin (https://www.slideshare.net/HammadAhmad14/lower-indus-basinpakistan)

1.2 Kirthar Range

Kirthar Range consists of mountains marking a boundary between province of Sindh and Balochistan. It covers an area of 9000 sq kms 1. The Khasa Hills and Mulri Hills close to the Arabian Sea coast are sub-ranges of the Kirthar Mountains which extend into the city limits of Karachi.

The Kirthar Fold Belt is part of the lateral mountain belts in Pakistan linking the Himalayan orogeny with the Makran accretionary wedge. This region is deforming very obliquely, nearly parallel to the regional plate motion vector (Figure-1, Mohadjer et al., 2010). The Chaman fault, a largescale strike-slip fault, is considered to represent the lithospheric plate boundary (transform fault) in this lateral collision zone (Bannert et al., 1992). East of the plate boundary, a 150-200-km-wide deformation zone is present (Bannert et al., 1992; Szeliga et al., 2009). Due to the highly oblique orientation to the plate vector, strain partitioning is ongoing in this lateral deformation zone (i.e., dividing overall displacement into components of shortening and strike-slip deformation, cf. Szeliga et al., 2009, and references therein). For the frontal part of this deformation belt neither the deep structural architecture nor many aspects of the complex deformation are well understood.

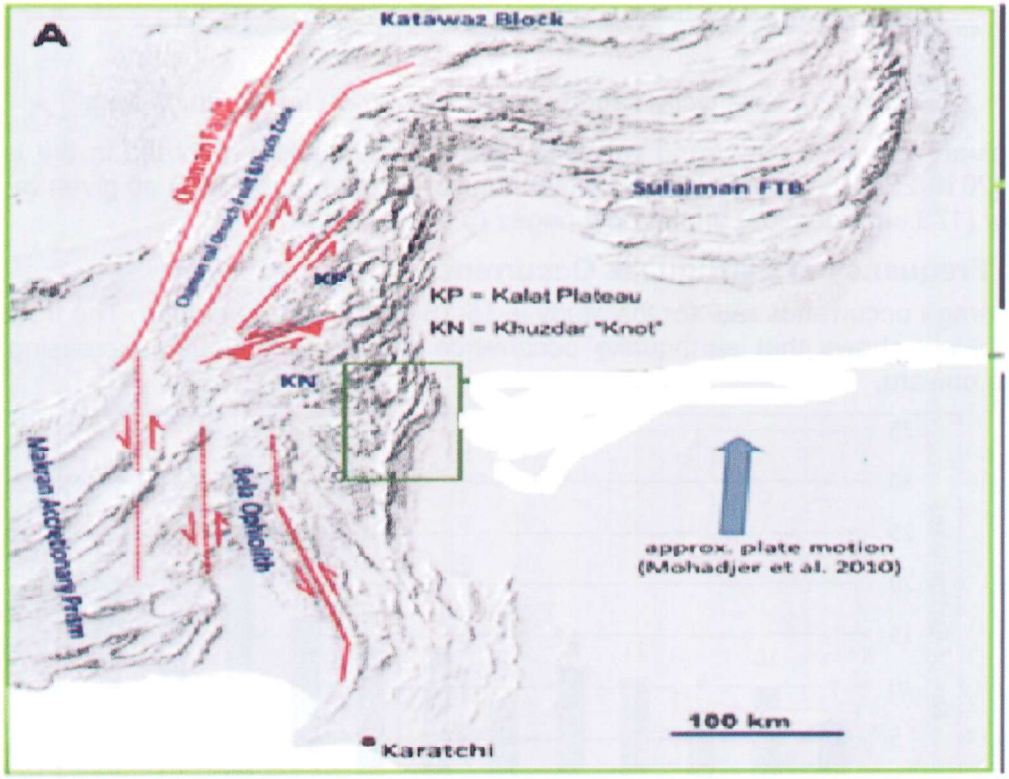


Figure-19: Simplified structural sketch of the wider Kirthar fold-belt area. (Modified from https://www.searchanddiscovery.com/pdfz/documents/2018/30546hinsch/ndx_hinsch.pdf.html)

3.3 Seismicity Pattern:

A seismicity map showing the seismicity pattern of the study area is given below.

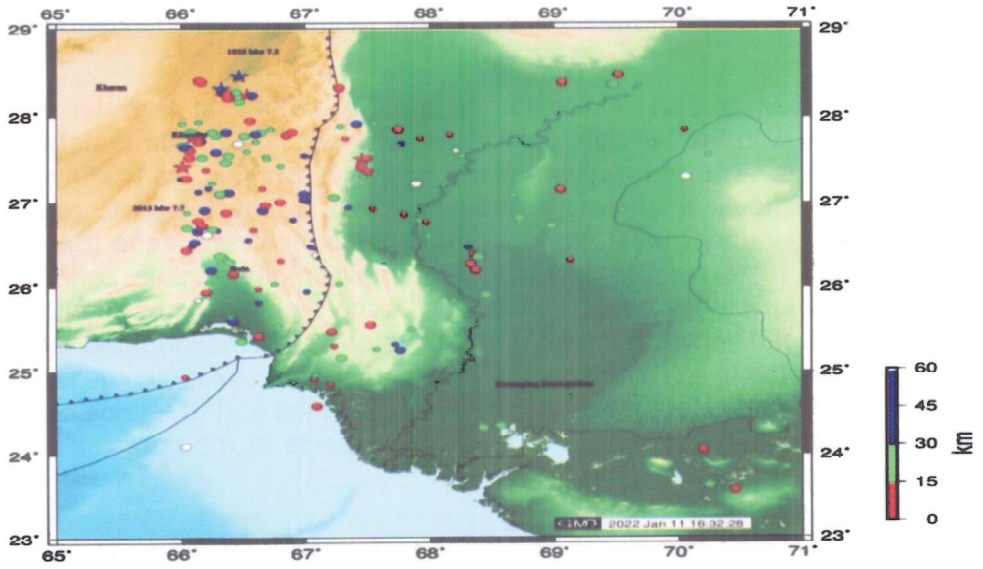


Figure-20: Seismicity pattern map (2010-2022) for the study area

To evaluate the seismicity trend we used data of earthquakes recorded in the last 12 years (2010-2021) by the Pakistan Meteorological Department (PMD) as given by table 1 below (173 earthquakes) on the next pages (p.5-11).

3.4 Frequency of Earthquake Occurrence

The average occurrence rate for the study is 15-16 earthquakes per year. The frequency graph below shows that earthquake occurrence rate is continuously increasing from 2010 to onward.

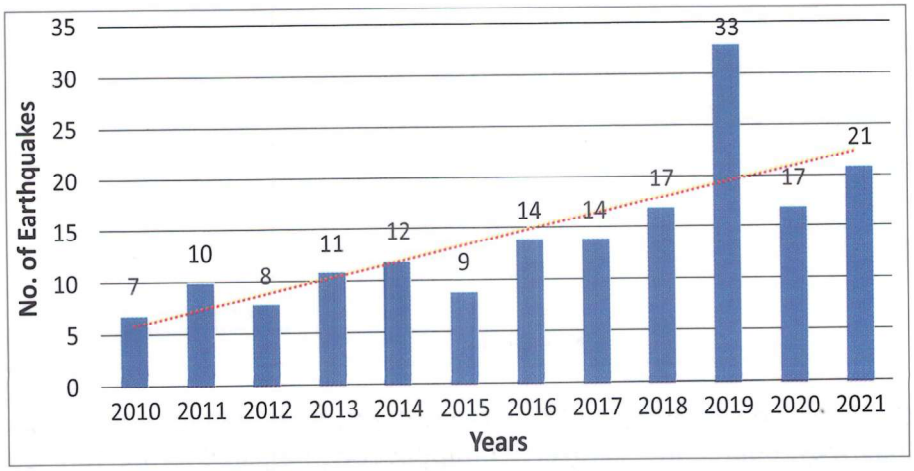


Figure-21: Year wise distribution of earthquakes

This increasing trend seems to involve tertiary reactivation of segments of rift structures caused by the fold and thrust belt on the western side and tectonic plate motion disturbances alongside presence of Major Chaman Fault along with other faults in the study area. Most active year was 2019 – while the year 2010 has been the minimum active one.

3.5 Probable Reason for Reactivation of Segments

The earthquake which occurred in N-W Pakistan on 09-24-13 nucleated on strike-slip segment, south of Chaman fault (Jean-Philippe Avouac et al, 2014). As result of this earthquake, parts of Makran mega thrust along with some thrust faults in Kirthar range and strike-slip faults within the Chaman fault mechanism were brought closer to failure by the earthquake. So, there is possibility that regional deformation and resulting stress field be reorganized to induce strike slip motion along Hoshab fault (Figure-5).

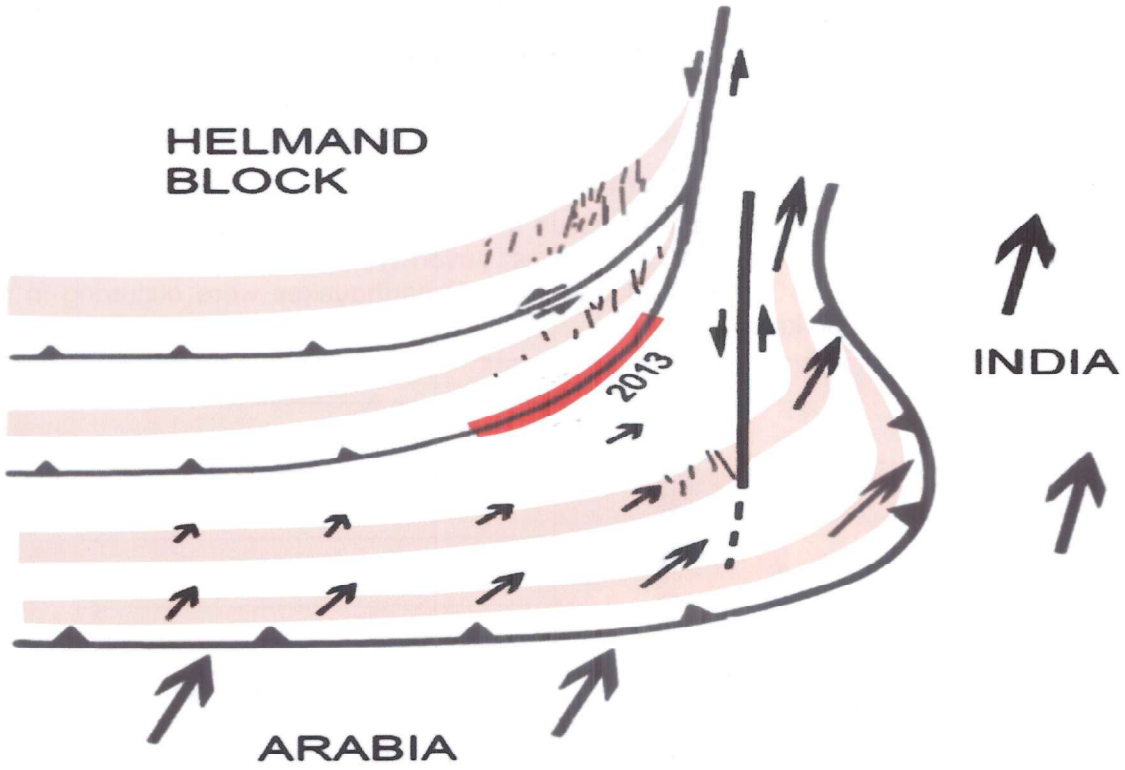


Figure-22: (Modified after Jean-Philippe Avouac et al., 2014) possible interpretation of regional tectonics. Sketch of faults pattern based on Lawrence et al. (1981). Thin N–S trending line represents normal faults. Vectors show long term velocities relative to Iran assuming that a fraction of the oblique convergence between Arabia and central Iran is absorbed within the Makran accretionary wedge. The fold-and-thrust belts within the Makran are dragged and stretched due to left-lateral shear along the Chaman fault system. The eastern part of the wedge is squeezed out and bulges eastwards.

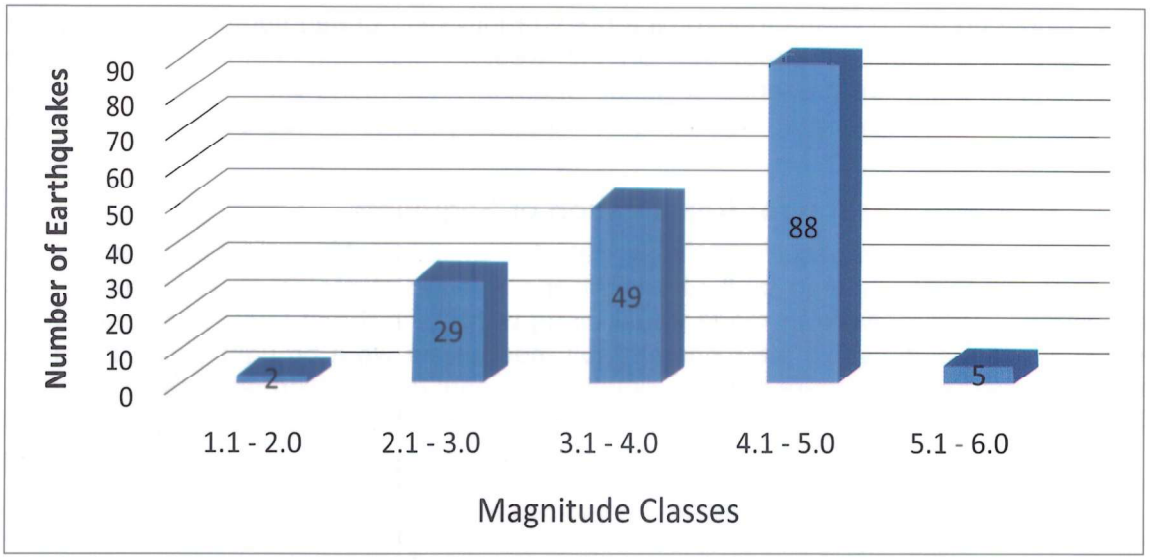


Figure-23: Number of earthquakes of different magnitudes.

3.6 Depth Vs Earthquakes Number

Depths comparison for earthquakes tells us that in the study region 182 earthquakes occurred in the depth range of 10 to 50 kms, seven (7) earthquakes occurred in the depth range of 50.1 to 100 kms and only four (4) earthquakes were occurring in the depth range of 100- 250 kms.

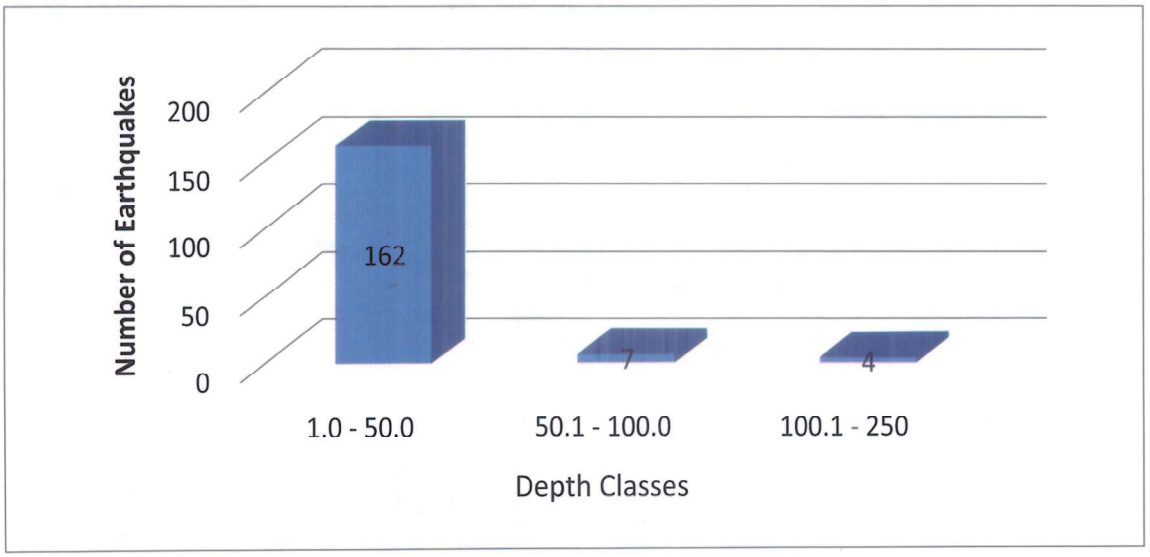


Figure-24: Depth & number of earthquakes

3.7 Time (Year) vs Specific Magnitudes

Graph given below gives information about specific magnitudes and corresponding number of earthquakes occurred in the study region from 2010 to 2021 time duration. Clearly the most earthquakes occurring in the region from 2010 to 2014 were of 4.0 to

5.0 magnitude range – but onward till 2021 earthquakes of magnitude less than 4.0 also have been occurring in the study region. Moreover, a decreasing trend in magnitude of occurring earthquakes is visible from 2016 and onward.

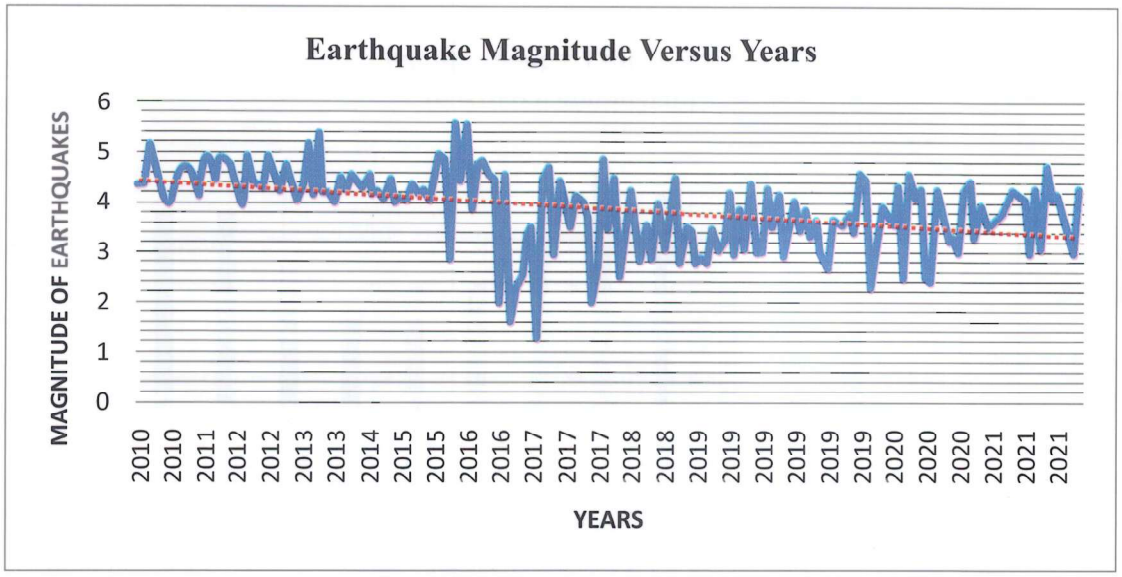


Figure-25: Year vs Magnitude trend, Year Wise Frequency of Earthquakes Occurrence Vs Magnitudes

Range, Magnitude less than 4.0 Earthquakes

Graph below shows that maximum earthquakes of magnitude less than 4.0 occurred in the year of 2019, while minimum occurred in the year 2016.

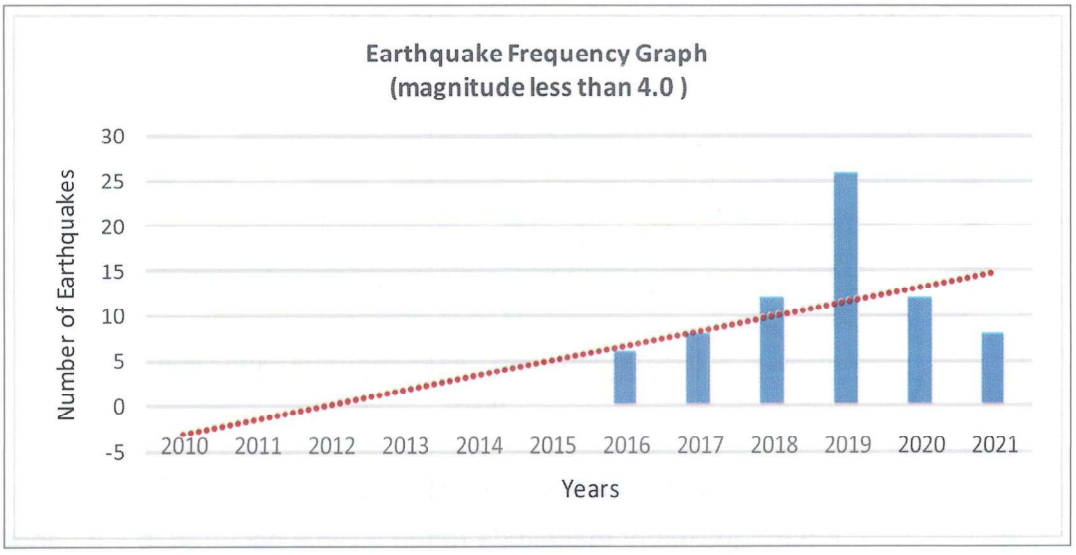


Figure-26: Year vs Earthquakes with Magnitude<4.0

1.8 Magnitude Range 4.0-4.9 Earthquakes

Graphs below depict the frequencies of earthquakes corresponding to a certain magnitude range.

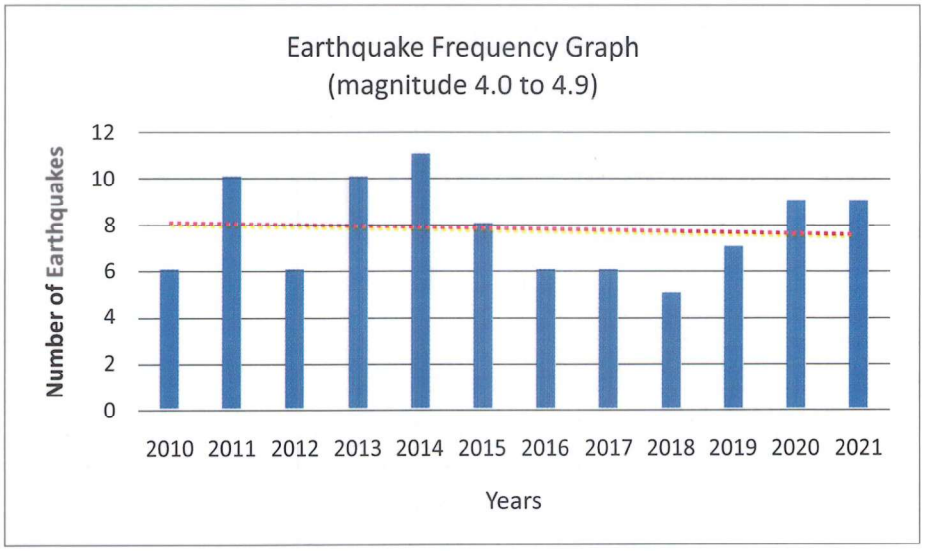


Figure-27: Number of earthquakes with magnitude 4.0-4.9

Above graph shows that maximum number of 4.0 -4.9 earthquakes occurred in the year of 2014 – and minimum number of such earthquakes was in the year of 2018.

1.9 Magnitude Range 5.0-5.9 Earthquakes

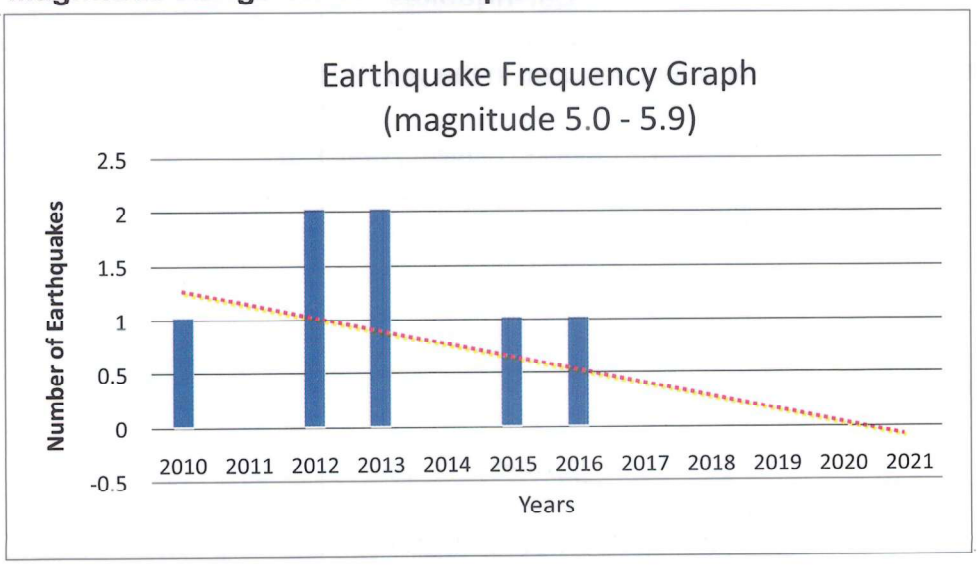


Figure-28: Number of earthquakes with magnitude 5.0-5.9

Graph above shows 8-earthquakes of magnitude range 5.0-5.9 occurred in the period of 2010 to 2016. However, if we see the catalogue, only 1 earthquake of 5.6 magnitude

(maximum magnitude range) falling in the range – which occurred on 21st March 2016 within the depth of 10 km.

3.10 Level of Seismicity

Size-frequency distribution of earthquakes is called b-value, which tells us the level of seismicity or how often an earthquake of certain magnitude will probably occur in a region.

Calculated b-value 0f 0.53, by least square method, shows that seismicity level in the study region is of moderate level.

Section-4: Seismic Trend in Baluchistan and Makran Subduction Zone

INTRODUCTION

Pakistan is directly influenced by the ongoing oblique convergence between the Indian plate and Eurasian plate. In the Baluchistan region, the convergence is highly oblique, involving the large Chaman Fault; a left-lateral strike-slip fault structure. While a large portion of the boundary is accommodated by strike-slip faulting, the region also hosts the Sulaiman fold and thrust belt. The more recent and larger magnitude 7.7 quake in 2013 in Baluchistan was the result of oblique-slip faulting along this highly oblique boundary.

The Makran Subduction Zone (MSZ) is unique due to its geological and seismological characteristics. It shows relatively low seismicity in comparison with other Subduction zones globally. The Makran is seismically relatively quiet compared to other margins such as Chile and Nankai and more similar to quiescent margins such as Cascadia. However, the region has experienced significant historical earthquakes.

Makran Subduction Zone (MSZ) possesses the source of 1945 Makran earthquake. In Makran Subduction Zone, the denser micro oceanic Arabian Plate is going to be subducted underneath the less dense large continental Eurasian Plate. This subduction results thrust faulting in the area, which is the major source of generating the tsunamigenic events.

In Arabian Sea the modern seismicity occurs along the northeastern portion of Murray Ridge. The elevated plateau of the ridge and parallel to it is the site where most of the earthquakes have occurred. The Chaman fault is a major, active geological fault in Pakistan and Afghanistan that runs for more than 850 km. It is actually a system of related geologic faults that separates the Eurasian Plate from the Indo-Australian Plate. It is a terrestrial, primarily transform, left-lateral strike-slip fault. The Chaman fault system has a compressional component as the Indian Plate is colliding with the Eurasian plate. From the south, the Chaman fault starts at the triple junction where the Arabian Plate, the Eurasian Plate and the Indo-Australian Plate meet, which is just off the Makran Coast of Pakistan.



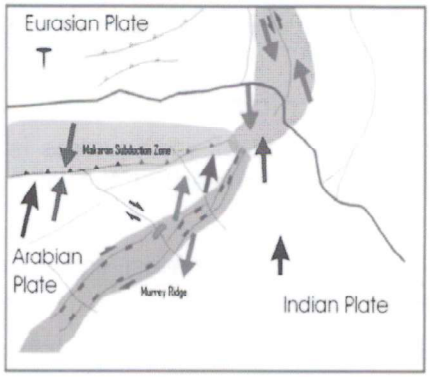


Figure-29a: 3D image of Makran Coast Figure-29b: Subduction of Arabian Plate into Eurasian Plate

The northward movement and subduction of the Oman oceanic lithosphere beneath the Iranian micro-plate at a very shallow angle and at the high rate is responsible for active orogenesis and uplift that has created a belt of highly folded and densely faulted coastal mountain ridges along the coastal region of Makran, in both the Baluchistan and Sindh provinces. The same tectonic collision process has created offshore thrust faults.

4.1 The Present Study

The present work is to study the seismic trend of Baluchistan and Makran Coast using recent seismic activities from 2010 to 2021. The following data recorded at seismic stations installed by PMD from 2010 to 2021 has been used to analyze the seismic trend of the area. A seismicity map of study area is given below. The area is divided in to three different zones as shown in the seismicity map.

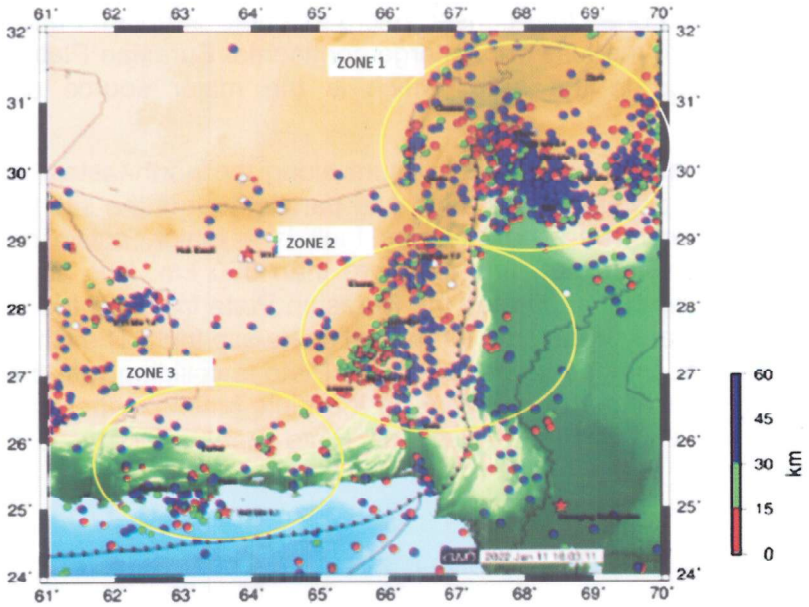


Figure-30: Seismicity Map of Makran Subduction Zone and Baluchistan

- Zone 1. Suleman fold and thrust belt
- Zone 2. In the second zone seismicity is due to Chaman fault, Local thrust fault and effect of Subduction zone is also responsible to produce seismic activity.
- Zone 3. Major seismicity is due Makran Subduction Zone.

To evaluate the seismicity trend of the study area we used data of earthquakes recorded in the last 12 years (2010-2021) by the Pakistan Meteorological Department (PMD).

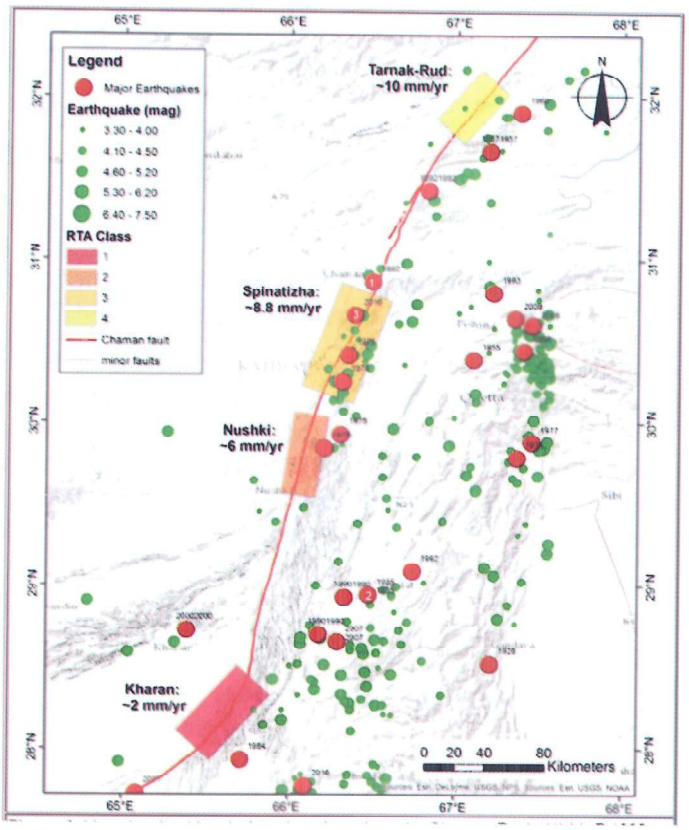


Figure-31: Many large earthquakes (Mw7.5 Quetta, along with historical 1505, 1892, and 1975 earthquakes with magnitude between 6 and 7) have been recorded in the study area.

This would suggest that either aseismic creep plays a large role in accommodating the long term slip rate on the Chaman fault – playing role to neucleate low level seismicity on the Chaman fault system (Jean-Philippe Avouac et al., 2014). Hence the time to time reactivation of segments in the region is common. Chaman fault that start from Heart, Afghanistan and move toward east, enter in Pakistan. The direct ion of that fault in Pakistan is southward. This fault has many branches which generate small to intermediate level of earthquakes in Balochistan. Figure-6: Map showing the historical earthquakes (M 7.0 in 1892 & M 7.7 in 1935) generated by Chaman fault (source: Crupa *et al.,* 2017).

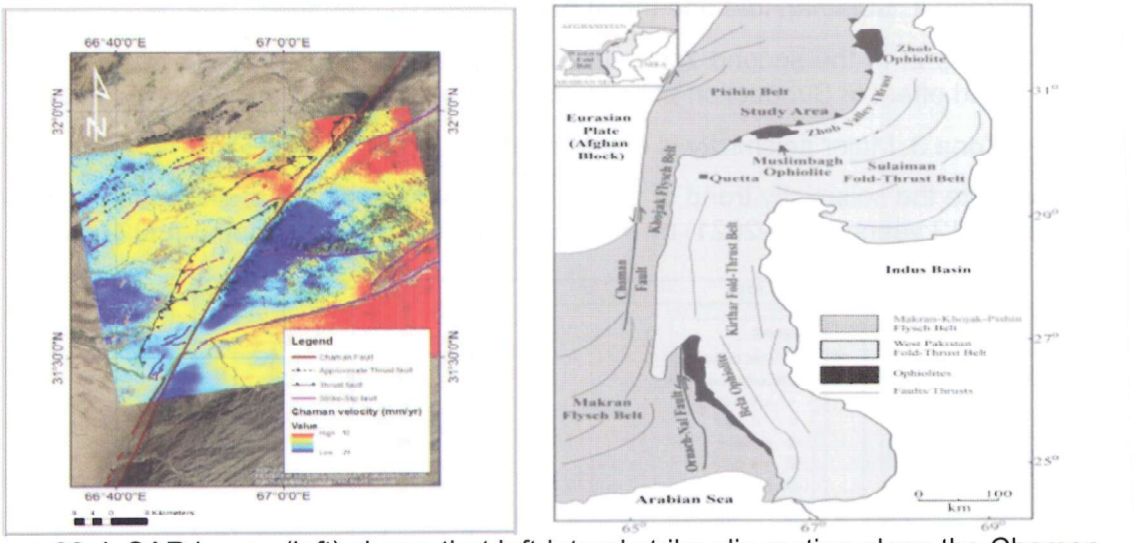
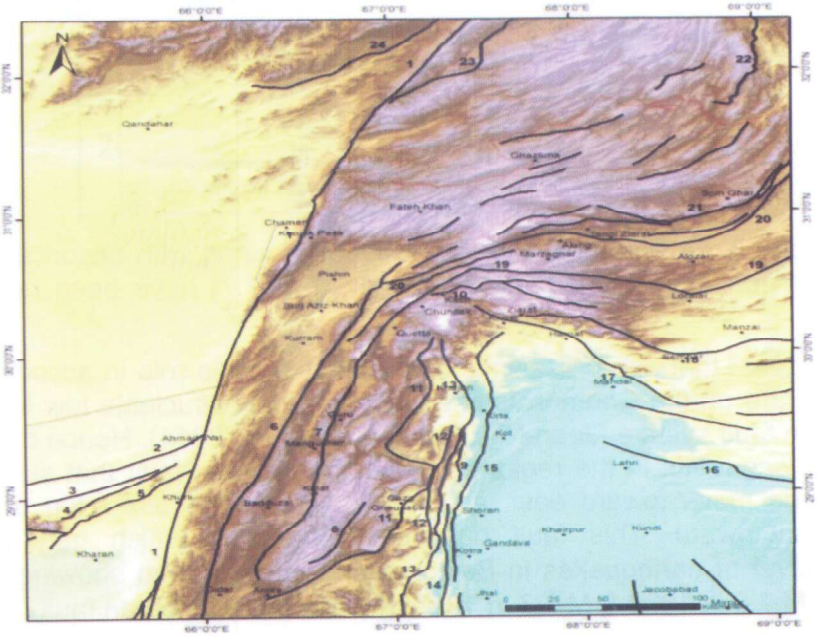


Figure-32: InSAR image (left) shows that left-lateral strike slip motion along the Chaman fault. The speed of movement is ~10mm/yr.

Earthquake distribution along active faults is very significant. It helps identify recently active segments of fault it can also indicate sites that were active in the past but are stable in recent years that could be potential sites of future earthquakes. The earthquakes with higher magnitude (right) are particularly intense in the north Balochistan region where earthquake activities are utmost active along the Chaman fault. The earthquakes having moderate magnitudes were predominantly rigorous in southern Balochistan.



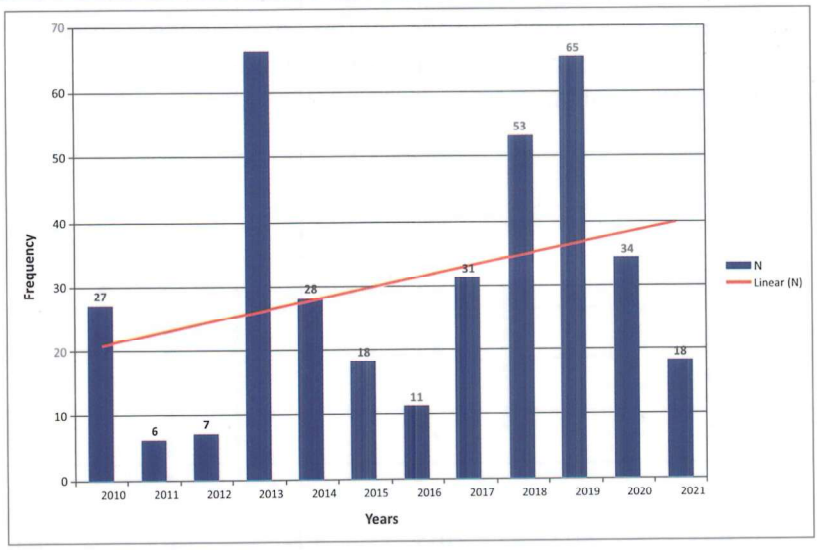


Figure-33: Fault system around Quetta city. Explanations: 1-Chaman Fault, 2Dalbadin Fault, 3-Ahmadwal Fault, 4-Ban Fault, 5-Usman Fault, 6-Ghazaband Fault, 7-Kalat Fault, 8-Pandran Fault, 9-Gokurt Fault, 10-Bibai Fault, 11-Anjira Fault, 12-Nagau Fault, 13-Bolan Zardak Fault, 14-Kotra Fault, 15-Gandava Fault, 16-Pirkoh Thrust, 17-Harnai Tatra Fault, 18-Karahi Fault, 19-Chinjan-Zakriazi Fault, 20-Zhob Valley Thrust, 21-Dasht Murga Fault, 22-Katawaz Fault, 23-Chaman Fault splay, 24-Mokur Fault. Source: Khan et al. (2012).

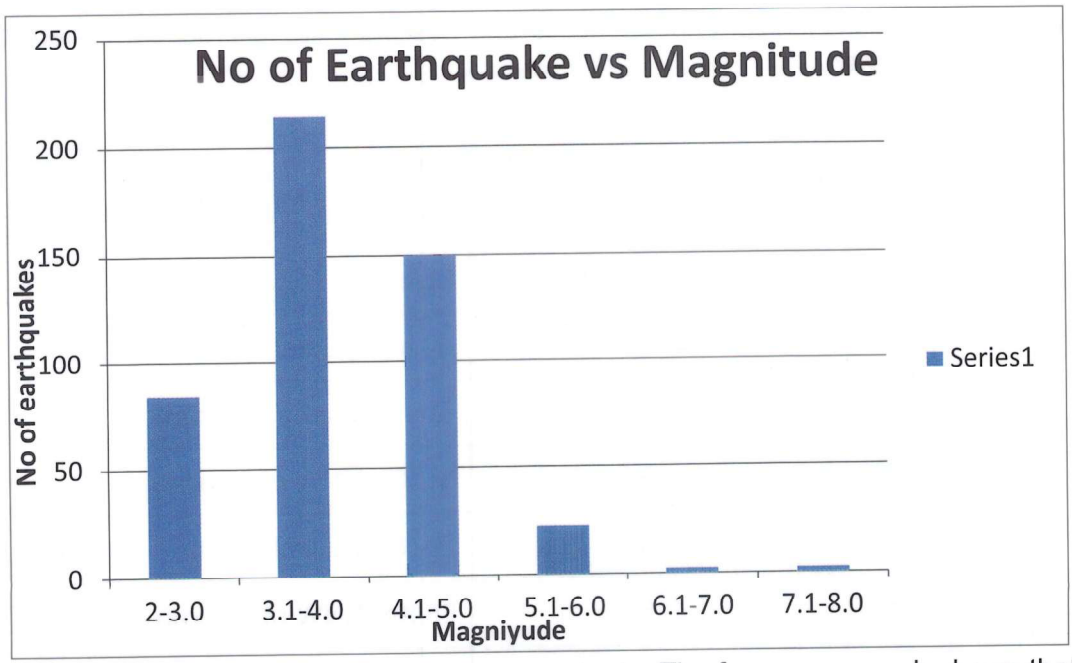


Figure-34: Number of earthquakes vs magnitude. The frequency graph shows that earthquake occurrence rate is going relatively on high side after 2016 except in 2013.

The graph represents that area under study experienced moderate to major earthquakes. Majority of earthquakes are in the magnitude range of 3 to 5. Major events are rare in and with larger seismic gap.

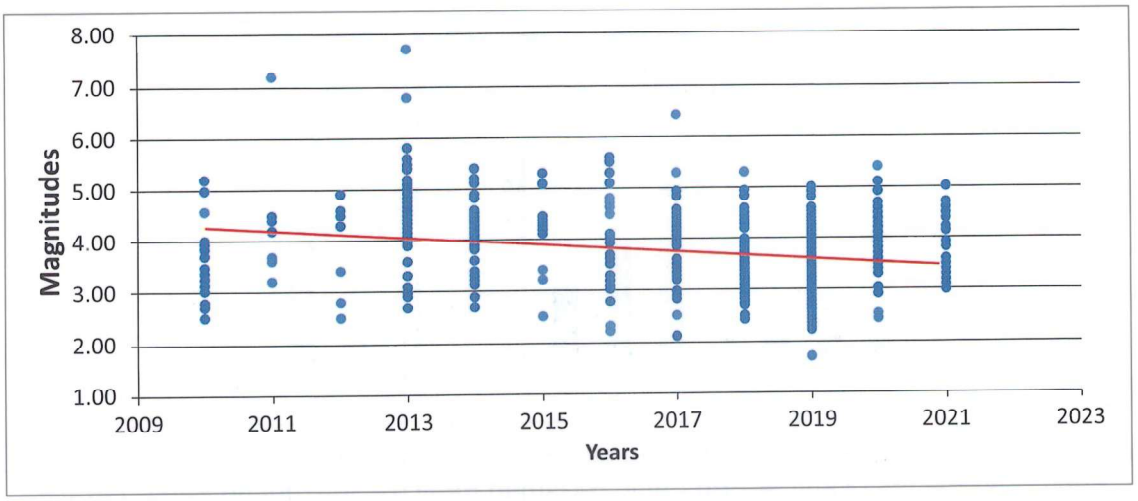


Figure-35: Earthquake Trend with time scale

The trend of seismicity seems to be decreasing according the graphical representation for the study period due to massive energy released in recent time 2013(Awaran earthquake) followed by the series of aftershocks. Now the time window is very small for seismic activity to reoccur in the specified time. The study area is unique due to its geological and seismological characteristics and has potential to produce moderate to major seismic activity.

The list of major earthquakes in the stipulated time and area are given below;

Table-2: Major Earthquakes in the study area

Date	Magnitude	Epicenter
24-9-2013	7.7	Awaran, Balochistan
18-1-2011	7.2	Southwestern Pakistan
28-9-2013	6.8	85 Km NNW of Awaran
7-2-2017	6.4	23 Km west of Pasni
24-9-2013	5.8	85 Km NNW of Awaran
21-3-2016	5.6	Near Khuzdar

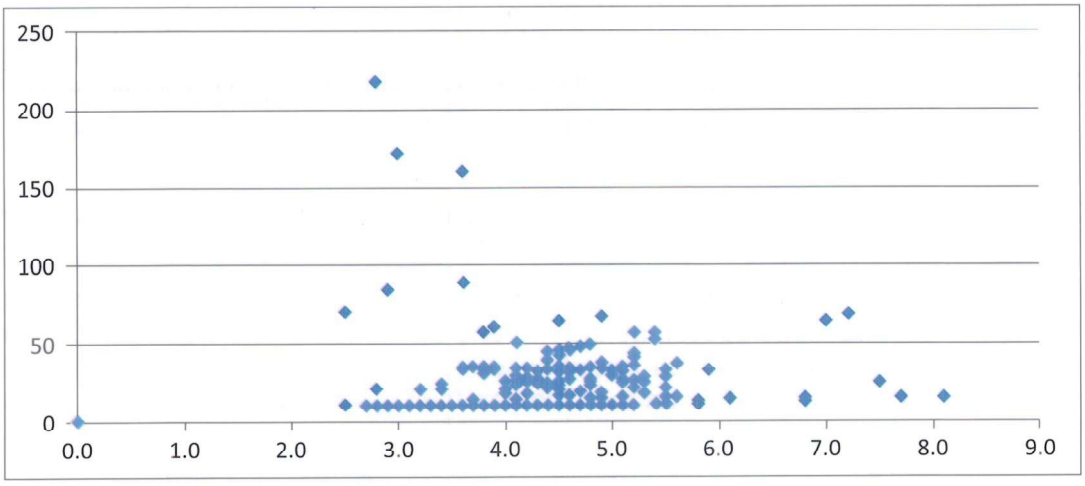


Figure-36: Depth profile of earthquakes.

The depth profile graph shows that most earthquakes occur in the upper crust, with the crustal shortening produced by continental collision accommodated entirely by thickening and distributed deformation.

Result and Discussions

1. The results of seismicity trend analysis in northern and northwestern Pakistan revealed that more than 10,000 earthquakes occurred in the Hindukush and Northern Pakistan between the periods of Jan 2000-Jan 2022. It is also obvious that the frequency of earthquakes is higher in the Hindukush region as compared to rest of the areas in Pakistan. Intermediate depth seismicity (70 – 300km) was observed across this zone. Repeating seismic events is a feature of Hindukush Region which causes strong shaking in adjacent areas of Pakistan.

Hazara Kashmir Syntaxis and Northern Pakistan are seismically active regions which produce shallow earthquakes. For this reason, any strong earthquake activity (Mw≥6.0) in these zones can cause prominent damage to live and properties.

The maximum earthquake magnitude potential observed in the Hindukush region is Mw > 7.0 with a probability of occurrence 10-15 years and Mw > 6.5 in 5 - 7 years period from the recent earthquake patterns. Hazara-Kashmir Syntaxis region has potential of Mw>7.0 earthquakes but it takes about 100 years longer time span. Northern Pakistan region has potential of Mw>6.0 with a probability of occurrence 20-30 years. Higher b-values, annual seismicity rate (a-value) and new seismic hazard maps show high tectonic stress release. Based on these maps and above analyzed seismicity pattern it is confirmed that damaging earthquakes are relatively high in Northern and Northwestern Pakistan so it is important to quantify the hazard in the future preparedness against major earthquakes in the region.

- Historically study area is active for minor to moderate level seismicity.
- Eastern and Western margins of Salt Range where Kalabagh and Jhelum faults are present are more active for minor to light magnitude of earthquakes.

- An increasing trend is observed in frequency of earthquakes with respect to magnitude ranges from 0.1 to 4.9.
- Although time window is very small it can be speculated that b- value trend suggests an increasing stress in the region.
    - The study region is under influence of tertiary reactivation of segments of rift structures caused by the fold and thrust belt on the western side - and tectonic plate motion disturbances to accommodate the long term strike slip transformation on the Chaman fault system along with other faults in the study area.
    - Earthquake occurrence trend is increasing for the study area.
    - Earthquakes mostly occur in the depth range of 10-100 kms.
    - Mostly the earthquakes of magnitude greater than 4.0 occurred from 2010 to 2014- but onward earthquakes with magnitude less than 4.0 are also occurring.
    - No earthquake with magnitude 6.0 or above occurred in the study area, The maximum magnitude has been 5.6, and the only earthquake with this magnitude occurred on 21st March, 2016.
    - Seismicity in the region is of moderate level.

In the first zone seismicity is dense and responsible source is Suleman thrust fault. Mostly it can produce moderate seismicity and its return period is less. This area experienced

1. Chaman fault Zone-2

Seismicity pattern of the Second zone is also dense the major source of seismicity in this region is Chaman fault, thrusted inclusion due to upper area and smaller local thrust faults. It can produce major earthquake but its return period is major. This zone experienced 7.6,1935 Quetta and Awaran earthquake 7.7, 2013.

2. Makran Subduction Zone-3

Third zone is the Makran Subduction zone shows strong variation in seismicity between its eastern and western segments and has one of the world's largest forearcs. The seismicity pattern shows that MSZ has potential to produce big earthquakes which can generate tsunami. It can produce great earthquakes but return period is very large. The largest earthquake experienced is 8.1 in 1945 which generated Tsunami.

References

1. Generic Mapping Tools Wessel, P., et al. AGU, 2019.
2. A software package to analyze seismicity: Zmap, Wiemer, S., 2001.
3. Geology & Tectonics of Pakistan Kazmi & Jan, 1997.
4. Seismological Observatory Software: Seisan 10.2, Havskov, J. and Ottemoller, L. (2020).

5. Tectonics of the Nanga Parbat Syntaxis and the western Himalaya Treloar, Peter J. et al. Geological Society, London, Special Publications (2000).
6. Htwe, Y. M. M., & WenBin, S., Gutenberg-Richter Recurrence Law to Seismicity Analysis of Southern Segment of the Sagaing Fault and Its Associate Components. World Academy of Science, Engineering and Technology 2009.
7. Kazmi, A.H. &Jan, M. Q., 1997. Geology and Tectonics of Pakistan. Graphic Publishers. pp410,414.
8. Kazmi, A.H. &Rana, R.A. (1982) Tectonic Map of Pakistan, Geological Survey of Pakistan.
9. Naveed Ahsan H. Jawad Sohail Hammad Ahmad Sheikh, A brief introduction about the structure, Petroleum Play and tectonics of the Lower Indus Basin Pakistan 2016.
10. Ralph Hinsch et al., Structural Modeling in the Kirthar Fold Belt of Pakistan: From Seismic to Regional Scale
11. https://www.searchanddiscovery.com/pdfz/documents/2018/30546hinsch/ ndx_ hinsch.pdf.html
12. https://www.slideshare.net/HammadAhmad14/lower-indus-basinpakistan
13. https://www.britannica.com/science/earthquake-geology/Earthquake-magnitude
14. Jean-Philippe Avouac et al.,2014, The 2013, Mw 7.7 Balochistan earthquake, energetic strike-slip reactivation of a thrust fault