Chapter 7:

CONCLUSIONS AND FUTURE PROSPECTIVE

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7.1. Conclusions

The present investigation did utilizing the location parameters information that was procured over a significant long stretch term utilizing the broadband seismometers put on a noteworthy confinement to the epicentral parameters instability in the NW Himalaya. The 423 earthquakes which are studied and are relocated using the hypoDD software (Waldhauser and Ellsworth, 2000), utilizes the re-estimated local 1 D crustal velocity model is utilized for the present seismicity relocation analysis. The location parameters uncertainty for the relocated seismic events are being reduced to ≤ 2 km in the study area. Through process of travel time inversion, it is found that a new highly active seismic window lying in the latitude range of 31.8 °N to 32.8 °N and longitude range of 76.8 °E to 78.8 °E along with the previously active region for the Kangra earthquake of 1905 and Kinnaur earthquake of 1975 which indicates high tectonic activity in this part of the Himalaya. In view of this, the telesismic tomography using receiver function analysis may be able to infer the crustal structure up to more depth and also suggests that the discrepancy of Moho depth is determined more accurately in this study region.

The geometry of the MHT plane have been reasoned in this present work, which changes along the strike of the Himalaya in level and incline portions and its dip shifts from 4° to 19° beneath the HFT in south to STD in the north. The depth constraint to the well documented crustal ramp in the region, i.e. the mid-crustal ramp and the great Himalayan ramp below the MCT and STD varies from 12 to 22 km and 28 to 40 km depth, respectively. The earthquake hypocenters reported beneath the sub surface are seen to be distributed within a depth range from 2 km to 47 km along the depth-distance profile. The earthquake focus exhibits anentire depth range distribution characterizing the seismogenic nature of the entire Indian crust. The observedseismicity in the region signifies a higher level of tectonic activity in this region.This also states for the reactivation of the major fault the Kauirik fault which can led to considerable number of earthquakes in Himachal Pradesh.

According to the estimation in light of this relation $Mw=2/3log_{10}M_0-10.7$ (Kanamori, 1983) by considering the present rates for convergence and seismic energy release in various small and large earthquakes (ISC-EHB catalogue; WIHG catalogue) just a portion (3–5%) has been discharged of the aggregate obliged (95–98 %). By considering the present status it might be surmised that the aggregate sum of vitality discharged since the last greatevent is just a small amount of the obliged vitality and is not adequate to keep a great earthquakeaway in future.

Different stress condition prevailing in the NW Himalaya, India around the source zone of the past four major earthquakes i.e. 1905 Kangra earthquake, 1975 Kinnaur earthquake, 1991 Uttarkashi earthquake and the 1999 Chamoli earthquake is shown. The 1905 Kangra earthquake zone shows a significant stress high near Jwalamukhi Thrust (JMT), new earthquake potential zone has been detected in previously stress shadow zone towards the west of the 1905 Kangra earthquake epicenter. The 1975 Kinnaur earthquake that occurred due to the activation of the major fault that is the Kaurik fault which was under stress shadow at that time of the earthquake but now a number of earthquakes in its vicinity show that this fault has been reactivated in the recent years and can be the locale to major earthquakes in future. The new hazard potential zones near the epicenter of 1975 Kinnaur earthquake has been detected due to the emplacement of the recent earthquake epicenters in the previously seismic shadow zone of the 1975 Kinnaur event. Therefore these regions are still under high tectonic stress and can be a home to major earthquake occurrences in future. The computation of coulomb stress for 1991 Uttarkashi earthquake is seen to have a propagation of rupture along the NW-SE direction along the major structural trends including the MHT. The aftershocks that been plotted shows a maximum abundance in the high stress zone propagating along the direction of the rupture and also along the direction orthogonal to the rupture plane. It may be suggested that the occurrence of 1991 Uttarkashi earthquake along the MHT detachment can only be attributed to the ongoing tectonic convergence of the India-Eurasia plate. The 1999 Chamoli earthquake has been clearly associated with the up dip thrusting of the MCT in the NW-SE direction. The aftershock sequence of the Chamoli earthquake shows that it is associated with the activation of the major structures like the Alaknanda fault and had imparted enough stress to the regional tectonic stress condition of the NW Himalaya that can trigger major earthquakes similar to it. So our coulomb stress model is very much useful in accessing the present tectonic stress condition of the NW Himalaya that further details about the future earthquake scenario in the NW Himalaya, India region.

The computed lithospheric model constrained from 2D density modelling of gravity anomaly along NE-SW profile and seismic investigations in this region suggests the underthrusting of the Indian lithosphere beneath the Eurasian plate at about 75–80 km. The model shows Moho depth of about 35–37 km in the Indo Gangetic plain (IGP) towards the south of the HFT and it gradually extends to about 40-45 km beneath MBT and about 50 km below the MCT. The Moho depth gradually increases and reached about 55–60 km beneath the STD and it reaches a maximum of 75–80 km below the ITSZ, which defines the boundary between the India-Eurasia plates in the NW Himalaya. This Gravity modelling along the SW–NE profile crosses the major tectonic element in the NW Himalaya is modelled as the large wavelength gravity anomalies which are interpreted due to crustal thickening. This subsidence of the Indian plate beneath the Eurasian plate has greatly resulted in subsequent shallow crustal earthquakes and hence characterizing the entire Indian crust as seismogenic in nature with a majority of the earthquake focus coinciding with the upper crustal layer of the Indian plate. Due to this underthrusting phenomena arising in the region, this region is becoming a home to several thrusts in the Indian and Asian plate. The subsequent high density within the low density arising between the MCT and STD can be attributed to the presence of extended surface structures in to the subsurface. This can be confirmed as the MHT plane as observed from seismic profile detailed in chapter 6 designated by Figure 6.3.The low density in the region towards the western side of the Kaurik-Chango Fault may have been resulted due to the soft-sediment deformation taking place within different lacustrine sedimentary bodies present. This presence of soft-sediment deformation features can be characterized inlake sediments in the immediate vicinity of theseismically active belt between the Tso MorariLake and the Leo Pargil gneiss dome that suggests acogenetic origin of soft sediments associated with the normal faulting (Hintersberger et al. 2010*)*. Hence the present study suggests that the sites of large topographic relief and isostatic anomalies in the NW Himalaya, where strong earthquakeshave not occurred in historic times, should beconsidered as potentially seismic hazardous zones.

7.2. Future Prospective

The result of this study provides major tectonic implications to the crustal structure along with major heterogeneities prevailing within it. The study has greatly helped in relocatingthe seismicity in NW Himalayan region using local earthquakes recorded within the region with higher degree of accuracy in location and reduced errors in origin time, latitude, longitude and depth. Source characteristics of earthquakes ($M_L \geq 4.0$) inferred in the study has immensely helped to understand the physics of the earthquake sources and the fault kinematics in the study region. The stress scenario delineated in the NW Himalaya has help in identification of new earthquake potential zones having their epicentres in the seismically NW Himalaya region. Modelling of seismicity and source mechanism results with gravity data through the present study has a better explanation the tectonics of the Northwestern Himalaya.

After all these extraordinary results achieved utilizing the present study still upper mantle structure is poorly constrained. This can be obtained carrying out major integrated seismological and geophysical studies such as the telesismic tomography using receiver function analysis and seismic anisotropy that may be able to infer the upper mantle structure up to more depth with more accuracy along with a proper addressing and explanation to the geodynamic evolution of the various surficial and sub surficial structures of the Northwestern region.